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Correlation of radon anomalies with microseismic events in Kangra and Chamba valleys of N-W Himalaya

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RESUMEN

El monitoreo de radón en Palampur y Dalhousie, en los valles de Kangra y Chamba, utiliza la emanometría por medición discreta de radón desde 1992, dentro del programa de Sismicidad del Himalaya del gobierno de la India. Se observa una correlación en ambas regiones investigadas con el número de microtemblores registrados por el Departamento de Meteorología de la India en el período 1992-1997. Se estudió el efecto de parámetros meteorológicos (temperatura, precipitación, humedad y velocidad del viento) sobre el nivel de radón. En la estación de Palampur se presenta correlación positiva de los niveles de radón con la temperatura, la precipitación y la humedad, y negativa con la velocidad del viento.

PALABRAS CLAVE: Radón, anomalías, emanometría, alpha-logger, microsismos, precursores.

ABSTRACT

Radon monitoring was carried out at Palampur and Dalhousie stations in Kangra and Chamba valleys using emanometry for discrete measurements of time-series radon data since 1992 under Himalayan Seismicity programme of Government of India. The correlation of radon data with micro-earthquakes recorded by Indian Meteorological Department (IMD) network during the time window 1992-1997 shows a rising trend both in microseismicity as well as radon in Kangra and Chamba valleys of N-W Himalayan region under investigation.

The effect of meteorological parameters (temperature, rainfall, humidity and wind velocity) on radon emanation was studied. The correlation co-efficients of radon data and the meteorological parameters recorded at Palampur suggest that temperature, rainfall and humidity have positive correlation, whereas wind velocity has negative correlation with radon.

KEYWORDS: Radon, anomalies, emanometry, alpha-logger, microseismicity, precursor.

INTRODUCTION

Geochemical and hydrological anomalies preceding significant earthquakes have been reported since the 1960s and played a prominent role in the successful prediction of the Haicheng earthquake in China. Such observations are part of monitoring programs in China, Japan, Uzbekistan (Tashkent), Mexico, Italy, India and Germany (Liu *et al*., 1984/85; Ulomov and Mavashev, 1971; Segovia *et al*., 1989, 95; Heinicke *et al*., 1992,95). However, studies of these pre-seismic phenomena have been controversial for several reasons (Silver and Wakita, 1996; Wakita, 1996). Hydrogeochemical phenomena and radon are strain indicators but the physical mechanism and their relationship with the strain are not yet well understood. During the last decade some useful data on correlation of radon anomalies with seismic events which occurred in N-W Himalaya have been reported (Virk, 1986, 90, 95; Ramola *et al*., 1990; Singh *et al*., 1988, 92; Virk and Singh, 1992, 93, 94; Virk *et al*., 1995, 97; Virk and Sharma , 1997) .

Our present investigations are based on radon monitoring in soil-gas and spring waters in the N-W Himalaya at stations Palampur and Dalhousie in Himachal Pradesh (Figure 1). The radon data is recorded in both media using instantaneous (discrete) measurements from June 1996 to September 1997. Meteorological parameters influence radon emanation in the soil-gas; hence correlation co-efficients are worked out for radon emanation with various meteorological parameters at Palampur, the central station in our radon project under the Coordinated Himalayan Seismicity Programme of Department of Science and Technology, Govt. of India.

EXPERIMENTAL TECHNIQUE

An emanometer (Model RMS-10) manufactured by the Atomic Minerals Division, Department of Atomic Energy, Hyderabad is used to measure the alpha emanation rate in the gas fraction of a soil or water sample by pumping the gas into a scintillation chamber using a closed - circuit technique (Ghosh and Bhalla, 1966). This technique gives instant values of radon concentration and is highly suitable for quick radon surveying.

Auger holes, each 60 cm in depth and 6 cm in diameter,

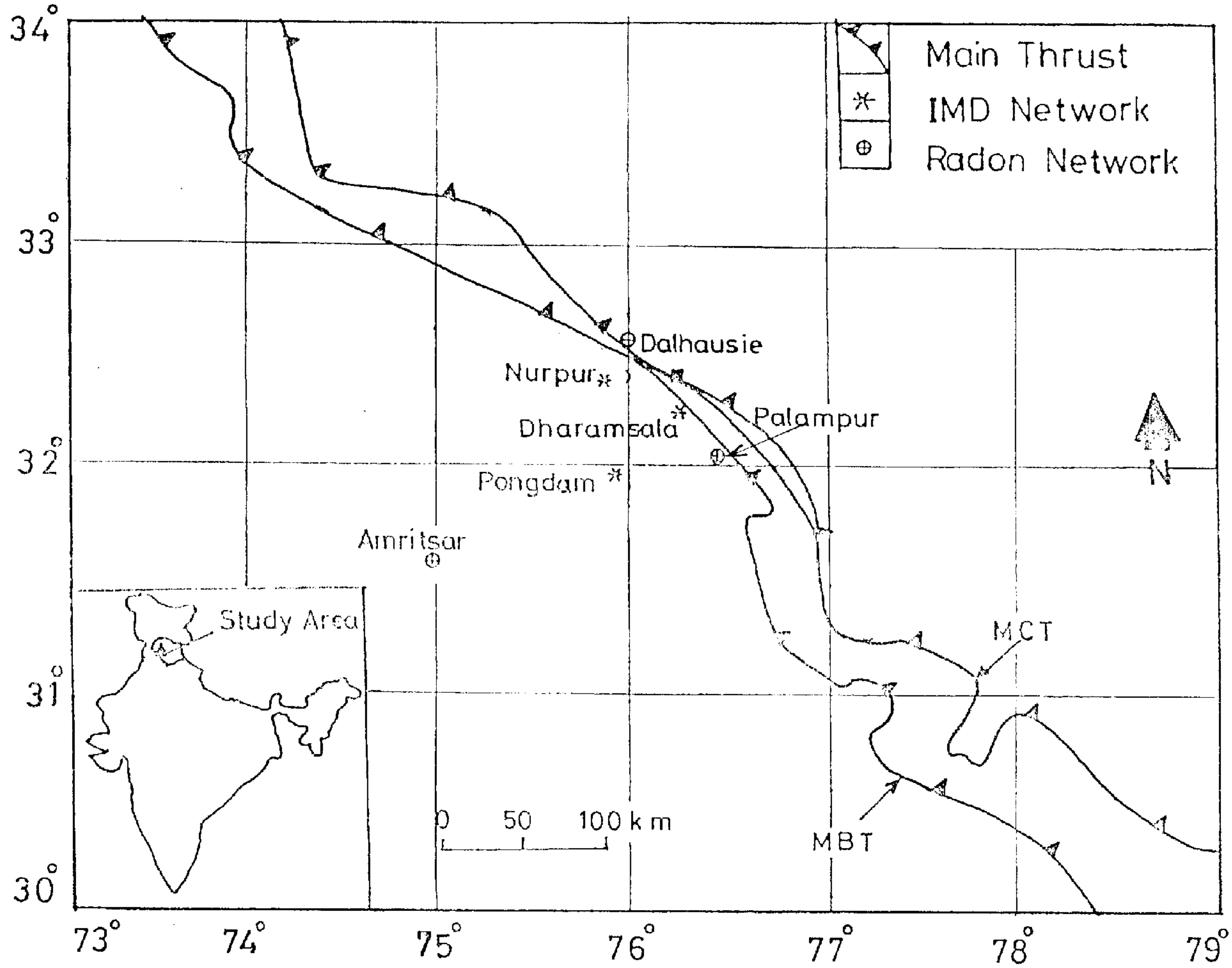

Fig. 1. Map showing radon monitoring sites along with IMD network in N-W Himalaya.

are left covered for 24 hours so that soil-gas radon and thoron become stable. The auger hole forms an air-tight compartment. A rubber pump, soil-gas probe and alpha detector are connected in a closed circuit. The soil-gas is circulated through a ZnS coated chamber (110 ml) for a period of 15 minutes allowing the radon to form a uniform mixture with air. The detector is then isolated by clamping both ends and observations are recorded after four hours when equilibrium is established between radon and its daughter elements. Alpha particles emitted by radon and its daughters are recorded by a scintillation assembly consisting of a photomultiplier tube and a scalar-counter unit.

Radon monitoring in water is also carried out by using the closed-circuit technique. Groundwater samples are collected daily from a 'bauli' (natural spring) in a sample bottle (250 ml). The air is circulated in the closed-circuit containing a hand-operated rubber pump, a water sample bottle, a drying chamber and a ZnS(Ag) detector cell for 10 minutes. The alpha counts are recorded after four hours during which the equilibrium between radon and its daughters is established.

RESULTS AND DISCUSSION

Diurnal radon concentrations in soil-gas and groundwater (natural springs) have been monitored regularly at Palampur and Dalhousie stations since 1992 using radon emanometry. The radon data trend and its analysis for the period February 1992 to July 1995 was reported by Virk and Sharma (1997). There are large scale fluctuations in the entire time-series radon data but the general trend is similar to the previous years. Radon emanation in soil-gas is enhanced during the summer months and is suppressed during winter at both stations. However, this trend is not observed in groundwater. Obviously, temperature fluctuations do not affect radon emanation in water to the same extent as in soil-gas. Both Palampur and Dalhousie stations are located in the vicinity of MBT and MCT, the two major thrust faults in the Himalayan orogeny. The high micro-seismicity in the Kangra and Chamba valleys of Himachal Pradesh in the N-W Himalaya appears to be due to these major thrust faults.

The micro-seismicity trend during the period of observation under reference is observed to agree with a general trend during the period 1992-1995 (Annual Reports on Seismic Activity around Pong, Pandoh, Bhakra and Salal Dams, 1992-97; Govt. of India, India Meteorological Department, New Delhi). The micro-seismicity is confined to areas in and around the major thrust faults represented by MCT and MBT (Figure 1). In general, the micro-seismicity is showing a rising trend as evidenced from the study of microseismic data and its correlation with the radon data monitored in Kangra and Chamba valleys (Figure 2). The total number of events recorded by IMD network during 1996 and 1997 in the grid (30-34°N, 74-78°E) is 83 and 85, respectively, with almost a three fold increase in the microseismic events (27) recorded during 1992. A similar trend is also observed in radon emanation during the time window 1992-1997; the average radon emanation of the emanometry network per year rises from 9000Bq/m^3 to 22022 Bq/m^3. Hence, the Kangra and Chamba valleys in N-W Himalaya are experiencing a build-up of strain along the major thrust faults during recent years. It is important to monitor radon, helium and other geochemical precursors in the region over a wider network to investigate further the micro-seismicity trends in N-W Himalaya. Talwani *et al.* (1980) also reported a correlation of radon anomalies with microseismicity at Lake Jocassee, South Carolina, USA.

Meteorological parameters like temperature, pressure, wind velocity, rainfall and humidity also affect the radon emanation rate from the soil-gas to some extent (Fig. 3a and b). However, their effect is observed to be negligible in

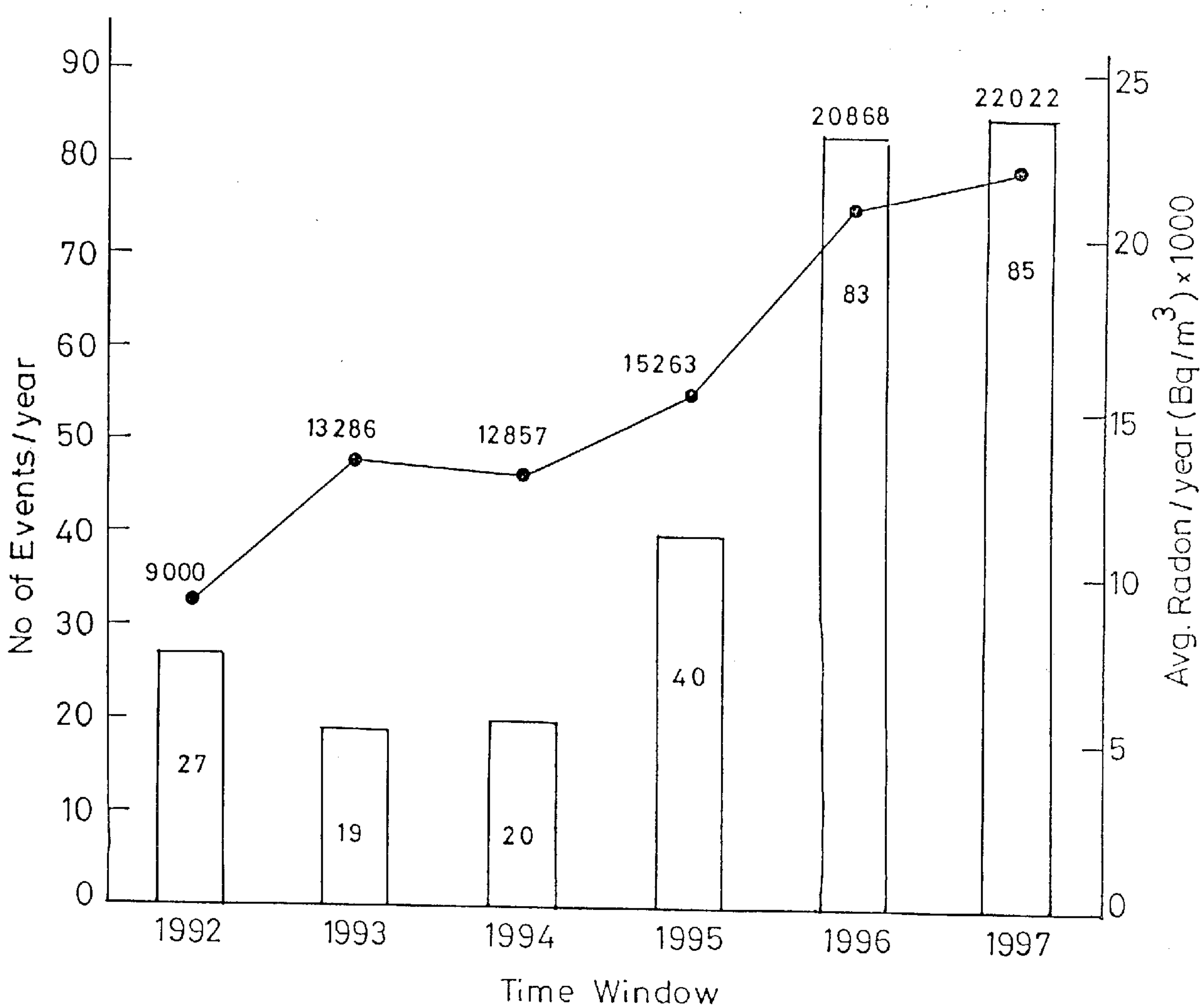

Fig. 2. Microseismic trend in the grid (30-34°N, 74-78°E) during 1992-1997 based on Radon and IMD network data.

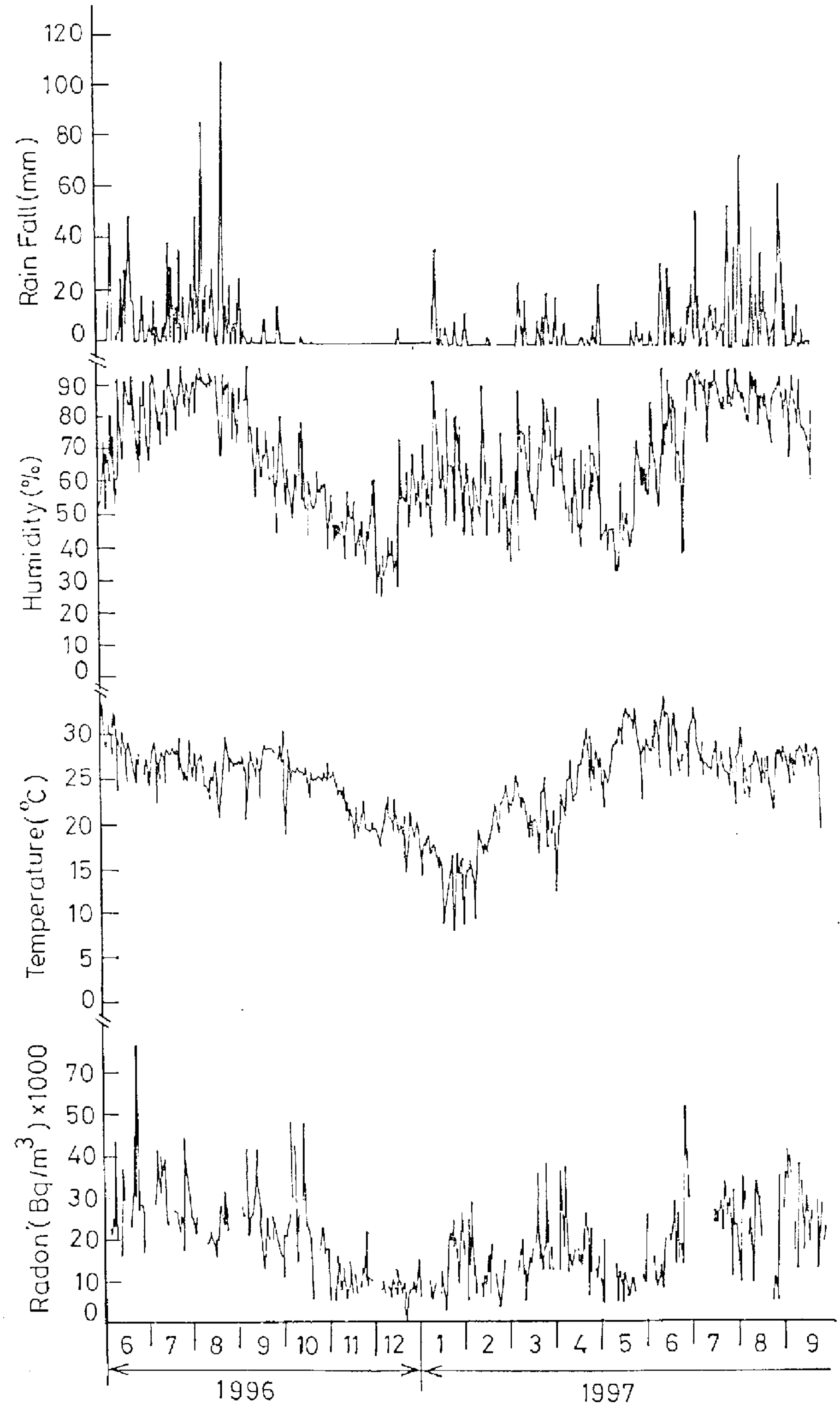

Fig. 3a. Radon data plotted against soil temperature, relative humidity, and rain fall during June 1996 to Sept. 1997 at Palampur.

groundwater. The average values of radon emanometry techniques for soil-gas at Palampur are reported to be 18750 Bq/m^3 with a standard deviation (std) of 10311 Bq/m^3 and a percentage variation coefficient (std/avg) of 55%. Correlation coefficients of radon emanation in soil with different meteorological parameters are summarized in Table 1. The

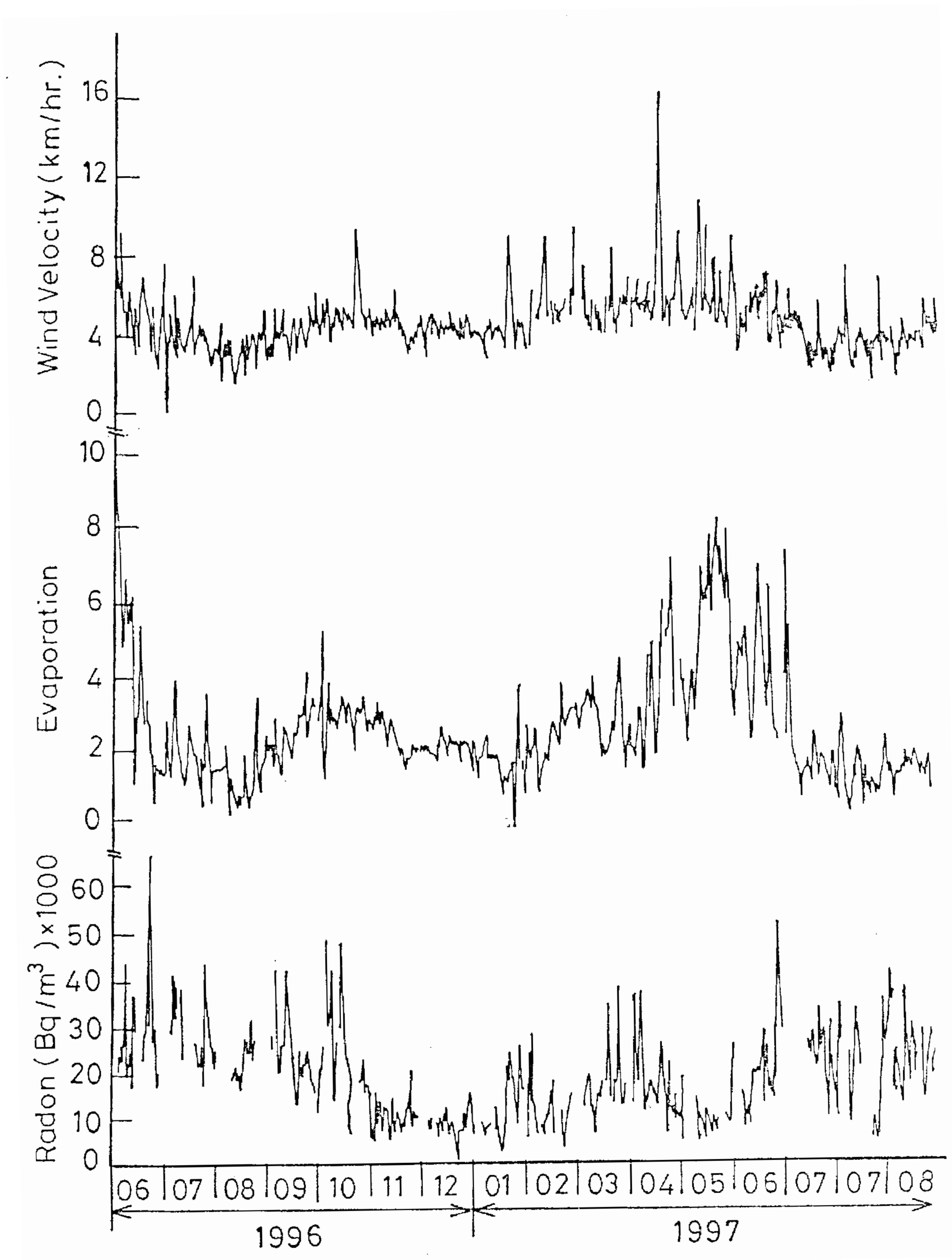

Fig. 3b. Radon data plotted against evaporation and wind velocity during June 1996 to Sept. 1997 at Palampur.

soil temperature is found to be positively correlated with radon emanation. An increase in surface temperature causes the soil -gas radon to expand and escape, and also tends to release the vapour adsorbed to the surface of soil particles. Radon values are generally found to increase in mild rain. When there is heavy rain, the radon value initially falls and then starts rising over a period of some days. This increase may be explained due to the capping effect of wet soil layers at the surface preventing radon from escaping into the atmosphere. High temperature and increase in relative humidity enhance radon emanation, whereas wind velocity has an inverse correlation with it. Strong wind causes the

Table1

Statistical analysis of correlation coefficient of radon data (in soil gas) with different meteorological parameters at Palampur

	Avg	Std. dev.	Percentage variation. coefficient (C%) Std/Avg	Correlation coefficient
Radon (counts/200s)	563	315	56	—
Temperature (^{o}C)	24.43	4.90	20	0.37
Rainfall (mm)	4.95	11.32	229	0.20
Relative humidity (%)	64.72	18.79	29	0.45
Wind velocity (km/h)	4.75	1.57	33	-0.21

upper layer of soil to blow away thus allowing radon to escape into the atmosphere. In general, the meteorological parameters do not have a predominant effect on diurnal variations of radon content in soil as emanometry data is recorded at a depth of 60 cms. Meteorological data was available for Palampur station only, where a meteorological observatory already exists in the campus of the Himachal Pradesh Krishi Vishvavidyala (HPKV), the site of our radon monitoring station. But the weather pattern is almost identical in the two valleys and the data can perhaps be extrapolated to other stations.

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BIBLIOGRAPHY

GHOSH, P. C. and N. S. BHALLA, 1966. A close-circuit technique for radon measurement in water and soil, with some of its applications. Proc. All India Symp. on Radioactivity and Meterology of Radionuclides, A.E.E.T., Bombay, pp. 226-239.

HEINICKE, J., U. KOCH and G. MARTINELLI, 1992. Investigation of the connection between seismicity and $^{222}Rn-CO_2$ content in spring waters at the Vogtland area (Germany): First results. Proc. XXIII General Assembly of the ESC, Prague, v.II,pp. 317-323.

HEINICKE, J., U. KOCH and G. MARTINELLI, 1995. CO_2 and radon measurement in the Vogtland area (Germany) - a contribution to earthquake prediction research. *Geophys. Res. Lett., 22,* 771-774.

LIU, K. K., T. F. YUI, Y. B. TASI and T. L. TENG, 1984/85. Variation of radon content in groundwater and possible correlation with seismic activites in the northern Taiwan. *PAGEOPH, 122,* 231-244.

RAMOLA, R. C., M. SINGH, A. S. SANDHU, S. SINGH and H. S. VIRK, 1990. Use of radon gas as earthquake precursor. *Nucl Geophys., 4,* 275-287.

SEGOVIA, N., M. MENA, J. L. SEIDEL, M. MONNIN, E. TAMEZ and P. PENA, 1992. Short and long term radon -in-soil monitoring for geophysical purposes. *Radiat. Meas., 25,* 547-552.

SEGOVIA, N., S. DE LA CRUZ-REYNA, M. MENA, E. RAMOS, M. MONNIN and J. L. SEIDEL, 1989. Radon-in-soil anomaly observed at Los Azufres geothermal field, Michoacán: A possible presursor of the (M_S =8.1) Mexico earthquake. *Nat. Haz.*, 1, 319-329.

SILVER, P. G. and H. WAKITA, 1996. A search for earthquake precursors. *Science, 273,* 77-78.

SINGH, M., R. C. RAMOLA, B. SINGH, S. SINGH and H. S. VIRK, 1992. Radon anomalies: Correlation with seismic activities in Northern India. Proc. 2nd Int. Workshop on “Radon Monitoring in Radioprotection, Environmental/Earth Sciences, Trieste, Italy, 1991. World Scientific, 199, pp. 359-377.

SINGH, M., N. P. SINGH, S. SINGH and H. S. VIRK, 1988. Measurement of soil gas radon at Amritsar. *Geophys. Res. Bull, 26,* 8-12.

TALWANI, P., W. S. MOORE and J. CHIANG, 1980. Radon anomalies and microearthquakes at Lake Jocassee. *South Carolina. J. Geophys. Res.*, *85*, 3079-3088.

ULOMOV, V. I. and B. Z. MAVASHEV, 1971. Forerunner of Tashkent earthquakes. *Izv. Akad. Nauk Uzb. USSR*, 188-200.

VIRK, H. S., 1986. Radon monitoring and earthquake prediction. Proc. International Symposium Earthquake Prediction-Present Status. University of Poona, Pune, India, pp. 157-162.

VIRK, H. S., 1990. Radon studies for Earthquake prediction, Uranium exploration and Environmental pollution: A review. *Ind. J of Phys.*, *64A*, 182-191.

VIRK, H. S., 1995. Radon monitoring of microseimicity in the Kangra and Chamba valleys of Himachal Pradesh, *India. Nucl. Geophys.*, *9*, 141-146.

VIRK, H. S. and A. K. SHARMA, 1997. Microseismicity trends in N-W Himalaya using radon signals. Proc. 3rd Int. Conf. on Rare gas Geochemistry, Amritsar, India, Dec. 10-14, 1995, 117-135.

VIRK, H. S., A. K. SHARMA and V. WALIA, 1997. Correlation of alpha-logger radon data with microseismicity in N-W Himalaya. *Curr. Sci.*, *72*, 656-663.

VIRK, H. S. and B. SINGH, 1992. Correlation of radon anomalies with earthquake in Kangra valley. *Nucl. Geophys.*, *6*, 293-300.

VIRK, H. S. and B. SINGH, 1993. Radon anomalies in soil-gas and groundwater as earthquake precursor phenomena. *Tectonophysics, 227*, 215-1-224.

VIRK, H. S. and B. SINGH, 1994. Radon recording of Uttarkashi earthquake. *Geophys. Res. Letters., 21*, 737-740.

VIRK, H. S., V. WALIA and A. K. SHARMA, 1995. Radon precursory signals of Chamba earthquake. *Curr. Sci.*, *69*, 452-454.

WAKITA, H., 1996. Geochemical challenge to earthquake prediction. Proc. Natl. Acad. Sci. (USA), 93, 3781-3786.

Annual report on Seismic Activity around Pong , Pandoh , Bhakra and Salal Dams (1992-97). Govt. of India, India Meteorological Department, New Delhi.

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