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Short communication

Radon activity measurements around Bakreswar thermal springs

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ABSTRACT

^{222}Rn concentrations were measured in the bubble gases, spring waters, soil gases and in ambient air around the thermal springs at Bakreswar in West Bengal, India. This group of springs lies within a geothermal zone having exceptionally high heat flow about 230 mW/m^2, resembling young oceanic ridges. The spring gas has a high radon activity (~885 kBq/m^3) and is rich in helium (~1.4 vol. %) with appreciably large flow rate. The measured radon exhalation rates in the soils of the spring area show extensive variations from 831 to 4550/mBqm^2 h while ^{222}Rn concentrations in the different spring waters vary from 3.18 to 46.9 kBq/m^3. Surface air at a radius of 40 m around the springs, within which is situated the Bakreswar temple complex and a group of dwellings, has radon concentration between 450 and 500 Bq/m^3. In the present paper we assess the radon activity background in and around the spring area due to the different contributing sources and its possible effect on visiting pilgrims and the people who reside close to the springs.

1. Introduction

Radioactivity in thermal springs is geologically attributed to the abundance of ^{226}Ra and its decay product ^{222}Rn brought to the surface by the thermal waters. During its long passage within the earth's crust, thermal waters come in contact with large surfaces of radioactive eruptive rocks like granites, quartz porophyry, basalt etc. which contain radium to the extent of 10^{-12} g Ra per gm of rock (Schynoll and Chatterjee, 1958). Water–rock interaction causes radon trapped within the micro-crystallites of rock forming minerals along with radium salts to be leached out of the source rocks (Sakoda et al., 2007).

In the soils around the thermal springs the sub-surface radioactivity is primarily due to decay of ^{238}U and the radioactive mineral make up of the underlying rocks and sediments. However, surface radon concentration may depend predominantly upon a host of factors other than only the presence of an underground ^{238}U source matrix. The release and transport of radon into soil surface and thermal waters of the springs depends upon the distribution of faults and tectonic discontinuities, the existence of micro cracks within rocks, fluid up flow, soil porosity and permeability, moisture content, meteorological factors as well as several other causes that are not connected to radon generically. Thus local geomorphology and hydrology play an important part in observed radon concentration at a place and its near surface natural background level.

2. Geology of the area

The thermal springs at Bakreswar (23°52′48″N; 87°22′40″E) lies in the Precambrian of the western margin of Birbhum district in West Bengal, India. This geothermal tract comprises a group of seven springs, each with a different local name ending with 'kunda' (reservoir of hot water) that are heated naturally and vary in temperature between 37 and 69 °C covering a total surface area of about 3350 sq. m. The springs are presumably linked to the extinct (115 Ma) Rajmahal volcanic activity located at 25 kM away from the monitoring site. The geological conditions of the area maintain a constant flow of hot waters that issue out of fractures in a reactivated composite mass comprising predominantly Precambrian granitic rocks. These rocks lie along an E–W belt of sparsely occurring sedimentary outliers of Gondwana formation (Lower Permian to Middle Jurassic) (Majumdar et al., 2000). The spring, namely 'Agnikunda', discharges a high outflow (3.5 slpm) of helium rich gas (1.4 vol.%) besides N_2 ~ 92.1 vol.%, Ar ~ 2.1 vol.%, O_2 ~ 0.9 vol.%, CH_4 ~ 3.4 vol.% and CO_2 ~ 0.1 vol.%, with a water discharge rate of about 5 m^3/h. High level of helium discharge is indicative to deep seated origin of helium. A Geochemical Monitoring Station (GMS) adjacent to the 'Agnikunda' (the spring with the highest temperature, 69 °C), continuously monitors temporal variations of helium, methane and radon concentrations in the spring gas at preset time intervals with regard to pre-seismic

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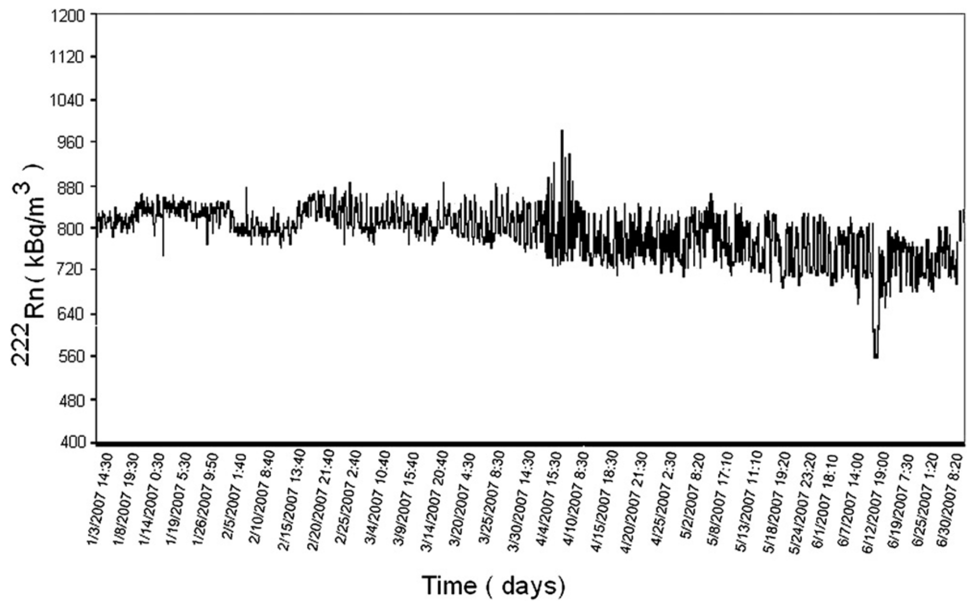

Fig. 1. Trends of radon content in the spring emanation at Agnikunda, Bakreswar, during the period January–June 2007.

surveillance studies (Das et al., 2006). Results indicate that the mean radon concentration at 'Agnikunda' as high as $\sim 885 \pm 41$ kBq/m^3. Radon emanation is continuously transferred and dispersed into the surrounding atmosphere of evaporating thermal waters, through formation of micro bubbles and molecular diffusion. The heat flow in this area is more than three times the recent estimates of the mean heat flow 65 ± 1.6 mW/m^2 for all continents and twice for all oceans 101 ± 2.2 mW/m^2 (Gilat and Vol, 2005) and is similar to that of young spreading ocean ridges.

3. Experimental methods

The study was undertaken through the six-month dry season, January–June, 2008. During this period the mean relative humidity and mean temperature variations stand between 52 and 78% and 20.1–31.7 °C respectively in the region.

Radon concentration in the spring gas was measured with an open ended ionization chamber type radon monitor – AlphaGuard PQ2000 PRO (Genitron Instruments, GmbH, Germany) in a manner similar to that as described by Das (Das et al., 2005). Water radon concentrations were measured using a parallel AlphaGuard PQ2000 PRO equipped with an appropriate unit (AquaKit), following a protocol proposed by the manufacturer. ^{222}Rn concentration in the water samples have been determined using the following equation provided in the equipment literature,

$$C_{\text{Water}} = \frac{C_{\text{Air}} \times \left(\frac{V_{\text{System}} - V_{\text{Sample}}}{V_{\text{Sample}}} + k\right) - C_0}{1000} \quad (1)$$

where, $C_{\text{Water}} = {}^{222}$Rn concentration in water sample [Bq/l], (Estimated); C_{Air} = radon concentration [Bq/m^3] in the measuring set up after expelling the radon [recorded by the radon monitor]; $C_0 = {}^{222}$Rn concentration in the measuring set up before sampling [Bq/m^3]; V_{system} = Interior volume of the measurement set up [1204 ml]; V_{sample} = volume of the water sample [100 ml]; k = radon distribution coefficient which has been calculated from the graphical plot [k vs temperature] as provided in the literature (Clever, 1985).

For measurements of radon exhalation rate in soil a radon exhalation chamber and a similar radon monitor was used, which is essentially an ionizing chamber and measures radon via alpha spectrometric techniques. Radon concentration inside the exhalation chamber was determined using the instrument in diffusion mode. The exhalation rate was calculated using the formula used by Ramola and Choubey, 2003.

Table 1
Activity concentration levels of ^{226}Ra and ^{222}Rn in the spring waters and ^{222}Rn in the gas discharges of the different springs at Bakreswar.

Sl no.	Sampling code	Spring	Temperature (°C)	pH	^{226}Ra (spring water) kBq/m^3	^{222}Rn (spring water) kBq/m^3	^{222}Rn (spring gas) kBq/m^3	He (spring gas) (ppm)
1	WR 1	Agnikunda (23° 52′50.0″N; 87°22′41.9″E)	69.0	9.2	BDL*	38.9 ± 3	830 ± 48	14,600
2	WR 2	Kharkunda (23° 52′50.4″N; 87° 22′42.0″E)	66.0	9.3	BDL	46.9 ± 5	850 ± 42	14,200
3	WR 7	Bhairabkunda (23° 52′49.4″N; 87° 22′41.1″E)	62.2	9.3	BDL	34.7 ± 4	377 ± 32	11,236
4	WR 4	Soubhagyakunda (23° 52′43.5″N; 87°22′40.4″E)	50.5	9.1	BDL	9.9 ± 2	684 ± 30	9218
5	WR 5	Suryakunda (23° 52′49.6″N; 87° 22′43.2″E)	63.3	9.3	1.18 ± 0.06	14.2 ± 3	–	–
6	WR 3	Brahmakunda (23° 52′50.2″N; 87° 22′43.6″E)	46.1	9.2	1.70 ± 0.005	18.7 ± 2	570 ± 18	12,586
7	WR 6	Jibatsakunda (23° 52′50.2″N; 87° 22′42.8″E)	37.0	7.5	1.68 ± 0.005	3.18 ± 1	–	–