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Seismicity Analysis Using Radon Anomalies in the Exhalation Rate at Huarangal 2018: First Results

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Abstract: The goal of this study is to use anomalies in the exhalation of radon (222Rn) from the floor of a building, as a way to predict the appearance of an earthquake days or hours before it happens. The methodology used is based on the study of the change of radon exhalation using an airtight container placed on the floor of the interior of a building continuously measuring the radon concentration inside with a Radon Scout monitor. These measurements were made in the Radiological Safety Bunker of the Nuclear Power Plant of Huarangal, Lima, Peru.

Keywords: seismicity, radon, tracer.

1 Introduction

Several studies have been carried out on radon concentration anomalies in soil, air and / or water, with the aim of using them as predictors of seismic activity (Singh et al., 1993; Ghosh et al., 2009; Jaisy et al., 2014; Kuo et al., 2018). A review of radon measurements taken around the world was analyzed in detail, attempting to distinguish between discrete and continuous measurements, and between measurements in soil, water, or air (Riggio et al., 2015).

There are places in the earth's crust that have been in motion for millions of years, specifically in this case the Nazca plate and the South American plate, which could be responsible for radon leaks, making the chosen study area a natural laboratory in which observe the exhalation of radon as a precursor to seismicity due to the movement of the Nazca plate, which is being forced under the South American plate at a rate of approximately 5-6 cm/year (Figure 1).

Our study presents the first results based on measuring the variation in radon exhalation inside a home, correlating it with seismic activity.

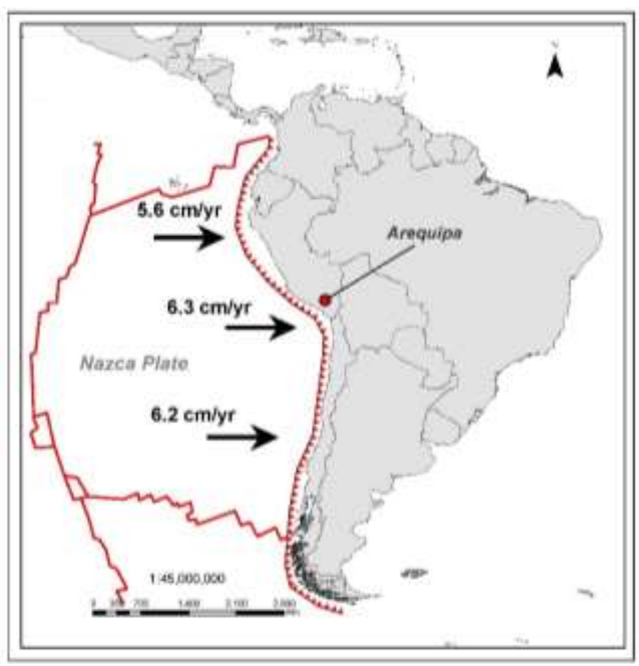

Fig. 1: Movement of the Nazca Plate towards the South American coast.

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2 Experimental Section

If a container is placed on the floor of a house and the concentration of radon gas inside it is measured from the beginning, it will increase until a state is reached in which the production of the gas is balanced by its radioactive decay. Under these conditions, the main factor related to this increase is the process of diffusion through the concrete that connects it to the ground, and is almost independent of external meteorological conditions (Renken and Rosenberg, 1993). Thus, if this state of equilibrium is altered, it could be due to the possible presence of underground seismic activity. It is these variations in the concentration of radon gas in the container over the equilibrium state that we have studied and correlated, through the following stages:

Stage 1:

As previously indicated, a 3 x 4 m house was chosen with a 20 cm thick concrete layer (Radiological Safety Bunker of the Rasco Nuclear Power Plant, Lima, Peru). An airtight stainless steel cylindrical container, 48 cm in diameter and 34 cm high, was placed on the floor of the house, fixed with radon-impermeable acrylic paint in order to prevent radon from leaking from the container (Figure 2).

Fig. 2: Steel container.

Stage 2:

Inside the container, a Radon Scout continuous radon monitor (SARAD GmbH.) was placed, calibrated by the Laboratory of Environmental Radioactivity of the University of Cantabria (LaRUC) (Fuente et al., 2018). The monitor is battery operated and has a data storage time of 4 months. The detection limit is 50 Bq/m^3 for a measurement time of 30 minutes.

Stage 3:

The Geophysical Institute of Peru provided information on earthquakes during the measurement period (Table 1).

Stage 4:

The correlation study between the variables was carried out for the study period.

3 Results and Discussion

Exhalation in the floor of the building

According to the Geophysical Institute of Peru, measurements were made for a period of 300 hours, without seismic activity, in order to know the equilibrium concentration of radon inside the container to determine the natural background (Figure 3).

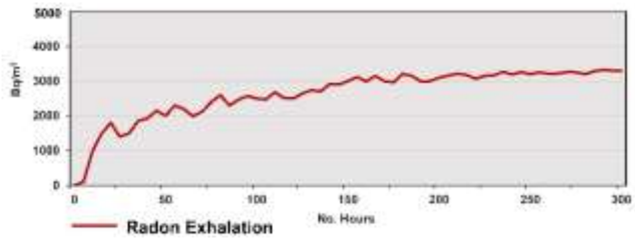

Fig. 3: Radon concentration rates at equilibrium inside the container.

The equilibrium value found was 3600 ± 500 Bq/m^3 and this was the chosen reference value. With this value, any measurement above 5100 Bq/m^3 was considered a "radon anomaly" because it assumed three standard deviations above the background.

Figure 4 shows the set of measurements carried out during the study period, 5000 hours, with the specific occasions in which this value was exceeded.

Of special interest was an earthquake in Mala, measuring 5.5 on the Richter scale, 110 km from the place of measurement and Huacho, of 4.9 on the Richter scale, which was even felt at the Huarangal Nuclear Power Plant in Puente Piedra, Lima and which is located 124.01 km from the epicenter for which radon concentrations inside the container showed higher values to 8700 Bq/m^3.

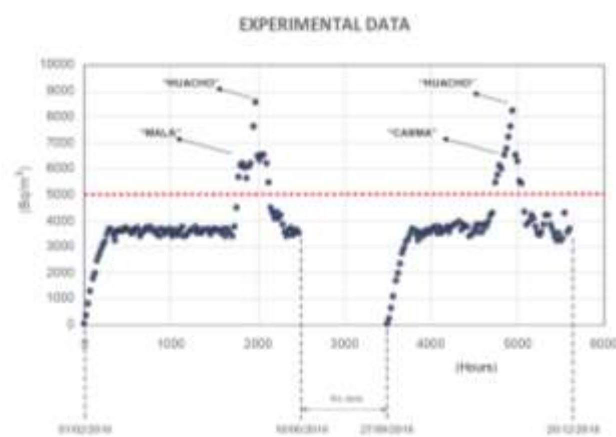

Fig.4: Measurements of radon inside the container.

Radon disturbances are expected to be clearer and greater the closer the epicenter of the earthquake (Table 1) is to the place where the measurements are taken, as is the case of the Huacho earthquake of 05/22/2018, in which the exhalation began to grow back in the previous days. Similarly, this change caused by seismic activity is reflected in November 2018 there were a series of seismic events, one in Casma, 296 km from the epicenter with an intensity of 5.7, and another in Huacho, 124.05 km from the epicenter with an intensity of 4.5 on the Richter scale, which produced unusual radon exhalations of approximately 6000 Bq/m^3 and 8000 Bq/m^3, respectively.

4 Conclusions

Using the described methodology, it is shown that seismic events, especially those stronger than five on the Richter scale, produce easily detectable radon anomalies in the rate of exhalation from the ground of a home. However, to confirm this correlation, it would be necessary to have a more extensive chronological series, a task in which we are currently working.

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Appendix

Table 1. List of the most recent earthquakes recorded on the coast during the measurement of radon exhalation from the floor of the building. (Source: Geophysical Institute of Peru (IGP 2018)).

Item	Date time	Place	Depth	Magnitude	Reference	Latitude	Longitude	Distance
1	4/28/2018 09:33	Chilca	42	3.9	27 km SW Chilca Lima	12° 36´ 36´´	76 ° 58´12´´	89.98
2	4/28/2018 09:02	Chilca	47	3.8	7 km SW Chilca Lima	12° 31´48´´	76 ° 48´00´´	84.2
3	4/29/2018 12:58	Callao	22	4.5	140 km West Callao Lima	12° 20´ 24´´	78° 23´24´´	161.49
4	5/8/2018 01:18	Lunahuana	95	4.1	5 Km SW de Lunahuana Lima	13° 00´00´´	76 ° 09´00´´	162.89
5	5/13/2018 07:28	Ancon	48	3.8	53 Km SW de Ancon Lima	11° 52´ 48´´	77 ° 23´24´´	42.07
6	5/16/2018 05:01	Matucana	84	4	36 km South Matucana Lima	12° 09´ 36´´	76 ° 22´12´´	80.49
7	5/17/2018 08:06	Mala	49	5.5	30 km SW Mala Cañete Lima	12° 47´ 24´´	76 ° 52´12´´	110.95
8	5/22/2018 08:08	Huacho	48	4.9	61 Km SW Huacho Lima	11° 15´ 24´´	78° 9´00´´	124.01
9	6/17/2018 11:24	Yauyos	104	4.1	18 km SW Yauyos Lima	12° 33´ 36´´	76 ° 18´00´´	118.59
10	6/20/2018 13:22	Casma	16	4.1	85 km SW Casma Ancash	09° 54´ 24´´	78° 55´48´´	297.15
11	6/23/2018 18:18	Ancon	48	3.8	53 km SW de Ancon Lima	11° 17´ 24´´	77 ° 39´00´´	89.82
12	6/25/2018 03:44	Lima	67	4	24 km West Lima Lima	12° 00´ 00´´	77 ° 14´24´´	33.21
	NO DATA	NO DATA	NO DATA	NO DATA	NO DATA	NO DATA	NO DATA	NO DATA
13	12/8/2018 07:21	Casma	34	4.1	62 km SW Casma Ancash	9° 55´ 12´´	78° 52´48´´	292.23
14	9/27/2018 17:00	Huacho	52	4.9	72 km SW Huacho Lima	11° 30´ 18´´	78° 7´48´´	121.84
15	10/13/2018 19:21	Huacho	64	4.2	58 km SW Huacho Lima	11° 18´ 00´´	78° 6´00´´	131.05
16	10/14/2018 02:26	Huacho	97	4.2	55 km NE Huacho Lima	10° 56´ 24´´	77° 7´48´´	96.58
17	10/25/2018 01:36	Ancon	24	3.8	62 km SO de ancon Lima	11° 53´ 24´´	77° 43´12´´	77.71
18	10/31/2018 21:23	Chimbote	34	3.6	34 km West Chimbote Ancash	9° 10´ 48´´	79° 16´12´´	415.54
19	10/31/2018 16:50	Chilca	36	3.7	36 km South Chilca Cañete Lima	12° 34´ 12´´	77° 42´00´´	79.24
20	11/20/2018 02:56	Casma	44	4.7	86 km SW Casma Ancash	9° 57´ 00´´	78° 55´12´´	292.94
21	11/20/2018 01:38	Casma Huarmey	46	5.7	90 km SW Casma Ancash	9° 57´ 00´´	78° 57´36´´	296.07
22	11/23/2018 08:10	Chimbote	69	4	46 km West Chimbote Ancash	9° 7´ 12´´	79°0´00´´	368.95
23	11/25/2018 06:34	Huarmey	42	3.8	78 km SW Casma Ancash	9° 49´ 12´´	78° 55´12´´	303.29
24	11/25/2018 15:20	Huacho	68	4.5	59 km SW Huacho Lima	11° 23´ 24´´	78° 4´12´´	124.05
25	12/11/2018 16:51	Chilca	55 km	3.9	18 km South Chilca Cañete Lima	12° 39´	76° 48´36´´	96.85