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EVALUATION OF THE RELATION BETWEEN BUILDING MATERIALS AND INDOOR RADON POLLUTION

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Abstract: In this work the relation between building materials and Radon indoor pollution is evaluated. The work is part of a larger monitoring in progress in the Calabria Region (Southern Italy).

The area under investigation is San Giovanni in Fiore (CS) located in the Sila upland plain. An annual monitoring is carried out in many buildings of Sila area, with reference to their different building materials.

Nuclear tracks detector has been used (SSNTD, Solid State Nuclear Track Detector). Obtained results underline that the buildings realized with the local granite rock have greater indoor radon concentrations.

The local granitic rocks, representative of the geologic area, have been analyzed by gamma spectrometry constituted by Canberra system HPGe fixed detector cooled by liquid nitrogen high radio-emission values of standard radionuclides as ^{226}Ra, ^{232}Th and ^{40}K.

Keywords: Measurement system, radon, radionuclide, building materials, nuclear track detector.

1. INTRODUCTION

The Distributed Measurement System [1] and the design of new measurement instrument [2],[3] allows the continuous monitoring of the human health both as concerning the monitoring of existent diseases [4],[5], the prevention for possible disease and injury [6]-[9], the monitoring of environment for prevention of possible diseases[2],[10]. Aim of this work is the evaluation of the relationship between the annual values of indoor radon concentration and the building materials in order to prevent cancer diseases[11]-[13].

All building materials contain various amounts of natural radioactive nuclides. Materials derived from rock and soil contain mainly natural radionuclides of the uranium (^{238}U) and thorium (^{232}Th) series, and the radioactive isotope of potassium (^{40}K) [15]. Radioactivity of natural families in the building materials gives a notable contribution to the equivalent dose related to natural radiations background.

This radioactivity gives place to two different dose contributions: external gamma dose and internal alpha dose, the last related to radon emanation and accumulation [14]. Individualization and knowledge of natural origin pollution sources absolutely represent a necessary step for the formulation of correct reclamation and prevention improvement [14],[15].

Gas Radon is a natural gas with a high impact on public health, classified as carcinogenic agent of group 1 (agents of verified cancerogenity for man) by the International Agency for Research on Cancer (IARC/OMS) [11]-[13].

In a building the gas Radon accumulation, first of all, depends on the Uranium/Radium concentration into the soil [16], but also on other contingent factors such as building material typology, isolation, etc.

Inside the same building, every environment represents a particular case to itself. On the other hand it can be possible to identify some common typical elements of buildings with high radon concentrations.

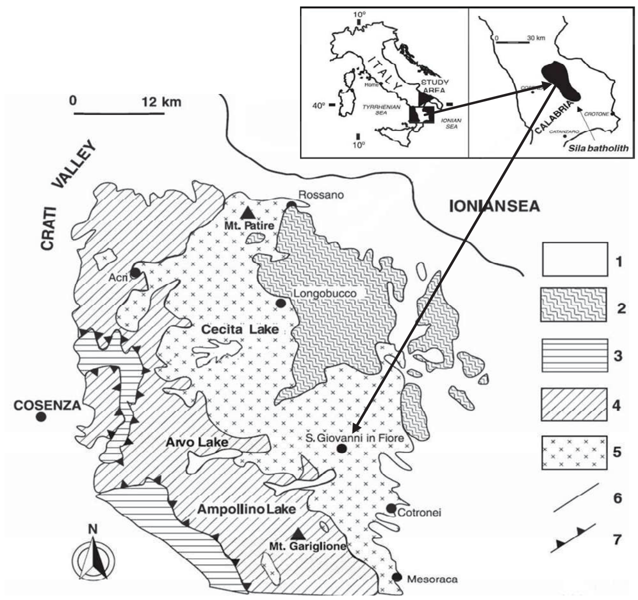

Figure 1. Geological sketch map of the study area (after Messina et al., 1991, modified) [18a]: (1) clastics (Recent to Tortonian); (2) sedimentary and metamorphic rocks (Oligocene to Devonian); (3) phyllites+schists and ophiolitic rocks (Cretaceous to Palaeozoic); (4) gneissic rocks (Palaeozoic); (5) Sila batholith (Palaeozoic); (6) stratigraphic contact; (7) thrust fault.

In this work, “Sila” area of San Giovanni in Fiore (CS) Calabria Region (Southern Italy), was monitored, for its geological setting of granitic nature. In a second step buildings are chosen for their characteristic:

- public buildings;
- typology and nature of building materials.

2. GEOLOGICAL SETTING

The Sila Massif is included in the Northern sector of the Calabro-Peloritan Arc, a section of the Western Europe Alpine orogenic chain, where allochthonous crystalline rocks presently outcrop in the uppermost tectonic Unit of Apenninic chain [17].

The Sila Massif is characterized by different metamorphic and plutonic Hercynian rocks (Sila Unit), consisting of rocks of medium-high, medium-low and low metamorphic grade, with intrusions of plutonic rocks of the late Hercynian Sila batholith [18] (Figure 1).

The granite outcropping in San Giovanni in Fiore belongs to the Sila Unit and is a granitoid with an isotropic texture. The composition of the outcropping rocks ranges between the quartz-diorite and the granite with more or less weathered portions, as it has also been macroscopically observed.

3. MATERIALS AND METHODS

3.1 Indoor Monitoring

In the present work the following measurement procedure is used to evaluate the level of indoor radon concentration in a building [10].

1) Placing the nuclear track detectors in the building.
2) Waiting for 12 months.
3) Bring the detectors to the laboratory.
4) Microscopic analysis.
5) Results.

The technique used to measure radon concentration is based on nuclear track detectors. The radon detector type is the RSFS type detector for indoor radon test. This is the standard type. Each detector is sealed into radon-proof pouch. The sealing is carried out in absolutely radon-free atmosphere. In particular this study is carried out by using the RSFS made by Radosys Ltd (Figure 2).

Figure 2. Dosimeter RSFS type with CR-39 inside

This, with size Ø 60mm × 30mm of has a double function as filter and as diffusion chamber: there is an overgap of 20-30μ., that only permits the entry of radon (^{222}Rn). In this chamber, where is located the polymer film (CR-39), ^{222}Rn can spread and decay bringing to the formation of its decay products.

The CR-39 type (SSNTD, Solid State Nuclear Track Detector) [19] is a time-integrated passive radon dosimeter. CR-39 are polymeric films sensitive only to alpha radiations located in to dosimeters. More details about the functioning of the CR-39 and RSFS are reported in [10].

Alpha particles, with a particular mass and speed, during the interaction matter release their energy during the crash leaving on polymeric film a track.

After collection of the dosimeters, the CR-39 have been sealed in suitable way and in brought in laboratory. Here they were located in their apposite slides, and chemically treated in 25% NaOH solution, at 90°C for about 4 h, in a Radobath.

In this way the traces released on the polymeric films by the radon alpha particles were amplified allowing the reading to the microscope. The tracks were counted by optical transmitted light microscope, using an automatic image analysis system (Figure 3).

Using a calibration factor the measured number of tracks per unit area of the film was converted into indoor exposure levels in Bq/m^3 (RAC) by Radosys software.

To measure the time-integrated radon activity concentration (RAC) was used the following expression:

$$RAC = (\gamma_v \times f_c)/\Delta t \qquad (1)$$

where γ_v is density tracks (number of tracks for dosimeter area considered), f_c is a factory depending from type used detector and Δt is the exposure time (days). More details are reported elsewhere [10]

Obtained radon concentration were been compared with the characteristics of the various analysed building.

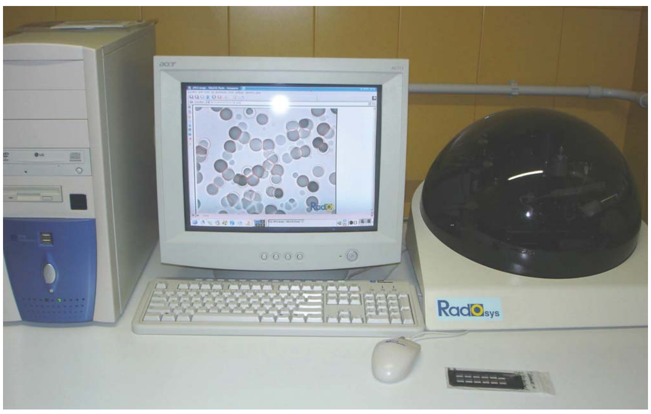

Figure 3. Optical microscope of Radosys system.

3.2. Spectrometric analyses

Radioactivity content in the granitic rock sample was measured by gamma spectrometry constituted by a Canberra system HPGe fixed detector cooled by liquid nitrogen. The measures required a day in order to obtain the right high reliability of data and the probe header has required the use of sample holders with Marinelli geometry (cylindrical with a central hole to insert the probe).

Granitic rock sample was also characterized by electronic microscopy (Cambridge, mod. 360S), provided of a detector of backscattering scan (BSE) and microanalyses (Link). Backscattering scan observation allows finding the presence of heavy minerals, easily recognizable for their colour and brighter with respect to the surrounding minerals. The grey tonalities are function of the average atomic weight of the material examined.

From spectrometric data it was possible to isolate, by a peak analysis, the values of standard sample concentration for ^{226}Ra, ^{40}K, and to estimate the ^{232}Th value, deduced by an evaluation of the secular equilibrium factors. At the last activity index and dose excess are been calculated [14],[15].

4. PRELIMINARY RESULTS AND DISCUSSION

The geological setting was based on sampling site choice. Indoor radon monitoring involved 24 buildings, selected on the ground of their building materials:

- masonry (cement blocks): 3 buildings;
- reinforced concrete and tiles: 17 buildings;
- local rocks (granite): 4 buildings.

It was not possible to consider the same number of buildings for each typologies of building materials because the area under investigation was limited. Moreover, the owners of the private houses were not enthusiastic to participate to the measurement campaign. This is probably due to ignorance about the phenomenon and the scarred to know the measurement results. In particular, they were scared that a positive result can imply the declaration of not fit for habitation of their properties.

Monitoring sampling has been planned to entirely cover the year [21], from December 2006 to December 2007. After exposure time dosimeter CR-39 were subjected to chemical attach in 25%NaOH, at T = 90°C for a time of about 4 hours.

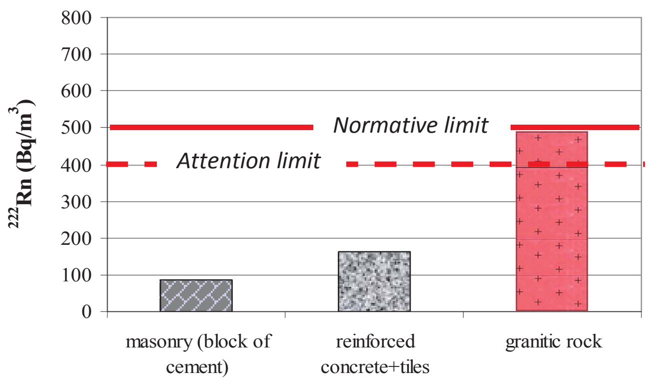

Figure 4. Annual average radon concentration related to different building materials for all 24 buildings.

The data obtained from radiometer indoor monitoring show an average annual radon concentration for masonry buildings and reinforced concrete +tiles buildings of about 85.13 Bq/m^3 and 163.57 Bq/m^3, respectively. In opposition, buildings entirely built in granitic stone present an average annual radon activity of about 488.89 Bq/m^3. The average data related to all 24 buildings built with different building materials are correlated in Figure 4.

These data show different building materials can influence indoor radon concentration. In particular meaningful differences of gas radon concentration were not observed among masonry buildings and reinforced concrete + tiles buildings, while data related to the buildings realized by stone appear interesting. Gas radon concentration infact in some cases exceeds the normative limit of 500 Bq/m^3 [21].

In order to understand the higher radon concentrations in buildings realized with stone, the granite rock outcropping in the area of San Giovanni in Fiore was further analyzed.

By macroscopically observation it is a granitoide with an isotropic structure, olocrystaline, fine-medium grain. Mineralogical association recognized by optical microscope analysis is: quartz, plagioclase, k-felspar, biotite, muscovite and chlorite. Accessory minerals are granato, zircon e iron oxides, mostly altered as evident also through a macroscopic

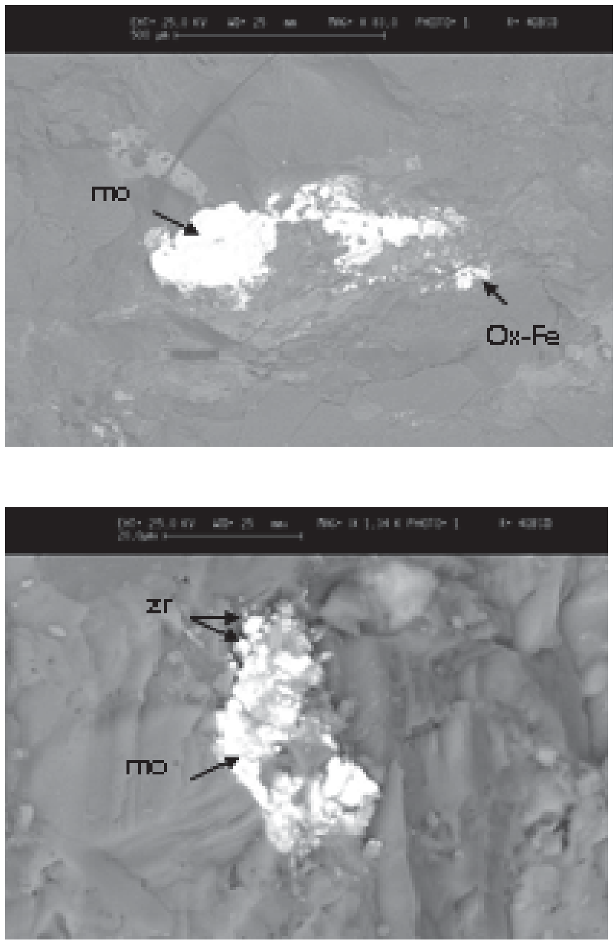

Figure 5. Backscattered scanning electron microscope images of heavy radioactive minerals of analyzed granite sample: Mo = monazite; Zr = zircon; Ox-Fe = iron oxide.

survey. Through electron microscope (SEM) and microanalysis (EDS) are been recognized as heavy radioactive crystal of monazite, zircon, zircon silicate (Figure 5). These minerals contain Uranium in ppm quantities [22].

From radiometer survey on analyzed Silano granite shows in fact, an expected elevated level of radioactivity. High precision spectrometric analyses allowed to evaluate radionuclides as ^{226}Ra, ^{232}Th e ^{40}K [15],[23], of 52 Bq/Kg, 62 Bq/Kg and 1606Bq/Kg respectively. Activity index and dose excess were also calculated. The first one results of 1,02, higher of suggested one [15], and the second one result to 1.03 (mSv/year).

5. CONCLUSIONS

The knowledge of natural radioactivity levels of building materials is of fundamental importance for the evaluation of the ionizing radiations exposure in indoor environment.

Annual values of indoor radon concentration of the masonry and reinforced concrete + tailes building are inferior to the annual normative limit of 500 Bq/m^3 [21].

The granitic stone buildings radon concentration values are higher of the attention limit of 400 Bq/m^3 and in some cases even overcome the limit of 500 Bq/m^3 [21].

From here the remarkable contribution of building materials, how it can show from high radio-emission values of ^{226}Ra, ^{232}Th and ^{40}K radionuclides.

More in general the above reported results confirms that the indoor radon concentrations depend on the nature of the building materials and suggest, for the new constructions, to optimize the choice of the buildings materials, with particular reference to the local geological setting.

On-going research is devoted to evaluate the relation between indoor radon concentration and the isolation system of the buildings.

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