Tectonic control on enhanced geogenic Radon as a first order factor in Radon hazard assessment

(Proposer: Raffaele Sassi)

Scientific Collaborations

Dip. Geoscienze, Padova: Di Toro G., Galgaro A., Mazzoli C.
Istituto di Geologia Ambientale e Geoingegneria – CNR, Roma : Ciotoli G.
Sezione di Sismologia e Tettonofisica, INGV, Roma: Sciarra A.; E. Spagnuolo
Radioactivity Environmental Monitoring (REM), Joint Research Centre (JRC) of the European Commission: Tollefsen T, Cinelli G.

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DOR - R. Sassi, C. Mazzoli
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Population is exposed to ionizing radiation from different natural and artificial sources, including the geochemical concentration of radioactive elements in rocks, soils and artificial building materials, the cosmogenic radiation, the anthropogenic contribution from military use, nuclear plants for energy production, and nuclear medicine. Among them, indoor Radon (IR) is a major health hazard when inhaled (main cause of lung cancer after smoking). Besides specific constructional features favouring Rn concentration in buildings, geogenic Radon (GR) exerts the main control on IR, thus the identification of areas with enhanced GR is critical in hazard assessment. This reflects the recent EU directive on Basic Safety Standard (BSS) for protection against ionizing radiation (CD 2013/59/Euratom).

Radon, due to its short half-life (3.82 days), generally displays a short-scale mobility in purely diffusive systems, thus occurring close to the source point (i.e., soil grain) in the soil pores. In such systems, surface features such as composition and pore structure of outcropping or shallow sitting rocks and soils, as well as biogenic and meteorological factors mainly control its concentration in soil gas. Deep signals may arise only when advection occurs, increasing flux rate of soil gas and Rn mobilization from fissure walls, often along more permeable fractures of fault zones with active fluid circulation. In such a condition, ^{222}Rn has the possibility to migrate for longer distances before decay originating anomalies at surface that in general follow the orientation of the fault zone. Rn anomalies may also be related to U adsorbed to clay minerals and hydroxides under reducing conditions.

Considering Rn as a trace component of soil gas composition, its mobility is determined by the action of carrier gases (e.g. CO_2 and CH_4) and the permeability of the system determining the flow rate of fluids. When flow rate is high, Rn dilution may also occur. Therefore, to quantitatively describe the spatial distribution of GR anomalies, it is necessary to study the association of various gases (e.g., radiogenic Rn and ^{4}He, diagenetic CO_2 and CH_4, and other gases from deep sources such as ^{3}He and H_2), collect a sufficiently large number of soil gas samples from a grid over the area of interest in a period of stable meteorological and soil moisture conditions, and perform adequate geostatistical treatment, in order to construct prediction maps of soil gas distribution. In this way, it is possible to evaluate how the characteristics of the tectonic structures influence intensity, extension, and symmetry/asymmetry of soil gas anomalies, or determine the presence of active tectonic structures buried under alluvial deposits, which may contour areas of enhanced GR, and allow evaluating Rn hazard with respect to the distribution of buildings in Rn prone areas (RPAs).

This PhD project will be conducted in two case study areas:

1) Euganean Hills (Northern Italy), characterised by upper Eocene to lower Oligocene volcanic and sub-volcanic bodies emplaced within upper Jurassic to lower Oligocene limestones and marls, and by NNW-SSE and ENE-WSW trending fault systems partially buried under Quaternary alluvial deposits;
2) The eastern segment of the Periadriatic Lineament (Giudicarie, Pustertal and Gailtal Lines), a major (dextral) tectonic lineament separating the Southalpine from the Austroalpine metamorphic basements, associated to important Oligocene magmatic activity.

In both cases, maps of IR are available with average data referring to the single municipalities. They show that these areas display Rn concentration anomalies, but assessment of the control exerted by tectonics and other geological features on enhanced GR distribution is missing, as well as any distributional information. Thus, the proposed study, which will be carried on in the frame of a collaboration with the Radioactivity Environmental Monitoring (REM) international group of the Joint Research Centre (JRC) of the EC, is addressed to the understanding of the effect of tectonics on enhanced GR, and to the potential use of detailed geostatistical models in taking decisions within Rn priority areas.

Potential of the project.
The United Nation Scientific Committee on the Effect of Atomic Radiation (UNSCREAR) recognizes Radon as the main source of ionizing radiation related to indoor air quality. The most recent European directive regarding human exposure to natural radiation (2013/59/EURATOM) deals primarily with indoor Rn, indicating Rn levels of below 100 Bq/m3 as target level, encourages national action plans at least to identify buildings (i.e., areas) where annual Rn average is expected to exceed the national reference level defined at 300 Bq/m3 (i.e., Radon Prone Areas, RPA) and propose remediation. Understanding and quantifying factors controlling enhanced geogenic Rn through direct measurements of soil gases, coupled with geological data, is essential to define the Geogenic Radon Potential (GRP) of an area, which can be used to guide indoor surveys, and project remediation strategies and actions. Therefore, it is expected for the project to have a strong social impact, and results of the research, besides being presented to the scientific community and published on appropriate journals, in synergy with LIFE-RESPIRE project (Radon rEal time monitoring System and Proactive Indoor Remediation) and Radioactivity Environmental Monitoring (REM) international group of the Joint Research Centre (JRC) of the European Commission, will be adequately disseminated to the public and authorities, and made available by a WebGIS geodatabase.

Expected outcomes.
a) Scientific products. Besides contributing to the European Atlas of Natural Radiation, this research will produce 2 to 3 manuscripts be submitted in peer-reviewed scientific ISI Journals (Journal of Environmental Radioactivity, Journal of Geophysical Research (Solid Earth), G3, etc.).
b) International collaborations. This work will be carried on in the frame of the already established collaboration with the REM-JRC, for the compilation of the European Atlas of Natural Radiation. It will also be in synergy with the LIFE-RESPIRE Project, aimed at designing cost-effective solutions for keeping Rn levels in study areas below 100 Bq/m3 and constructing a real time LIFE-RESPIRE geodatabase of collected continuous Rn measurements, coupled with other geological, geochemical and building characteristics data, integrated within the European Atlas of Natural Radiation.
c) Impact of the society. Considering that IR represents a first order health hazard, and that Rn sources are geologically controlled, the identification of the geological factors determining enhanced emission of GR is fundamental for the identification of RPA, and for the monitoring of buildings where prevention and remediation of high IR concentration should be taken with priority. This represents the main social outcome of the research. An important issue in public health hazard is social awareness. For this reason, special care will be devoted to dissemination, specifically designed on the audience (citizens, secondary school pupils, economic operators).