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MEDICIONES DE LA CONCENTRACIÓN DE RADON 222 EN AMBIENTES INTERIORES EN LIMA – PERÚ

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Concentration measurements of radon 222 indoors in   Lima – Peru.

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Concentration Measurements of Radon 222 Indoors in Lima – Peru

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Abstract The measurement of the levels of 222Rn was accomplished during autumn to spring season in 2014 at residences distributed throughout 30 districts of Lima Metropolitan Area, including the north, centre and south areas of the city. The houses where the measurements were achieved were selected considering several variables as type of construction, age, construction materials, coatings, soil type, occupational use of rooms monitored, etc. For all the measurements of 222Rn passive detectors was used (Solid State Nuclear Track Detectors SSNTDs) of cellulose nitrate (LR- 115). Procedure and data acquisition are described and results; this monitoring is the first realized in this city. The results are only indicating the presence of 222Rn, the detectors used do not allow to the discrimination of its descendants.

Resumen Se realizó la medición de los niveles de Radón 222 en las estaciones de otoño y primavera del 2014 en residencias correspondientes a 30 distritos de Lima Metropolitana, incluyendo a las zonas Norte, Centro y Sur de la ciudad. Las casas en donde se realizaron las mediciones fueron seleccionadas considerando diversas variables como antigüedad, materiales de construcción, revestimientos, tipo de suelo, uso de las habitaciones monitoreadas, etc. Para las mediciones de Radón 222 se utilizaron detectores pasivos (Detectores de Estado Sólido de Huellas Nucleares) de nitrato de celulosa (LR – 115). En el trabajo se muestra el procedimiento de toma de datos, lectura de los dosímetros y los resultados de la medición, que es la primera que se realiza en esta ciudad. Los resultados solo indican la presencia de Rn 222, los detectores empleados no permiten discriminar la presencia de los descendientes del Radón 222.

A María Pía, mi familia, profesores, amigos y todos los que de alguna forma me animaron a seguir tras mis huellas…..

Concentration Measurements of Radon 222 Indoors in Lima – Peru

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Abstract The measurement of the levels of ^{222}Rn was accomplished during autumn to spring season in 2014 at residences distributed throughout 30 districts of Lima Metropolitan Area, including the north, centre and south areas of the city. The houses where the measurements were achieved were selected considering several variables as type of construction, age, construction materials, coatings, soil type, occupational use of rooms monitored, etc. For all the measurements of ^{222}Rn passive detectors was used (Solid State Nuclear Track Detectors SSNTDs) of cellulose nitrate (LR- 115). Procedure and data acquisition are described and results; this monitoring is the first realized in this city. The results are only indicating the presence of ^{222}Rn, the detectors used do not allow to the discrimination of its descendants.

Keywords: Monitoring of ^{222}Rn, nuclear tracks detectors, cellulose nitrate

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1. Introduction

^{222}Rn Gas, natural radioisotope that presents imperceptibly in our senses is the main contributor to the natural radiation received by humans. ^{222}Rn is an inert gas that emits alpha particles and has a relatively short average life (3.8 days). Radon proceeds from the decay of ^{226}Ra.

Radon gas emanates in small quantities from the soil and building materials. It incorporates to the air, usually in low concentrations; decays in his daughters (^{218}Po, ^{214}Po) but it can be risky in poorly ventilated or closed areas where it is susceptible to be inhaled by living beings. In ideal conditions it should not exceed 200Bq•m^{-3} [10].

Research works establish a close relationship between inhalation of significant concentrations of radon indoors and lung cancer. This risk increases in active smokers and even in passive smokers up to in a factor of 10. In this case, Radon is the most important factor about lung cancer incidence [11].

Although ground radon is the main source of this natural radioactivity contaminant indoors, it can sometimes come from well water or watershed. On the other hand, in certain types of houses, the building materials can also emit radon, increasing its presence, but rarely does this constitute the main cause of a high concentration. Radon can enter a house through cracks in the foundations, cracks in the walls, through the joints of the walls or internal cavities in the walls, through the spaces around the pipes, through water, etc.

The main interest of this study is the measurement of radon concentration in different types of houses in the city of Lima, considering its geographical location and give suggestion if it is suitable.

Nuclear tracks solid state detectors used in this ^{222}Rn monitoring have been used in similar investigations; methodology and fundamentals of the technique are known [4].

2. Rationale

Lima, the capital of Peru, is a city with near 10 million inhabitants located on the west coast of South America, in front of the Pacific Ocean at 12° South Latitude and 77°3' West Longitude, it covers an area of 3900 km^2. Lima is a flat city, rounded by some hills and mountains irrelevant. Geological outcrops correspond to intrusive, extrusive and lesser sedimentary rocks amount. It is located on the valleys of Rimac, Chillon and Lurin rivers. Presents mostly alluvial gravel soils and rocky outcrops; also it presents some areas of sandy soils (seismic micro zonation of Lima).

The urban development of the city of Lima throughout its history has been increased in recent 40 years, in which its population has tripled. Mostly on the new city is over a desert terrain, but also comprises fertile areas. Due to excessive and disordered urban growth, the city extends in the so called north, south and west cones, growing on rocky, sandy terrains, slopes and hills of surrounding terrains. The province of Lima is divided into 43 districts, distributed for this study in 4 areas: North, East, Central and South.

The aim of this research is to know concentration levels of ^{222}Rn in some houses for begin to do a Radon map from Lima and to be a beginning to identify an eventual

sanitary risk to its inhabitants related about lung cancer and others.

To conduct the measurements some houses of teachers, students and workers of Pontificia Universidad Católica del Perú (PUCP) were selected, who voluntarily collaborated to host detectors in their homes. Formerly mails were sent with concise information (scope of the project, reason of the measurements and how it would be done.) Those who answered affirmatively and were selected due to their geographic location were given additional information and guidelines for site selection of measurements in their houses and the commitment to place detectors properly. Volunteers themselves removed and placed detectors.

3. Materials and Methods

To conduct measurements of ^{222}Rn on the selected buildings we used passive detectors using the Nuclear Tracks technique (SSNTDs). The detectors are made of cellulose nitrate LR115 Type 2, 12 μm thickness, high sensitivity, capable of recording the passage of low energy alpha particles. These detectors are not affected by electrons or other type of electromagnetic radiation (gamma radiation, X-rays, etc.). They can be stored in standard conditions for periods of time that exceed one year. Naked passive detectors were used, of square shape,

20 mm by side, supported to a square bracket of 60 mm a side, taken from a transparency film, duly coded as shown in Figure 1.

Figure 1. LR 115 detectors used in Radon 222 monitoring

3.1. Sampling Conditions

Three sampling areas were taken in consideration in Lima: North, Central and South. The distribution of the number of districts and number of houses monitored are shown in Table 1 and in Figure 2. The total population of this districts is 7 252 455 inhabitants [12] it represents about 74.5 % from Lima population.

Table 1. Dwellings monitoring Radon in Lima by zone.

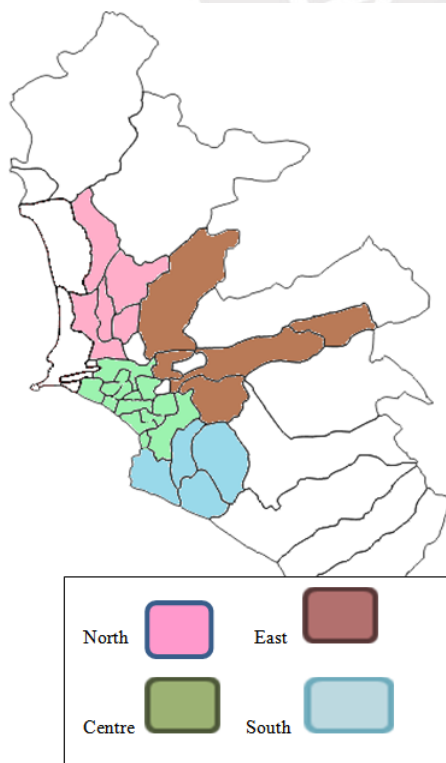| Zone	Districts by zone	Districts	Number of dwellings by zone
Central	13	Lima Cercado, San Borja, Miraflores, Magdalena, Pueblo Libre, San Miguel, Jesús María, Breña, Lince, La Victoria, Surco, Surquillo, San Isidro	50
South Cone	3	San Juan de Miraflores, Villa María del Triunfo, Chorrillos	11
North Cone	5	Independencia, Puente Piedra, San Martín de Porres, Los Olivos, Comas	18
East Cone	4	La Molina, El Agustino, Ate-Vitarte, San Juan de Lurigancho	18

The detectors were coded according to the area, and then the district selected, houses of that district A, B or C and finally the detector number (from 1 to 6). In total 396 detectors were processed.

Sampling was given in periods from 7 to 8 weeks during autumn and winter in 2014. During this period 2 detectors were placed per house, this is to say that six detectors were recorded in total for each sampling site. Indications were given to consider placing the detector at the less ventilated area of the house (bedroom, bathroom, basement, garage ....) Participants filled out a form where the characteristics of the building and lining the walls of the room and the floor were indicated, as well as the average time spent by the family in the rooms studied. Other data recorded were the age of the house, building materials and if the people who lived there were smokers or other relevant data.

3.2. Etching and Reading Process

Etching was made under standard conditions in a thermostated bath using NaOH solution. It was shown in Figure 3a. For the reading an optical microscope was used (Figure 3b), counting four fields per detector to determine the average reading. It can be used the usual procedure for these detectors [3,9]. After that, the density of traces per mm^2 was determined using the calibration factor corresponding [7].
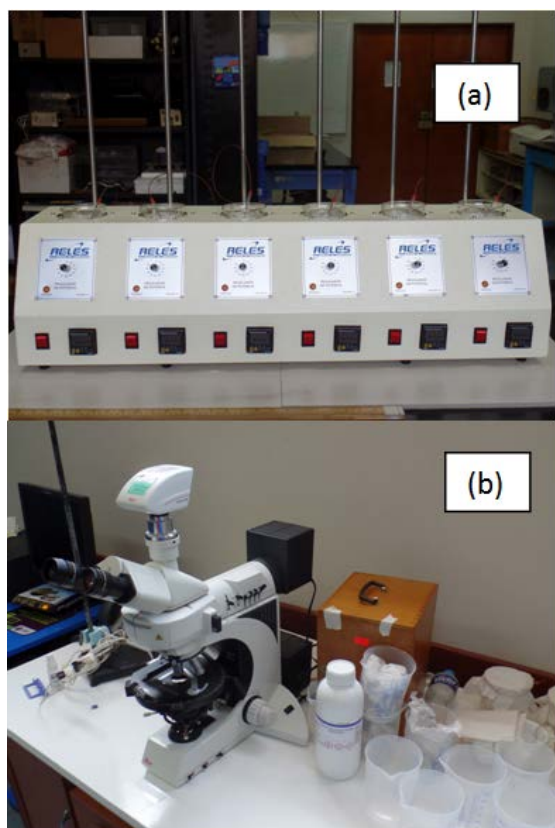

Figure 2. Geographical location of LR 115 detectors used in ^{222}Rn monitorin

Figure 3. (**a**) Etching process (**b**) Reading process

4. Results

Results are shown by zones and districts in the following tables. The North zone is in Table 2; the east zone is in Table 3; the south zone is in Table 4 and the center zone is in Table 5. The measurements above 500 Bq/m^3 of Rn 222 concentration are highlighted. Some detectors were loses and the time of monitoring each of them could be inexact. Detectors were placed in basements or closed rooms, without ventilation and non-habited.

North Zone

Monitoring was made in 5 of 8 districts of north zone, with more population and area. The population in this area is about 2 129 075 inhabitants [12]. It represents near 86% population in north zone. Results are shown in Table 2.

Table 2. Monitoring results of ^{222}Rn in the Northern Area of Lima City

District	Dwellings monitoring	Minimum value Bq/m^3	Maximum value Bq/m^3	Mean value Bq/m^3	Percent dwellings less tan 200Bq/m^3	Percent dwellings less than 400Bq/m^3	Percent dwellings up to 400Bq/m^3
Puente Piedra	1			562	0	0	100
San Martín de Porres	8	20	632	205	62.5	25	12.5
Los Olivos	4	48	162	108	100	0	0
Comas	3	122	141	129	100	0	0
Independencia	2	64	97	81	100	0	0

East Zone

Measurements were made in 5 of the 8 districts in this zone; the districts with more population and area were selected. In the selected districts live 2 101 866 inhabitants [12], it represents near 81% population in the east zone. Results are shown in Table 3.

Table 3. Monitoring results of ^{222}Rn in the Eastern Area of Lima City

District	Dwellings monitoring	Minimum value Bq/m^3	Maximum value Bq/m^3	Mean value Bq/m^3	Percent dwellings less tan 200Bq/m^3	Percent dwellings less than 400Bq/m^3	Percent dwellings up to 400Bq/m^3
Ate	2	9.48	257	133	50	50	0
Chacla cayo	2	214	251	232	0	100	0
El agustino	1	1		272	0	100	0
San juan de Lurigancho	10	81	432	173	70	0	30
La Molina	3	22	180	96	100	0	0

South Zone

Measurements were made in 5 of the 7 districts in this zone, with most demographic density. In this selected districts live 1 618 049 inhabitants [12], it represents near 71% population in the east zone. Results are shown in Table 4.

Table 4. Monitoring results of ^{222}Rn in the Southern Area of Lima City

District	Dwellings monitoring	Minimum Value Bq/m^3	Maximum value Bq/m^3	Mean value Bq/m^3	Percent dwellings less tan 200Bq/m^3	Percent dwellings less than 400Bq/m^3	Percent dwellings up to 400Bq/m^3
Chorri llos	2	17	75	46	100	0	0
San Juan de Mira flores	5	23	387	219	20	80	0
Villa el Salvador	1			173	100	0	0
Villa María del triunfo	3	18	319	214	33	66	0

Centre Zone

Measurements were made in 12 of the 16 districts in this zone; the districts with more population and area were selected. In the selected districts live 1 543 180 inhabitants [12], it represents near 83% population in the east zone. Results are shown in Table 5.

Table 5. Monitoring results of ^{222}Rn in the Central Area of Lima City

District	Dwellings monitoring	Minimum Value Bq/m^3	Maximum value Bq/m^3	Mean value Bq/m^3	Percent dwellings less tan 200Bq/m^3	Percent dwellings less than 400Bq/m^3	Percent dwellings up to 400Bq/m^3
Breña	2	156	348	252	50	50	
Jesús María	3	70	136	112	100		
Lince	2	129	269	199	50	50	
Magdalena del Mar	4	90	305	181	40	60	
Miraflo res	5	57	942	312	40	40	20
Pueblo Libre	6	118	268	185	67	33	
San Borja	4	0	658	221	75	0	25
San Miguel	11	20	480	178	64	27	9
La Victoria	2	109	129	119	100	0	0
Lima Cercado	7	61	604	246	42	29	29
Surco	2	109	285	197	50	50	0
Surqui llo	1			584	0	0	100

Summarizing results by zone are shown as follow

	Mean (Bq/m^3)
North	177
East	168
South	182
Central	205

Districts were shown now in relation with the concentration level measures obtained. It is noted that detectors with higher concentration was located in central zone. In this zone the dwellings are older (overall in Lima Cercado). San Juan de Miraflores and Villa el Salvador are the highest means at south zone; they are located in granular and sedimentary soils. Most of them who present low levels of Radon are located in rocky soils. In the case of Puente Piedra and Surquillo only one dwelling has been monitoring, so the result are not representative.

A tentative radon map is shown in Figure 4. Level concentration mean of ^{222}Rn by zone are shown in Figure 5 for each district. Districts with only one dwelling were not considered [8].
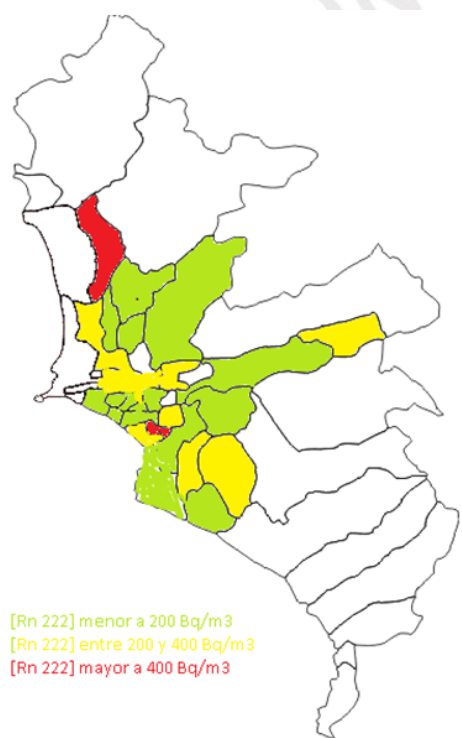

[Rn 222] menor a 200 Bq/m3
[Rn 222] entre 200 y 400 Bq/m3
[Rn 222] mayor a 400 Bq/m3

Figure 4. Districts of Lima and concentration of ^{222}Rn registered
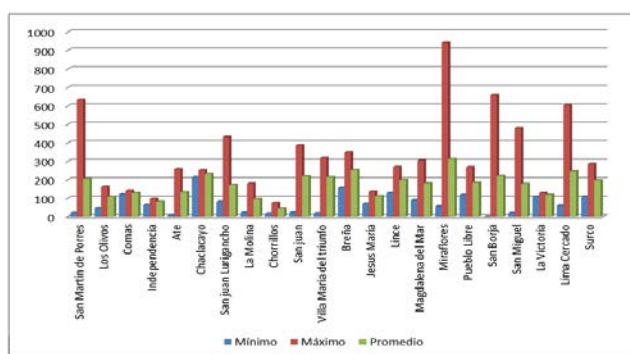

Figure 5. Concentration levels of ^{222}Rn in Bq/m^3 – Average values by district in Lima

5. Conclusions

The first approach in environmental monitoring of Radon 222 in the city of Lima has been accomplished. Reports of similar investigations employing SSNTDs in other cities have similar results [1,5,6]. In general most detectors recorded values corresponding to concentrations below 200 Bq/m3; when registering high values, it may indicate a correlation between the age of the house and the level of ^{222}Rn; these levels are increased in basements considerably, and are just 3 of the 4 cases with a higher concentration of ^{222}Rn measured. It can also be understood that in the case of basements, water pipes increase radon levels with poor ventilation, a key factor in the diffusion of radon. Variables such as building materials and floor and wall coverings require further analysis and data number. In general the methodology is consistent and concentration gives similar results to other methods in similar geographic locations.

Acknowledgment

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