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Measurement of soil gas radon at Amritsar

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ABSTRACT

Radon signals are continuously monitored for several months over a single non-mineralized site. The recorded emanations showed the impulsive increase considerably larger than the meteorologically induced variations. The anomalous radon values served as precursory signals to some of the earthquakes that followed in the region.

INTRODUCTION

In recent years, radon has been used as a possible tool for earthquake prediction. (Sadvosky *et. al.,* 1972, Mogro-Campero and Fleischer, 1977, King. 1978). The first observation of significant changes in episodic radon content in deep well water prior to Tashkent (USSR) earthquake in 1966 is reported by Ulomov and Mavashev (1967). Since then the radon isotopes have been extensively monitored in many seismic areas of the world for the purpose of earthquake prediction. Anomalous radon changes in groundwater and soil-gas during earthquakes at favourably located stations as far away as several hundred kilometers from their respective epicenters have already been reported by some authors (King, 1980, Birchard and *Libby,* 1980, Mogro-Campero *et. al.*, 1980, Shapiro *et. al.*, 1980 Teng, 1980, Jiang and Li, 1981). It has been noted that both the spatial and sequential measurements will probably be needed for earthquake prediction using radon signals. The radon emanation at a single non-mineralized site is continuously monitored in an effort to detect fluctuations in radon concentration occurring in both time and space. This paper reports the results of the investigations carried out for the period March, 1984 to September, 1986.

EXPERIMENTAL TECHNIQUE

The time variation study in radon emission is recorded with short and longterm integrated techniques using Alphameter-400 and the Track Etch Methods, respectively. Alphameter-400 (Alpha Nuclear Company, Canada) contains 400 mm^2 diffused junction (DJ) detector for the detection of alpha particles with its associated electronic circuits. Alpha particles striking the active surface of the detector are counted and data stored until a read mode is initiated. Its sensitivity is such that a 24 hrs exposure gives sufficient counts in most of the soils (Gaucher, 1976, Warren, 1977). The continuous measurement of radon was carried out in the soil of G.N.D. university campus area, Amritsar. The detector unit is placed in the auger hole about 50 cm in depth (Fig.1) for a day and accumulated alpha activity read the next day.

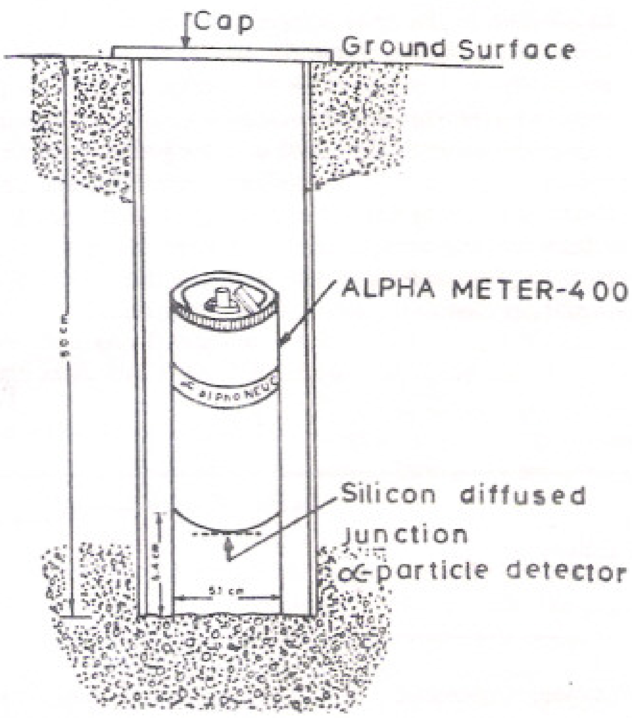

Fig.1 Schematic diagram showing cross-section of bore hole logs with soil structure.

An integrated radon flux in soil gas over monthly time interval is recorded using the Radon-Thoron discriminator with alpha sensitive plastic track detector (LR-115 Type 2) as described else where (Singh *et. al.*, 1984; Ghosh and Soundararajan, 1984). The retrieved detector films are then chemically etched in 2.5 N NaOH solution at 60°C for 120 min and the enlarged α-particle tracks are counted per unit area. The measured track density is then assumed to be proportional to the average radon concentration.

The meteorological variables viz. temperature wind velocity humidity barometric pressure and rainfall are continuously measured using maximum-minimum thermometer, annemometer, Fortins Barometer and raingauge, respectively at Irrigation and Power Research Institute,Amritsar (India) for correlation purposes.

RESULTS AND DISCUSSION

A correlation matrix analysis is computed for the entire data set of radon emission and secondary influences. In addition to the daily interval data, an average radon concentration is calculated for one, two and four weeks period. Table 1 contains the correlation coefficients for radon with each of the meteorological variables. The radon emission is strongly correlated with temperature and wind velocity. An increase in surface temperature not only causes soil air to expand and escape but also tends to release the vapour species absorbed to the surface soil particles. The increasing wind velocity accelerates the flow of soil gas thereby increasing the radon content.

A negative correlation is observed between the radon emission and the barometric pressure (Table. 1). A varying barometric pressure may exert a pumping effect on the soil-gas. An increase in atmospheric pressure tends to push the radon poor atmospheric air into the ground

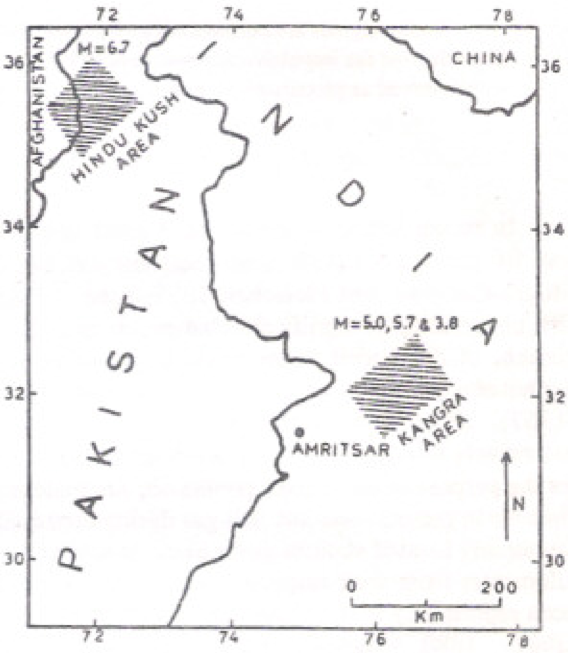

Fig. 2 Location of measurement site (dot) and epicenters of earthquakes (shaded rectangular areas).

Table 1
Correlation of soil gas radon with meteorological variables

Variables	Correlation Coefficients				
	Alphameter-400				SSTD
	Daily	7 days	15 days	30 days	30 days
Maximum temperature	0.36	0.40	0.44	0.52	0.47
Minimum temperature	0.11	0.20	0.24	0.30	0.26
Barometric pressure	-0.21	-0.23	-0.26	-0.29	-0.25
Wind velocity	0.42	0.64	0.63	0.85	0.52
Humidity	0.02	-0.04	-0.05	-0.12	-0.32
Rainfall	-0.09	-0.11	-0.08	0.05	-0.09

resulting in the fall of radon concentration while the decrease in pressure lets the radon rich gas escape from the deeper part of the ground. The radon release also shows a week inverse relation with the humidity and rainfall. This is due to the presence of high humidity and moisture in the soil which dissolves the diffusing radon and deep percolation of rain water removes the radon by transport mechanism (Gableman, 1972, Ghosh and Bhalla, 1981).

Several impulsive radon increases with amplitudes much larger than the background level are recorded under different weather conditions with Alphameter-400 and Track Etch Method (Fig 3 and 4) respectively. The

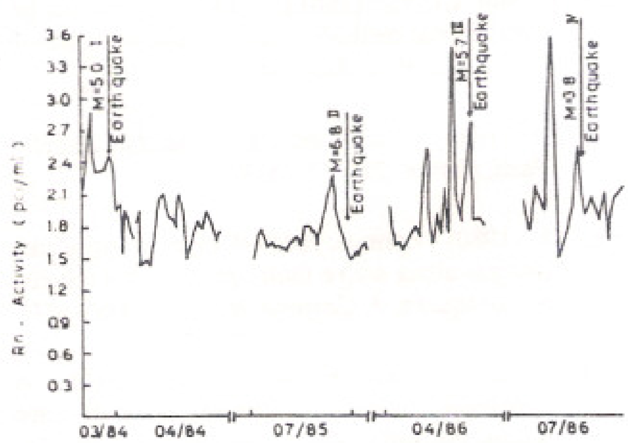

Fig. 3 Radon time series indicating the recorded earthquake events measured with Alphameter-400.

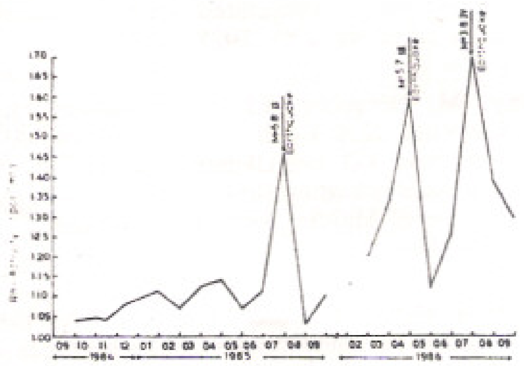

Fig. 4 Radon time series indicating the recorded earthquake events measured with track etch method.

recorded radon concentration varies greatly with time. First abrupt increase in the soil gas radon (geneally three times the average flux) is recorded in the last week of March, 1984 (Fig. 3). No rainfall or unusual barometric presure is recorded during this time but an earthquake of magnitude 5.0 on Richter scale occurred on March 29,1984 (I) whose epicentre was about 200 km away in North East direction (Kangra area) from the recording station at Amritsar (Fig. 2). The peak value a few days before an earthquake suggests that the radon increase is more likely to be caused by some crustal disturbance than by atmospheric disturbance.

Second earthquake of magnitude 6.8 occurred on July 29, 1985 (II) whose epicenter was about 500 km away in North-West direction (lat. 35.3°N and long 71.5°E in Hindu Kush area) from the recording station at Amritsar (Fig. 2). Daily monitoring of radon with Alphameter-400 recorded the low level peak (Fig. 3), as the season's heaviest rainfall occurred during that period before the earthquake. But the peak value almost twice the average radon flux is observed with Track Etch Method (Fig. 4) which records the signal from the greater depth and also smooths the short term noise.

Another impulsive radon increase is recorded on April 21, 1986 (III) at the same site following the heavy rainfall (Fig. 3). This increase was followed by an earthquake of magnitude 5.7 on April 26, 1986 whose epicenter was about 200 km away in North-East direction (lat . 32.09°N and long. 76.311°E in Kangra area) from the recording station at Amritsar (Fig. 2). The radon anomaly is three times the average flux as observed with the Track Etch Method (Fig. 4).

The fourth noticeable radon anomaly occurred in August, 1986 (IV) following the heavy rain fall. The peak level is estimated to be three times the average level (Fig. 3 and 4). An earthquake of magnitude 3.8 occurred on July 17, 1986 whose epicenter was about 150 km in North-East direction (Kangra area) from the recording station Amritsar (Fig. 2)

From the available data it is inferred that the observed radon anomalies are more likely to be related with seismicity than atmospheric disturbances. it is evident that the recorded radon concentration varies greatly in both space and time. The temporal variations appear to consist of short-term local fluctuations superimposed on episodic changes that occur synchronously. The anomalously high radon concentration may be due to an increase in crustal compression impending an earthquake that squeezes out the soil-gas into the atomsphere at an increased rate (King, 1978). An increased outgassing rate may perturb the vertical subsurface radon concentration profile (radon concentration is known to increase rapidly with depth), such that the deeper soil gas containing more radon is brought upto the detection level.

CONCLUSION

Similar type of results were reported by other workers (Mogro-Campero and Fleischer, 1977; King, 1978, 1980, Shapiro *et al.* 1980). They observed the precursor time usually in the range 0.1 to 10 days. We also recorded the precursor time within this range. On the basis of our results as well as those of other workers reported in literature it is concluded that the radon measurement techniques may prove useful for the prediction of earthquakes.

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REFERENCES

Birchard, G.F. and Libby, W.F. (1980)- Soil radon concentration changes preceding and following four magnitude 4.2-4.7 earthquakes on the San Jacinto Fault in Southern California, *J. Geophys. Res.*, 85, 3100-3106.

Gableman, J.W. (1972) - Radon emanometry of starks salt dome, Calcasiey Parish, Lowsiana, *U.S. Atomic Energy Commission Report, RME*-414,75.

Gaucher, E. (1976) - Alphameters: uranium prospecting by radon detection, *Canadian Mining Journal*, 97, 28-34.

Ghosh, P.C. and Bhalla, N.S. (1981) - On the behaviour and measurement of thoron (Rn^{220}) in soil, *Ind. J. of Earth Sci.*, 8, 1-9.

Ghosh, P.C. and Soundararajan, M (1984) - A technique for discrimination of radon (222_{Rn}) and thoron (220_{Rn}) in soil gas using solid state nuclear track detectors, *Nucl. Track and Rad. Meas.*, 9, 23-27.

Jiang, F. and LI, G. (1981) - The application of geochemical methods in earthquake prediction in China, *Geophys. Res. Lett.*, 8, 469-472.

King, C.Y. (1978) - Radon emanation on San Andreas Fault, *Nature*, 271, 516-519.

King, C.Y. (1980) - Episodic radon changes in subsurface soil gas along active faults and possible relation to earthquake, *J. Geophys. Res.*, 85, 3065-3078.

Mogro-Campero, A. and Fleischer, R.L. (1977) - A hypothesis for long distance migration of radon within the earth, *Earth Planet. Sci. Lett.*, 34, 321-325.

Mogro-Campero, A., Fleischer, R.L. and Likes, R.S. (1980) - Changes in subsurface radon concentration associated with earthquake, *J. Geophys. Res.*, 85, 3035-3057.

Sadvosky, M. Nersesov, I.L. Nigmatullaev, S.K. Latynina, L.A. Lukk, A.A., Semenov, A.N., Simbireva, I.G. and Ulomov, U.I. (1972) - The processes preceding strong earthquakes in some regions of Middle Asia, *Tectonophysics*, 14, 295-307.

Shapiro, M.H. Melvin, J.D. and Tombrello, T.A. (1980) - Automated radon monitoring at a hard rock site in the southern California transverse ranges, *J. Geophys Res.*, 85 3058-3064.

Singh, M. Singh, N.P., Singh, S. and Virk, H.S. (1984) - Radon thoron estimation using LR-115 plastic track detectors, *Nucl. Tracks and Rad. Meas.*, 8, 415-418.

Teng, T. (1980) - Some recent studies on ground water radon content as an earthquake precursor, *J. Geophys. Res.*, 85, 3089-3099.

Ulomov, V.I. and Mavashev, B.Z. (1967) - A precursor of a strong tectonic earthquake, *Dokl. Akad. Sci. USSR Earth Sci. Sect.*, 176, 9-11.

Warren, R.K. (1977) - Recent advances in uranium exploration with electronic alpha cups, *Geophysics*, 42, 982-989.

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Teng, T. (1980) - Some recent studies on ground water radon content as an earthquake precursor, *J. Geophys. Res.*, 85, 3089-3099.

Ulomov, V.I. and Mavashev, B.Z. (1967) - A precursor of a strong tectonic earthquake, *Dokl. Akad. Sci. USSR Earth Sci. Sect.*, 176, 9-11.

Warren, R.K. (1977) - Recent advances in uranium exploration with electronic alpha cups, *Geophysics*, 42, 982-989.

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