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Radon, volatile organic compounds and water chemistry in springs around Popocatepetl volcano, Mexico

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Abstract. Popocatepetl volcano is a high-risk active volcano in Central Mexico where the highest population density in the country is settled. Radon in the soil and groundwater together with water chemistry from samples of nearby springs is analysed as a function of the 2002–2003 volcanic activity. Soil radon indicated fluctuations related both to the meteorological and sporadic explosive events. Groundwater radon showed essentially differences in concentration due to the specific characteristics of the studied springs. Water chemistry showed also stability along the monitoring period indicating differences between springs. No anthropogenic pollution from volatile organic compounds was observed.

1 Introduction

Popocatepetl volcano (19° 03′ 36″ N; 98° 31′ 18″ W) is a high-risk active volcano located in Central Mexico, where the highest population density of the country is settled. Since 1994, the volcano started an eruptive phase that has been subject of intensive study, using all the available monitoring methods due, essentially, to the location of the volcano, 60 km from Mexico City. The eruptive history of Popocatepetl is documented since 1347. In 1519 an eruptive stage maintained the activity until 1530. The previous eruptive event in the 20th century occurred between 1920 and 1927, having an explosive character of moderate magnitude, very similar to the present eruptive phase (De la Cruz-Reyna et al., 1995; CENAPRED, 2003). Among the monitoring methods, volcanic seismicity, soil and groundwater radon and water chemistry of nearby springs have been used at Popocatepetl between 1994 and 2003 (Segovia et al., 2001, 2002; Varley and Armienta, 1999, 2001). The main purpose of the present paper is to analyse the effect of the recent volcanic activity (2002–2003) on soil and groundwater radon and the chemical composition of groundwater.

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2 Experimental

2.1 The volcano activity

The Popocatepetl activity in 2002–2003 showed an interesting variation characterised by periods of intense seismic activity of short duration that, in occasions, accompanied the formation of small domes (24 January, 19 February and 29 April 2002) inside the volcano crater. In other episodes (14 May, 23 July and 15–17 August 2002) dome formation did not accompanied the seismic activity increase. The dome formation resumed on 17 September and on 2 December 2002, with a dome 40 m tall and 180 m radius. From 4 to 23 February 2003, the volcano entered an important state of activity, where 13 explosions destroyed the domes formed during 2002. Some of these explosions produced ash columns of more than 4 km in height, which travelled and were detected by the GOES satellite all the way to Florida.

2.2 Monitoring sites

Soil radon monitoring was performed at two fixed stations: Paso de Cortes (3400 m altitude and 7.5 km from the crater) and Tlamacas (4000 m altitude and 4.7 km from the crater). Three springs, Atlimeyaya, Axocopan and Calvario, in the southern flank, were systematically monitored during this period of time for radon and major chemical compounds. Anthropogenic volatile organic compounds (VOC's) were also studied in the water samples in order to determine possible contamination paths.

2.3 Measuring techniques

Long term soil radon determination (70 cm depth) was performed with Solid State Nuclear Track Detectors (SSNTD), LR 115 type II, from Dosirad Co. France. The details of the methodology have been previously reported (Segovia et al., 2002). The water samples were analysed for dissolved radon with a Packard TRI-CARB 2700TR liquid scintillation detection system and with an ALPHAGUARD from Genitron

Instruments. In the field, electrical conductivity, temperature and pH were also determined. Chemical analyses were performed by standard methods, as given in APHA-AWWA-WPCF (1995). The ionic charge balance checked the accuracy of the analyses. VOC's identification was performed with a TekmarTM 3000 (GC-MS) equipment using the EPA method 524.2 (Cisniega et al., 2002).

3 Results and discussion

Soil radon at Paso de Cortes and Tlamacas showed striking differences between the two monitoring stations. The average soil radon concentration values at both stations were quite low, but systematically the values at Paso de Cortes were twice higher than those at Tlamacas, in accordance with previously reported results (Segovia et al., 2002). In the present monitoring period the radon values at Tlamacas decreased between June and October (rainy season) as compared with the values obtained during the dry season. On the contrary at Paso de Cortes, the higher values during the year correspond to the rainy season. This behaviour is probably related to the specific soil characteristics at each station. Tlamacas is located at the cinder cone with scarce vegetation and Paso de Cortes is settled in the forest, having a top soil organic matter layer up to 70 cm. At Tlamacas the soil radon values increased in February and April 2002, when the domes appeared and, after a depletion pattern from may to October, an increase was observed in correlation with the activity of February–March 2003. At Paso de Cortes the behaviour was quite smooth with almost no fluctuations along the monitoring period.

Average groundwater radon at the three springs showed higher levels at Atlimeyaya followed by Axocopan and Calvario respectively. There were low fluctuations with time at each one of the springs, and no changes were observed during the times of volcanic activity. The groundwater radon was measured by two methods: liquid scintillation and ionisation chamber (Alphaguard). The results obtained by the two methods had a correlation factor of 0.8, that can be considered reasonably good since the two methodologies of radon extraction from the samples were quite different. Effectively, the liquid scintillation method implied the separation of radon in the organic phase of an aromatic liquid dissolved in the water sample, and the ionisation chamber method used the bubbling of air to extract radon from the sample.

The water chemistry of the three springs showed stability for each spring and indicated, as previously stated (Segovia et al., 2002), that each spring had chemistry values that were stable in the time but different water characteristics indicating differences in the water origin. Volcanic gases emanating from the eruptive stage do not seem to had affected the surrounding aquifers.

As stated previously (Segovia et al., 2002; Varley and Armienta, 2001), the present eruptive stage was marked by low radon and gases emissions of magmatic origin at both the aquifers and the soil of the volcanic cone, due to the absence of significant migration of magmatic gas to the surface on the flanks of the volcano.

The analysis of the presence of volatile organic compounds (VOC's) in the water samples due to a possible anthropogenic pollution was performed because the sampled springs are used for domestic and industrial activities. In rural areas, the occurrence of VOC's in surface and groundwater's can originate from solvents, gasoline, aromatic hydrocarbons, herbicides and pesticides (Cisniega et al., 2002). The results showed that water of the three springs are free of VOC's.

The monitoring of Popocatepetl volcano for radon and water chemistry along the period from the beginning of the eruptive stage, started in 1994, until 2003, has shown that soil radon had its maximum peaks in correlation with the initial phase of the eruption in December 1994 at Tlamacas (Segovia and Mena, 1999), while smaller fluctuations appeared in correspondence with periodic lower crisis and the meteorological influence. On the contrary, groundwater chemistry including radon has shown smaller effects due to the volcanic activity.

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