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Relationship between of the radon concentration on air inside the residences and the rocks in Metropolitan Region of Belo Horizonte-MG.
- A review -

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1. Introduction

Radon - Rn is a natural radioactive element, belonging to the family of noble gases. It originates from the decay of uranium and thorium, therefore, present in their natural series. The ^{222}Rn isotope is the most abundant, longest lasting, with a half-life of 3.8 days. The other isotopes ^{220}Rn and ^{219}Rn have half-lives of seconds. The ^{222}Rn daughter elements, ^{214}Po, ^{214}Bi and ^{214}Pb are solid and radioactive.

Radon is found in rocks, soils and building materials that contain Uranium, Thorium and Radium. High concentrations can occur in varieties of granitic and alkaline igneous rocks, monazitic sands, shales, limestones, uranium deposits, coal, metallic minerals and others. Equivalent values can be found in soils derived from these rocks. Thus, geological environments that contain U, Th and Ra will form important substrates to Rn emanation.

This nuclide and its daughter elements are recognized by the World Health Organization and national health agencies as the second leading cause of lung cancer, behind smoking [1].

UNSCEAR (2000) estimates that the annual average effective dose received by the world population is 2.40 mSv, from Rn and its decay products being the most important human exposure from natural sources [2]. On average, about 90% of the Rn present in a dwelling comes from underground, 5% from building materials and less than 1% released from consumed water [3].

Recent studies of Rn and its effects are improving the understanding of the environmental processes that affect exposure to this element, but there are still many issues associated with the accurate assessment of exposures and doses. It is possible to observe then, the importance of Rn gas for the annual effective dose received by the human being and the contribution of geological factors in the emanation and exhalation of Rn. WHO recommends that member countries implement national mapping programs to determine the increasing risk of exposure to Rn, based on geologically and geographically studies.

Scientific interest in Rn in homes increased in the mid-1970s, when nuclear instrumentation suitable for measurements became available [4]. Since then, research has intensified and revealed that Rn levels in households are very variable, reaching, in some cases, up to 100,000 Bq.m^{-3}. This means that some members of the population are exposed to levels of Rn equivalent to those found in mines professionals [5].

The importance of multidisciplinary characteristics about Rn is highlighted, national geogenic mapping programs should involve interaction between different bodies and areas of knowledge, including government organizations, political authorities, research institutions, laboratories and the media [6]. The fundamental purpose of Rn mapping is to prevent the population from being exposed to high values of gas concentration. Thus, government organizations and research centers have identified areas of greater risk through the elaboration of geogenic maps indicative of radon risk. Therefore, these maps work as a management tool for the authorities, helping them to make decisions in priority areas [7].

International regulatory bodies recommend that countries identify the areas most susceptible to Rn and investigate

the geological and construction characteristics that may contribute to increased population exposure. Studies on Rn exhalation and its contribution to the dose of indoor environments have been developed around the world in order to create a database to compose a geogenic mapping of countries, and identify areas of greatest risk of this gas.
The Metropolitan Region of Belo Horizonte has geological characteristics that suggest the existence of high concentrations of Rn indoors. Most of the geological basement of this area is constituted by Archean rocks from the granitic gneiss complex and by metasedimentary sequences from the large Precambrian unit of the Quadrilátero Ferrrífero of Minas Gerais, Brazil. As is known, granitic rocks have high concentrations of natural radionuclides in general, and uranium in particular [3]. Therefore, the main objective is to review and discuss bibliographical references to improve the knowledge about the relationship between rocks and soils and the potential risk of radon in the Metropolitan Region of Belo Horizonte (MRBH).

2. Methodology

The work was developed from a literature review. The words used for the search were: radon in air, radon in soil, detection of natural radioactivity and geology of the RMBH. Among all the publications obtained, those selected form: Santos (2010), Lara (2017), Taveira (2020), WHO (2009) and UNSCEAR (2000) for contemplating the purpose of this study. The methodology of Rn study can be varied, so, it is important to follow well-established methodologies recommended by reference entities. The measurements performed with the ionization chamber detector, alphaguard, this detector being considered the gold standard in the analysis of radon in closed circuit and in soil gases. The Environmental Protection Agency (EPA) recommends using type CR-39 polymers for alpha detection from Rn decay. Both methodologies were used by the reviewed authors [8].

3. Results and Discussion

The aim of this study was to present and discuss the findings in the literature involving Rn and natural radioactivity. In this context, the publications were read and five important categories were selected and will be applied to obtain the ratio of Rn concentrations in the indoor air of homes and rock outcrops in the metropolitan region of Belo Horizonte-MG, they are: a) studied area b) detectors c) sampling; d) analysis of results and recommendations. The results compiled for each case can be seen in Table 1. In the study of Taveira (2020), it was finally possible to relate the radon concentration data obtained by the other mentioned authors and the geology of the MRBH. Uraniferous rocks, for example, do not always have the highest radon exhalation rates [10]. To implement the study, it is necessary to consider petrographic and textural factors.

Table I: Results of a compiled data base from a literature review

Author	Studied area	Studied Object/Sampling	Detectors	Resuts	Recommendations
Santos *et al*, 2010	Metropolitan Region of Belo Horizonte	^{222}Rn in air within the residences	AlphaGuard, CR39, Electrets	Approximately 15% of the results obtained are higher than the levels of recommended international reference	The use of the building materials analyzed, for use in buildings, should be better evaluated, as it may represent a potential increase in radiological exposure, especially due to radon exhalation and gamma emissions.
Lara *et al*, 2013	Metropolitan Region of Belo Horizonte	^{222}Rn in soil	AlphaGuard	The results of the distribution of Rn in soil gases from the RMBH	Need for specific studies to find out if the high levels of ^{222}Rn

				showed that about 17% of the points sampled in the different pedologies and lithologies had ^{222}Rn concentrations above 40.0 $kBq.m^{-3}$, a value suggested as a reference	concentration in the soil are due to lithology and/or pedology and other physical and geological characteristics.
Corrêa *et al*, 2011	Paraná	^{222}Rn in air and water	AlphaGuard, CR39	Exposure to ^{222}Rn in homes in Paraná, the concentration results were within normal limits, no value was found above 400 Bq/m^3, which would mean some mitigation proposal. The concentration levels of ^{222}Rn in well waters in the Curitiba Region were high, as around 70% of the investigated well water samples were above 11.1 Bq/L. There was no clear relationship between indoor and well water measurements.	the proposal was made to repeat the only indoor measurement that was above 200 Bq/m^3; Improving the method for obtaining initial concentrations of ^{222}Rn and ^{226}Ra and increasing investigations into these concentrations for the South region of Brazil.
Taveira *et* al, 2020	Quadrilátero Ferrífero Metropolitan Region of Belo Horizonte	Gamma survey from U,Th e K	AlphaGuard, RS230	The determination of radon exhalation rates allowed to verify the presence of uranium minerals does not always determine, or is proportional, to the amount of ^{222}Rn emanated and consequently exhaled. For this purpose, it is necessary to consider from the petrographic and textural factors of the rocks to their field layout.	-

4. Conclusions

The development of this review showed the best methodologies to study radon in air and soil. All authors studied agreed on the concentration of radon in the study regions in Belo Horizonte. Comparatively, the authors from Paraná also used a similar methodology and evaluated important factors such as ventilation rate, types of aquifers and rocks, corroborating for an improvement in the experimental procedures. It can be concluded that, in the RMBH, some radon concentration elevations are due to the local geology and the pavement of streets and avenues may contribute to a higher radiation dose in the population. . It is intended to use this database to develop the author's doctoral work in order to increase this same database, thus contributing to the mapping of general Brazilian radon, as well as to build a map of contribution of external radon doses . These data can help other authors to define the materials and methods needed for a study with the same purpose. Finally, determine whether some of the anomalies found by Santos (2010) Lara (2013) and Taveira (2020) are in fact due to local geology or whether they are due to anthropic action on street pavement, considering measurements at two different times of the year (winter and summer), thus approaching the real living conditions in the house.

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