6th Newsletter, January 2021

LIFE-Respire

Radon r**E**al time monitoring **S**ystem and **P**roactive **I**ndoor **Re**mediation - LIFE16 ENV/IT/000553

[Website: www.liferespire.eu, www.liferespire.it]

The LIFE-RESPIRE (**R**adon r**E**al time monitoring **S**ystem and **P**roactive **I**ndoor **Re**mediation) project, which started in September 2017, is approaching the end of its first year. The project is realized with the financial contribution of the European Union LIFE programme (LIFE16 ENV/IT/000553).

The main objective of the project is **to demonstrate in 4 areas** (Caprarola, Celleno, and Ciampino in Italy and Jalhay in Belgium) characterised by different Geogenic Radon Potential (GRP), a cost-effective and eco-friendly solution for Rn real-time measurement and remediation **to keep indoor Rn levels below 300 Bq/m^3** (as indicated in European Directive 2013/59/EURATOM). The RESPIRE project will implement an intelligent, adaptable and versatile hybrid Rn remediation system composed of sensors, an Air Quality Balancer (SNAP) and an external additional fan-system (eolian and/or electric) working on positive pressure method. A control model based on a IoT protocol will be also implemented.

The LIFE-RESPIRE geodatabase, consisting of collected continuous and discrete Rn measurements coupled with other geological, geochemical and building characteristics data, will be linked to a WebGIS for easy data management, analysis and visualization by the consortium, and available to the local authorities for land use planning and health risk assessment, helping to prepare relevant national action plans (see Articles 54, 74 and 103 in 2013/59/EURATOM).

This newsletter highlights the main actions conducted in the 5th semester of the project and lists some of the dissemination activities at conferences. Some of the mentioned material is available to the public on the Document section of the LIFE-Respire website.

Any interest and collaboration with the LIFE-Respire Group is appreciated, please contact us!

More information about the purposes of the project can be found on the LIFE-RESPIRE website.

COMUNE DI CAPRAROLA

Comune di Celleno

CITTÀ DI CIAMPINO

CITTA' METROPOLITANA DI ROMA CAPITALE

LIFE-Respire Consortium

CERI-Sapienza: Centre for Research of the Sapienza University of Rome, Italy

Consiglio Nazionale delle Ricerche

CNR-IGAG: Institute of Environmental Geology and Geoengineering of the National Research Council, Rome, Italy

INGV: National Institute of Geophysics and Volcanology, Rome, Italy

FANC: Federal Agency for Nuclear Control, Brussels, Belgium

federaal agentschap voor nucleaire controle

Elica: Elica S.p.A., Fabriano (AN), Italy

Main Contacts

Sabina Bigi (CERI-Sapienza), Earth Science Department, University of Rome Sapienza , P.le A. Moro 5, 00185 Roma, Italia email: sabina.bigi@uniroma1.it

Giancarlo Ciotoli (CNR-IGAG), Institute of Environmental Geology and Geoengineering, National Research Council, 00015 Monterotondo, Roma, Italia, email: giancarlo.ciotoli@igag.cnr.it

Alessandra Sciarra (INGV), National Institute of Geophysics and Volcanology, Via di Vigna Murata, 00143 Roma, Italia, email: alessandra.sciarra@ingv.it

Boris Dehandschiutter (FANC), Federal Agency for Nuclear Control, Rue Ravenstein 36, 1000, Brussels, Belgium, email: boris.dehandschutter@fanc.fgov.be

Mauro Castello, Strategic External Resourcing Area, Elica S.p.A., Via Ermanno Casoli, 2, 60044 Fabriano (AN), Italia email: m.castello@elica.com

IN THIS ISSUE

1. Respire Remediation System

The new Respire Radon Remediation System (R3S) is the second and final prototype created within the LIFE-RESPIRE project. The R3S is shown to be a robust system that is capable of controlling different types of ventilation systems based on measured radon values, and transmitting the results to Web-based database for archiving and visualisation. The R3S is the culmination of multiple iterations focussed on the development of an integrated sensor-ventilation system capable of reducing indoor radon concentrations below legislative limits when the proper remediation approach is chosen and correctly sized.

The R3S control unit consists of a commercial radon sensor (FTLab RD200M) integrated with a pressure/temperature/relative humidity (P/T/RH) sensor (Bosch BME280) and a mini-computer (Raspberry Pi model Zero W) equipped with Wi-Fi, Bluetooth, and data logger capabilities. Bespoke firmware written in Linux interrogates the sensors, saves the data, and transmits it via Wi-Fi or cellular hot-spot to a central server that manages the database and projects it on the web in the form of a WebGIS (Geographic Information System). Based on the indoor radon threshold value chosen (either 100 or 300 Bq/m3 for the tests reported here) the Raspberry Pi uses either a direct cabled connection or a Bluetooth signal to activate / deactivate the ventilation system installed for remediation (Tab. 1).

A total of 25 R3S units were installed in Italy (Fig. 1). Of these, 18 are still operating while the remainder were removed or abandoned due to logistical problems with the site, due to lack of support from the owner or, more commonly, site administrator/worker at public buildings, or because the locations were used only for controlled experiments. Of the 18 operating units, 15 pilot in-wall heat recovery fans, 1 pilots an in-wall heat exchange fan, and 2 pilot sub-slab extraction fans. In-wall air exchange fans were used at the 16 sites due to the fact that the radon, in most cases, originates from the building materials; air exchange is presently one of the few solutions for this type of source. The effectiveness of the air exchange approach depends on a number of factors, each of which was highlighted in the various Italian deployments reported here. When building materials are the principle radon source, the rate of radon exhalation has a strong impact on the final equilibrium concentration that can be obtained using air exchange.

Fan type, installation and behaviour were also found to be important, as shown by the testing of three different configurations: one heat recovery fan, two heat recovery fans, and one heat exchange fan (Fig. 2). In the first case, the oscillating flow direction risks to draw radon-rich air from other rooms during the exhaust cycle, whereas the second and third options guarantee that fresh outdoor air is always introduced into the building. Occupant habits also have a significant impact, especially the Italian habit of aerating a home by opening the windows for a period in the morning.

	Version 1 - SNAP-Rn	Version 2 - R3S
Radon sensor	FTLab™ RD200M	FTLab™ RD200M
T, P, RH	sensors in SNAP fan	added sensor to control unit
Control electronics	In-house developed	Raspberry Pi mini-computer
Data logger	none	SD card
Data transfer	Wi-Fi capabilities of SNAP fan	Wi-Fi of Raspberry Pi
Fan type	extraction	Heat recovery or heat exchange units
Fan control	Remote control unit of SNAP fan	Bluetooth wireless control or cabled

Table 1. The following table compares this version with that described in Deliverable 1.5 to clearly highlight the various changes made. As the previous version took advantage of some capabilities of the smart SNAP extraction fan, the decision to use other ventilation options required that these capabilities be added and integrated into the R3S itself (thereby making it more flexible and universal).

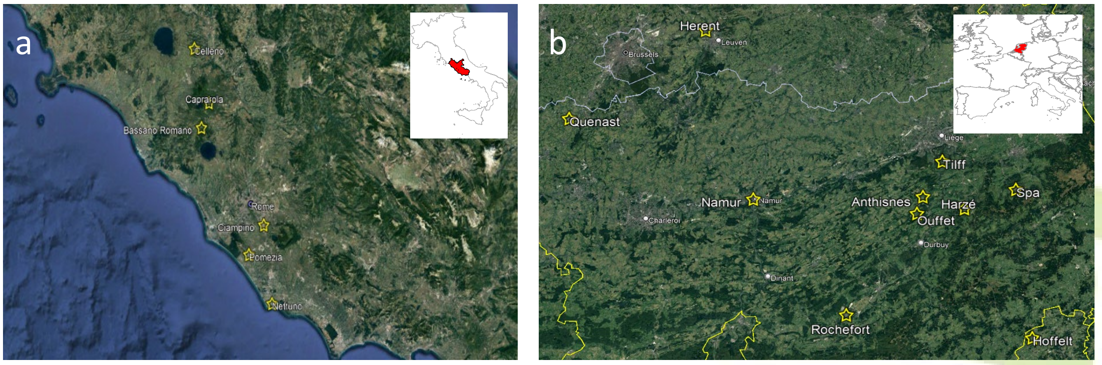


Figure 1. Location maps (yellow stars) of the communities where R3S units have been installed in (a) Italy (Lazio region) and (b) Belgium (Ardenne).

A total of 10 R3S units were installed in Belgium, of which all are still operating. All are located in private homes except for one that is in a public library. Six of these R3S units pilot an exhaust fan that depressurizes a crawlspace or similar while the remaining four pilot sub-slab sumps to depressurize the soil beneath the building.

As the radon source at the Belgium sites is exclusively the underlying soil, the depressurizing approach is the most effective because it prevents the radon from ever entering the building. Because of this the impact of the remediation system tends to be quite dramatic and is much more efficient that the air exchange systems described above (which are necessary when the radon comes from the building materials themselves). Where it was possible to conduct short term tests, with values monitored before and after the remediation system was turned on, reductions in radon concentrations were on the order of 50 to 80%, even for large homes.

R3S results from the Belgium sites show that this automated approach is very valid for these types of conditions, with fan activation being adjusted continuously as radon entry rates or owner activities change due to short-term environmental and long-term seasonal conditions.

In conclusion, the basic concept behind the Respire Radon Remediation System (R3S), that involves autonomous, real-time control of a ventilation system based on continuous radon measurements, has been proven to function well if the remediation system is properly sized and configured. Actuating units only when required, which changes both on a daily and seasonal level, saves electricity, is heat-efficient, and maintains indoor comfort. In addition, the constant collection of radon data gives the occupant the possibility to continually assess the effectiveness of any installed remediation system, highlighting changes that may be necessary or maintenance that should be undertaken.

Figure 2. Drawings and photos of (a) the Elica SNAP extraction fan;(b) Fantini Cosmi EcoComfort 100 heat recovery unit; (c) Prana 150 heat exchange unit and (d) an in-line exhaust fan.

1.1. Some results from two test sites

During the periods when the COVID-related lock-down rules were most strict it was essentially impossible to gain access to public or private buildings for experimentation, testing of system modifications, or maintenance of the installed units. Fortunately, through close personal connections of the researchers, the project was given access to two sites (in Nettuno and Bassano Romano, Figure 1a) together with local support from the home owners to conduct experiments. The Nettuno site is located in a semi-basement with walls made of volcanic tuff blocks. The advantage of this site is that there are two, similarly sized rooms adjacent to each other where it was possible to put radon sensors in both rooms but the heat recovery fan was installed in one room. This set-up allowed us to account for natural variations induced by environmental conditions to more clearly assess the effectiveness of the installed remediation system. Instead, the Bassano Romano site is a standalone, single volume, un-used guest house, again made of tuff blocks.

Figure 3 shows the impact of the heat recovery fan installed at the Nettuno test site. Figure shows a period of data collection first with the fan off and then with the fan on (set to bi-directional flow and high speed). For the first 8 days when the fan is off the two sensors register almost identical trends and absolute values. Instead when the fan is turned on significantly lower absolute values in the room with the fan were measured. In any case, for this site and this period, radon concentrations appear to be reduced by almost 50%.

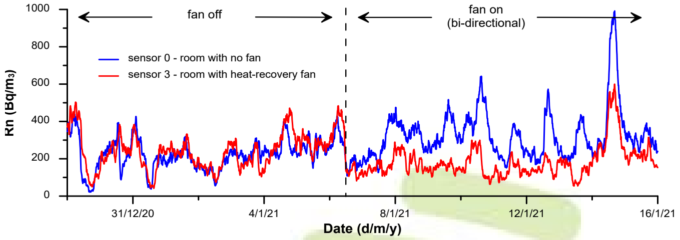


Figure 3. Results from the Nettuno site showing radon concentration data from sensor 3 (room with fan) and sensor 0 (control room, no fan) for an 18 day period straddling the moment when the fan was set to maximum bi-directional flow.

Results of tests conducted at Bassano Romano site using the heat recovery fan (Figure 4a,b) and the heat exchange fan (Figure 4c,d) show the clear impact that the Respire remediation system can have on indoor radon concentrations. For example, the range of radon values tend to be relatively narrow and the median value is consistently near 400 Bq/m3 for the various tests conducted with the heat recovery fan on (Figure 4b), compared to the higher and more variable median values when the fan was off. The heat exchange fan results are similar, with a median value of 600-700 Bq/m3 when the fan is off, 275 Bq/m3 when the fan is set at “2”, 185 Bq/m3 with the fan set at “5” and 160 Bq/m3 with the fan set at “10” (note that if one considers only the second half of this last period the median drops to 140 Bq/m3; transparent blue box in figure).

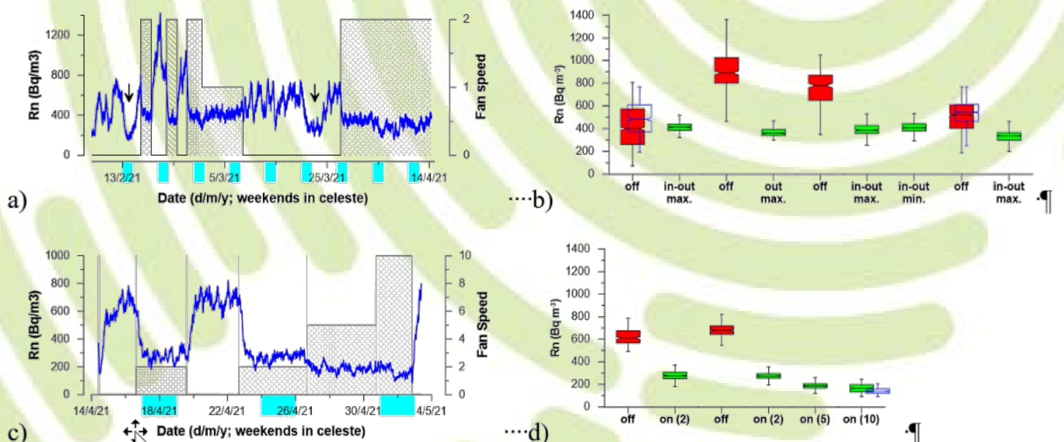


Figure 4. Results from the Bassano Romano test site using the heat recovery fan (a, b) and heat exchange fan (c, d). The time series data on the left illustrate how radon concentrations (in blue) change with activation and speed of the fans (hatched areas); note the arrows in (a) indicate periods of high winds that reduced indoor radon levels when the fan was off. The box plots on the right show the same data in statistical form, with periods when the fan was off in red and when it was on in green.

2. Geogenic Radon Potential Maps

The geogenic potential of radon (GRP) is a natural characteristic linked to the territory and representative of the radon risk. Unlike the mere cartographic restitution of indoor radon concentrations detected by measurement campaigns in buildings, the GRP produces a more robust estimate of the "radon released by the Earth" which depends exclusively on the geological environment. In fact, the concentration of radon in confined spaces is highly dependent on natural and anthropogenic factors (such as climate, type of construction, building materials, lifestyle habits, etc.) which make it inadequate for a spatial representation of the radon hazard. Furthermore, the concept of PGR is strictly connected to the concept of Radon Priority Areas (RPA) reported in the European Directive 2013/59 / Euratom (Art. 103), therefore a correct estimate of the GRP provides important information for the identification of RPAs above all when the quality and number of indoor measurements is inadequate.

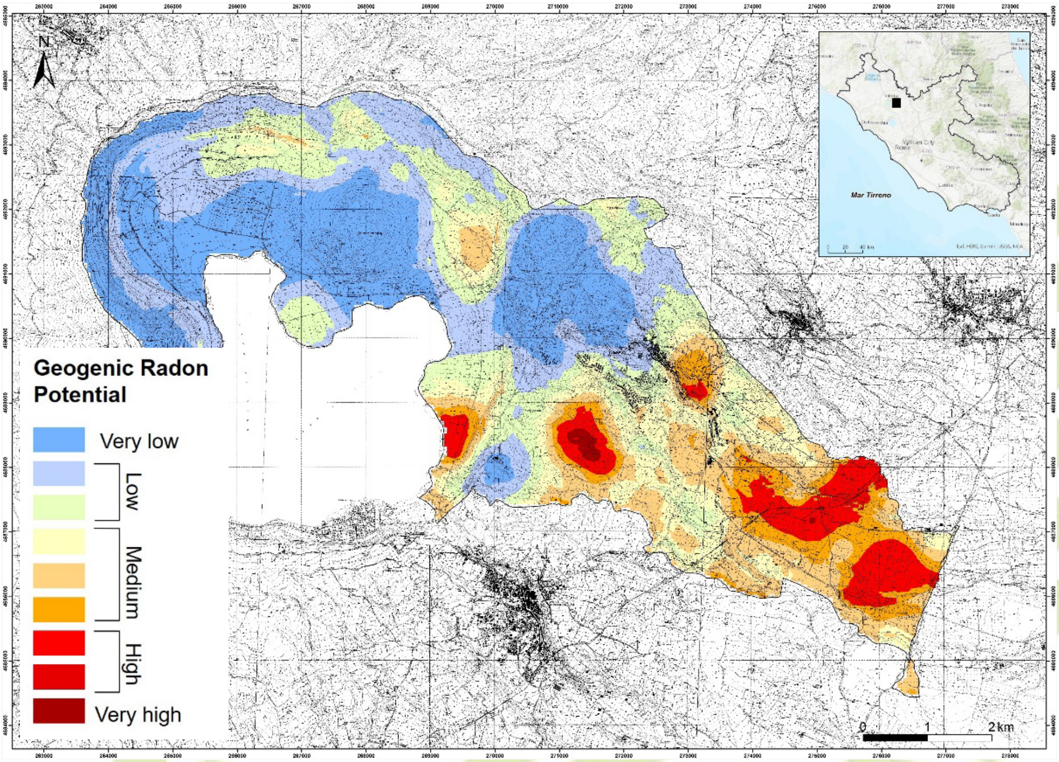
For over ten years, researchers from different countries have been using various multivariate spatial statistics techniques to define the relationships between the radon production capacity in rocks and its transport to the surface, up to entering our homes, with the final aim of producing maps of the GRP through the combination of several geological factors. The use of geological factors is more suitable for building GRP maps because they are characterized by:(i) greater spatial autocorrelation; (ii) lower variability; and (iii) above all they do not depend on anthropogenic factors, such as the constructive parameters of the building or the habits of the inhabitants, which affect the concentration of radon in confined spaces.

The geological and geochemical information collected within the LIFE-Respire project and stored in the Respire geodatabase were used to construct the GRP maps of the three Italian municipalities involved in the project, Caprarola, Celleno e Ciampino (Fig. 5a,b).

In particular, a conceptual model was established based on geological, geochemical, structural and geomorphological data collected from the literature, and through field surveys, such as the content of uranium, thorium and radium in soils and rocks, soil permeability, gamma radiation in the air, the emanation coefficient of rocks, the presence of faults and / or fractures, the activity of toron (^{220}Rn) in soil gases and radon dissolved in groundwater (wells and / or springs). All data were correlated with the measured activity of radon (^{222}Rn) in the soil using multivariate spatial regression techniques that allowed the elaboration of the final map of the GRP without the need for indoor concentration measurements. The superimposition on the GRP of the radon concentrations measured in the buildings map will allow the recognition and delimitation of the Radon Priority Areas, as required by the European Directive 2013/59 / Euratom.

All data were correlated with the measured activity of radon (^{222}Rn) in the soil using multivariate spatial regression techniques that allowed the elaboration of the final map of the GRP without the need for indoor concentration measurements. The superimposition on the GRP of the radon concentrations measured in the buildings map will allow the recognition and delimitation of the Radon Priority Areas, as required by the European Directive 2013/59 / Euratom.

The construction of PGR maps is an important tool for the analysis of the hazard and for the identification of Radon Priority Areas. These two maps are both fundamental: for land-use planning by national and local authorities, for the organization of indoor investigations (for risk prevention), and for remediation actions.



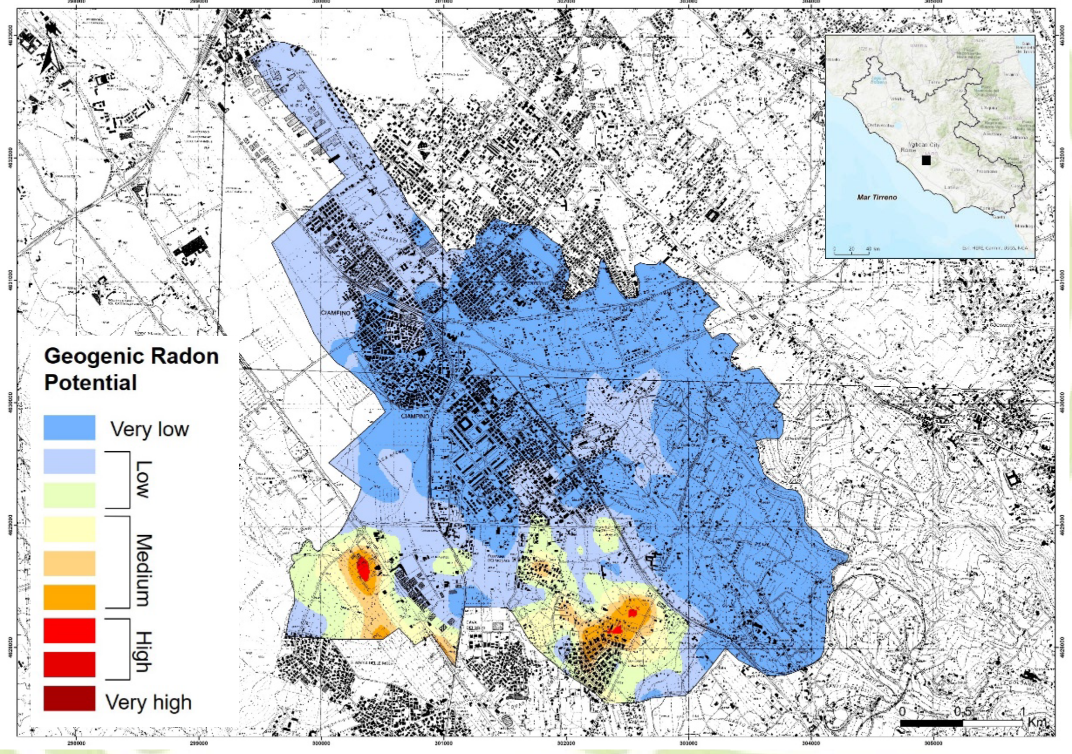


Figure 4. Geogenic Radon Potential maps of the municipality of Caprarola (above) and Ciampino (below).

3. Public awareness and dissemination of results (Action D1)

In this last year of the project, despite the limitations caused by the covid-19 pandemic, dissemination activities was conducted regarding the organization of public events for local people and stakeholders, as well as the participation at Italian and International meetings. Some of the LIFE-RESPIRE results were presented at virtual conferences and workshops addressed to researchers, public, local and regional authorities and building professionals.

- **European Geosciences Union-General Assembly** 2021 (vEGU21), 19-30th April 2021 (virtual event). The meeting hosted a session "Radon: geogenic sources, hazard mapping, and health risk" chaired by the Respire Consortium
- **90th Congress of the Italian Geological Society**, 16-18th September, Trieste (Italy). The meeting hosted a session " Geology, food and health " chaired by the Respire Consortium
- **ROOMS International workshop**, 14th October 2021, Fribourg (Switzerland). A RESPIRE booth hosted the Respire prototype of the indoor radon monitoring system.
- **Webinar MAPEI Academy (18th November 2021).**
    - G. Ciotoli (CNR-IGAG). Il potenziale geogenico di radon.
    - P. Tuccimei (ROMA TRE). Valutazione sperimentale dei livelli di radon indoor in una “scale mode room”
- **European Geosciences Union-General Assembly 2022** (vEGU21) (22-27th April 2022, Vienna (Austria) (virtually and onsite).
- **LIFE-Respire Final Event** *“Il radon dalla geologia alla gestione del rischio indoor”* organised by the LIFE-Respire Consortium in collaboration with the Ministry of the Ecological Transition at the Sala Zuccari of the Senate, 9th May 2022.
- **IRSOIL 2022**, organised by Assoradon and Associazione Italiana di Radioprotezione (AIRP). *Measurements of the concentration of radon activity in the soil*, 2nd National Inter-comparison, 19 – 20th May 2022, Appia Antica Park, Rome.

4. Networking

In 2022, an agreement with **traceRadon** project (http://traceradon-empir.eu/) funded from the EMPIR programme co-financed by the Participating States and from the European Union's Horizon 2020 R&I programme was finalised. The main topic of this collaboration concerns activities to develop improved methods and geospatial models for the elaboration of Geogenic Radon Potential maps and identification of Radon Priority Area (RPAs) using outdoor radon activity concentration data, radon flux data and radon flux maps.

5. Upcoming events

International Conference on Radiation Applications RAP 2022 will be held from 6th -10th June 2022, Thessaloniki, Greece.

Goldschmidt Conference, 10-15 July 2022, Honolulu, Hawai (USA). The Conference will host a session "Radon: geogenic sources, hazard mapping, and health risk" chaired by the Respire Consortium

6. Publications

- Gruber V., Baumann S., Alber O., Laubichler C., Bossew P., Petermann E., Ciotoli G., Pereira A., Domingos F., Tondeur F., Cinelli G., Fernandez A., Sainz C., Quindos-Poncela L. (2021). Comparison of radon mapping for the delineation of radon priority areas – an exercise. Journal of European Radon Associations, 2, 5755, 2021 - doi: 10.35815/radon.v2.5755
- Giustini, F.; Ruggiero, L.; Sciarra, A.; Beaubien, S.E.; Graziani, S.; Galli, G.; Pizzino, L.; Tartarello, M.C.; Lucchetti, C.; Sirianni, P.; Tuccimei, P.; Voltaggio, M.; Bigi, S.; Ciotoli, G. Radon Hazard in Central Italy: Comparison among Areas with Different Geogenic Radon Potential. Int. J. Environ. Res. Public Health 2022, 19, 666. https://doi.org/10.3390/ijerph19020666
- Peter Bossew, Igor Čeliković, Giorgia Cinelli, Giancarlo Ciotoli, Filipa Domingos, Valeria Gruber, Federica Leonardi, Jovana Nikolov, Gordana Pantelić, Alcides Pereira, Eric Petermann, Natasa Todorović, Rosabianca Trevisi (2022). On harmonization of radon maps. Journal of European Radon Associations, JERA, 3, 7554, doi: 10358/radonv3.7554.
- Coletti C., Ciotoli G., Benà E., Brattich E., Cinelli G., Galgaro A., Massironi A., Mazzoli C., Mostacci D., Morozzi P., Mozzi P., Nava J., Ruggiero L., Sciarra A., Tositti L., Sassi R. (2022). The assessment of local geological factors for the construction of a Geogenic Radon Potential map using regression kriging. A case study from the Euganean Hills volcanic district (Italy). Science of The Total Environment, 808, 1-16, 2022, doi: 10.1016/j.scitotenv.2021.152064
- Benà, E., Ciotoli, G., Coletti, C., Galgaro, A., Mair, V., Massironi, M., Mazzoli, C., Morelli, C., Morozzi, P., Ruggiero, L., Tositti, L., and Sassi, R.: The role of Pusteria fault zone (North-Eastern Alps, Italy) on enhancing the Geogenic Radon component, EGU General Assembly 2022, Vienna, Austria, 23–27 May 2022, EGU22-2684, https://doi.org/10.5194/egusphere-egu22-2684, 2022.
- Giustini F. and Ciotoli G. (2022). Il rischio radon negli ambienti chiusi. Contenuto realizzato nell’ambito del progetto CNR 4 Elements. www.rinnovabili.it. 23 Aprile 2022