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Radon Time Series and Earthquake Signals—a Study by SSNTD at Matigara (Darjeeling), India

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Abstract

A survey of radon concentration in the soil gas in order to get premonitory signal of earthquakes is being carried out by us since last 4 years in Kolkata, West Bengal, India—which is known to be situated at non-active fault zone and since last 2 years in an active fault zone—Jalpaiguri (26°32′N, 88 °46′E), West Bengal. In extension of our work we have started the experiment in another active fault zone: Matigara, Darjeeling (26º43' N, 88º23'E), West Bengal, India, to have more confirmatory signal. We present the description of signal of the terrestrial gas ^{222}Radon observed for a period of more than one year at a depth of 70 cm in the soil using passive detector –Solid State Nuclear Track Detector (SSNTD). The time series of radon shows a distinctive anomalous fluctuation prior to seismic events that occurred within 1000 km from the measuring site. The results are obtained at two fault zone sites are compared and the present analysis provides further evidence in favour of using radon signal as a precursor of earthquake.

Introduction

Terrestrial gases in soil gas or groundwater have been studied in different fault regions all over the world in search of premonitory changes useful for earthquake prediction. Among all the isotopes Radon222 (^{222}Rn) is the most significant contributor in gas concentration. The displacements that produce an earthquake are assumed to represent the premonitory strains. Prior to an earthquake, the build up of stress effects the strain field within the crust. The radon gets effected by opening or closing of cracks resulting releasing or confining the gas from the or into the deep earth. Crustal stress change creates new solid-fluid interfaces causing more emanation of radon. Radon gas in rocks partly remains in the solid matrix and partly moves to pore fluids where it migrates through interconnected pores, fissures by diffusion and fluid flow (King, 1986). The out-gassing process from the earth crust is not uniform in spaces and also is controlled by the distribution and stress conditions of fractures in crust. At the same time the emanation rate of ^{222}Rn seems to be capricious— influenced by other physical factors like the condition of the soil, its porosity, temperature, moisture content, atmospheric pressure (UNSCEAR 1982, 1988). The spatial association of high radon emanation with active faults indicates that the faults have major paths in the crust for radon gas to come out to the atmosphere (King, 1986). Quite a few years before studies have been started in connection with radon emanation and seismic activity all over the world. Hatuda preformed a study in 1953 at active fault zone at Japan (Hatuda, 1953). In 1956, Okabe discovered that there is a positive correlation between the daily change of atmospheric radon concentration near ground surface and local seismicity occurred at Tottori, Japan (Okabe, 1956). In later years several important works have been performed all over the world on prediction of earthquake by radon anomaly observation (Israel and Bjornsson, 1967; King and Slater, 1978; Honkura and Isikara, 1991; Monnin and Seidel, 1991; Zmazek *et al.,* 2002; Crockett *et al.,* 2006).

Since in active faults the tectonic strain gets amplified, those areas are sensitive to tectonic stress change and thus suitable for choosing the site for earthquake prediction programme. In the previous paper in this serial study (Ghose *et al.,* 2007), we have described an analysis of radon fluctuation surveyed over a non-active fault zone—Kolkata (22°32′N, 88 °24′E), India. We have correlated the radon anomaly peak with the earthquakes that occurred within 1000 km of the site and had distinct precursor peak before seismic events. As the study is more relevant to carry in seismic fault zone, we have extended our work to other two stations –Jalpaiguri and Matigara, situated in active fault area in Himalayan foothills. At Jalpaiguri (26°32′N, 88 °46′E) site, the work is being carried over since September 2006 and the results obtained so far have been communicated. In further extension we have started our research programme at Matigara from September 2007, which is more close to Himalayan region. In the present study, we present the time series of radon concentration with its fluctuation observed at Matigara, for the period of September, 2007 to November, 2008. In many cases, clear pre-signature of earthquake has been observed. The result observed at Jalpaiguri and Matigara has also been compared corresponding to earthquakes.

Experimental Method

The track etch method has been applied here for radon monitoring by the following procedure. In this case we have used CR-39 plate – a useful solid state nuclear track detector (SSNTD) for registering the alpha tracks generating from radon gas. The detector was obtained from Page Moulding Pershore Ltd., England. A container of dimension of 4.7 cm in height, 6.3 cm of diameter at the open end and 5.9 cm diameter at the closed end. The CR-39 plate of size 1cm x 1cm was attached inside the bottom i.e. closed end of the container and was then covered with semi-permeable membrane (figure1). This membrane allows only radon to flow into the container. The container containing the SSNTDs was placed 0.7 m deep in the soil at measuring site. Silica gel was kept surrounding the container inside the hole to absorb excess moisture. The plates were exposed to the soil gas for two days (48 hours). The retrieved plates were chemically etched in 6N NaOH solution at 70^0 C for 6 hours, to enlarge the alpha tracks registered for making them visible under microscope. The etched plates were washed under the cold water for 20 minutes and then the number of tracks in the plates was counted with the help of Carl-Zeiss Microscope with 10X ocular lens. Finally the track density *i.e.* radon count / sq cm was calculated in each plate. In the present communication, the result is shown in tack density. As it is a comparative assessment, the density has not been converted to conventional concentration unit.

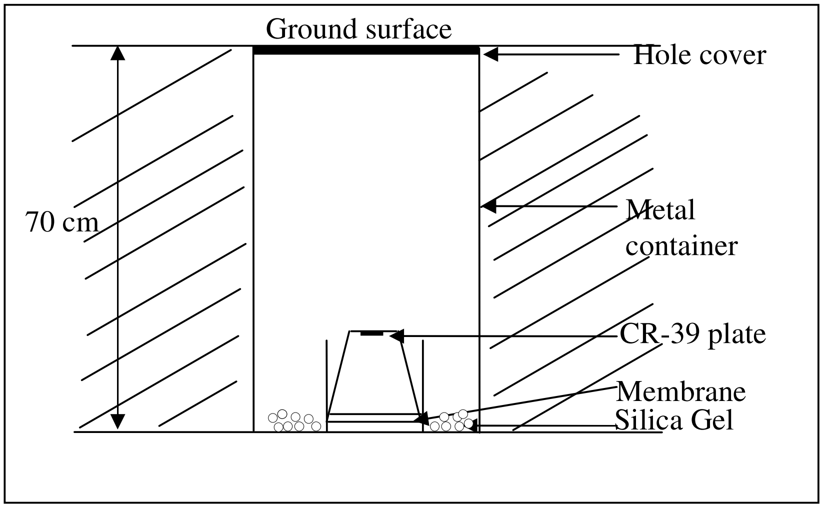

Fig. 1: Experimental arrangement for radon monitoring

Result and discussion

The time series of radon concentration (track/sq cm) over the mentioned period has been shown in figure 2 and 3 observed at site Matigara and Jalpaiguri respectively. There are some discontinuities in series as due to some unavoidable reasons, data at Matigara was not possible to collect. The logging of water at measuring site is one of the main reasons among them. The solid and dotted lines in the figures indicate the average radon concentration ($\overline{X}$) and radon concentration deviated from average concentration ($\overline{X} \pm n\sigma$, n=1,2,3…, σ =standard deviation). The detail of the observation has been given in Table 1. No data was available in April, 2008 at Matigara site and again during rainy season –June-Sept'08. Exposure of plates was not possible due to excess water logging at measuring site. The observations made are listed as follows:

1. The distinct peak showing radon anomaly has been observed corresponding to seismic events occurred on 18th September'07, 29th October'07, 7th December'07, 12th January'08, 26th February'08, 13th March'08, 29th May' 08 during the observational period. The precursor time varies from 2-24 days.
2. In some cases post-cursor peak has been observed instead of pre-signal as after 18th September'07, 7th December'07, 12th January'08 quakes. The radon anomaly occurred 1-6 days after those events. This may be due to the aftershocks pertaining after main shock.
3. The radon anomaly was 2-3σ in all the cases which may be considered as significant signal of seismic activity.
4. Jalpaiguri and Matigara sites are close to each other and both are situated in active fault zone. So a comparative analysis of the observations made at two sites has been done. Apart from April, 2008 (data not available at Matigara site), in some cases there are distinct signal of earthquake at both the places. But in few cases (18th September'07, 7th December'07, 12th January'08 quakes) though pre-signal was observed at Jalpaiguri, whereas it was post signal at Matigara.
5. In some cases anomalous radon peak was observed at Matigara (7th December'07, 26th February'08 EQ), whereas no signal was observed at Jalpaiguri site. The reverse has also been observed. No anomaly was seen at Matigara, where 2-3σ radon anomalies occurred at Jalpaiguri (7th, 29th November 2007

EQ). For 10th Nov'08 EQ, no anomalous radon signature was seen at both the sites, though it occurred within 1000 km.

6. The precursor time (T) has no particular range for the two places—in some cases T is greater at Matigara than that at Jalpaiguri and in some cases vice versa.

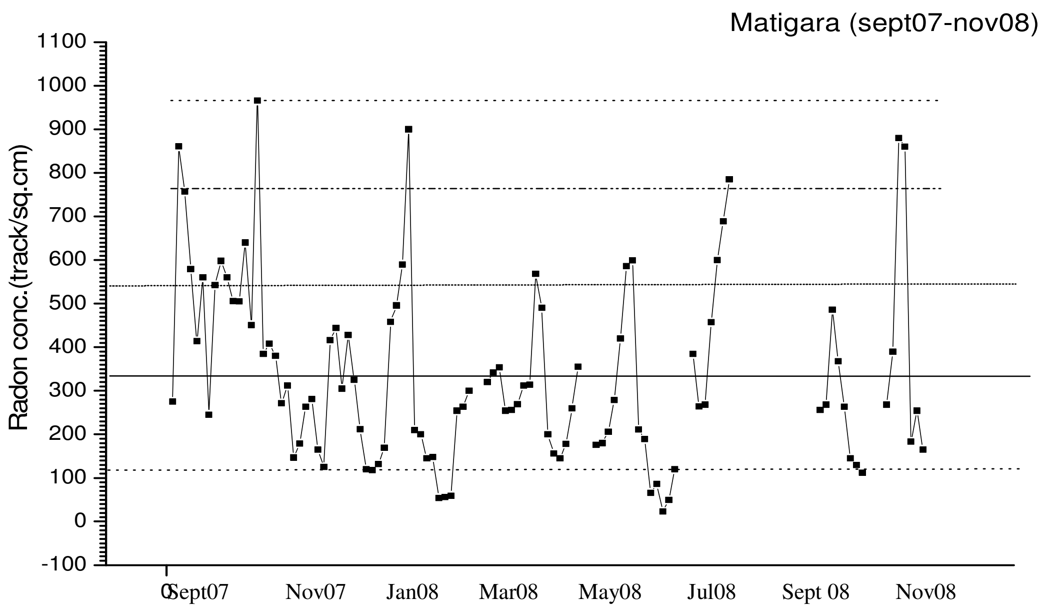

Fig. 2: Radon time series observed at Matigara (Darjeeling) during Sept'07-Nov'08

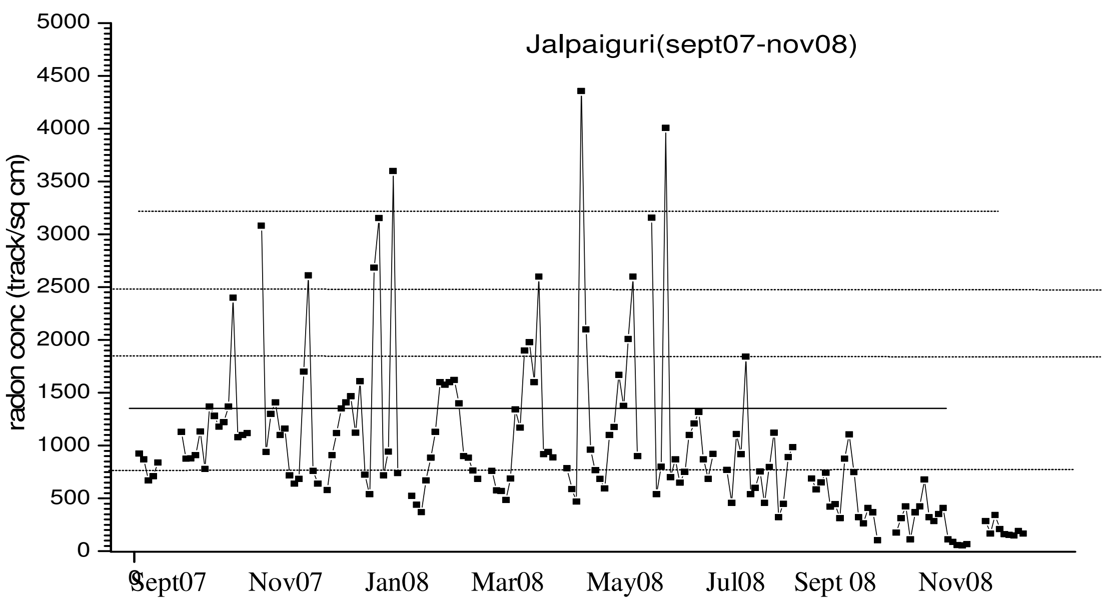

Fig.3: Radon time series observed at Jalpaiguri during Sept'07-Nov'08

Table 1: Details of radon anomaly observed at Matigara (MTG) and Jalpaiguri (JLPG) and corresponding EQs

Date of EQ	Region	M (richter)	Date of occurrence radon anomaly MTG	JLPG	Distance of epicenter km MTG	JLPG	Anomaly from average value MTG	JLPG	Precursor time(days) MTG	JLPG
18th Sept`07	Myanmar	5.1	24sept	13sept	970	661	2σ	σ	6(post)	5
18th Sept`07	Meghalaya	4.0	Nil		350	280				
29th oct`07	Nepal	4.0	20oct	22oct	300	98	3σ	2σ	9	7
7th Nov`07	Bangladesh-(Mizoram) Border	5.3	Nil	22oct	700	594	-	2σ	No peak	15
29th Nov`07	Myanmar-India Border	4.7	Nil	2nd nov	750	674	-	3σ	No peak	27
7th Dec`07	Myanmar (India) Border	3.5	9th Dec	Nil	750	674	2σ	-	2(post)	No peak
12th Jan`08	India (Mizoram)-Bangladesh Border	5.0	15th Jan	27Dec	650	595	σ	2σ	3(post)	15
26th Feb`08	Myanmar-India Border	4.4	14Feb	Nil	710	676	2σ	-	12	No peak
13th Mar`08	Darrang (Assam)	4.0	12Mar	6Mar	350	334	2σ	σ	1	7
8th Apr`08	Bangladesh	4.5	No Data	2nd Apr	610	560	-	3σ	No data	6
17th Apr`08	Mizoram (Assam)	4.3	No Data	2nd Apr	425	594	-	3σ	No data	15
20th Apr`08	Assam Manipur Border India	4.4	No Data	2nd Apr	540	530	-	3σ	No data	18
29th May08	Darrang Assam	4.2	5th &7th May	11th May	350	334	2σ	2σ	24&22	18
10th Nov'08	Myanmar	5.0	Nil	Nil	750	674	-	-	--	

Conclusion

The present analysis provides further significant results in favour of radon monitoring for seismic surveillance and proposes more similar work of radon monitoring in different spots of both active and non-active fault zones.

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