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Meteorological parameters contributing to variability in ^{222}Rn activity concentrations in soil gas at a site in Sapporo, Japan

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Abstract

Continuous ^{222}Rn monitoring in soil gas since November 22, 2004 has revealed variability in activity concentration with time in the semi-natural woods on the campus of Hokkaido University in Sapporo, Japan. Among various factors affecting soil radon levels and variability, temperature was found to be dominant during three seasons when activity concentrations of ^{222}Rn showed a diurnal high and nocturnal low with a boundary around 10 o'clock in the morning. This pattern was disturbed by low pressure fronts with occasional rain. The activity gradually decreased as soil temperatures decreased from late November to mid-December. After the ground surface was completely covered with snow, soil radon levels became low with a small fluctuation. There were several peaks of ^{222}Rn on the time-series chart in winter. Those peaks appearing in early winter and early spring may be interpreted by considering meteorological parameters. In a few cases, the radon activity suddenly increased with increasing pressure in the soil at a depth of 10 cm, which may be associated with subsurface events such as seismic activity in the area.

Keywords: ^{222}Rn; Soil gas; Continuous monitoring; Meteorological parameters; Seismic effects

1. Introduction

There are many factors affecting radon activity concentration in soil gas, and meteorological parameters such as temperature, pressure and precipitation are known to be important contributors. Seasonal variation of soil radon has been discussed with controversial observations. Winkler et al. (2001) compared the variability resulting from different methods, spatial heterogeneity and seasonal fluctuations at a test site located at Neuherberg in Germany. Among several notable results, they observed a winter-high in radon levels due to frozen topsoil. An extreme case was reported by Sundal et al. (2004) who measured soil radon together with geochemical analyses of bedrock, groundwater and sediment at an ice-marginal deposit in Western Norway. They ascribed anomalously high seasonal changes in soil (and also indoor) radon concentration to subterranean airflows caused by temperature differences between soil air and atmospheric air. Iskandar et al. (2004) investigated the dependence of radon emanation power on soil temperature using radium rich soil samples collected in Japan. They obtained a temperature-dependent equation to calculate emanation power at

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various temperatures from −20 °C to 45 °C. Over more than 1 year, Kitto (2005) measured radon flux from soil, along with meteorological and indoor radon measurements, finding that radon flux from soil has a slight seasonal pattern with the greatest exhalation occurring during the late summer months due to the lower moisture content and cracks in the clay soil in summer. The measured flux ranged from 0 to 140 mBq/m^2 s with a mean of 37±22 mBq/m^2 s. The low flux in winter was caused by a combination of frozen ground and periodic snow melt, whereas low flux in spring most likely resulted from increased precipitation.

Changes in soil radon are thought to be a possible precursor of earthquakes. Among many studies concerning radon and earthquakes, Zmazek et al. (2005) reported a statistical technique to identify soil radon anomalies caused by earthquakes in Slovenia by monitoring soil radon concentration, barometric pressure and soil temperature using a Barasol probe (MC-450, ALGADE, France), along with other meteorological data like air temperature and precipitation, and also seismic data. Changes in radon concentration that deviated significantly from the mean value were related to seismic activity.

Walia et al. (2003) also investigated relationship between radon anomalies and seismic parameters in the northwest Himalayas in India. They compared their results of soil radon monitoring from 1992 to 1999 with seismic data supplied by the Indian Meteorological Department and developed an empirical relationship between earthquake magnitude, epicentral distance and amplitude of radon anomaly. The proposed relationship was a linear relationship between log of the magnitude and log of the product of radon anomaly amplitude and epicentral distance. They concluded that there is no universal empirical relationship that relates radon data with all earthquakes occurring around the world. They further investigated spatial variations in radon and helium concentrations in soil gas across the Shan-Chiao fault in northern Taiwan (Waila et al., 2005). They confirmed that evaluation of both radon and helium was a powerful tool for the detection and mapping of active fault zones.

In our previous study, soil radon was measured temporally with a scintillation Lucas cell at a site on the campus of Hokkaido University, Sapporo, Japan. Soil radon level was varied to a large extent everyday even after the probe was permanently emplaced at the point and sampling time was set constant as far as possible. The result together with those by a laboratory experiment suggested that the changing air-filled porosity due to changing soil humidity may be an important parameter controlling soil radon variability (Fujiyoshi et al., 2005). The current study has further investigated factors affecting soil radon levels by continuous monitoring with a Barasol probe since November 2004 at the same location on the campus of Hokkaido University. The obtained data extends these observations to evaluate the influence of meteorological parameters on soil radon levels and variability.

1.1. Monitoring site and methods

Details of the monitoring site and characteristics of the soil were described previously (Fujiyoshi et al., 2005). A continuous monitoring probe for soil radon (Barasol, Algade, France) was buried in the soil at a depth of 10 or 30 cm. This instrument has a battery powered solid state silicon detector and monitors temperature and barometric pressure with a data logger. It detects alpha-particle emissions of radon in soil gas hourly. The detector sensitivity is 0.02 pulses/h for 1 Bq/m^3 and the saturation volumetric activity is 3 MBq/m^3. Barometric pressure was also measured hourly just above the ground surface (KADEC-U21, Kona System, Japan) and the data set was collected at the end of each month. Humidity of the soil at depths of 20 and 50 cm was monitored hourly with a probe which could store data obtained for about 6 months (Profile Probe, Delta-T Devices Ltd., UK). Instruments were kept in the snow during the winter months from November 2004 to late March 2005, and also from December 2005 to March 2006.

2. Results and discussion

Soil radon has been measured temporally by an active technique utilizing a scintillation Lucas cell (Pylon, Canada) at a point in the woods on the Hokkaido University campus since June 2002. In an earlier study, changing air-filled porosity caused by meteorological phenomena was found to affect soil radon levels (Fujiyoshi et al., 2005). During the observation period, there was a sudden increase in soil radon, which coincided with a large local earthquake on September 26, 2003 with the epicenter located offshore near Tokachi in Hokkaido, Japan. Because of the perceived link between earthquakes and changes in soil radon, the present study was undertaken to obtain detailed data on other factors that may contribute to changes in soil radon levels. The current data was obtained from continuous monitoring with a Barasol probe at the same location as the previous study.

Fig. 1 shows time-series plots of soil radon levels together with hourly mean values of soil temperature