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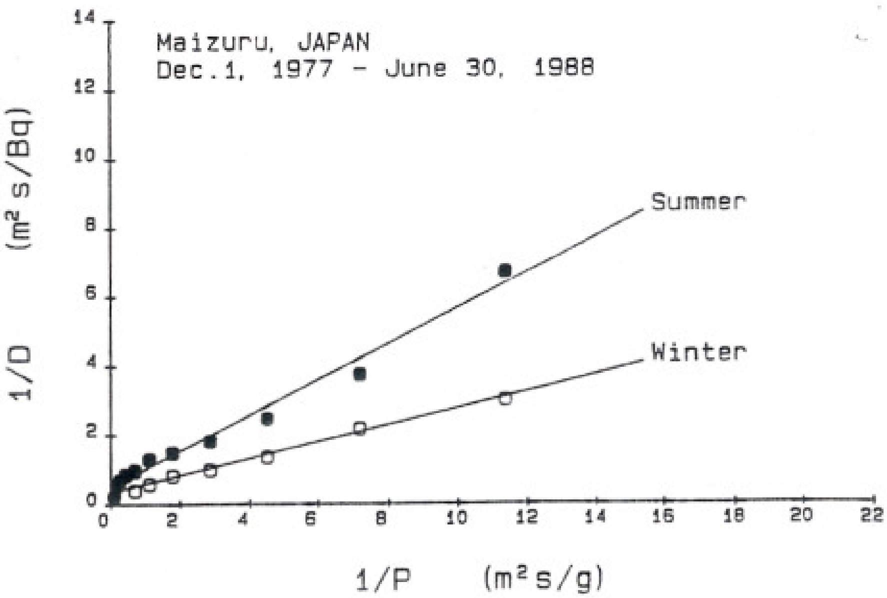

Fig. 1. Relationship between the reciprocal of precipitation rate $1/P$ and that of deposition rate $1/D$ of Ra(B + C).

Assuming $d(AH)/dt = 0$, from Eq. (1) we obtain

$$AH = \frac{SH}{\lambda + \Psi} \quad . \tag{2}$$

The precipitation rate P is given by the equation

$$P = \Psi MH \ , \tag{3}$$

and the deposition rate D of Ra(B + C) can be written as

$$D = \Psi AH \exp(-\lambda T) \ , \tag{4}$$

where

P = precipitation rate ($g/m^2 \cdot s$)

D = deposition rate of Ra(B + C) ($Bq/m^2 \cdot s$)

M = liquid-water content of cloud (g/m^3).

Substituting Eqs. (3) and (4) into Eq. (2) yields

$$\frac{1}{D} = \exp(\lambda T)\left(\frac{M}{S/\lambda} \cdot \frac{1}{P} + \frac{1}{SH}\right) \quad . \tag{5}$$

DATA AND ANALYSIS

Table I presents some available data on the Ra(B + C) concentration in precipitation and the precipitation rate, which has been reported by many researchers in various parts of the world. Figure 1 shows the relationship between the reciprocal of the precipitation rate $1/P$ and that of the deposition rate $1/D$, which are calculated from our data in Table I. The slope $(\lambda M/S)\exp(\lambda T)$ and the intercept $(1/SH)\exp(\lambda T)$ in Eq. (5) can be determined by the least-squares method for each data group in Table I because an approximately linear relationship exists between $1/P$ and $1/D$ for each, similar to Fig. 1.

CONCLUSIONS

Table I gives cloud parameters, such as MH, SH, $(S/\lambda)/M$, and Ψ, estimated with the present model. These values are consistent with common views on cloud physics. This result suggests that the model is convenient for obtaining cloud information using the radon daughter in precipitation as a tracer.

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4. P. E. DAMON, P. K. KURODA, "On the Natural Radioactivity of Rainfall," *Trans. Am. Geophys. Union*, **35**, 208 (1954).
5. C. RANGARAJAN, C. D. EAPEN, "Some Observations on the Concentrations of Short-Lived Decay Products of Radon and Thoron in the Monsoon Rains of Bombay, India," *J. Geophys. Res.*, **90**, *D5*, 8155 (1985).

4. Radon Measurements for Earthquake Prediction in Northern India, *Baljinder Singh, H. S. Virk (Guru Nanak Dev Univ–India)*

Earthquake prediction is based on the observation of precursory phenomena, and radon has emerged as a useful precursor in recent years. In India, where 55% of the land area is in active seismic zones, considerable destruction was caused by the earthquakes of Kutch (1819), Shillong (1897), Kangra (1905), Bihar-Nepal (1934), Assam (1956), Koyna (1967), Bihar-Nepal (1988), and Uttarkashi (1991). Radon (^{222}Rn) is produced by the decay of radium (^{226}Ra) in the uranium decay series and is present in trace amounts almost everywhere on the earth, being distributed in soil, groundwater, and lower levels of atmosphere. The purpose of this study is to find the value in radon monitoring for earthquake prediction. Recording stations were set up at Guru Nanak Dev University in Amritsar, India, in 1984 and at Himachal Pradesh Krishi Vishav Vidyalya, Palampur in the Kangra Valley for Himachal Pradesh in 1989. Radon monitoring was carried out at sites free from uranium mineralization to reduce background effects.

Radon emission is very sensitive to environmental disturbances and is influenced by meteorological and seasonal variations that must be understood to discriminate between a genuine signal and noise. To eliminate the effects of spurious fluctuations, meteorological variables such as air and soil temperature, barometric pressure, wind velocity, humidity, and rainfall are continuously recorded using appropriate instruments. A correlation matrix is computed for the entire data set of radon emission and meteorological variables. We find that radon emission shows a positive correlation to both temperature and wind velocity and a negative correlation to rainfall, humidity, and barometric pressure.

The temporal variation in soil gas recorded at Amritsar using different techniques is shown in Fig. 1 and that in soil gas and groundwater recorded at Palampur is given in Figs. 2 and 3.

Daily and weekly measurements in soil gas recorded at Amritsar indicate an average value of radon concentration of 6.03 ± 0.15 and 23.5 ± 0.3 Bq/ℓ with standard deviations of 2.89 and 17.2, respectively. The average value of radon concentration recorded at Palampur using daily and weekly measurements is 27.5 ± 2.5 and 28.48 ± 3.0 Bq/ℓ with standard deviations of 11.49 and 25.81, respectively. The average value of daily radon concentration in groundwater in Palampur is 48.86 ± 3.0 Bq/ℓ with a standard deviation of 14.89.

The recorded anomalies at Amritsar and Palampur followed by seismic events are given in Table I. An empirical criterion is adopted in this paper to define the radon anomaly as the positive deviation that exceeds the mean radon level by more than twice the standard deviation. From October 1988

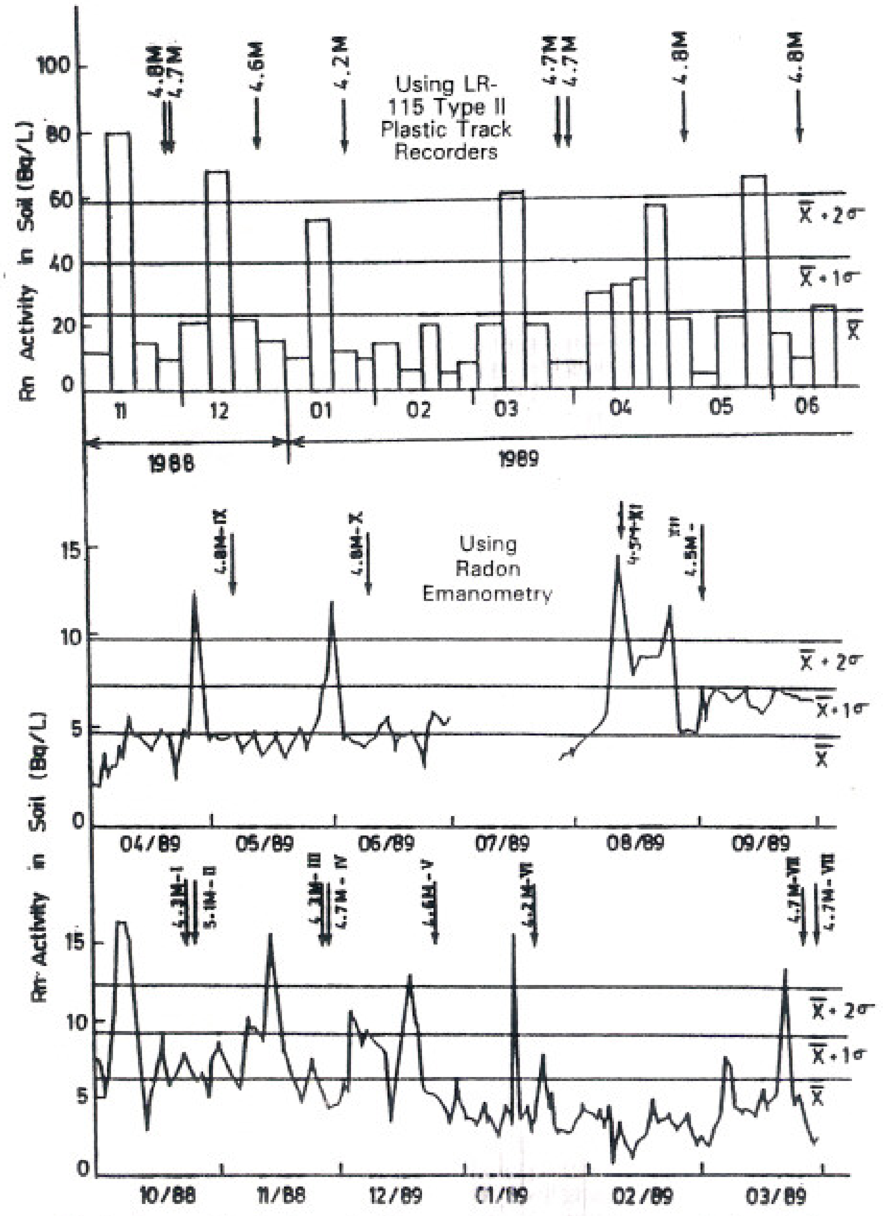

Fig. 1. Temporal variations of soil gas radon concentration recorded at Amritsar.

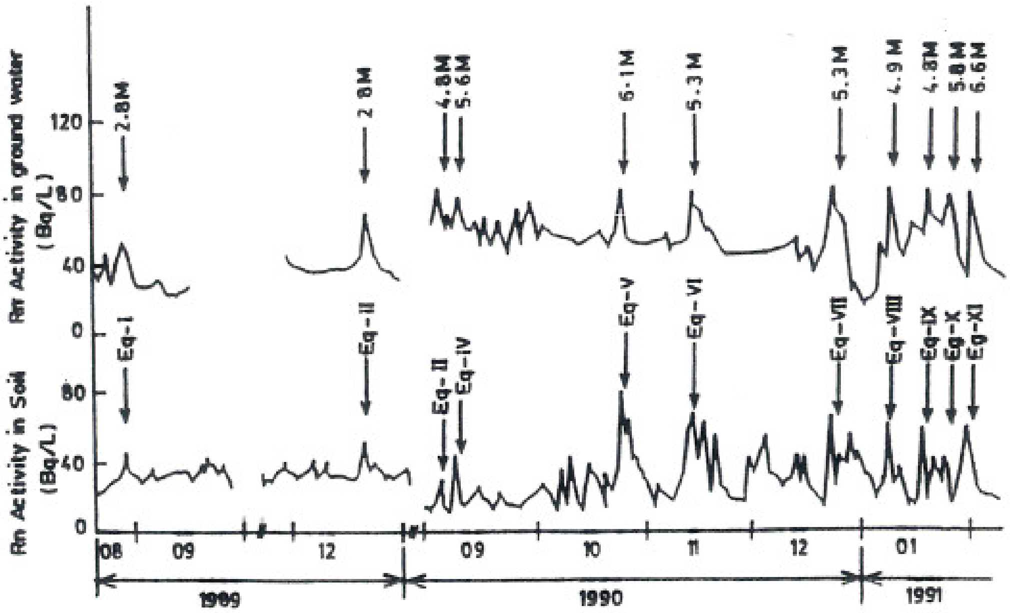

Fig. 2. Temporal variations in soil gas and groundwater radon concentration recorded at palampur using radon emanation.

TABLE I

Recorded Anomalies of Amritsar and Palampur

Date of Seismic Event	Latitude	Longitude	Magnitude	Date of Radon Anomaly in Soil Gas and Groundwater
Recorded at Amritsar				
October 24, 1968	36.4°N	69.9°E	4.3	October 7, 1988
October 26, 1988	36.5°N	70.8°E	5.1	
November 27, 1988	35.8°N	70.5°E	4.3	November 4, 1988
November 28, 1988	36.5°N	70.7°E	4.7	
December 25, 1988	36.5°N	70.9°E	4.6	December 19, 1988
January 19, 1989	36.8°N	70.7°E	4.2	January 14, 1989
March 28, 1989	36.4°N	70.5°E	4.7	March 23, 1989
March 31, 1989	36.9°N	69.5°E	4.7	
May 6, 1989	36.5°N	70.1°E	4.8	April 27, 1989
June 6, 1989	36.4°N	70.7°E	4.8	May 31, 1989
August 12, 1989	36.4°N	70.3°E	4.5	August 12, 1989
September 5, 1989	36.0°N	70.4°E	4.5	August 25, 1989
Recorded at Palampur				
August 31, 1989	In Chambra area		2.8	August 30, 1989
December 23, 1989	In Dharamsala area		2.8	December 24, 1989
September 3, 1990	36.40°N	70.63°E	4.8	September 2, 1990
September 8, 1990	27.48°N	66.10°E	5.6	September 7, 1990
October 25, 1990	35.19°N	70.63°E	6.1	October 24, 1990
November 16, 1990	27.43°N	66.10°E	5.3	November 14, 1990
December 24, 1990	33.30°N	75.65°E	5.3	December 23, 1990
January 10, 1991	33.61°N	76.0°E	4.9	January 8, 1991
January 20, 1991	36.65°N	77.3°E	4.8	January 18, 1991
January 26, 1991	36.0°N	70.1°E	5.8	January 24, 1991
February 1, 1991	36.3°N	70.2°E	6.6	January 30, 1991