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Pronounced soil-radon anomaly—Precursor of recent earthquakes in India

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Abstract

The real time radon monitoring is an extensively studied area in order to give premonitory signs prior to an earthquake. The strain changes that occurred within the earth surface during earthquake is expected to enhance the radon concentration in soil gas. In order to support this theoretical view, we have performed an experiment on measuring radon concentration in soil gas with the use of CR-39—solid state nuclear track detector (SSNTD). The study has been performed at Jadavpur University, Kolkata, India. This paper reports essentially the observation of radon anomaly for the earthquakes that occurred during the period of November 2005–October 2006 within the range of 1000 km from the measuring site and of $M \geqslant 4$. The study is important as no such work has been done at Kolkata, India, which is a relatively geologically stable area.

Keywords: Soil gas; SSNTD; Earthquake; Radon anomaly

1. Introduction

Radon is an important terrestrial gas whose presence and concentration are easy to detect. Radon concentration levels are strongly affected by geological and geophysical conditions, as well as atmospheric influences such as rainfall and barometric pressure rather than by chemical processes as it is an inert gas.

Formed as a result of radioactive decay of the element uranium, radon is a radioactive gas that is fairly ubiquitous. The emission of radon could be useful in detecting oil and uranium deposits, in predicting earthquake or volcanic eruption, in confirming fault zones, for dating of ancient ceramics by thermoluminescence, etc. (Denagbe, 2000). However, radon as a tracer of earthquake may be considered to be the most useful of these. In geothermal area seismic changes result in changes in rock pressures and fluid convective flows that lead to changes in gas transportation and rise of volatiles from deep earth to the surface (Fleischer, 1997; Thomas, 1988). As stress–strain develops within earth crust before an earthquake, unusual quantities of radon comes out of the pores and fractures of the rocks on surface. Thus due to seismic activity, changes in underground fluid flow may account for anomalous changes in concentration of radon and its progeny (Steinitz et al., 2003). Despite the complex behaviour of the earth crust, simple correlation between changes in soil radon concentration and earthquakes has been observed by many. This is a feature that raises the expectation that radon can be used to help predict earthquakes.

The impressive development in the study of the earth's crust permits to estimate probabilities for earthquake risks. The study involves the prediction of precursor time, distance from epicentre, magnitude of incoming earthquake and other parameters. Investigations throughout the world started in 1956 when Okabe studied the correlation between variation of radon content in atmosphere and local seismicity (Okabe, 1956). The studies provide evidence which indicates that significant variations of radon concentration may occur in association with major geophysical events such as earthquake. In the following decades very important and relevant studies have also been performed (Ulomov and Mavashev, 1971; Sultankhodzhayev et al., 1976; Fleischer and Mogro-Campero, 1978, 1985; Mogro-Campero et al., 1980; King, 1980). Most of the work in this field is study on soil gas. Radon emanation studies are currently underway in several tectonically active regions on earth especially in China (Linpei, 1994), Japan (Igarashi and Wakita, 1990),

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Table 1
The details of the earthquakes observed during the experiment [Data of EQ details taken from Indian Meteorological Department (IMD), website]

Date of EQ	Time HRS (UTC)	Latitude	Longitude	Depth (km)	Magnitude (M)	Region
28 November 2005	16:57:10.7	21 °N	88.2 °E	27	4.2	Bay of Bengal
27 December 2005	16:19:32	24.7 °N	94.1 °E	33	5.2	Manipur
29 December 2005	7:20:52.7	24.9 °N	96.5 °E	14.6	5.1	Myanmar
11 February 2006	5:4:16.4	27.6 °N	92.3 °E	33	5.0	Arunachal–Tibet border
14 February 2006	19:17:30.1	30.4 °N	80.4 °E	33	5.0	Uttaranchal–China border
23 February 2006	20:.4:52	27.2 °N	92.0 °E	33	5.7	Bhutan–India border
25 March 2006	20:13:30	23.4 °N	93.9 °E	96	5.4	Myanmar–Mizoram border
14 April 2006	16:24:54.2	24.0 °N	94.9 °E	38.8	4.8	Myanmar–India border
11 May 2006	17:23:3.6	23.9 °N	93.39 °E	85.8	5.5	Myanmar–Mizoram border
21 May 2006	6:10:19.70	16.2 °N	93.0 °E	33	5.0	East Central Bay of Bengal
19 June 2006	16:57:30	26.3 °N	90.8 °E	65.2	4.0	Assam
22 June 2006	19:16:1.9	24.7 °N	94.5 °E	58	5.0	Myanmar–India border
17 July 2006	8:19:22.4	9.9 °N	107.9 °E	33	7.1	South Java
17 July 2006	13:47:53.3	26.8 °N	89.0 °E	66	4.1	Jalpaiguri, West Bengal

Central America and Mexico (Segovia et al., 1995), Croatia (Planinic et al., 2000) and Taiwan (Yang et al., 2005). The time delay between the occurrence of a radon anomaly and an earthquake varies from place to place depending on regional parameters. Observations show it started before 3 days at Izu peninsula, Japan (Nishizawa et al., 1998), before 14 days at Thailand (Wattananikorn et al., 1998), before 10–12 days at Caucasus (Tsvetkova et al., 2001, 2005) and before 1–33 days at different places in Slovenia (Zmazek et al., 2005). These programs are designed to provide information needed to develop a sound understanding of mechanisms responsible for observed variations in radon concentration.

To have an early evidence of tectonic disturbance within earth crust, variation of radon concentration has been measured in groundwater (Igarashi et al., 1995; Segovia et al., 1996, 1997; Singh et al., 1999; Amrani et al., 2000) as well as in spring water (Nishizawa et al., 1998; Zmazek et al., 2000). It was suggested by King (1980) that the measurement of radon content was more advantageous in soil gas than that in groundwater. As soil gas is enriched in radon in fault zone and the adoption of track etch technique smoothes out meteorological fluctuations when measured over a long period, the variation of radon concentration would be significant in soil gas. In the present study we have performed the experiment in soil gas. The measurement has been done at ‘School of Studies in Environmental Radiation and Archaeological Sciences’ and ‘Nuclear and Particle Physics Research Centre’, Jadavpur University, Kolkata, India—which is not situated in an active fault zone. Our radon monitoring site is situated at latitude of 22°32′N and longitude of 88°24′E. The earthquakes that have been observed are listed in Table 1.

The study shows that radon anomalies before the earthquakes are appreciable and are of similar importance to study in seismically lesser active regions also.

2. Experimental method

The method that has been applied here is track etch technique of cellulose nitrate film, in this case CR-39 plates. The plates of dimension 1 cm × 1 cm were cut and placed at the bottom of a plastic cup. The cup was of 4.7 cm in height, 6.3 cm of diameter at the open end and 5.9 cm of diameter at the closed end. After taping the plates inside the cup, the open end of the cup was covered with membrane. It allows only radon to flow into the cup. A metal container with upper and lower sides open was placed inside the hole of 70 cm deep below the earth surface. The cup was placed upside-down within that container in the hole. Not to tear the membrane, the cup was placed slightly above the ground with a support of two stands (Fig. 1). Silica gel was provided in the hole surrounding the cup to absorb moisture there. The upper end of the metal container that was almost in the level of the upper ground surface was covered with a lid. The arrangement reduces the effect of external meteorological effect on radon flow. The CR-39 plate was exposed for 48 h in such an undisturbed condition. On completion of the exposure time the old plate was withdrawn and a new plate was placed in the same manner. After exposing, chemical etching of the plates was done. In this process the plates were etched in 6 N NaOH solution for 6 h at 70 °C. The temperature was carefully maintained at constant value. The tracks in the plates formed due to alpha particles were counted under Carl Zeiss Jenaval microscope with 10× objective in conjunction with 10× ocular lens. The radon count/sq cm was calculated.

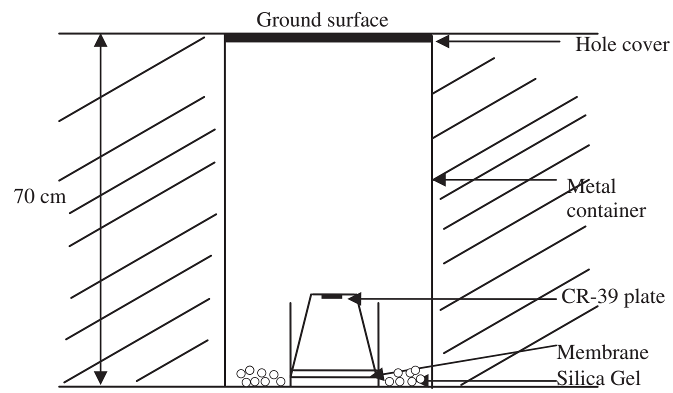

Fig. 1. The experimental set-up during the measurement of radon count.