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Investigation of the relationships between seismic activities and radon level in Western Turkey

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HIGHLIGHTS

- Distribution of radon levels are found to be statistically governed by a normal distribution for both pre and post-seismic activities.
- In compressive fault lines, radon level tended to increase before the earthquake and decrease towards the time of earthquake occurrence.
- For dilation fault lines, no change in radon levels beyond normal variation was observed.

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ABSTRACT

The distribution of radon activity is determined from pre-earthquake data. Analysis using Normal, Gamma, Weibull and Rayleigh distributions indicates that the variation of radon levels in seismically active regions is best described by a normal distribution. It was observed that radon levels would change in compressive fault lines prior to earthquake. Besides that it tended to increase before the earthquake and then decrease towards the time of earthquake occurrences.

1. Introduction

It is known that the transport of radon in the soil depends on the geological and geophysical structure of the region. Therefore, it is important to characterize their probability distribution that governs radon anomalies during seismic activities. A wide range of statistical studies were reported (Dueñas and Fernandez, 1988; Wattananikorn et al., 1998; Negarestani et al., 2002; Negarestania et al., 2003; Viñas et al., 2004; Zmazek et al., 2005; Tansi et al., 2005; Das et al., 2007; Pérez et al., 2007).

Crockett et al. (2006) found that analysis of the radon time-series displayed a positive correlation to the Dudley earthquake (M 5.0) in England. A study of radon activity in Seferihisar-İzmir, one of the most seismically active regions in the Western Anatolia, showed that the radon concentration varies notably beyond expected normal fluctuations prior to the April 2003 earthquake. Sac et al. (2011) and Viñas et al. (2007) analyzed the temporal and spatial variation of radon data using filtering techniques, to remove the effect of some atmospheric parameters, confirming the existence of a the correlation between radon data and volcanic reactivity. Baykut et al. (2010) used detection and separation algorithms, based on the empirical mode decomposition method to remove and detect daily quasi-periodic components from radon data. Barbosa et al. (2010) investigated the variations of radon concentrations and environmental parameters at the Amram tunnel in the southern Negev desert of Israel to obtain scale-based description of the radon and environmental signals using the wavelet multiresolution decomposition method. They demonstrated that variation of the radon concentrations is characterized by a rich and nonstationary temporal pattern.

The purpose of this work is to examine the relationship between radon anomalies and the formation mechanism of crustal movements. In addition, the statistical characteristics of radon data in the pre- and post-earthquake period are investigated through using normal, Weibull and Raighleigh distributions. First, radon data was grouped daily and analyzed using these statistical distributions. The parameters for Gauss, Rayleigh, Weibull and Gamma probability density functions (pdf) were calculated by

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using the root-mean square error methods. Second, radon data were grouped into 10-day intervals in the pre- and post-earthquake. These data were tested for compression, dilation and inactive geological cases. Focal mechanism analysis was then applied to determine the compression and dilation effects in the studies. As a result, it is shown that how radon concentrations in the cases of dilation and compression of study region change in the pre and post earthquake periods.

2. Materials and methods

İzmir city is located in the middle of the active Karaburun fault, Tuzla fault and Gediz graben. It is a right lateral strike slip fault. Micromorphologic structures associated with surface ruptures are clear along the fault, and which is characterized by three fault segments trending NE–SW between the İzmir-Cape of Doğanbey (Bozkurt and Sözbilir (2004); Benetatos et al., 2006).

A radon monitoring station is situated at Tuzla fault line in the İzmir-Seferihisar region of Western Turkey. The system was installed at a latitude 38°07′29.24″N and longitude 26°54′43.42″ E about 80 km SW of the city of İzmir. This system consisted of an AlphaMeter 611 (manufactured by AlphaNuclear Corporation, Canada), datalogger, power supply unit and GSM modem. The Alpha detector was an Alphameter 611 based on a 400 mm^2 silicon junction diode. The detector was covered by waterproof polymeric material to allow alpha-particle penetration. Radon measurements were recorded at 15-min intervals. The detector unit was placed under one meter in the soil.

The collected data exhibited many perturbations due to the seismic activity of this area and the fault lines in its proximity. However, we considered a single exponential type probability density functions (pdf) as done by Inan et al. (2008) and Papoulis (1991). Continuous soil gas radon data was grouped into daily intervals, and the parameters (scale and shape) associated with the distributions were estimated through using the maximum likelihood method. Statistical analysis was then performed to determine the most suited distribution, among those given in Table 1. The root-means square error (RMSE) differences between the experimental and theoretical pdf's were examined to determine the goodness of fitting between theoretical and experimental data. Data grouped with 10-day intervals in the pre- and post-earthquake periods were analyzed to examine the change in the radon concentration.

Table 1
Statistical distributions used in the study.

Distribution type	Probability density function (pdf)	
Gauss distribution	$f(x\|\mu,\sigma)=\frac{1}{\sigma\sqrt{2\pi}}e^{-\frac{(x-\mu)^2}{2\sigma^2}}$	$(-\infty<x<\infty)$
Rayleigh distribution	$f(x\|\mu)=\frac{x}{\mu^2}e^{-\frac{x^2}{2\mu^2}}$	$0\le x<\infty$
Weibull distribution	$f(x\|\alpha,\beta)=\frac{\beta}{\alpha}\left(\frac{x}{\alpha}\right)^{\beta-1}e^{-(x/\alpha)^{\beta}}$	$x\ge 0$
Gamma distribution	$f(x\|\alpha,\beta)=x^{\alpha-1}\frac{e^{-(x/\beta)}}{\beta^{\alpha}\Gamma(\alpha)}$	$x\ge 0,\alpha,\beta>0$

3. Results and discussion

Fig. 1 shows the radon measurements between 2007 and 2011. The daily average concentration of radon within this period was 338 ± 38 kBq/m^3.

Fig. 2 shows the correlations values for the radon data of consecutive days. As shown in Fig. 2, most of the Spearman's linear correlation coefficients are near zero, which indicates that radon variations do not exhibit diurnal periodicities.

Radon emission is associated with the changes in the stress of the eart's crust (Nazaroff and Nero, 1988; Plastine et al., 2002). During an earthquake there can be relaxation or stretching in the earth's crust. The earthquake focal mechanism explains the relationship between crustal stress and earthquake. In the study, the radius of the zone within which a precursory phenomenon may be manifested (so-called Dobrovolsky's radius in km), R_D, was calculated through using Dobrovolsky's (2003) relationship:

$$R_D=10^{0.4\cdot M_L} \tag{1}$$

where M_L is the local magnitude of earthquake. All calculated R_D values were compared with R_E which is the distance between the epicenter and the measuring site. The earthquakes for which R_E equal and less than R_D have been used in the interpretation.

Table 2 lists the seismic activities observed between 2007 and 2010 and their focal mechanism (compressive or dialational) as revealed by U.S. Geological Survey National Earthquake Information Center (USGS-NEIC) and National Observatory of Athens, Institute of Geodynamics (NOA-IG) (2011). The radon data analyzed in this work were correlated to these events.

Using the daily-grouped radon data, the parameters for the distributions listed in Table 1 were determined, and grouped in accordance to the fault line conditions as identified by the USGS-NEIC: National Earthquake Information Center. The radon data was grouped in 10-day periods. Then, the skewness, kurtosis and the goodness of fit were calculated (Table 3). The results show there is no significant difference between the statistical characteristics of radon fluctuations pre- and post-earthquake. The kurtosis values of near 3 and skewness

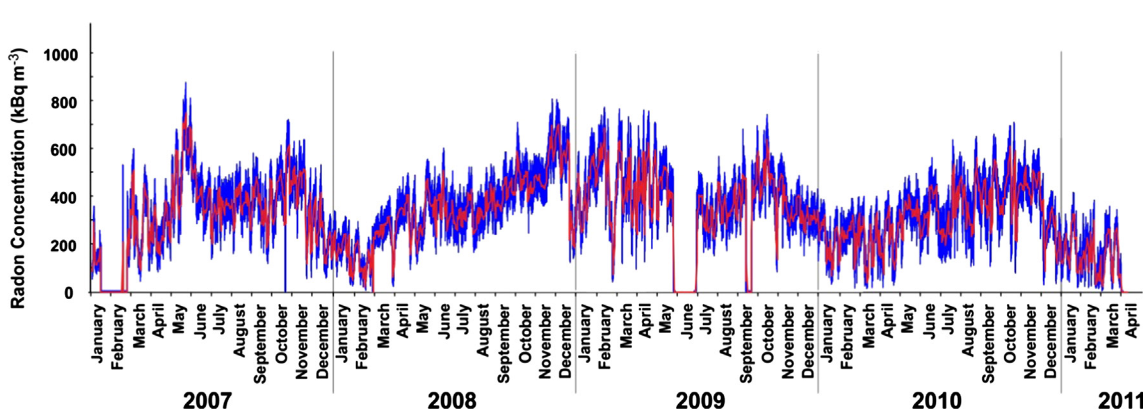

Fig. 1. Radon in soil gas measurements data recorded at monitoring station between 2007 and 2011.