Applied Radiation and Isotopes 66 (2008) 1523–1530

Contents lists available at ScienceDirect

Applied Radiation and Isotopes

journal homepage: www.elsevier.com/locate/apradiso

Soil-gas radon as seismotectonic indicator in Garhwal Himalaya

R.C. Ramola [a],*, Yogesh Prasad [a], Ganesh Prasad [a], Sushil Kumar [b], V.M. Choubey [b]

[a] *Department of Physics, H. N. B. Garhwal University, Badshahi Thaul Campus, Tehri Garhwal– 249199, India*
[b] *Wadia Institute of Himalayan Geology, Dehradun-248001, India*

ARTICLE INFO

Article history:
Received 22 August 2007
Received in revised form
3 April 2008
Accepted 3 April 2008

Keywords:
Radon
Earthquakes
Soil-gas
Meteorological parameters
Himalaya

ABSTRACT

Research on earthquake-related radon monitoring has received enormous attention recently. Anomalous behaviour of radon in soil and groundwater can be used as a reliable precursor for an impending earthquake. While earthquake prediction may not yet be possible, earthquake prediction research has greatly increased our understanding of earthquake source mechanisms, the structural complexities of fault zones, and the earthquake recurrence interval, expected at a given location. This paper presents some results of continuous monitoring of radon in soil-gas in Garhwal Himalaya, India. Daily soil-gas radon monitoring with seismic activity and meteorological parameters were performed in the same laboratory system, located at H.N.B. Garhwal University Campus, Tehri Garhwal, India. Radon anomalies along with meteorological parameters were found to be statistically significant for the seismic events within the magnitudes M2.0-M6.0 and epicentral distances of 16–250 km from the monitoring station. The frequent positive and negative anomalies with constant environmental perturbation indicate the opening and closing of micro cracks within the volume of dilatancy by strain energy. The spike-like and sharp peak anomalies were recorded before, during and after earthquakes occurred in the area. The variations in radon concentrations in soil-gas are found to be correlated with seismic activities in the Garhwal Himalaya. The correlation between radon level and meteorological parameters is also discussed.

1. Introduction

Radon is a practically inert gas and its concentration changes are a subject of geological interest due to its sensitivity to tectonic disturbances. Sudden disturbance within the earth is manifested at the surface by ground shaking caused by seismic waves. The origin and distribution of most of the major earthquakes can be explained in terms of reactivation of faults/thrust and plate tectonics theory. The first evidence of a correlation between radon and earthquake occurrence came from the observation of radon concentration in well water prior to the Tashkent earthquake (Ulomov and Mavashev, 1967). Since then, the occurrence of anomalous temporal changes of radon concentrations in soil-gas and groundwater were studied by various researchers (King, 1978, 1980, 1986, 1988, 1990; Mogro-Compero et al., 1980; Ramola et al., 1990, 1998, 2003; Ramola, 2006; Singh et al., 1988a, b; Virk and Singh, 1992; Yang et al., 2005). The precursor time (the time interval between the beginning of a radon anomaly and the subsequent earthquake), the anomaly duration and the amplitude are found to depend on earthquake magnitude and epicentral distance (Allergri et al., 1983; Chyi et al., 2005; Ramola et al., 1990). The origin and mechanism of observed radon anomalies and their relationship to earthquakes is still poorly understood, although several constraints from laboratory experiments have been described (King, 1978; Ramola et al., 1990; Singh et al., 1988a, b;Steele, 1985; Talwani et al., 1980; Virk, 1995; Virk et al., 1997). King (1978) proposed a compression mechanism for radon release. According to this mechanism the anomalous high radon release may be due to an increase in crustal compression before an impending earthquake that squeezes out the soil-gas into the atmosphere at an increasing rate. Many experimental and theoretical studies indicate the geometry of the pore structure changes during the pressure buildup (Ramola et al., 1988; Sprunt and Nur, 1977; Vogel et al., 1998). Some observation sites are said to be sensitive to earthquakes and some are not (King 1990), and directional sensitivity is thought to be important in some cases (Whitehead and Lyon, 1999). In the present study, the observation points are common in both space and time for the measurement of radon concentrations in soil-gas, the seismic record and meteorological data. The long-term data are available on the basis of daily records. These data provide a good opportunity to discuss the relation between the observed variation and the earthquake process.

2. Experimental

The changes in the near surface soil-gas radon concentration and seismic activities were measured at the same location in HNB

---

* Corresponding author.
E-mail address: rcramola@gmail.com (R.C. Ramola).

0969-8043/$ - see front matter © 2008 Elsevier Ltd. All rights reserved.
doi:10.1016/j.apradiso.2008.04.006

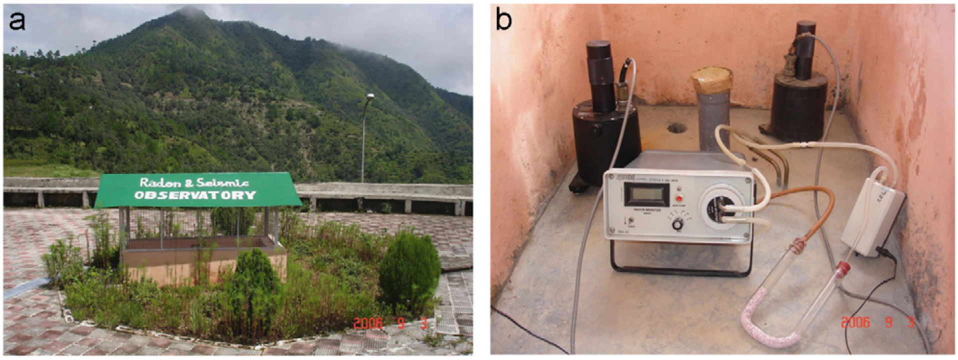

Fig. 1. (a) View of radon and seismic observatory with (b) equipments installed inside the observatory.

Garhwal University Campus, Tehri Garhwal (Fig. 1) using a scintillation counter called the radon emanometer and an analogue seismograph installed by Wadia Institute of Himalayan Geology, Dehradun, India. Soil-gas radon was measured daily in auger holes, 1 m in depth and 6 cm in diameter. In this technique, the soil-gas probe is fixed in the auger hole and forms an airtight compartment. The electric/hand-operated pump, soil-gas probe and alpha detector were connected in a closed circuit. The air is circulated through a ZnS-coated chamber for a period of 15 min until the radon forms a uniform mixture with the air and the resulting counts were recorded.

The filter setting and instrumental attenuation setting of the seismograph were controlled by local site conditions, but the frequency pass band and recorder magnification were maintained throughout the measurement, in the ranges of 5–15 Hz and 60–78 dB, respectively. The standard time broadcast of the National Physical Laboratory, New Delhi, India, was used for the clock adjustment of the seismograph. By synchronizing the radio signal daily and maintaining a drum speed of 120 mm/min, the timing accuracy was obtained between 0.01 and 0.05 s. The seismic records of events having an epicentre less than 250 km from the measuring station were chosen for the regional stress and strain buildup study. The meteorological parameters were measured by using thermometer, hygrometer and rain gauge.

3. Seismotectonic setting

Himalaya is experiencing vertical uplift and transverse block movements due to the compression caused by the continued northward movement of the Indian plate, since the collision with the Eurasian plate in Palaeocene (Argand, 1924; Dewey and Bird, 1970; Kumar and Sato, 2003; Ramola et al., 1998). As a result, the Himalayan region is being subjected to intense neotectonic movements and seismic activities. The Himalaya has risen as a result of repeated refracturing of India's advancing limb under persistent compression and stacking of its sliced front onto itself over a long geologic period that began about 55 million years ago. The occurrence of great earthquakes is inherent in such a process. Valdiya (1980) has made an elegant exposition of its structural framework and tectonics. As in other segments of the Himalaya, the Garhwal Himalaya is also subdivided into four broad tectonic units, which are proceeding northwards from the Indo-Gangetic Plains as the outer, lesser and higher Himalaya (Fig. 2). Garhwal Himalaya is the seismically sensitive and neotectonically active region. During the past decade two major earthquakes struck in the Garhwal region alone, i.e. the Uttarkashi earthquake (October 20, 1991) of 6.5 Mb and the Chamoli earthquake (March 29, 1999) of 6.3 Mb.

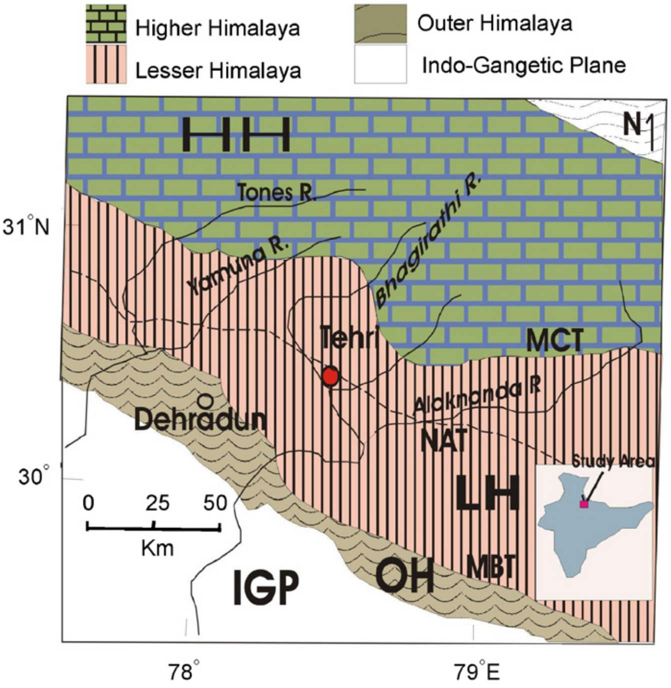

Fig. 2. Geological map showing the locations of higher Himalaya (HH), lesser Himalaya (LH), outer Himalaya (OH) and Indo-Gangetic Plane (IGP) in study area.

4. Results and discussion

The soil-gas radon data show anomalous behaviour with different meteorological and geophysical parameters. The variations in average radon concentrations in soil-gas at Badshahi Thaul, Tehri Garhwal, for different seasons are given in Table 1. The radon data recorded at a depth of 1 m have been analysed with several patterns of rainfall and other meteorological parameters. A wet layer of soil with low gas permeability tends to prevent radon appearing in the radon tight auger hole. If the wet layer is so thick that it reaches below that depth, the measured radon value tends to be reduced (King, 1988; Singh et al., 1988a, b). The main meteorological parameters that affect the radon emanation from host material are surrounding temperature, barometric pressure, wind velocity, rainfall and humidity. The recorded values of air temperature, relative humidity and rainfall at study area are given in Table 1. The soil-gas radon concentration was recorded continuously at the monitoring site from March 2004 to May 2006. During this period, soil-gas radon concentrations were found to vary