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INDOOR RADON MEASUAREMENTS IN DWELLINGS AND OTHER BUILDINGS IN THE METROPOLITAN REGION OF BELO HORIZONTE, BRAZIL

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ABSTRACT

Radon is a radioactive noble gas derived from the natural decay series of ^{238}U, ^{235}U, and ^{232}Th, which are present in rocks and soils. By diffusion and convection, radon migrates from the rocks and soils to the surface and through fissures, pipes and holes it may enter the dwellings and other buildings. Another important indoor radon source is the building material construction. Therefore, it may accumulate indoor environments with reduced ventilation rates. Radon progeny attach to the aerosol particle in the air. The attached and unattached radon progeny may deposit in the lungs and irradiate to the lung tissue as they decay. Radon has been recognized as a radiation hazard, that causes excess of lung cancer among underground miners and there is an evidence that radon is also a heath hazard in dwellings and other indoor environments. Radon accounts for about half of all human exposure to natural radiation. Radon concentration measurements were carried out in dwellings, schools and shopping centers in the Metropolitan Region of Belo Horizonte - RMBH. Most part of the inhabitants of the RMBH lives over the granitic gneissic complex, which has a variable depth out coming in some areas. For the radon concentration measurement continuous detectors, AlphaGUARD PQ2000PRO, RAD7 and Pylon Lucas Cells were used and, for Potential Alpha Energy Concentration-PAEC measurement a solid state alpha spectroscope, the DOSEman PRO was used. The experiments showed that most results are below 50 Bqm^{-3} (mean+3σ). This value is bellowing the action levels of the USEPA, ICRP and others, which varies in the range from 148 to 200 Bqm^{-3}. The values are in the low range, as it was expected for a tropical climate.

1. INTRODUCTION

Radon is a radioactive noble gas derived from the natural decay series of ^{238}U, ^{235}U and ^{232}Th, which are present in rocks, soils and waters.

Radon decay by emitting alpha particles, generating a sequence of decay products known as radon progeny or daughter products. Part of this radon decay product attaches to the aerosol particles in the air. The fraction radon progeny that do not attach to aerosol particle in the air are termed the unattached fraction. If inhaled, the radon progeny, attach and unattached, may deposit in the lung, especially in the upper respiratory tract and irradiate to the lung tissue as they decay. The radon and its progeny account for about half of all human exposure to natural radiation [1]. Radon has been recognized as a radiation hazard, that causes excess of lung cancer among underground miners and there is an evidence that radon is also a heath hazard in dwellings and other indoor environments [1]. This fact has been confirmed by epidemiologist studies of human populations, and currently International Agency of Research in Cancer (IARC) classifies radon as a class I carcinogen [2].

Soils and rocks constitute the main sources of radon in indoor environments. By diffusion and convection, radon produced in the soils and rocks migrate to the surface and through fissures, pipes and holes it may enter the dwellings and other buildings. However, other mechanisms can affect the indoor environment radon concentration. Some construction materials can also act as significant radon source. Such construction materials have the combination of raised ^{226}Ra level and high porosity, which allow radon emanation. Domestic water use and the air renewal constitute radon sources too, however, less significant. This way, high radon concentration may accumulate indoor environments with reduced ventilation rates and, thus, represent a potential risk to the population health that frequents or lives in these places.

The radon concentration in indoor environments depends strongly of the geological place, being significantly more raised in granitic bedrock areas. Moreover, the radon emanation is still related to soil properties as permeability and porosity and to meteorological parameters as temperature, humidity and atmospheric pressure.

The short-lived radon progeny concentration is given in terms of collective concentration: the potential alpha energy concentration (PAEC). For a given PAEC, the concentration of each decay product considering secular equilibrium is defined as EEDC (The Equilibrium-Equivalent Decay-Product Concentration). The ratio of the EEDC and the radon concentration is called the equilibrium factor. This factor is equal to unity if the radon and all of its short-lived daughters are in secular equilibrium. Equilibrium factor for most indoor atmospheres is in the range of 0.2 to 0.6 [3].

This work presents radon concentration measurements in the air carried out in dwellings, schools and shopping centers in the Metropolitan Region of Belo Horizonte – RMBH. Most part of the observed values is below of the action levels of the United States Environmental Protection Agency (USEPA) and of the International Commission of Radiological Protection (ICRP), which are 148 and 200 Bqm^{-3}, respectively.

Most part of the inhabitants of the RMBH lives over the granitic gneissic complex, which has a variable depth, out coming in some areas [4]. Therefore, knowing the radon concentration in dwellings and other buildings in this area is important in the point of view of protection against natural radiation.

The objective of this work is to perform a preliminary short term monitoring of radon with continuous passive detectors in some indoor environments in the RMBH, as dwellings, schools and shopping centers. For radon concentration measurement were used continuous detectors as Alpha*GUARD* PQ2000PRO (Genitron), RAD7 (Durrridge) and Lucas Cells (Pylon). The Potential Alpha Energy Concentration-PAEC was determined by solid state alpha spectroscope, the DOSEman PRO (Sarad). Such methods aim to evaluate if the concentration level founded is above maximum limits recommended internationally, so that intervention actions are justified. Another objective of this preliminary work is to help in looking for radon prone areas.

2. MATERIALS AND METHODS

Most radon concentration measurement was carried out with the continuous detector Alpha*GUARD* PQ2000PRO (Genitron), a pulse ionization chamber, in diffusion mode at intervals of 60 minutes, so acting as a continuous passive detector. The Alpha*GUARD* was installed in the environment so that radon diffuses through a wide surface glass fiber filter getting inside the ionization chamber. This instrument measures a range of radon from 2 to $2x10^6$ Bqm^{-3} and gives simultaneous measurement of temperature, pressure and humidity [5].

Others continuous monitors used for the alpha radiation detection were the RAD7 and the PYLON AB-5. The Durridge RAD7 is an active instrument that uses a solid state alpha detector for the radon activity determination. Air samples are pulled through a filter to avoid radon progeny of getting inside of the RAD7 chamber, where just the alpha radiation emitted by the short lived ^{218}Po and ^{214}Po are considered to determine the radon concentration. RAD7 is not progeny measurement equipment. The Pylon model AB-5 Counter measures the radon activity in the air by using LUCAS Cell. Air samples are introduced in the LUCAS cell through a proper device. After a delay time of about 3 hour to allow equilibrium of radon progeny, the LUCAS Cell is connected to the unit of measure, the Pylon AB-5 alpha counter.

Potential Alpha Energy Concentration - PAEC measurements was carried out by alpha spectrometry using a solid state alpha detector, DOSEman PRO (Sarad). In this equipment, air samples are forced through a filter that is continuously analyzed by a silicon detector. DOSEman PRO is an instrument that measures the radon decay products in the air and, therefore, is classified as a “working level” monitor [6].

3-RESULTS AND DISCUSSION

Measurement values of radon concentration and PAEC including the respective EEDC and the Equilibrium Factor F are presented in Table 1, for indoor environments in the RMBH. The uncertainty values presented are confidence intervals with 90% of probability. About 15% of the indoor environments show values above the action level of the United States Environmental Protection Agency (USEPA) and of the International Commission of Radiological Protection (ICRP), which are 148 and 200 Bqm^{-3} respectively. This set of results suggests the existence of radon prone areas. Additional investigations looking for radon prone areas are under way. The arithmetic and geometric means of the remaining results are 40.9 Bqm^{-3} and 30.6 Bqm^{-3} respectively, which are very close to the outdoor environment concentration. The Equilibrium Factors F presented in Table 1 is in the range of 0.2 to 0.6 as described in the literature [3].

Table 1. Examples of Radon Concentration in Dwellings and other Buildings

Place		Radon Concentration (Bq/m^3)	PAEC (nJ/m^3)	EEC (Bq/m^3)	Equilibrium factor [a]
City of RM BH	**Quarter**				
Belo Horizonte	Cachoeirinha	85.8 ±1.9	214.4	38.1	0.5
Belo Horizonte	Caiçara	21.3 ±1.4	33.6	6.0	0.3

Belo Horizonte	Céu Azul	16.7 ± 1.1	29.9	5.3	0.3
Belo Horizonte	Cidade Nova Minas Shopping	27.4 ± 8.6			
Belo Horizonte	Cruzeiro (2nd Floor)[b]	7.8 ± 1.3			
Belo Horizonte	Goiânia	19.0 ± 1.1			
Belo Horizonte	Nova Floresta (3rd Floor)[b]	14.0 ± 3.1			
Belo Horizonte	Ouro Preto - 1	12.9 ± 0.4	15.6	2.8	0.2
Belo Horizonte	Ouro Preto - 2	54.1 ± 1.2	93.2	16.6	0.3
Belo Horizonte	Planalto	59.7 ± 2.7	54.3	9.6	0.3
Belo Horizonte	Prado - 1	90.5 ± 4.1	168.2	29.9	0.3
Belo Horizonte	Prado – 2	57.6 ± 2.6	127.9	22.7	0.4
Belo Horizonte	Renascença	296.9 ± 9.1	35.4	374.0	0.3
Belo Horizonte	Serra (3rd Floor) [b]	20.6 ± 1.3			
Belo Horizonte	Pampulha / CDTN[c] LTA[d]	20.5 ± 1.1			
Belo Horizonte	Pampulha / CDTN[c]-LTA[d]	103.3 ± 2.2			
Belo Horizonte	Pampulha / CDTN[c]-LMN[e]	80.8 ± 2.6			
Belo Horizonte	Pampulha / São José	330 ± 9.5			
Belo Horizonte	Pampulha / São Luís	26.2 ± 1.4	40.2	7.1	0.3
Belo Horizonte	CEFET [f] Radiologia	10.4 ± 2.6			
Cachoeira do Campo	Tripuí	10.0 ± 7.1			
Contagem	Eldorado	46.2 ± 2.1			
Florestal	Centro	170.0 ± 3.2	329.5	58.5	0.5
Nova Lima	Chácara dos Cristais	39.6 ± 1.0	58.4	10.4	0.3
Rio Acima	Formação Gandarela	1000 ± 73.3			
Sabará	Morada da Serra	76.1 ± 2.0	50.3	9.0	0.2

a. Equilibrium factor: ratio between the Equilibrium-Equivalent Decay-Product Concentration (EEDC) and the radon concentration calculated for intervals without effect of additional ventilation)

b. (2nd floor) – Measurements carried out on second and third floor in apartments buildings

c. CDTN - Centro de Desenvolvimento da Tecnologia Nuclear

d. LTA - Laboratório de Trítio Ambiental

e. LMN - Laboratório de Medidas Nucleares

f. CEFET - Centro Federal de Educação Tecnológica de Minas Gerais

In order to be sure that the indoor measured radon concentrations values are related rather to the soil gas instead to the construction materials, some samples of the most used construction materials in the RMBH were analyzed for uranium and thorium activities by Instrumental Neutron Activation Analysis. The results in Table 2. shows uranium and thorium content of about the same order of magnitude as it is found in the literature for this kind of material. On the other hand, radon measurements in soil gas to the depth of 70 cm carried out in the same granitic gneissic complex area range from 6.5 to 93.5 kBqm^{-3}, which are results suggesting the existence of some radon prone areas. Table 2 shows also uranium and thorium content in some soil samples collected in the same local where soil gas radon was measured. For the samples "Soil 2(Mutuca)" and "Soil 3(Tripui)" high values of radon in soil gas were found also indicating possible radon prone area. In the last two areas, there is no construction and therefore no indoor radon was measured.

Table 2. Specific Activities of ^{232}Th and ^{238}U in the construction material and some soils samples of the RMBH

Samples	Specific Activities (Bq kg^{-1})	
	Neutron Activation	
	^{232}Th	^{238}U
Sand	56.8 ± 4.1	61.8 ± 12.4
Rock	40.6 ± 4.1	98.8 ± 24.7
Cement	20.3 ± 4.1	160.6 ± 24.7
Dust of rock	36.5 ± 4.1	49.4 ± 12.4
Roofing tile	134.0 ± 8.1	86.5 ± 24.7
Brick	105.6 ± 8.1	172.9 ± 24.7
Brick of flagstone	113.7 ± 8.1	111.2 ± 24.7
Soil 1(Fechos)	8.1 ± 4.1	12.4 ± 12.4
Soil 2(Mutuca)	60.9 ± 4.1	61.8 ± 12.4
Soil 3 (Tripuí)	194.9 ± 8.1	86.5 ± 24.7

3. CONCLUSIONS

Most part of the values founded is in the low range when compared with same studies carried out in tempered climate country. Average annual concentrations in dwellings above 200 Bqm^{-3} are frequent in areas of granitic bedrocks [7,8]. In the present study such lower results were expected due to the semi- tropical climate of the RMBH area, where indoor environments are well ventilated, even though during the winter time. The conclusion of this work indicate the necessity of more radon measurement to be carried out in soil gas and in indoor air in dwellings with long term radon passive detectors. Although some soil gas radon concentration measurements shows values in the range classified by the Swedish criteria as "high" [9], some indoor environments shows values above the action levels of the USEPA that indicate the existence of radon prone areas, there is still also the necessity to adapt the Swedish criteria for a tropical country.

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