Measurement xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Measurement

journal homepage: www.elsevier.com/locate/measurement

Passive and active methods for Radon pollution measurements in historical heritage buildings

V. Nastro [a], D.L. Carnì [b,*], A. Vitale [c], F. Lamonaca [d], M. Vasile [e]

[a] Dept. of Chemistry and Chemical Technology, University of Calabria, Rende (CS), Italy
[b] Dept. of Computer Science, Modeling, Electronic and System, University of Calabria, Rende (CS), Italy
[c] Dept. of Civil Engineering, University of Calabria, Rende (CS), Italy
[d] Dept. of Engineering, University of Sannio, Benevento, Italy
[e] Medical School, Ovidius University Constanta, Romania

ARTICLE INFO

Article history:
Received 16 March 2016
Received in revised form 31 August 2016
Accepted 2 September 2016
Available online xxxx

Keywords:
Road traffic
Kernel function
KNN
State measurement
Regional traffic attractor

ABSTRACT

Radon is a dangerous pollutant causing lung cancer. The main protection against it is the monitoring. Recent literature has highlighted that historical buildings and archeological sites could be polluted by Radon not only due to the geological site but also due to the building materials and usage. In this paper, measurement techniques for the evaluation of Radon's concentration level (^{222}Rn) are compared. This evaluation allows to determine most appropriate technique to be used in this type of buildings. The study is justified by the fact that the buildings are often attended not only by specialists but also by tourist that with their behaviour could misstate Radon gas measurement. The study is effectuated analyzing the situation of three old churches located in San Giovanni in Fiore (Cosenza, south of Italy). The measurement results are compared with the ones obtained by performing the same monitoring in public buildings attended by different kind of users. The monitored sites, churches and public buildings, are erected on the common granite massif of Sila (South Italy), by using local granite stone.

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1. Introduction

Nowadays, the pollution effects on artworks and archeological sites are widely investigated [1–6], and many systems are often used to preserve them. For artworks made with paper, woods and other organic materials, literature suggests to protect against sulfur dioxide [2] and fungal spores [7] by means of air-conditioning systems [2]. The painting must be protected by the direct sunlight or ultraviolet light sources that can modify the brilliance of the colours and alter the chemical composition of pigment causing crack or flake off [5,6].

The literature and legislation related to protect artefacts as museum and historical building do not consider the evaluation of gas Radon concentration to increase the safety of archaeologists, operators and visitors of the archeological sites.

Historical buildings and museums are closed environments that favour the concentration of Radon gas, generated from the natural radioactivity of the ground, and the inhalation of this gas is the second cause of lung cancer after smoke. Moreover, the Radon gas can be generated by building materials of the historical heritage building, or from artworks made with particular kind of stone as granite. Because Radon is a noble gas it cannot be filtered and for this reason its monitoring is the only solution to protect people health [8,9].

Uranium (U) and thorium (Th) are the progenitors of all Radon on Earth. The genesis of the bedrock plays, therefore, a fundamental role as the concentration of ^{238}U and ^{232}Th, that are radioactive, varies depending on the type of rock [10,11]. As a consequence of this natural environment, the presence of Radon in a specific area mainly depends on the geological features of the area itself, whereas the concentration in indoor environments depends on the materials and the construction technologies adopted [8,9,12].

The instrumentation for the Radon's concentration level (^{222}Rn) measurement can be by classified as:

- Active: if the analysis is done on Radon samples obtained by forcing with a pump of a known volume of air;
- Passive: if the sampling of the Radon is obtained by the natural diffusion of the gas.

The main and more commonly used Radon active measurement instrumentations are:

* Corresponding author.
E-mail address: dlcarni@dimes.unical.it (D.L. Carnì).

http://dx.doi.org/10.1016/j.measurement.2016.09.002
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Please cite this article in press as: V. Nastro et al., Passive and active methods for Radon pollution measurements in historical heritage buildings, Measurement (2016), http://dx.doi.org/10.1016/j.measurement.2016.09.002

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- electret ion chambers;
- Scintillation chamber;
- Superficial barrier devices;

The electret ion chamber measures the Radon concentration by charging an electret to a known voltage. A pump force a known volume of air which enters into the chamber. The alpha particles from ^{222}Rn and ^{218}Po and ^{214}Po ionize the air and discharge the voltage on the electret proportionally to their concentration. Then the Radon concentration is measured with a voltage meter. This kind of instrumentation is used for the measure of the average Radon concentration in a time range of 2–14 day, usually.

In the scintillation chamber the collision of the α particle with sensible material generate light impulses. The sparkling lights are transformed by a photomultiplier and counted. Their number is directly proportional to the α particles and then to the Radon concentration.

For the superficial barrier devices two main filters are used. A pump forces the air inside a decay chamber and the first filter eliminates the big particle not related to the Radon. The second filter accumulate the results of the decay obtained during the passage of the air in the chamber. Special detectors included in the filter evaluate the α particle emitted by the Radon and then from their concentration is obtained the concentration of the Radon in the air.

The most diffused passive measurement instrumentations are:

- Alpha track detectors;
- Active carbon absorption detector;
- Electret detector.

Alpha track detectors evaluate the Radon concentration by using the tracks generated by the interaction of α particles in sensible solid-state. The image of the tracks is digitalized in order to allow to a proper software to analyse this last and determine the average concentration of Radon in a long time period. In fact, this kind of technique is used for the annual average concentration measurement of the Radon.

Activated carbon detectors are composed by metal or plastic collectors containing activated carbon that absorb ^{214}Pb and ^{214}Bi obtained from the decay of the Radon inside the container. The spectrometric gamma analysis of the carbons is used to estimate the particle absorbed.

The Electret detector is similar to the active electret ion chamber with the difference that does not need the pump.

In [7] passive and active measurement methods for the evaluation of the Radon's concentration level in historical heritage buildings placed on the Sila massif in Calabria, South of Italy are compared. The accumulations of significant quantities of heavy metals in the granite/metamorphic crystalline basement of the Calabrian Peloritano produces anomalies in the normal radioactive background. The Sila massif is included in the Northern sector of the Calabro-Peloritan Arc, which is a section of the Western Europe Alpine orogenic chain, where allochthonous crystalline rocks outcrop in the uppermost tectonic unit of the Apenninic chain [13]. Sila Massif is characterized by different metamorphic and plutonic rocks Hercynian (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 [14]. The granite outcropping in San Giovanni in Fiore and the composition of the outcropping rocks are showed in Fig. 1 [8].

In [7] is highlighted that the suitability of active and passive monitoring methods mainly depends on the use of the historical heritage building and that the monitoring results are influenced by the habits of the users. The aim of the paper is to complete the analysis the achievable results by the comparison with that of the public buildings also, placed near the historical buildings. The buildings, taken into consideration, as the historical heritages, are open to the public and therefore requires special care. The comparison between the passive and active measurement techniques is relevant because gives a broader vision of Radon gas accumulation in the various confined spaces and suggests the most effective solution to be used in this type of buildings, normally open to the public.

The paper is organized as follows: initially, the both the monuments and the public buildings objects of investigation monitored are described. Then, the measurement techniques compared are introduced. Successively, the experimental results with passive and active monitoring systems are discussed. At the end some conclusions.

2. Environmental monitoring

In order to select the geological area to be monitored, the geological characteristics of the ground, so as the presence of historical heritage buildings, have been analysed. From this analysis, San Giovanni in Fiore is chosen due to the presence of the historical churches made by autochthonous granitic rocks and the presence of granitic rock in the ground containing heavy metals. San Giovanni in Fiore is the largest municipality in the granite Sila massif, located at about 1000 m altitude (Fig. 1). In the municipality the indoor Radon gas concentration in the three old churches and in three public building, is evaluated by means of passive and active monitoring systems.

The passive monitoring technique is obtained by using nuclear tracks detectors CR-39 (SSNTD, Solid State Nuclear Track Detectors) of Radosys Enterprises Ltd. Instead, the active monitoring technique is implemented by using ionization chamber Alphaguard PQ2000 PRO.

The three monitored historical churches of San Giovanni in Fiore (CS) are shown in the pictures of Fig. 2. They are:

(a) the abbey of San Giovanni in Fiore,
(b) the church of Santa Maria delle Grazie,
(c) the convent of Padri Cappuccini.

All the churches are open for worship.

The three public buildings are:

- Municipal building of San Giovanni in Fiore;
- Library of San Giovanni in Fiore;
- Hospital of San Giovanni in Fiore.

The abbey of San Giovanni in Fiore is the oldest church and the most important monument of San Giovanni in Fiore, established in 1189 by the abbot Gioacchino da Fiore. The body of the church, built of granite stone, consists of a nave and two aisles, ending in the apse with two chapels. The right chapel it leads into the crypt, made by two large basement rooms.

The church of Santa Maria delle Grazie or Chiesa Matrice is completely rebuilt in 1770 with three naves. The front of the church has three portals in sandstone, and the central portal is decorated with Renaissance motifs.

The church of the Padri Cappuccini, is placed in the highest part of the town at an altitude of about 1100 m above sea level. Its construction began in 1639, and the original building consists of two original aisles. Successively, a third adjacent structure was added and is used as convent. The architectural style is typical of the churches of the Capuchins monks. These monuments are detailed described elsewhere [15].

For the abbey of San Giovanni in Fiore, the underground crypt is monitored. The crypt is a large ambient, with two windows always

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