THE METHOD OF MEASURING RADON AND OTHER ENVIRONMENTAL PARAMETERS AS EARTHQUAKE PRECURSORS

Leonardo Nicolì, Giuseppe Massimiani, Massimo Zucchetti, Gianluca Mastrantonio

iAReSP - Tellus Project - Via Miraflores 11/A – 67100 L'Aquila, Italy

ABSTRACT

In Pizzoli (Abruzzo - Province of L'Aquila) in central Italy, emissions of Radon (Rn222) in a measurement station, with a frequency of once every 10 minutes, have been continuously monitored, from 2 November 2015 to December 14, 2015, using a sensor with ionization chamber. Moreover, all the environmental parameters, both inside and outside the station, have been recorded with the same frequency. In particular, the following values are measured: internal temperature, humidity, atmospheric pressure, air density. External temperature, humidity, atmospheric pressure, air density, speed and wind direction, amount of rainfall were detected too. The results were evaluated, and the relationship between radon levels and the seismic activity has not yet been discussed due to irrelevant seismic activity recorded in the period. There was a systematic relationship between the concentration of radon and the outdoor temperature but also with other factors such as wind and atmospheric pressure. Inside the detection station, the temperature and humidity are almost constant. The results show the potential of this acquisition technique in distinguishing the type of measured anomalies in Radon emissions.

KEYWORDS:
Earthquake precursors; radon; measurement

INTRODUCTION

Since earthquakes are natural physical phenomena, the techniques used in order to predict whether an earthquake is approaching are based on geophysical data, seismic data, magnetic fields, electric fields and geodetic data.

Different types of gas in the earth subsurface exhale from active faults and deep geodynamic processes: they can produce anomalies, i.e. a sudden change of the characteristics of the observed time series, emissions, changes in temperature and water levels, electrical conductivity, and more. In general, all the anomalies, observable before an earthquake, could be useful for a better understanding of seismic precursors [1].

Radon (Rn222), in particular is recognized as a possible precursor of earthquakes. It is a radioactive and inert gas generated by the radioactive decay of Radium (Ra226) in the decay chain of Uranium (U238) [2]. Variations of Radon concentration, both in water and in the ground, associated to seismic activity, are well known since more than half a century. A standard explanation for the variation in dissolved Radon concentration in faults and water wells before, during and after an earthquake in an area is the following: variation in release of the gases entrapped in crustal rocks due to pore collapse and/or opening of micro-fractures caused by stress variations.

In 1966 in Russia it was observed an increase of the concentration of radon in the waters inside a well, before the earthquake in Tashkent [3]. In 1974, the first underground station to study the relationship between radon emission and earthquakes was installed in Slovenia [4-6]. Since those studies, changes in the concentration of radon in soil and groundwater are considered as potential precursors of earthquakes.

Unfortunately, to this date, no reliable method has been developed for the successful application of earthquake prediction, based on a human scale. Nevertheless, based on long-term studies, some earthquake precursors, and in particular radon emissions, have been identified, and studies began to appear since many decades [7-13]. However, most of these precursors are subject to so many different influences that they behave erratically and therefore have been poorly understood so far, making earthquake prediction a controversial issue. The scientific detection of anomalies precursors of earthquakes and development early warning system can be possible just through the simultaneous detection of multiple factors.

Our study area is in central Italy, close to the epicenter of the earthquake of Magnitude 6.3, occurred on 6 April 2009, that struck the city of L'Aquila; our station, specifically, is located in the small town of Pizzoli, 10.9 Km N-NW from the epicenter. It is a part – being actually the first station - of the Tellus project [14], aimed to study what happens during the phase preceding an earthquake, and subsequent correlation and prediction of incoming events. The Tellus Project consists of multidisciplinary stations suitable for the measurement of chemical, electromagnetic, meteorological and physical parameters on Earth [9]. In particular, the study focuses on the measurements of radon emissions on limited areas in the presence of various measuring stations (Local Area Network). The measurements of radon emissions are collected in a specific database, updated every hour, in a central data analysis station, where anomalies are analyzed.

Radon concentration can be measured in many ways, depending on whether detectors in the air or in water, indoor or outdoor, are used, and with different types of tools [9]. The methodology we have used is an indoor measurement technique, by means of an ionization chamber with continuous measurement of Alfa particles produced by the decay of Rn222.

To minimize the most important error factor in such measurements, that is, uncontrolled ventilation-induced radon variations, the ionization chamber was placed in a well of 40x40x40 cm, where the basement is underground, on the land directly. The cockpit has been built inside a hole (size 350x100 cm), at a depth of 100 cm where temperature and humidity are almost constant. The hole is located within the Monitoring Station, whose structure is made by reinforced concrete (of 5x4 m and 3 m high) located within a green area.

In particular, we have provided to avoid ventilation of the hole, by paying maximum attention to avoid air leaks. The cap – with a thickness of 4 cm - was closed with rubber seals. The closure was carried out on October 31st, 2015. This operation has provided excellent results showing a significant increase in the concentration of radon inside the hole housing the instruments, already in the subsequent hours after the installation of the seals. Further proofs of the effectiveness of outside air leaks prevention turned out to be, in time, the absence of the usual variations in Rn222 measured concentration due to some external factors.

Monitoring radon and other precursors concentrations at one location only, however, precludes the investigation of spatial nature of measured changes. The surveys at two or more sites could indicate whether the changes are due to local factors or indicate that something is happening elsewhere. For this reason it is foreseen, now at design stage, the realization of other monitoring stations to be installed at a distance of about 5/10 Km from the current one.

The aim of our research is to verify the relationship between the geochemical variations we measure and the occurrence of earthquakes, including spatial indications of where the earthquake epicenter could be located: for that, once proven our detection station concept is working correctly, a net of several stations is necessary, as specified above, at close distance one to each other.

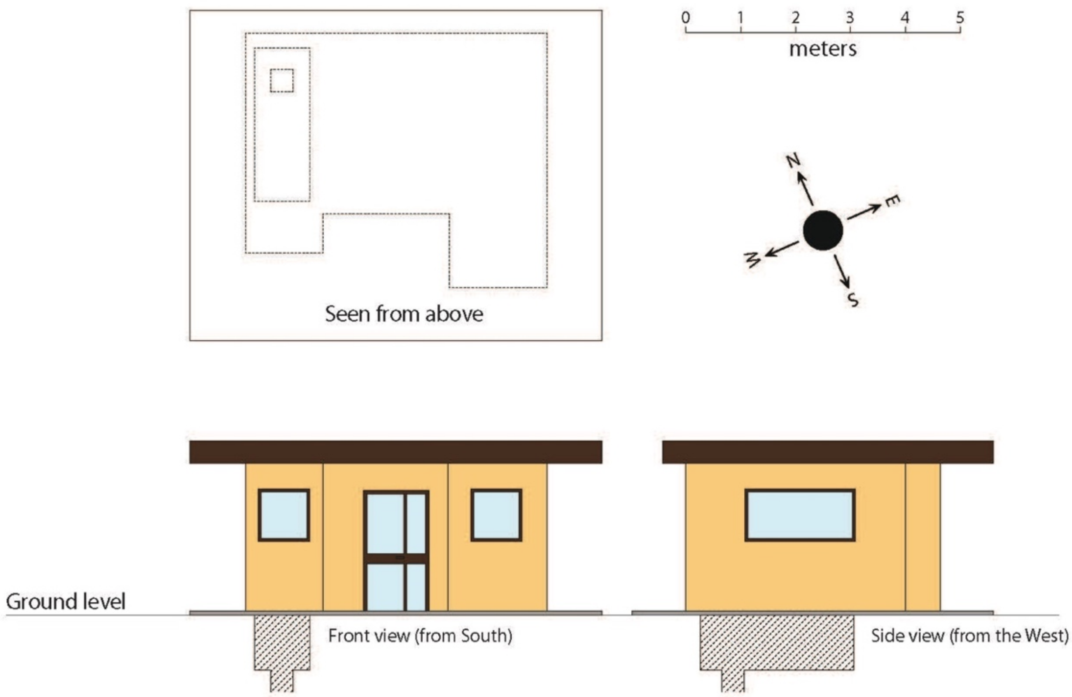

FIGURE 1
The monitoring station in Pizzoli, first of a kind of the Tellus project

DESCRIPTION OF THE DETECTION STATION AND RESULTS

The station (see Figure 1) is located in the municipality of Pizzoli (AQ) in location Marruci, at 803 m above sea level, the geographical coordinates Latitude and Longitude being 42.4307 and 13.2769 respectively.

The measurements of all atmospheric parameters, indoors and outdoors, are continuously monitored by the station instruments, with data collected every 10 minutes with a Davis Vantage Pro2 weather station software. Radon was measured with R.I.C. (Radon Ion Chamber) ionization chamber with two liters of characteristic volume. To measure indoor Radon concentration we use the method of Continuous Radon Monitoring (C.R. of EPA). The air is diffused into a counting chamber. The counting chamber is a ionization chamber. Scintillation counts are processed by electronic equipment, and radon concentrations for predetermined intervals are stored in the instrument's memory [9].

The measurements – as specified above – have been taken at the monitoring station of Pizzoli, L'Aquila Province, Abruzzo Region, Italy.

The radon detector is connected to the central detection forecast center via internet. The first positive result we have collected – as it will be shown – is the following: temperature and humidity inside the cockpit turned out to be almost constant, a necessary starting point for avoiding prediction errors.

Variations in Radon emissions do not only depend on earthquakes, but also on the combined effects of luni-solar tides, on winds, on the humidity, the temperature, the atmospheric pressure, volcanic activity, cosmic radiations, all disturbances which must be filtered and eliminated before hoping to detect variations due to telluric events [9, 12, 13].

The integrated multidisciplinary station provides multi-method measurement approach. Measurements both indoors and outdoors represent great asset to supply the correlation of these data and locate the detection anomalies of earthquake precursors. The measurement of environmental parameters, in particular temperature, pressure and humidity, is also part of the station. An external antenna, for the monitoring of the electrical component of the electromagnetic field in the bands ELF and VLF, is part of the equipment as well.

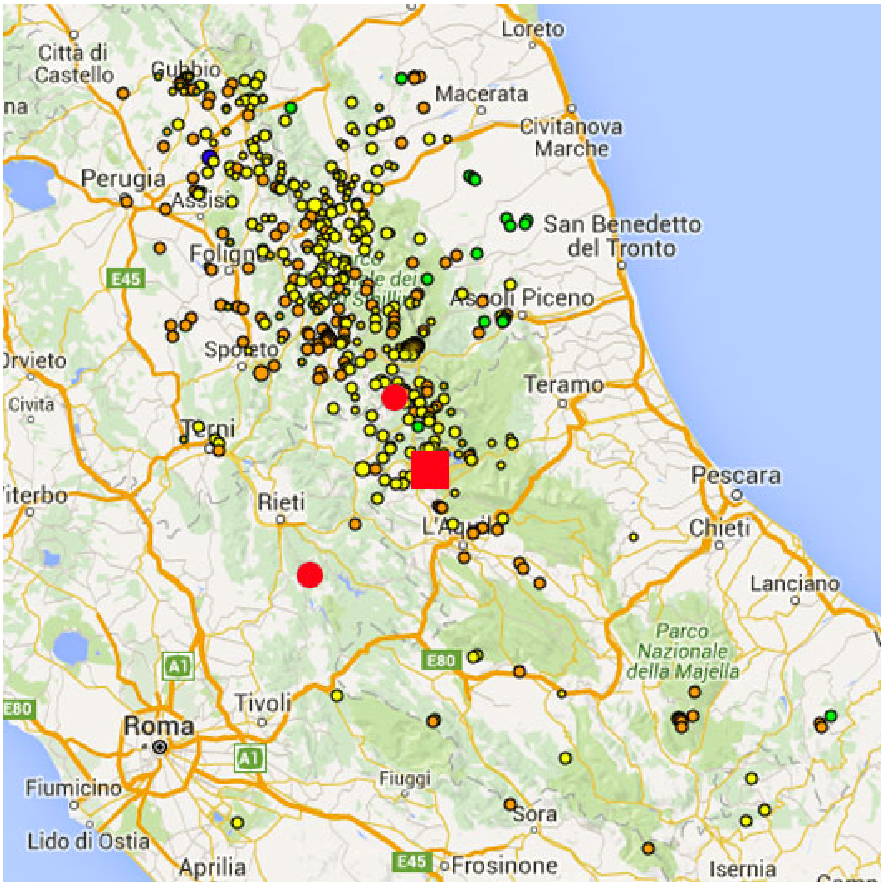

FIGURE 2
Earthquakes in the monitored area, November-December 2015. Monitoring station is a square red.

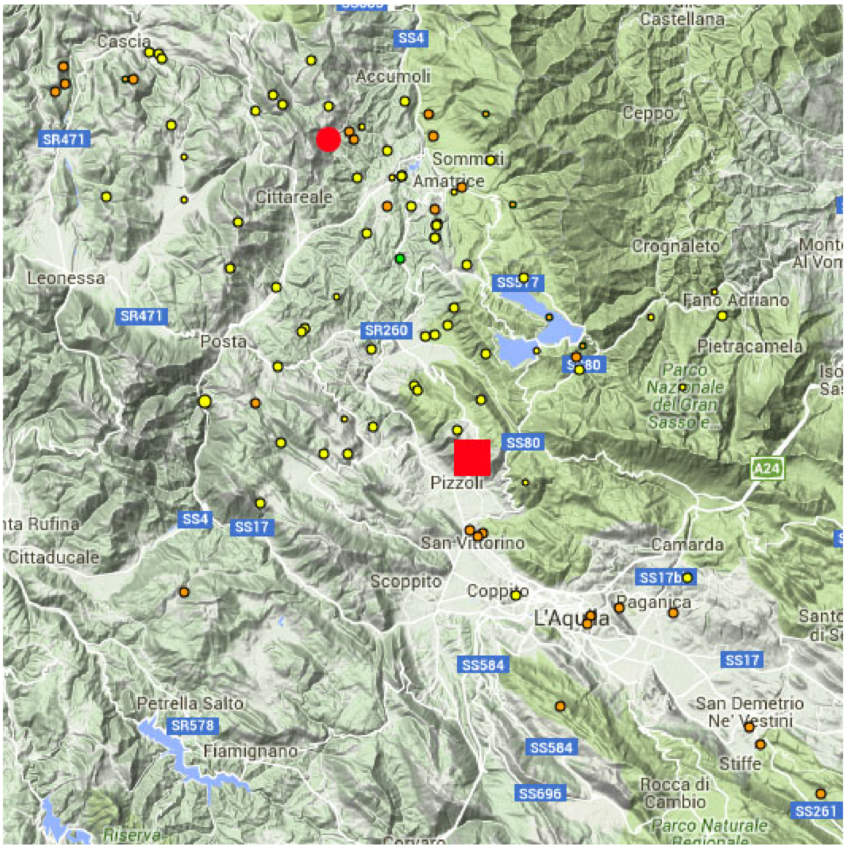

FIGURE 3
Earthquakes close to the monitoring station (square red), November-December 2015.

During the whole period examined, from November 2nd 2015 to December 14th 2015, there were a total of 547 seismic events recorded in a radius of 100 km from the station; they were all minor ones, with the maximum magnitude M 2.3 (November 23rd and 25th, 2015 – see Figure 2). Furthermore, 95 earthquakes within a radius of 30 km from the station were observed, with a maximum magnitude 2.3 M on November 25th 2015, see Figure 3. Those ones were minor too.

No major seismic event was detected near the detection point: strongest earthquakes, recorded in that period, occurred at relevant distances from the station. Radon anomalies detected in emissions over the examined period are all caused by external factors, not related with earthquakes.

The graph in Figure 4 shows the survey from November 2nd to December 14th, and in it we have highlighted the three major anomalies. In all the three cases, being able to measure other outdoors parameters as temperature, pressure, and wind speed, it turned out clearly that those changes in the Radon emissions coincide with change in the weather and in particular the atmospheric pressure and wind speed.

In Figure 5, we see more in detail a section of the observed series, precisely the ones between November 25th and December 6th 2015, where we see the classic pattern of regular daily Radon variations. Those collected data, with a time series of greater length, are useful to study the relationship between Radon concentration and atmospheric variables.

The amount of Radon due to diffusion processes through the components in structure and the closing cap of the hole where the detector is put, being well sealed, is negligible. The main cause of the inflow of radon is due to the pressure difference, which is created between outdoors and indoors.

Usually, the internal environment is in depression compared to the outside. This depression (only amounting to a few Pascal) is caused mainly by two factors: the chimney effect and the wind effect. The chimney effect is due to the temperature difference between inside and outside, in function of which a pressure difference is formed. In consequence of this internal depression, cold air containing radon is sucked from the soil. The greater is the difference between the outside and inside temperatures, the greater will be the effect. The wind effect is instead due to the difference in air speed between the outside and inside of the structure [15-16].

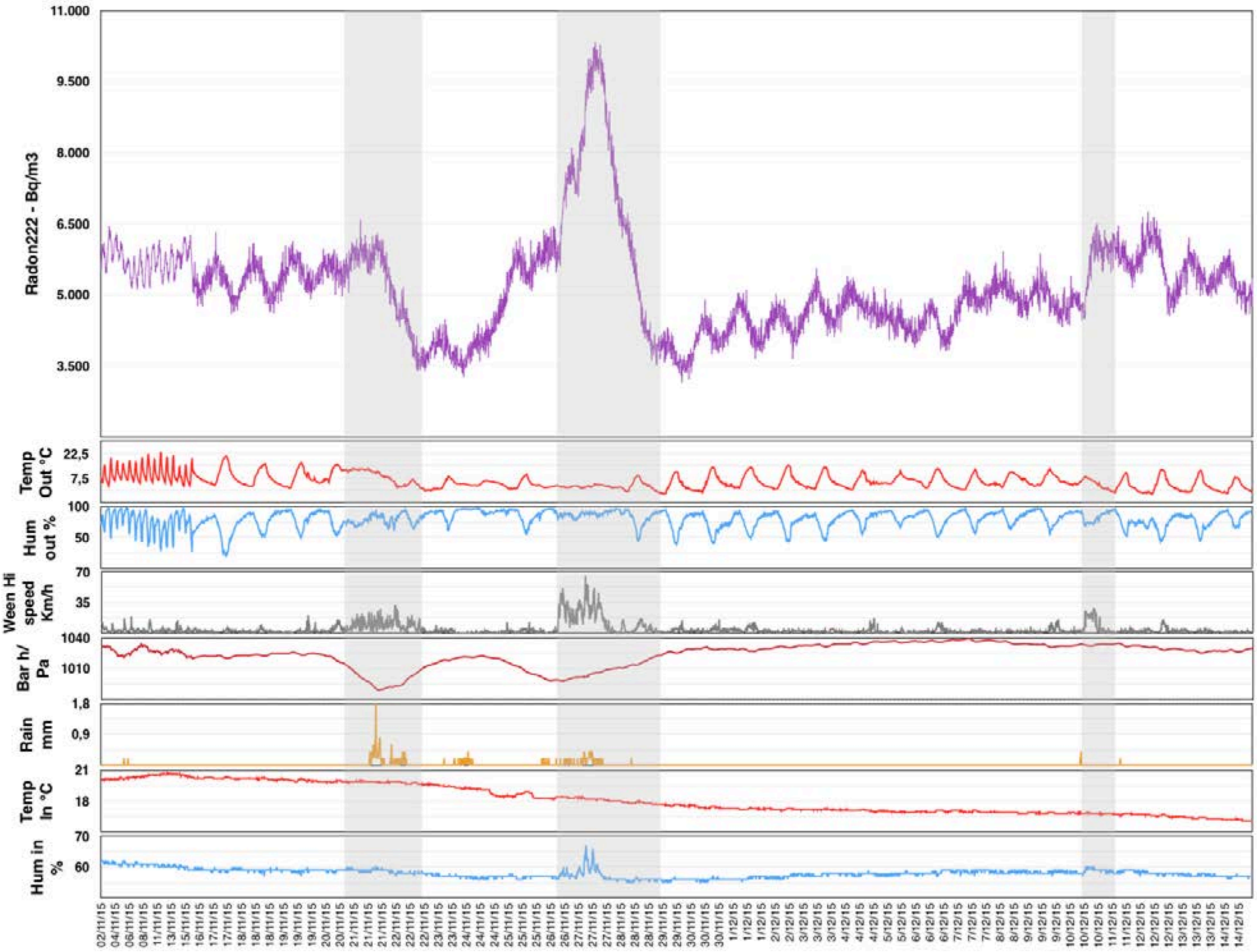

FIGURE 4
Summary of monitored parameters

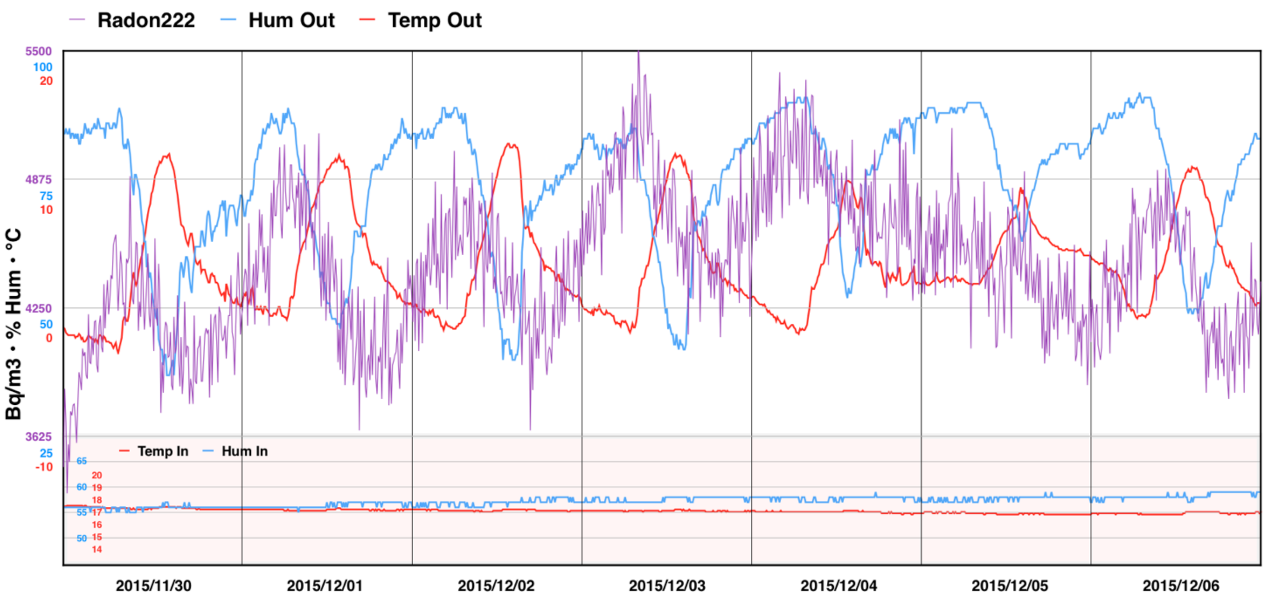

FIGURE 5
A detail of some of the monitored parameters (radon222, Outside humidity, Outside temperature)

CONCLUSIONS

During the period of measurement of the emission of Radon, we have not measured any anomalies, except those caused by meteorological factors, which we have been able to individuate and discard. We have recorded no false positives, and that is the main scientific result of this first survey period. For the moment, we have recorded no false negatives too, because the seismic activity was absent or of very low magnitude and there were no "significant" anomalous radon emissions.

Of course the relatively small observational period does not let us able yet to understand, in greater detail the relation between Radon emission and earthquakes, but further periods of observation are now being recorded and will be used for further assessments. We want to highlight that the contemporary measurement of other data than simple Radon concentration allows us to apply methods for distinguishing anomalies caused by climatic factors from those attributable to seismic activity, using modern statistical techniques.

The results we obtained demonstrate the potential of this acquisition technique to identify the type and origin of measured anomalies in Radon emissions.

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CORRESPONDING AUTHOR

Massimo Zucchetti
iAReSP - Tellus Project
Via Miraflores 11/A
67100 L'Aquila – ITALY

e-mail: info@iaresp.it