DEVELOPMENT OF METHODOLOGIES FOR THE STUDY OF RADON RISK AREAS

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The PhD's thesis has designed a methodology for the study of radon risk areas; radon gas (^{222}Rn) is the only gaseous element of the ^{238}U natural decay series.

This radioactive gas is present everywhere at different concentrations in terms of geological characteristics of the study area. So close a correlation between geomorphologic characteristics, structural subsoil characteristics and specific situations of the investigated area allow the identification of areas with different radon potential risk.

The methodology developed is the result of a synergy of several areas of research and study: nuclear physics, study and interpretation of the ^{222}Rn detection systems and their application to *in situ* measures (liquid scintillation method for the determination of Radon in groundwater and measures with semiconductor chambers to measure the Radon in subsoil air).

The methodology so developed is based on the development of:

1. Demarcation of investigated area.

2. Geological general study: collection and study of geological maps, geomorphological, hydrogeological and tectonic.

3. Geological detail study (where possible): collection and study of information about specific characteristics of the area of study, as different lithologic areas in contact, the subsoil and basement structure, presence of ascending geothermal, vulnerable character of the soil, phenomena of dissolution of basement rock, such as karst, etc.

4. Geological conclusions: identification of the Radon potential risk. The potential risk is a direct function of the presence of structural conditions that allow the formation, the emanation and diffusion of Radon towards the soil surface. A key role are the subsoil structure more or less altered, permeability, presence of hydrologic structure, lithologic genesis and development environment of geological formations, if with low energy lead to the formation of intercalation of biological origin, and so rich in elements such as the uranium, again the presence of abnormal situations which may alter the natural, anthropic interventions for example.

5. *In situ* measures distribution based on the potential risk (in the subsoil air and any points of groundwater), the most dense distribution where the hazard is higher, and outcrops lithologic sampling.

6. Processing and interpretation of results through Box-Plot of the Radon measures in the underground and creation of thematic maps.

The test areas identified are: the Trieste's Area and the Lecce's Area.

These zones are particularly significant because the results can be compared with each other and also with those of existing maps of concentration, produced in Italy in 1999 and 2002, obtained by other methods that are not based on geological studies, but on a distribution to regular mesh of indoor measures.

The methodology thus developed can then identify the likely source of high concentrations of radon gas and may allow the formulation of remedial measures to solve the problem both in terms of efficiency and optimization of available economic resources.

The study of general and detailed geology of the two areas has identified a Radon risk potential about Trieste is in line with that of papers produced in Italy in 1999 and 2002 and about Lecce, however, differs: from low to high.

In both test site that makes the high potential risk are:

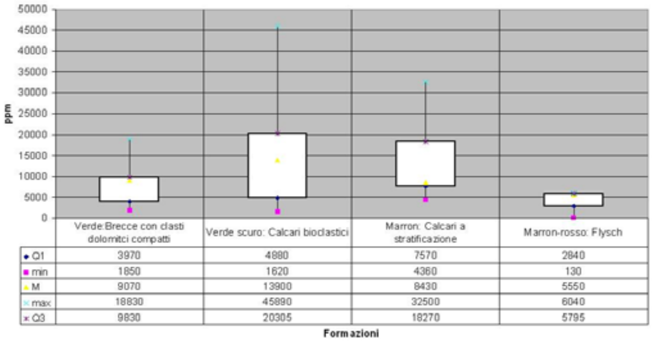
- Areas of contact between lithologic at different degrees of porosity and permeability;
- High permeability for fracting, cracking and karst;
- Bituminous and argillaceous intercalations in lithologic, a sign that the environment formation was the anoxic type, therefore the immobilization of uranium ions.

Using Box-Plot (Fig. 1 and Fig. 2), allowed to provide an initial interpretation of the results about measurements of radon in the subsoil air comparing the lithological formations in the same test area identifying alleged anomalies that may be brought in preparation of the final data in natural or anthropic situations.

The processing of point data like continuous data, digital processing, has made it possible to generate thematic maps of the Radon concentration in subsoil (Fig. 3 and Fig. 4).

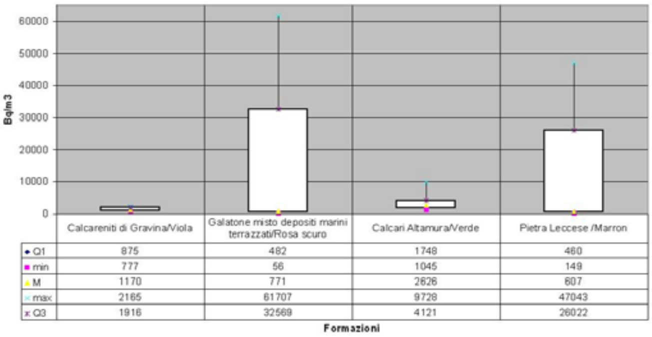
The Trieste's area, in line with previous papers generated at the national level, presents higher average values with a distribution to spot leopard; the largest concentration area is the central part, limestone bioclasts, which are deposits of opened platform with bituminous intercalations and a degree of karstification which has a rang from middle to higher, and high permeability for cracking and karstification.

The Lecce's area gave a final result that differs from that obtained from the national survey of 1999, in particular, as shown by the Fig. 2 and Fig. 4, the area is characterized by Hot-spot of Radon concentrations, have been recorded point with over 60.000 Bq/m^3; the direct study of area,



	Verde:Brecce con clasti dolomitci compatti	Verde scuro: Calcari bioclastici	Marron: Calcari a stratificazione	Marron-rosso: Flysch
Q1	3970	4880	7570	2840
min	1850	1620	4360	130
M	9070	13900	8430	5550
max	18830	45890	32500	6040
Q3	9830	20305	18270	5795

Fig. 1 – Box Plot Trieste Area



	Calcareniti di Gravina/Viola	Galatone misto depositi marini terrazzati/Rosa scuro	Calcari Altamura/Verde	Pietra Leccese /Marron
Q1	875	482	1748	460
min	777	56	1045	149
M	1170	771	2626	607
max	2165	61707	9728	47043
Q3	1916	32569	4121	26022

Fig. 2 – Box Plot Lecce Area

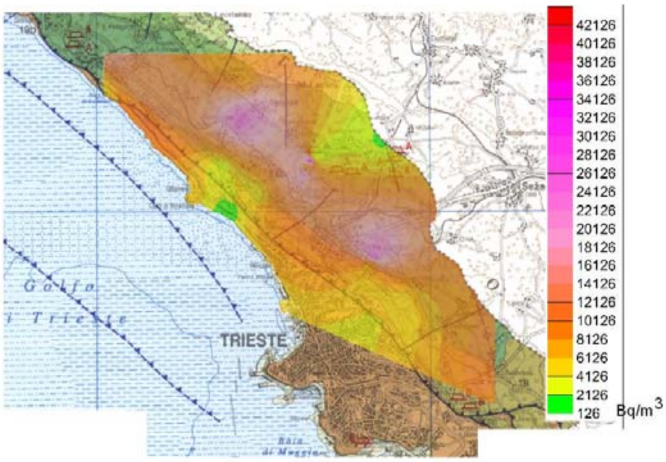


Fig. 3 – Radon Map Trieste Area

together with general and detailed geologic information and with gas measures in the underground, enabled to identify points of measurement like measures such “distorted”; these are all located in areas close to man, whose common feature is to have penetrated the layer of soil and bedrock to resolve the area and to construct buildings with higher volume.

Fig. 5 and Fig. 6 show the elaboration of Radon concentration maps in the air of subsoil, respectively of the measures called “Not disturbed” and measures called “disturbed”; it was noted that the absence of the latter allows to identify an area characterized by radon values are not too high and by small changes in concentrations between different lithological species.

Among the measures affected the higher were obtained in geological formation with greater permeability and fracturing and in contact areas between the different lithologic areas.

The complete study of a building, Radon indoor measures coupled with measures of Radon in the subsoil, with the characteristics listed above and positioned to straddle two different lithologic areas finally allowed to identify a situation of real danger to the residents’ building concerned (Fig. 7 and Fig. 8).

The abnormal situation generated by a distracted human intervention, has encouraged a formation and release of radon gas in high quantities.

In conclusion, this methodology allows analysis of the area investigated able to plan the distribution of measures in the subsoil and more importantly allows you to interpret the results obtained by identifying the factors, both natural and anthropogenic, that can characterize and generate abnormal situations.

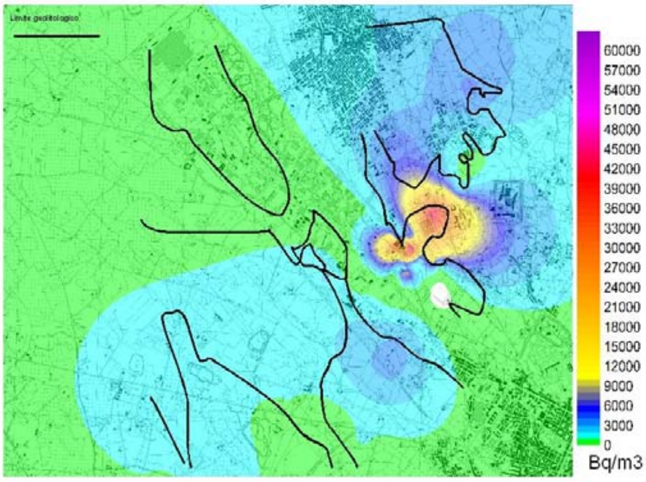


Fig. 4 – Radon Map Lecce Area

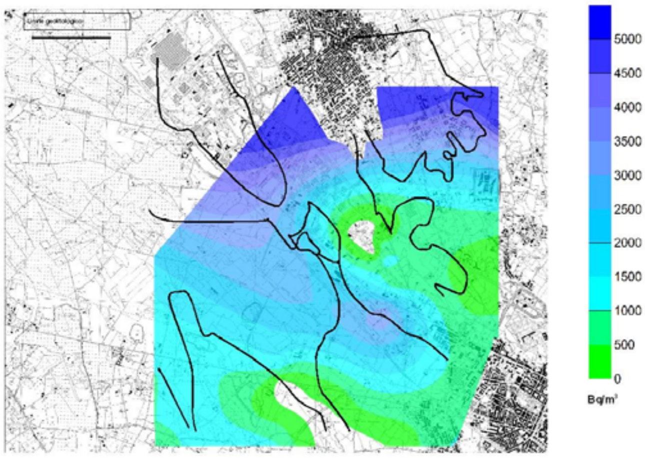


Fig. 5 – Measures “Not disturbed”

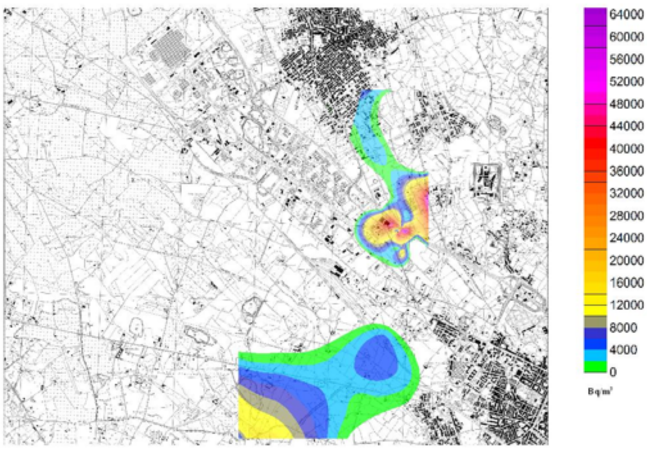


Fig. 6 – Measures “Disturbed”

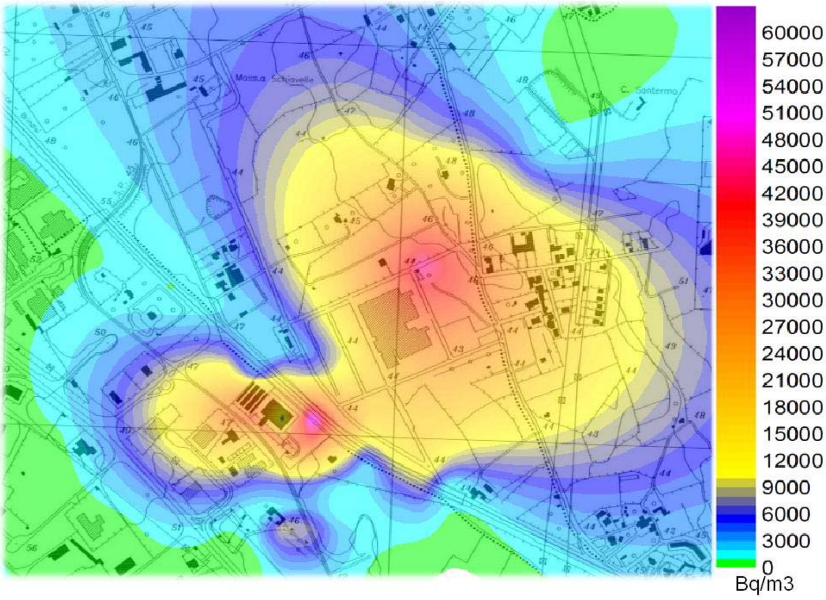


Fig. 7 – Anthropic Area

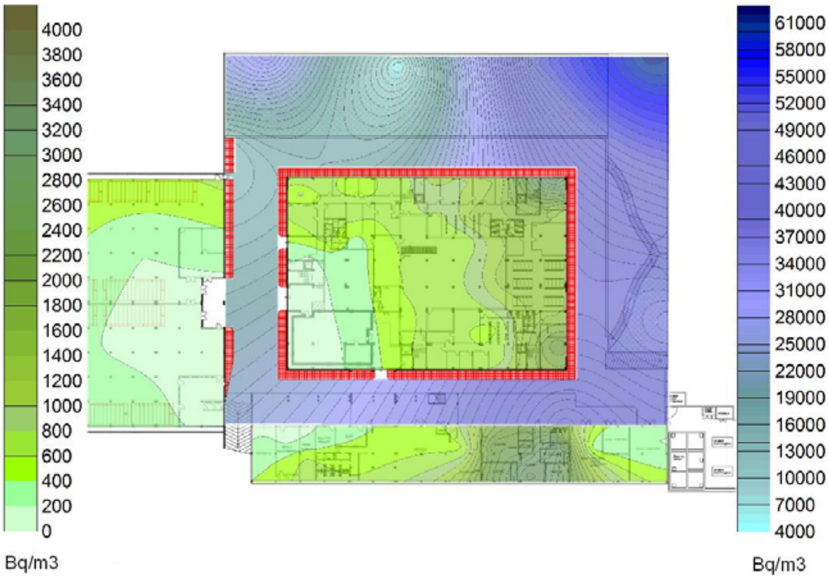


Fig. 8 – Measure indoor and outdoor Anthropic Area

This methodology also identified the structure of the subsoil, the presence of faults, the primary and secondary porosity, like the phenomenon able to adjust the lift of Radon gas, creating situations of strong accumulation and fast rising in areas where this problem seemed not present.