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Scope of Radon Monitoring for Earthquake-studies in India

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Introduction

Radon emanation and migration in the earth and in the atmosphere have been the subjects of numerous studies in Russia, China, Japan, USA and India. Radon has been exploited for earth science studies, for example, geochemical exploration of uranium (Ramola et al., 1989) and hydrocarbon deposits (Ishankuliev and Tretyakova, 1991), as a tracer of fluid motion in the earth (Varhegyi et al., 1988), as an indicator of faults, and as a possible tool for earthquake prediction. Possible correlation between pre-seismic radon concentration anomalies and actual seismic events were brought to the notice of the scientific community some decades ago. In India, there is a scope for investigating and exploiting radon as a precursor for earthquakes and for exploration of hydrocarbon deposits. This report mainly deals with the investigations carried out in Kangra and Chamba valleys of Himachal Pradesh under Himalayan Seismicity Project of Department of Science and Technology, Govt. of India.

Radon as an earthquake precursor

Okabe, (1956) exploited the precursor and discovered a positive correlation between the daily variation of atmospheric radon content near the ground surface and the local seismicity at Tottori, Japan. The first observation of significant changes in episodic radon content in deep well water prior to Tashkent earthquake of 1966 was reported by Ulomov and Mavashev (1967). Since then anomalous radon changes in groundwater and soil-gas have been reported for several earthquakes at stations as far away as several hundred kilometers from their respective epicentres (Sadvcsky et al., 1972; Liu et al., 1975; Noguchi and Wakita, 1977; King, 1980; Mogro-Campero et al., 1980; Hauksson and Goddard, 1981; Segovia et al., 1986; Virk, 1986; Ghosh et al., 1987). The successful predictions of the Haicheng and Songpan earthquakes in China made people think that perhaps a major breakthrough in earthquake prediction was not very far off. However, this jubilation was short-lived as the success in Haicheng became a failure in Tangshan where a devastating earthquake occurred in 1976.

Radon anomalies and earthquake prediction models

Radon anomalies depend to a large extent on the tectonic disturbance of the host minerals, whereby the surface areas of the microfractures are altered. The origin and mechanism of observed radon anomalies and their relationship to earthquakes are yet poorly understood. According to dilatancy-diffusion model (Nur 1972; Scholz et al., 1973), when regional stress increases, dilation of rock masses could cause an increase either in the surface area of rocks due to cracking, or in the flow rate of pore fluids. Both these processes will enhance the transport of radon from its original enclosures into the groundwater. The tremor due to an earthquake is instrumental in dislodging the suspended radon in the water and creating an anomaly. Radon anomalies can also occur in soil-gas prior to an earthquake when measurements are carried out in an auger hole. Scholz et al., (1973) found that the time of appearance and duration of radon anomaly are roughly proportional to the Richter magnitude of the subsequent earthquake.

King (1978) proposed a compression mechanism for radon release which explains radon anomalies due to an increase in crustal compression before an impending earthquake that squeezes out the soil-gas into the atmosphere at an enhanced rate. It is also observed that radon anomalies frequently, but not always, precede earthquakes. While a radon anomaly may be associated with an earthquake shock, the exact time when the shock will appear cannot be predicted with the available models. However, radon anomaly may be used as a precursor for an impending earthquake in the region.

Radon monitoring techniques

The fluctuations in near surface and groundwtaer radon concentration are monitored using both instantaneous and time-integrated techniques. Track-etch, alpha logger and emanometry techniques have been exploited for long term, short term and instantaneous radon recording, respectively. Physical principles involved in all these techniques are different but one common feature is the detection and recording of alpha particles emitted by radon and its daughters. It is imperative to calibrate all types of radon detectors under similar ambient conditions as prevailing at radon monitorinng sites.

Track-etch technique is quite appropriate for radon detection in the soil-gas because of its low cost, ruggedness, negligible background of spurious signals, and its nature as an integrating measurement. Radon emanometer (type RMS-10), manufactured by ECIL,

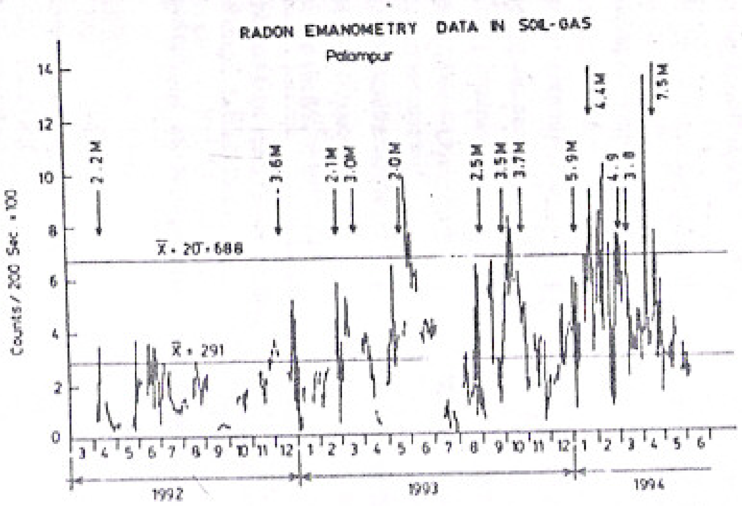

Fig. 1 : Radon activity in Soil-gas and corresponding Seismicity at Palampur

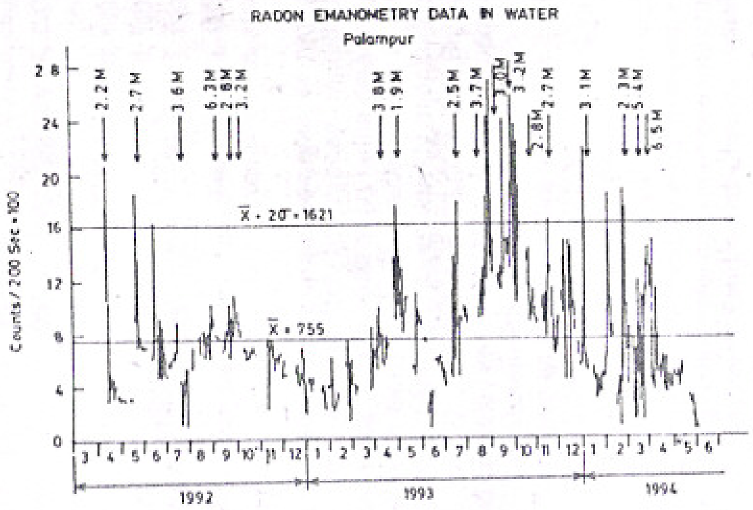

Fig. 2 : Radon activity in groundwater and corresponding Seismicity at Palampur

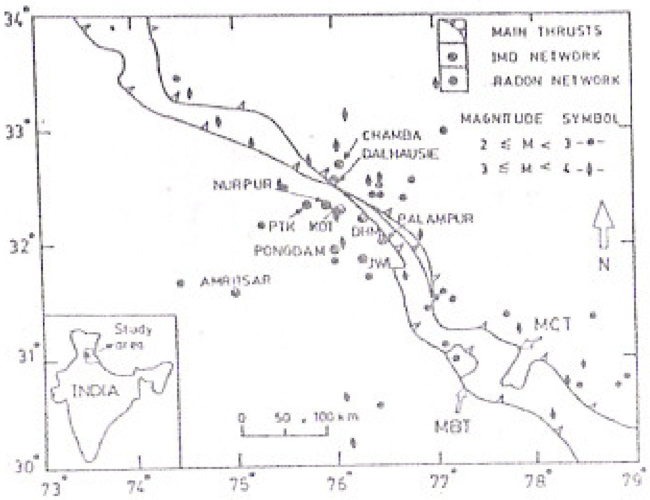

Fig. 3 : Map showing recording stations and microseismic activity

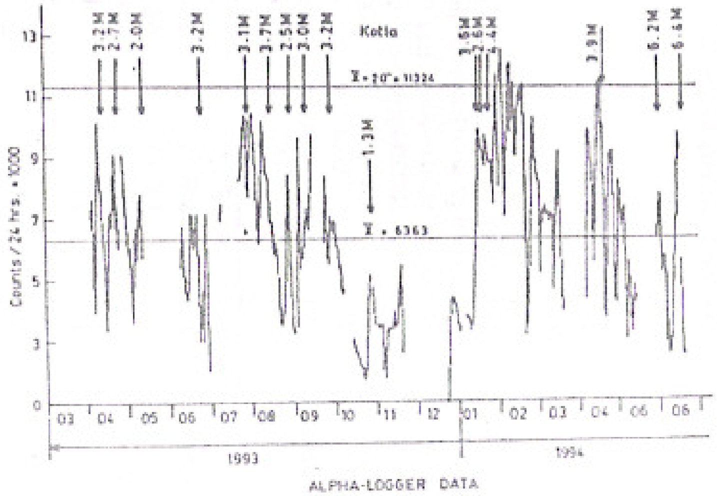

Fig. 4 : Alpha-logger radon data and corresponding Seismicity at Kotla (H.P.)

Table 1
Correlation of Radon anomalies recorded at Palampur with microseismic activity in N - W Himalayas

Date of Radon anomaly	Magnitude (M)	Latitude °N	Longitude °E	Depth	Date of Earthquake
August 30, 1989	2.8	In Chamba area		—	August 31, 1989
December 23, 1989	2.8	In Dharamsala area		—	December 24, 1989
September 02, 1990	4.8	36.40	70.63	33	September 03,1990
September 07, 1990	4.5	37.73	69.70	33	September 08, 1990
October 24, 1990	6.1	35.19	70.63	15	October 25, 1990
November 14, 1990	3.4	30.49	79.27	15	November 17, 1990
December 23, 1990	5.3	33.30	75.65	30	December 25, 1990
January 08, 1991	4.9	33.61	76.01	15	January 10, 1991
January 18, 1991	4.8	33.56	77.53	33	January 20, 1991
January 24, 1991	4.9	37.08	71.16	32	January 26, 1991
January 30, 1991	6.4	36.05	70.49	15	February 01, 1991
June 22, 1991	5.2	32.32	76.68	33	June 23, 1991
July 23, 1991	3.7	32.21	76.42	17	July 24, 1991
August 22, 1991	4.8	36.36	68.80	33	August 23, 1991
October 15, 1991	6.6	30.73	78.80	19	October 20, 1991
December 03, 1991	4.9	36.39	69.30	42	December 04, 1991
April 14, 1992	2.2	31.36	77.67	13	April 11, 1992
May 23, 1992	2.7	31.51	77.17	15	May 26, 1992
July 21, 1992	3.6	31.25	77.82	05	July 21, 1992
April 30, 1993	1.9	30.67	78.44	16	May 01, 1993
July 25, 1993	3.1	30.23	76.13	15	July 30, 1993
August 11, 1993	3.7	30.73	78.79	15	August 15, 1993
August 28, 1993	2.5	32.54	76.76	15	August 28, 1993
Septenmber 17, 1993	3.0	32.84	73.24	18	September 09, 1993
September 28, 1993	3.2	33.43	74.59	15	September 28, 1993

Hyderabad is one of the most sensitive instruments for radon monitoring in soil-gas and groundwater. Alpha-logger (Alpha Nuclear Company, Canada) is quite versatile, as it is a portable, battery-powered microprocessor based data acquisition and control system. An improved version, alpha-logger 611 system, can record radon alpha counts in 15 minute intervals over a period of 40 days non-stop. The detailed description of the techniques is given elsewhere (Virk and Singh, 1992, 93, 94).

Correlation of radon anomalies with seismic events

For the sake of definition, we define the radon anomaly as a positive deviation that exceeds the mean radon level by more than twice the standard deviation. The fact that an impulsive radon increase is recorded under a variety of weather conditions suggests that the radon anomaly is more likely to be caused by some crustal disturbance rather than by the atmospheric disturbance.

Daily and weekly measurements of radon in soil-gas and groundwater have been recorded at Palampur since August 1989 using radon emanometry and track-etch techniques. The mean values of radon concentration from daily and weekly monitoring in soil-gas are 27.50 ± 2.5 and 28.48 ± 3.0 Bq/l with standard deviation of 11.49 and 25.81 Bq/l respectively. The daily measurements in groundwater using radon emanometry give an average value of 48.86 ± 3.0 Bq/l with a standard deviation of 14.89 Bq/l.

Under Himalayan Seismicity Programme of DST, the range and scope of the activity were extended, eight radon recording stations along the main boundary thrust (MBT) of Himalayas in Kangra and Chamba valleys of Himachal Pradesh were setup in 1992. The area is showing enhanced microseismicity and about 50 earthquakes of magnitude 2-4 M have been recorded in the time span of April 1992 to September 1993 in the grid (30-34°N, 73-79°E) by seismic network being operated by Indian Meteorological Department, New

Delhi. It is interesting to note that radon emanometry data recorded at Palampur (Table 1) also show 25 anomalies correlatable to some of these events. Time-series radon emanometry data for Palampur station is shown for reference (Figs. 1-2).

Alpha-logger stations became operational after March 1992 in Himachal Pradesh and Punjab. Continuous monitoring of radon data has become possible at several stations, viz., Palampur, Jawalamukhi, Dalhousie, Chamba, Kotla and Pathankot. Radon anomalies are correlatable with seismic events showing a definite trend along the MBT (Figs. 3 & 4)

Concluding Remarks

From the soil-gas and groundwtaer radon monitoring results of the past decade, it may be concluded that radon anomalies are generally associated with seismic activity within a 500 km radius of recording station for earthquakes of magnitude 5 or more. Radon emanation is sensitive to lower magnitude events (2 - 5 M) within a radius of 200 km along the MBT. Another interesting feature of the study is that radon anomalies in both the media show perfect correspondence. This augurs well for accepting radon as an earthquake precursor even though peak radon values are widely different in both the media.

The northern boundary of the Indian sub-continent extending from the Hindukush in the west to hills of Assam and Burma in the east constitutes a vast zone of high seismicity where the Indian plate collides against the Eurasian plate. Hence it is of utmost importance to monitor radon, preferably alongwith helium and CO_2, along the major thrust faults of the Himalayas. It is also significant to select radon monitoring sites carefully, standardise experimental procedures and instruments to record data, perform rigorous statistical data analysis in order to identify radon signals from the noises and conduct theoretical and experimental studies of the physical basis of tectonically induced radon anomalies in a seismic zone.

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