Deliverable 6.10

European network of Citizen Science projects related to radon measurement and mitigation

Work Package 6

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Executive summary of the RadoNorm project

EU member states, associated countries and the European Commission are implementing the European Basic Safety Standards Directive for radiation protection. The EU-funded RadoNorm project focuses on all radiation risk management cycle levels for radon exposure, as well as situations of exposure to naturally occurring radioactive materials (NORM). The project intends to reduce scientific, technical and societal concerns by introducing research and technical developments, integrating education and training (E&T) and disseminating the results of the project through targeted actions to the public, stakeholders and related institutions. RadoNorm directs research and development on all levels of the management cycle, combine biomedical and ecological research with mitigation development and social science research and bring together researchers from national radiation protection entities, universities and SMEs.

Executive summary of the deliverable

One of the objectives of the RadoNorm project is to establish a citizen science incubator for radon priority areas and a network of citizen science projects to address radon testing and mitigation. For this, one of the first tasks within RadoNorm was to develop and test four citizen science pilot projects in France, Hungary, Ireland and Norway in order to propose a model for citizen science in EU Member State.

Through an open call, RadoNorm aimed to support citizen science initiatives related to radon testing and/or radon mitigation in radon priority areas. Nineteen projects were submitted and evaluated by independent reviewers based on four criteria: overall concept, implementation, impact, and team expertise. Following the evaluation process, six projects were selected for further improvement through negotiations. These negotiations aimed to address the shortcomings identified by the evaluators. Eventually, six projects were selected for funding, including **OCRA in Italy, AHS Radon Hunt in Poland, RadAR in Portugal, RadonGPS in Slovakia, RadoNorm-SLO in Slovenia** and **RADOHOW in Spain**. These projects focused on indoor radon measurements, with one project also exploring radon concentrations in tap water and water sold for drinking in spa resorts. Measurements were conducted in various settings, including schools, dwellings, offices, caves, spas, water treatment facilities, and underground mines, utilising both passive and active detectors. Furthermore, the citizen scientists did not only address mitigation techniques but also assessed their efficacy in reducing radiation exposure. By the end of May, 50% of the available resources were allocated to the selected projects. This allocation allowed them to commence procurement of materials and initiate dissemination activities crucial to the successful implementation of their respective projects.

These citizen science projects in the field of radon aimed to provide valuable advice on mitigation strategies in situations where high concentrations of radon are measured, ensuring effective measures are implemented to minimise potential health risks. This approach did not only contribute to the advancement of scientific research, but it did generate a host of additional impacts that reach beyond traditional scientific boundaries. These impacts spanned a diverse range of areas, including education, society, policy, and more.

This report collects the final reports submitted to RadoNorm from the six citizen science projects funded by the project and which have constituted the basis for a Citizen Science Incubator. In addition, the pilot citizen science project in Hungary continued its activities beyond the pilot phase of RadoNorm and is therefore also included as part of the Citizen Science Incubator in this report.

RadoNorm citizen science incubator was also featured on the European Union Prize for Citizen Science – Honorary Mentions List in June 2024. The prize honours innovative and creative projects that demonstrate significant merit and societal impact. Thus, the project earned official recognition by being selected from an impressive 288 entries for an 'Honorary Mention' in the European Union Prize for

Citizen Science. RadoNorm has thus secured a position among the top 10% of European citizen science projects.

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Acronyms

Abbadia SS	Abbadia San Salvatore
AHS	Akademeia High School
APA	Agência Portuguesa do Ambiente
ARPAT	Environmental Regional Protection Agengy of Tuscany
CS	Citizen Science
CSN	Nuclear Safety Council (Consejo de Seguridad Nuclear)
DIY	Do It Yourself
GDPR	General Data Protection Regulation
IAEA	International Atomic Energy Agency
IST	Instituto Superior Técnico
JSI	Jožef Stefan Institute
KK	dr. Katja König, coordinator of the RadoNorm–SLO project
NRAP	National Radon Action Plan
OW	Oligocene Well
PDS	Personal Development Scheme
RadoHOW	RAdon DOses in HOmes vs Workplaces
SSNTD	Solid state nuclear track detector
UK R	Jerry Board, UK Radon Ltd.
URSVS	Slovenian Ministry of Health's Radiation Protection Administration
ZIK Črnomelj	Adult Education Center in Črnomelj
WHO	World Health Organization

1 Introduction

Recognising the limited awareness, testing efforts and low mitigation numbers in high radon risk areas, RadoNorm has established a Citizen Science (CS) Incubator involving citizens and scientists from diverse scientific disciplines, from social sciences, dosimetry, epidemiology, engineering, radiobiology to medical doctors. The aim is to create a model for grassroots CS projects in radon risk areas. Nearly 600 citizen scientists were engaged across Europe. The Incubator showcases impactful outcomes on improved radiation protection behaviour by citizens to potential policy implications.

We started with four pilot projects. In France, citizens improved cutting-edge radon diagnostic tools, while in Ireland homeowners developed a Do It Yourself (DIY) toolkit. CS in Hungary invented a tool to measure CO2 and radon to be used in schools, and in Norway citizens decided to take on the role of science communicators. Transitioning from pilot to grassroots projects, the Incubator supports community-specific research questions. RadoNorm subcontracted organisations to carry out citizen science activities related to radon mitigation for a **six-month duration**. Applicants had the chance to co-design, test the RadoNorm toolkit and work together with RadoNorm researchers and professionals to tailor the support they need to achieve their goals. Each of the projects submitted a report to RadoNorm summarising the main objectives, the partners, engagement of citizens, results, evaluation and final reflections.

The open call was disseminated through the RadoNorm consortium partners, RadoNorm website, the European Citizen Science Collaboration Group and social media. It was made available to any European country (EU Member State or associated state) eligible to receive funding through Euratom Research and Training Programme (2019-20) grants or an associated country.

The total amount of funding available for all funded projects was 140,000 € (taxes included) and the maximum funding per applicant was set at 25,000€ (taxes included). The funding was distributed among various European countries. The funding could be spent on salaries, equipment, consumables, travel and indirect expenditure (calculated as 25% of the total direct costs), in accordance with Horizon 2020 guidelines[1].

RadoNorm organised two webinars of a duration of 1:30h each to help the applicants to submit their application. The first webinar was organised on 7th November 2022 and the second one on 17th January 2023. Both webinars were recorded and published on the RadoNorm website.

Information was available from the RadoNorm website and was also sent to RadoNorm partners and any interested organisation. The webinars included an overview of the RadoNorm citizen science open call and the "experience of the CS projects in the RadoNorm pilot projects: lessons learned to get inspired".

The CS Incubator funded and supported the following projects: **OCRA in Italy, AHS Radon Hunt in Poland, RadAR in Portugal, RadonGPS in Slovakia, RadoNorm-SLO in Slovenia** and **RADOHOW in Spain**. In Italy, citizens measure radon levels, analyse data and create an interactive radon map. Polish high school students collect and analyse samples of soil, water and air, contributing to both education and research. In Portugal students run a nationwide radon measurement, filling a scientific data gap. In Slovakia we investigate building mitigation strategies with citizens, high school for builders and authorities, while Slovenia's team conducts research on the effectiveness of different mitigation techniques and in Spain we target both workplaces and homes for radon exposure improvement.

Projects managed to raise awareness about radon, integrate radon into high school curriculums and even address building techniques in several countries. Data and solutions collected by CS contribute to

[1] https://ec.europa.eu/research/participants/data/ref/h2020/grants_manual/amga/h2020-amga_en.pdf

academic research within the H2020 project RadoNorm. High scientific quality ensures publications in accessible platforms such as Open Europe, fostering collaboration between academics and CS. We actively involve community members in testing, fixing, and ultimately saving lives. Our approach is rooted in shared responsibility and ownership, empowering communities to proactively address radon-related health risks. Through our efforts, we aim to raise awareness about radon, address scientific gaps, foster collaborative initiatives to protect from radon and promote community resilience. Our engagement extends to diverse communities, encompassing libraries in Norway and Ireland, schools in Hungary, Slovakia, Portugal, and Poland, as well as specific villages and regions in Slovenia and Italy.

We reach out to families and pensioners across all CS projects, fostering collective action. As our younger generation citizen scientists are deeply concerned about the climate crisis, we take actions that contribute to environmental rehabilitation and sustainability. For instance, while energy-saving and passive houses are environmentally friendly, they may pose challenges with increased radon concentrations. Not only our CS are testing different houses for radon concentration, our citizen scientists, armed with DIY tools, install devices to create environmentally friendly and healthier indoor spaces. This aligns with both environmental sustainability and the improvement of public health. Collaboration with national authorities is integral to our approach. Not only do we assist authorities in implementing Council Directive 2013/59/Euratom, mandating every EU Member State to establish a national Radon Action Plan, but we also actively contributing to the implementation of the European plan to combat cancer, the Green Pact for Growth, and the roadmap for reducing industrial and natural risks. By working together, we strive to address both immediate concerns and long-term policy objectives. We employ various communication channels, including TikTok, webinars, blogs and traditional media, especially local newspapers and local radio stations. We engage extensively; for instance, our citizen scientists can be found in shopping centers, at crossroads in villages, and in people's homes. Moreover, RadoNorm engaged a postdoctoral researcher to independently evaluate all citizen science projects. The objective was to identify lessons learned that can bolster new initiatives and to furnish both theory-based and empirical evidence supporting the hypothesis that active citizen engagement in radon-related research enhances compliance with necessary testing and potential home mitigation. The Incubator engaged citizens and academics in various research levels, from crowdsourcing to extreme CS and methods, creating an inclusive environment. Through active engagement, diverse CS projects important for communities, RadoNorm CS Incubator contributes to lowering lung cancer cases.

The chapter "radon and citizen science" co-authored by the WP6 leader (Tanja Perko) and the Task leader on citizen science (Meritxell Martell) and all the coordinators of the pilot citizen science projects (Sylvain Andresz and Caroline Schieber in France, Yevgeniya Tomkiv in Norway, Alison Dowdall and Leo McKittrick in Ireland and Veronika Oláhné Groma in Hungary) was published in the book "Communicating Public Health Risk. The Case of Radon Gas" edited by José Sixto-García, Sara Pérez-Seijo and Berta García-Orosa. Apart from this chapter, the RadoNorm citizen science incubator has been the subject of several scientific articles:

- Martell, M., Perko, T., Tomkiv, Y., Long, S., Dowdall, A., Kenens, J. (2021) Evaluation of citizen science contributions to radon research. Journal of Environmental Radioactivity 237. https://doi.org/10.1016/j.jenvrad.2021.106685
- Hoedoafia MA, Martell M and Perko T (2024) Evaluating citizen science projects: insights from radon research. Front. Environ. Sci. 12:1436283. doi: 10.3389/fenvs.2024.1436283
- Perko, T. Martell, M., Hoedoafia MA (2025) Beyond Data Collection: Unraveling the Motivations Driving Citizen Scientist Engagement (submitted in Nature - Humanities and Social Sciences Communications).

2 Hungary: RadoNorm Aerosol

In Hungary, the CS pilot project focused on high school students in three institutions that developed a toolkit consisting of various low-cost measurement sensors to measure air quality, including radon, and measured various components of air quality in the school and at home. Therefore, the research objective was level 3 defined as "participatory science" based on the levels of participation (Haklay, 2013). The research question defined in this CS pilot project was: "How can high school students help to raise awareness on radon and promote remediation actions?". The following sections briefly describe the rationale and objectives, partners, recruitment of citizen scientists, results and evaluation for the Hungarian CS pilot project.

The search for citizen scientists was initiated by the RadoNorm partner Centre for Energy Research (EK) in Hungary, mostly in collaboration with the schools. The start of the CS involvement was significantly affected by the COVID-19 pandemic, which coincided with the planned start of community involvement and CS workshops. COVID-19 regulations in all countries severely restricted in-person activities in most locations throughout the first and second year of the RadoNorm project.

The level of public awareness of air pollution and the associated risks to people's health and that of their children has grown significantly over recent years (EEA, 2021). However, the population's knowledge and awareness about radon in Hungary remains low and needs to be increased and deepened as highlighted in the National Radon Action Plan (2018). In particular, the population is too little aware of the correlation between the magnitude of various indoor air pollutants and the multiple beneficial effects of remediation. In addition, there is no available tool for testing indoor air quality that can be easily used and is capable of measuring simultaneously various components (radon, CO_2, particulate matter, NO_X, CO, methane, ozone).

In the first phase of the RadoNorm pilot CS project, the aim was to study the feasibility of developing a toolkit composed of multiple low-cost sensors, capable of measuring various air quality and radiation components. Nearly 30 students from 3 high schools participated in the development, communication, and dissemination of the project. During this period, the toolkit was created in several versions, with which citizen scientists conducted test and calibration measurements.

In the second phase of the project, based on the experiences from the initial measurements, we aimed to carry out further developments and perform measurements at as many public locations as possible. The holiday break between the two phases of the project interrupted the development process, resulting in some students dropping out and new ones joining the research work. Accordingly, introductory lectures and workshops had to be conducted with the new participants. The recruitment of students was carried out by both the previously involved students and the teachers. During this second period, two schools were involved with 2 teachers and 5 students.

The Budapest community focused on the development of the toolkit, while the students of the high school in Székesfehérvár demonstrated measurement campaigns involving numerous students and instructors. In its current form, the toolkit is more user-friendly and more compact than previous versions, but the measurement of all devices is not yet provided in a unified system. The measurement campaigns conducted in and around Székesfehérvár were mostly successful, although incomplete measurements still occurred frequently. The results are shared graphically on the website created by the citizen scientists and presented at forums and conferences for research students. Presentations were held on February 9-10, 2024, at a National Research Conference for High School Students event, and also on April 18-19, 2024, at the József Hlavay National Environmental Science and Engineering Student Conference (Figure 1.).

Figure 1. Hanna Takács presenting at a student conference

Based on the measurement results, we did not find any environment where significant critical radon exposure was detected, so no remediation actions were necessary anywhere. However, the effects of indoor movements and human activities were noticeable, particularly in the temporal variation of PM10 concentration, where we detected very high concentration levels. The evaluation of the measurement results is carried out jointly by the lead researchers and the citizen scientists in the form of personal discussions. However, we also intend to create a data evaluation and interpretation guide for the website, which will help the individuals conducting the measurements to assess the indoor air pollution levels in their properties.

Since the device has shown interest from numerous users, in the next phase, we plan to involve technical experts to carry out further development and create a final, compact device system that is easily usable by anyone. We plan to extend the measurement locations to areas that are considered more critical in terms of radon exposure based on preliminary knowledge, and with the involvement of colleagues from Transylvania, we plan to conduct measurements in Romania with the participation of local citizen scientists. Additionally, the device was presented at the Tech Sharing Corner of the ERPW conference in November 2024, which took place in Rome.

Since the reliability and measurement accuracy of low-cost sensors typically decrease over time, we consider it important to provide users with accurate guidance on this issue as well. Given that we are talking about a project that has been running for over a year, we have the opportunity to study the aging of the sensors, primarily through comparison measurement campaigns, which we also plan to perform.

3 Italy: Citizen Observatory of Radon (Osservatorio Cittadino sul Radon)

The project "Citizen Observatory of Radon" aimed to reduce indoor radon levels through measurement of exposure and increased awareness of radon risks and mitigation measures in houses, school rooms and working places in Abbadia San Salvatore, Siena, one of the most radon-affected municipalities in Italy. The project aimed also to create a radon distribution map to increase radon communication risk. The project started in September 2023 and finished in February 2024.

We created a citizen science initiative to measure exposure to radon in 231 places (147 homes, 37 rooms in 4 schools, and 47 workplaces) with passive radon detectors over a three-months period (mid-September up to mid-December 2023).
We created an interactive map of exposure of the entire municipality and all materials and information about the monitoring have been published on the project website together with the final scientific report, that has been sent to the main local and regional authorities as Municipality of Abbadia SS, Provincial Health Department, Environmental Department of Tuscany, and Regional Agency of Environmental Protection.

Through the direct involvement of 231 citizens and the indirect involvement of 700 students of four schools and the organization of 3 public events we raised awareness about the radon risks sharing mitigation strategies. We provided a supportive environment for building positive relationships between citizens and local authorities and create the prerequisite to expand the radon monitoring to more sites in the area that have never been monitored.

The regional environmental protection authority (ARPAT) took part into the project to deliver 98 radon samplers to citizens to cover the entire annual monitoring period. Based on this collaboration, now the ARPAT is monitoring radon in 98 of 231 dwellings of our investigation.

The project results acquired so far have highlighted the need for intervention measures: 21% of monitored dwellings has radon concentrations higher than the reference limit established by Italian legislation of 300 Becquerels per cubic meter. These dwellings (49 out of 231 in total) fall into the high-risk class, based on the radon risk classification method we applied based on Italian law limits: 31 houses, 9 school rooms and 9 work offices. The radon values measured in one of the four schools, the secondary school, are above the reference level of 300 Becquerels per cubic meter, even reaching double the permitted limit. Due to the high level of radon, we coordinated an online meeting to involve the School Head Master, the Mayor of Abbadia SS, and ARPAT to plan interventions actions. ARPAT started detailed investigations in this school to find radon sources and monitoring in real time the radon exposure to assess the best radon mitigation strategies.

The urgency of informing citizens about radon exposure and mitigation measures came out during public events and conversations with them, and data collected through the questionnaire confirmed that 40% of the citizens interviewed, had never heard about radon gas before.

During the final public meeting we shared the possible prevention and mitigations measures to be implemented and the structural works to be carried out in homes, workplaces and schools to reduce indoor radon concentrations. Some local and regional medias covered the news.

A short documentary on the project has been shared on our media channels, YouTube channel and newsletter and also shared by e-mails to citizens and local strategical stakeholders (ARPAT, Toscana region environment department, local civil society, health regional department, mayors of the Amiata region).

3.1 Rationale and objectives of the CS project

3.1.1 Why the citizen science project?

Involving citizens in such a scientific project helped those who never heard about radon gas before to learn more about the risk and exposure path; instead, to those who already had a little radon background information, the project also helped them to go deeper into some mitigation's aspects. Involving so many citizens in this project helped cover many dwellings in the small city of Abbadia San Salvatore, which has 6000 inhabitants. None of the governmental investigations in that area covered this percentage of monitored sites: 3,2% population covered by our study against the 0,3% by previous governmental investigations.[2]

3.1.2 What were the objectives of the CS project?

The three main objectives were: 1) increased awareness of radon risks and mitigation measures, 2) increased knowledge about radon distribution inside the municipality of Abbadia SS, 3) reduce radon exposure and 4) creation of an interactive map of exposure.

3.1.3 How would you classify your citizen science project based on the table below?

Following **Table 1** the project has been classified as level 3 - "participatory science" because it did not only recruit citizens who contributed to research by conducting radon measurements (according to Level 1), but citizens also contributed to a set of data collection as buildings information and radon perception risks (as reported in Level 3).

Table 1. Levels of participation applied to the RadoNorm citizen science projects

Levels according to Haklay (2013)		**Description**
Level 1.	Crowdsourcing	A centralised organisation recruits citizens who contribute to research by conducting radon measurements and collecting basic data (e.g. house type, year of construction, etc) according to a predefined protocol. The data are sent back to a centralised organisation for interpretation and dissemination.
Level 2.	Distributed intelligence	Projects are designed by scientists, and members of the public contribute with data, but also help with basic interpretation of the radon data.
Level 3.	Participatory science	Citizens refine the research questions, contribute to data collection, adjust protocols, draw conclusions and draft reports.
Level 4.	Extreme citizen science	Citizens are deeply engaged in most parts or the entire development of the scientific process together with researchers: • defining the research question, • collecting and analysing data, • interpreting the data and disseminating the results (e.g. writing papers).

[2] Zero Radon, Quanto radon c'è in Italia negli edifici, https://www.zeroradon.it/toscana.html

3.2 Partners and roles

The core team included two women team members of Source International Onlus. Laura Grassi was the project coordinator and she was responsible for selecting radon samplers, managing communication with stakeholders (civil society, communities, institutions, companies, laboratory, schools, etc.) and organizing each project steps and staff on field. Clara Masetti was in charge to work on the data, digital map, media communication and preparing monitoring materials to be shared with citizens.

The local committee "*Comitato per la Salvaguardia del Monte Amiata*" helped us in the dissemination steps and logistic aspects. Meanwhile, they increased their radon knowledge across the project.

ARPAT joined the project in December 2023, supporting our work and the acquisition of radon data for an additional nine months to obtain annual measurements of radon gas concentration at 98 of the 231 sites monitored by the project, including homes, schools, and workplaces.

The municipality of Abbadia SS supported the project with the patronage.

3.3 Citizen engagement

This section includes main aspects related to citizen scientist's engagement.

3.3.1 Role of citizen scientists

3.3.1.1 Who were the main participants/citizen scientists?

The project participants were inhabitants of the municipality of Abbadia SS Siena, Italy. Unfortunately, we did not analyse the demographic information in details so no statistics about gender or age information have been required by the questionnaires submitted.

3.3.1.2 From which community / region / school, etc?

They included citizens, workers, retired people, families, teachers and students of the municipality of Abbadia SS. Students and teachers have been involved in the project though the project presentation directly in the 4 schools. Students and teachers have been trained on how to collect radon data and how to install radon dosimeters during short briefing both in plenary sessions or directly in each of the 37 school rooms.

3.3.1.3 What was their role? What did they have to do?

They have been involved in the training sessions (monitoring and data interpretation) and the installation and collection of the radon samplers in their home, work offices, dwellings, and school rooms. They also have been part of the dissemination activities sharing project report results though different online and offline communication tools.

3.3.2 In which stages of the scientific process did they participate and how: problem definition, developing research question, designing research method, gathering data, analysing or interpreting data or disseminating results?

Citizens have mainly been involved in data sampling, information collection, and instrument return. They have been also trained to interpret data. Even if no activities have been planned to organize a dissemination strategy led by citizens, they have been invited to support the project results dissemination with the community, supporting the communication step. Days after the final public meeting, the local organization, Salviamo il Monte Amiata, reported us that project results and report have been shared within Abbadia SS.

3.3.3 Recruitment process

3.3.3.1 How were participants / citizen scientists recruited?

Participants have been recruited in September 2023 during four days of project presentation and radon samplers delivering in a public space of the municipality. Citizens were invited to join the project and Source staff members handed them the radon samplers and the questionnaire and collected personal information to maintain communication throughout the project.

The local environmental association, Comitato per la Salvaguardia del Monte Amiata, helped us in the early stage of the recruitment delivering flyers to citizens one week before the first public event of the project presentation and they also put up posters on the main public spaces of the municipality to invite people to join the radon project and the public event. Once on field, the Source's team manage all the following steps of project presentation, citizens engagement and communication.

During the public event, a low number of citizens joined the project, so we rescheduled our activities prolonging our stay in Abbadia SS to reach more citizens. A part of the team was in charge of receiving citizens and delivering samplers to an outdoor space, close to the Municipality, in the city centre, to gather more people. The other part of the staff directly reached citizens by stopping them in the streets and going to shop by shop presenting the project and delivering samplers to those who accepted to join the project.

3.3.3.2 Number of participants / citizen scientists - how many participants were recruited, how many were involved from the beginning to the end of the project; any participants drop out and possible reasons.

216 citizens were initially recruited but 43 people never returned the radon samplers for the analysis, so 43 data (citizens) were lost. Some of them have been reached by phone and e-mail, but many reasons are behind this drop out: impossibility to physically deliver the radon sampler in December, nor by shipping it directly to the laboratory; doubts about the safety of keeping the instrument in their home; and finally, some of them declared to have changed idea about their project involvement. Mostly of them never replied to the call, e-mail and phone messages. The final number of citizens recruited that completely joined the project are 173 including teachers, workers and inhabitants. No students have been directly involved in the radon collection data. Each radon dosimeter was entrusted to control and responsibility of the teacher in a specific room school.

3.3.4 Motivation of participants

3.3.4.1 Motivation of participants/citizen scientists – What motivated citizen scientists to join the project? What motivated scientists to launch this citizen science project?

Awareness of living in a radon-prone area encouraged citizens to be interested about the project and taking part in it. So, the "collective motivation and identification" was very predominant. Additionally, the health risk information shared during the project presentation further motivated them to engage in the project's activities over time.

Arazy & Anderson (2011) describe different types of motivations which must be identified at the beginning of the project based on observations and the questions raised prior and at the kick-off meeting. There could be a mixture of motivations. It might be interesting to identify the commonalities or overlaps in the motivations between the scientists and the citizen scientists (**Table 2**).

Table 2. Types of motivation

Type of motivation	Definition
Collective motivation	The citizen scientist sees the project aims as important.
Norm-related motivation	The participant hopes for positive responses from friends, family or work- mates.
Based on reward (extrinsic) motivation	Participation brings real benefits, such as building a reputation or making new friends.
Collective identification	The participant identifies with the group, its norms and its values.
Hedonistic / intrinsic motivation	Participation gives joy or pleasure.

3.3.5 Communication and engagement activities

3.3.5.1 Engagement: How were citizen scientists engaged throughout the project? Was the engagement maintained? Which activities were organised to involve citizens and/or the public?

Citizens were engaged to participate in the project through personal contact established with them through the public project presentation event and the following 4-days information point stand in the street of the municipality of Abbadia SS. In the weeks before the first public event (project presentation), we also engaged citizens through social media posts on local Facebook groups and published posts and articles to invite people to the public event to receive the radon samplers. Citizens have been maintained and updated throughout the project through e-mails, phone calls, and messages. Furthermore, monthly updates on the project evolvement have been done through social media posts and articles on our blog. Our personal contact information has been shared with them at the beginning, so they could reach us in any moment.

3.3.5.2 Communication: What modes of communication were used in communicating with participants/citizen scientists?

Considering radioactivity is a very sensitive and complex topic, we planned to establish a simple, comprehensive and pragmatic communication with citizens, touching all aspects (sources and origin of radon, diffusion pathways in houses, health impact, solutions to adopt) in a very concrete and simple way in every communication step with citizens.

3.3.5.3 Any communication to non-participants: what modes of communication were utilised in communicating the CS project to non-participants?

The communication strategy has been the same for both categories. A special and more simple language has been used to present the project and the radon sampling steps to primary and secondary school students and elderly people.

3.3.5.4 Activities in which the team has participated to disseminate the results (conferences, webinars, etc)

The team managed and developed three meetings in presence in the Municipality of Abbadia SS in September 2023, December 2023, and February 2024. A wide number of blog articles, social posts, newsletters, and media articles have been published and shared to disseminate the project, including the video project produced (on our YouTube channel).

- 5 posts published on Instagram profile reached 5832 accounts and 68 likes totally.
- 7 posts published on Facebook profile reached 1104 social coverage and 12 reactions totally.


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presso l'Hotel La Bussola, Via Adua, 15
Domenica 17 dicembre dalle 9 alle 11
presso il Teatro Servadio, Via Pinelli, 30


SOURCE International
Mi piace
Commenta
Invia
Condividi


A caccia di radon in case e scuole

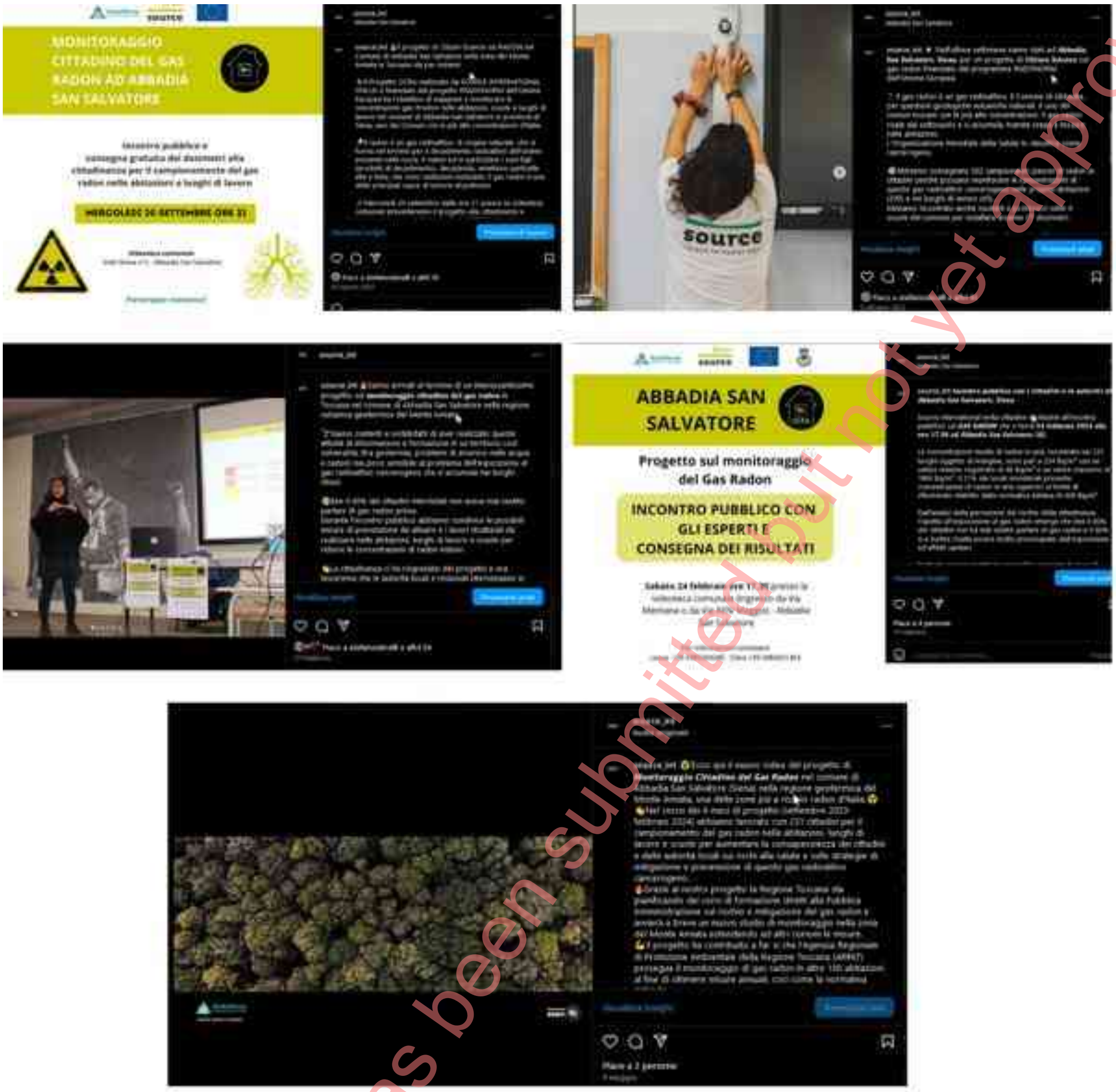


Figure 1. Screenshots of web, Instagram and Facebook

3.3.6 Behavioural and socio-cultural impact

The 40% (n = 62) of the citizens interviewed through the questionnaire at the beginning of the project (in September) declared to have never heard of radon gas before, and this data denotes the urgency to plan and adopt an information and awareness campaign to citizen and authorities who also showed a very low knowledge about the topic. So, citizens have benefited from the project by increasing their awareness of radon risks and mitigation measures and change also their perception about risk and mitigation cost interventions. Furthermore, the project represents a good opportunity for school students and teachers to gain more information on the topic under the environmental and health point of view.

Local authorities have now more updated data across the municipality that help them to push new urgent actions on radon risk management inside Abbadia SS. Environmental regional department gained more data and more citizens contacts to go ahead with their regional annual investigations in the Amiata region.

3.3.7 Outputs

From the analysis of the laboratory results emerges that the average concentrations of radon encountered in the 231 dwellings is 234 Bq/m³ with a minimum recorded value of 48 Bq/m³ and a maximum value of 1965 Bq/ m³. The 21% of the monitored sites have radon concentrations in the air higher than the reference limit established by Italian legislation of 300 Bq/m³.

3.3.7.1 Household

The results show, out of a total of 147 homes monitored, an average value of 248 Bq/m³, with a minimum value of 58 Bq/m³ and a maximum of 1014 Bq/m³. 53% of the homes investigated have a concentration higher than the value of 200 Bq/m³ recommended by the World Health Organization; and concentrations

higher than the European and Italian reference level of 300 Bq/m³ were recorded in 21% of the 147 homes (**Figure 2**).

Figure 2. Map of results of radon monitoring at homes in Abbadia San Salvatore

3.3.7.2 School rooms

Investigations were carried out in schools in the Municipality of Abbadia San Salvatore for a total of 37 rooms measured in 4 school buildings. These investigations concerned nursery schools, elementary schools, middle schools and high schools. The values measured in these investigations range from a minimum of 61 Bq/m³ to a maximum of 629 Bq/m³. The map shows the average value for each one of the four buildings monitored.

3.3.7.3 Workplace

The results show an average value of 239 Bq/m³, with a minimum value of 61 Bq/m³ and a maximum of 1965 Bq/m³. 38% of the monitored sites have a concentration higher than the value of 200 Bq/m³, recommended by the World Health Organisation. While 17% of the rooms have a radon concentration in the air higher than the European and Italian reference level of 300 Bq/m³ (**Figure 3**).

Figure 3. Map of results of radon monitors at workplaces in Abbadia San Salvatore

As a result of the final project results presentation event (February 2024), the headmaster of the school and its collaborators began to adopt different radon mitigation solutions, depending on the radon level found in every school room, as suggested by us and ARPAT. Many dialogue round tables have been opened between the municipality, school, ARPAT and regional health authority (ASL) to start working on the case. The mayor of Abbadia San Salvatore declared to move the secondary school to a new building in the next two years.

In general, thanks to this project we had the opportunity to raise attention to radon in the territory (both by citizens and authorities) and mostly, the final public event, had the power to push local and regional authorities to accelerate some activities concerning radon information and mitigation measures.

From one side, ARPAT started as early as March 2024, right after the public event, under pressure from the school headmaster concerned (at the urging of teachers and students' families), to investigate better the radon concentrations in all the secondary school rooms through some specific sensors to have daily concentration levels and observe possible radon sources.

From the other side, the regional authority (Regione Toscana) planned a meeting with all the mayors of the Amiata region and declared that a new investigation on radon will be developed quite soon in the Amiata area. Finally, ARPAT accelerated the opening of a training course on radon risk to local authorities and institutions.

Data are openly available on Source International website in the digital map and in the scientific report that can be downloaded in the same project webpage. Source International will work to publish the study as scientific article soon. The project was presented at the RICOMET, the 4th RadoNorm annual meeting in Slovenia in June 2024. Project main outputs and data have been constantly shared on Source International's social media channels, webpage and newsletter.

Data have been used to raise awareness about the radon risk and mitigation measures to citizens and authorities in the prone area of Abbadia SS. Furthermore, the final report has been shared with citizens and project participants, school head master, local and regional authorities and local journalists.

3.4 Evaluation of the citizen science project

All the project's main goals (increase citizens awareness and the radon data in houses, school rooms, and workplaces in Abbadia SS) have been successfully achieved. The project represented a powerful opportunity for citizens to protect their health and push the adoption of concrete actions to reduce radon indoor levels. All deadlines were perfectly achieved. More funds than expected have been spent in the project's first stage to reach and engage more citizens to participate. Despite no internal evaluation of satisfaction of the project have been submitted to the citizens involved, most of them, mostly during the final public event, thanked us for the project initiative.

3.5 Main conclusions and final reflections

The social-political impact level of the project has been extremely high since ARPAT, the regional authority, decided to support the project by delivering 98 additional dosimeters to the project citizen group to cover the rest of the nine months to have the annual medium radon indoor concentration as the national law suggests. The strong collaboration born between Source International and ARPAT increased the visibility of the entire project on national and regional scale as well as its sustainability in the next future due to the interest ARPAT showed to follow testing the neighbouring municipalities in the Amiata area.

We observed the following challenges and limitations:

- Low awareness about the radon risk, both in citizens and authorities (Municipality of Abbadia SS), encouraged them to be more curious but at the same time, also, to reject the involvement in the project. Proposed solution: campaign information and training course to representative members of institutions, authorities, workers, citizens.
- The concern to personally finance the radon remediation in work office/schools resulted in citizens/workers to not assess radon in those dwellings. Most of citizens and authorities are no well informed about the real cost of radon mitigation measures and they overestimate the real cost. This negatively influences their decision to adopt structural measures to reduce radon. Proposed solutions: information campaign that also cover economic aspect of radon mitigation measures.
- High percentage of not returned radon dosimeters (17%) – Proposed solutions: 1) offer more time (days) to re-collect instruments instead of two days as we did 2) put some "money deposit" to each dosimeter delivered to give economic value to the instrument free delivered.
- Citizen scientists' age limitations (majority of citizens were elderly people) implies low IT skills. For example, as part of the project activities we designed, the uploading step of the radon data on the digital map would be in charge by each one of the citizen scientists involved. But, since the majority of citizen scientists were elderly people with very low access to IT in general, we opted to upload data by ourselves.
- A good coordination with regional and local authorities helped us to have a proper health risk communication strategy to citizens without any form of alarmism or belittlement of the problem.

3.6 Way forward

We started to design and propose a new CS project on radon in two prone areas in north Italy, but we experienced a rejection from both schools invited. Talking about health and radioactivity in some situations is not so easy and accepted because there is a huge lack of knowledge. We already opened new communication with other environmental regional authorities in two regions, Piedmont and Lombardia, to co-design some future projects of CS on radon.

The radon topic is extremely interesting, and it is so urgent to inform and raise awareness about radon risk and mitigations that we, as Source International, are very excited to design and develop new project on it.

3.7 Resources

The main project costs are linked to "*Staff Salaries*" (12,000.00 euro) and to "*Equipment*" for radon dosimeters (4,500.00 euro). Then, "*Other Goods and Services*", which includes video editing and communication materials amounts to 2,369.10 euro and "*Travel, Accommodation and Subsistence*", for 2 staff for 3 missions on field, amounts to 2,133.30 euro.

The final project costs exceed the budget based mostly on: 1) extending days during the first mission in Abbadia SS to reach more citizens (+ 534 euro) and 2) extra cost due to communications materials and renting rooms for public events that were underestimated in the project design (+ 519 euro).

The project costs are show in the Table below.

Table 3. Breakdown of project costs

Staff salaries	Cost from original budget (w/o overhead)	Actual cost
Laura Grassi - Project coordinato	9.000,00 €	9.000,00 €
Clara Masetti - Trainer	3.000,00 €	3.000,00 €
	0,00 €	0,00 €
Subtotal	**12.000,00 €**	**12.000,00 €**
Travels	**Cost from original budget (w/o overhead)**	**Actual costs**
1° Travel and Subsistency- 2 staff from Garessio/Milan to Abbadia	533,33 €	1.259,32 €
2° Travel and Subsistency-- 2 staff from Massa to Abbadia	533,33 €	327,01 €
3°Travel and Subsistency-- 2 staff from Milan/Garessio to Abbadia	533,33 €	546,97 €
Subtotal	**1.599,99 €**	**2.133,30 €**
Equipment	**Cost from orginal budget (w/o overhead)**	**Actual cost**
Dosimeter including analysis	4.500,00 €	4.448,14 €
Shipment	50,00 €	51,35 €
Subtotal	**4.550,00 €**	**4.499,49 €**
Other goods and services	**Cost from orginal budget (w/o overhead)**	**Actual cost**
Miscellaneus	50,00 €	369,10 €
Video editing	1.800,00 €	2.000,00 €
Subtotal	**1.850,00 €**	**2.369,10 €**
Subcontracting	**Cost from orginal budget (w/o overhead)**	**Actual cost**
Subtotal	**0,00 €**	**0,00 €**
Total direct costs	19.999,99 €	21.001,89 €
Overheads (25%)	5.000,00 €	
Total costs	**24.999,99 €**	

3.8 References

Some links to articles published on our website and by local and regional mass media referring to the project.

Article 1 – La Nazione

https://www.lanazione.it/siena/cronaca/abbadia-indagini-sul-radon-in-alcuni-locali-livelli-elevati-tondi-ma-nessun-allarmismo-485e0323

Article 2 – CentriItalia News

https://www.centritalianews.it/abbadia-san-salvatore-il-24-febbraio-incontro-con-la-comunita-badenga-per-illustrare-i-risultati-del-primo-progetto-di-scienza-cittadina-sul-monitoraggio-del-gas-radon-in-231-locali/

Article 3 – Corriere di Siena “Studio sulla presenza del radon in città” (Newspaper, no online article available)

Abbadia San Salvatore L'indagine effettuata da Source International presentata a una consistente platea. Coinvolti anche 200 cittadini

Studio sulla presenza del radon in città

Article 4 – Source International webpage

https://www.source-international.org/news/gas-radon-ad-abbadia-san-salvatore-quanto-e-importante-linformazione

Article 5 – Source International webpage

https://www.source-international.org/news/evento-pubblico-sul-gas-radon-nellamiata-siena

Article 6 – Source International webpage

https://www.source-international.org/news/incontro-pubblico-sul-monitoraggio-del-radon-ad-abbadia-san-salvatore

Article 7 – Source International webpage https://www.source-international.org/news/incontro-pubblico-sul-monitoraggio-del-radon-ad-abbadia-san-salvatore

Project video

https://youtu.be/N8zZMQ8Jfic?si=xNZB8Kd1KY12UnzF

4 Poland: AHS Radon Hunt

The core idea for the project, described in the proposal was the following: "High school students doing their research devoted to radon in different locations around Poland sharing their findings with peers around the world via social media". For this purpose, we integrated the project with the Personal Development Scheme (PDS), which is our school program that enables students to explore a variety of topics outside the traditional curriculum. Dariusz Aksamit, who issued a grant proposal acted as PDS project coordinator.

Preparations for the project (including the purchase of equipment, preparation of materials, planning of trips etc.) started in August 2023, with the recruitment of students in September 2023, but the official project launch took place at the first student's group meeting at 04.10.2023, with its announcement to the school community during assemblies on International Medical Physics Day (07.11.2023).

We held 16 weekly meetings till 13.03.2024 (excluding exam sessions and holidays) and organized two laboratory/field trips (10.11.2023 and 22-23.02.2024). This was the end of the main phase of project, while we still do follow-up measurements.

4.1 Main objectives

Our main goal was to introduce citizen science as a pedagogical approach that builds students' agency and deepens their understanding of how science is created – the opposite of the traditional, textbook-based lecturing approach of well-established facts. For this reason, we performed a variety of different measurements (indoor air with passive and active measurements, soil air, and water samples) in nearby and remote locations (including underground laboratories and depleted uranium mines).

We also aimed to build a capacity for radon testing in future, including integrating outcomes of this project into Y11 Physics iGCSE lessons, to keep raising awareness about this topic every year. With the equipment bought and connections made we asses we succeeded with this task – since 2024/2025 school year we plan to disseminate active detectors among Y11 students on a weekly basis as a curricular activity which supports the teaching of "Section 7: Radioactivity and particles" and we proposed "Radon Club" as an extracurricular activity, to study etching process of CR39 under the microscope in cooperation with Chemistry Department

4.2 Main results

We performed:

- **50 measurements of indoor air using CR39 detectors**, including other schools

  For context – the average indoor radon concentration is low, around 50 Bq/m^3, while the reference limit for a living house that requires action is set to 300 Bq/m^3, according to the legal act implementing 2013/59/Euratom Directive to the law in Poland (including Atomic Act and Nation Radon Action Plan), apart from districts specified in act by Ministry of Health (27 regions in 6 voivodships), where the concentration might be higher. According to the National Geological Institute, 70% of Poland is located on grounds with low or medium radon potential, but especially in southern-west regions radon potential might be locally high, including the region of Sudety mountains, where we organized a field trip.[3] [4]

  Most of the results were around the average for Poland (50 Bq/m^3), but we identified some locations with elevated levels: 119±20Bq/m^3 in a single-family house in a Lubelskie Voivodeship countryside (Turze Rogi) with a remote underground pantry (348±20Bq/m^3) and 237 ± 40 Bq/m^3 in Żoliborz district in Warsaw. We placed there additional CR39 detectors as long-term (three months) follow-

[3] https://www.gov.pl/web/poznajradon
[4] https://www.gov.pl/web/gis/radon--podstawowe-informacje

up measurements, we expect the readout in mid-July 2024. **Table 4** presents a breakdown of results on indoor air by type of location and **Table 5** presents a breakdown of results by location of the detector.[5]

Table 4. Breakdown of results on indoor air by type of location

Category	Samples	Results above average
Single House	19	237 ± 40 Bq/m³ 119 ± 20 Bq/m³
Apartment building	16	
School	6	
Semi-detached house	1	
Other	5	348 ± 48 Bq/m³
Lost	3	
Total	50	

Table 5. Breakdown of results by location of the detector.

<table>
<tr><th>City/District</th><th>Voivodship</th><th>Samples</th><th>Results above average</th></tr>
<tr><td>Czerwona Niwa</td><td>Mazowieckie</td><td>2</td><td></td></tr>
<tr><td>Gdańsk</td><td>Pomorskie</td><td>1</td><td></td></tr>
<tr><td>Konstancin</td><td>Mazowieckie</td><td>2</td><td></td></tr>
<tr><td>Mazury Wygryny</td><td>Warmińsko-Mazurskie</td><td>2</td><td></td></tr>
<tr><td>Podkowa Leśna</td><td>Mazowieckie</td><td>2</td><td></td></tr>
<tr><td>Turze Rogi</td><td>Lubelskie</td><td>5</td><td>119 ± 20 Bq/m³
348 ± 48 Bq/m³</td></tr>
<tr><td>Wałbrzych</td><td>Dolnośląskie</td><td>2</td><td></td></tr>
<tr><td>Warsaw-Mokotów</td><td rowspan="9">Mazowieckie</td><td>6</td><td></td></tr>
<tr><td>Warsaw-Ochota</td><td>1</td><td></td></tr>
<tr><td>Warsaw-Old Town</td><td>1</td><td></td></tr>
<tr><td>Warsaw-Śródmieście</td><td>2</td><td></td></tr>
<tr><td>Warsaw-Targówek</td><td>1</td><td></td></tr>
<tr><td>Warsaw-Ursynów</td><td>2</td><td></td></tr>
<tr><td>Warsaw-Wawer</td><td>4</td><td></td></tr>
<tr><td>Warsaw-Wilanów</td><td>5</td><td></td></tr>
<tr><td>Warsaw-Żoliborz</td><td>4</td><td>237 ± 40 Bq/m³</td></tr>
<tr><td>Wrocław</td><td>Dolnośląskie</td><td>1</td><td></td></tr>
<tr><td>Zalesie Górne</td><td>Mazowieckie</td><td>1</td><td></td></tr>
</table>

[5] For the results of individual detectors please refer to the Appendix that combines readout reports obtained from the laboratory.

Zamienie	Mazowieckie	2	
Zgorzała	Mazowieckie	1	
Lost	-	3	
Total		50	

- **27 water samples**

According to the abovementioned legal acts, the reference limit for radon activity concentration in drinking water is set to 100 Bq/m^3. Unfortunately, the results of the measurement campaign organized in the past year (after the implementation of the Radon Action Plan) by the Chief Sanitary Inspectorate are not publicly available. From the scarce literature review, we conclude that in general radon activity concentration in tap water is relatively low, only occasionally exhibiting measurable concentration[6,7]. Though radon-rich springs can be found in the Sudety mountains[8].

As expected, the amount of radon in tap water in Warsaw is below the measuring limit of 0.2 Bq/l. This confirms our preconception, as Warsaw municipality is provided with water from the Vistula River.

We identified though two Oligocene wells with elevated levels of radon (35.4±10.7 Bq/l and 13.0±4.0 Bq/l). This confirms earlier measurements run a few years ago as an engineering thesis at Warsaw University of Technology[9], though now we obtained greater values. We want to investigate further if there is a seasonal change in radon concentration or if it was due to different laboratory techniques used.

We identified detectable levels of radon in tap water in Lesznowola district, 3.3±1.1Bq/l. We checked that water in this district is taken from a deep underground source – we tried to contact the supplier to measure water directly from the source, but so far, the company has not replied. We will continue this part as a separate project.

We measured also 472 Bq/m^3 in water from a depleted uranium mine (from a flooded mining shaft where commercial deep diving is organised). This sample was measured by Central Laboratory for Radiological Protection using AlphaGuard, not a liquid scintillation.

Table 6 shows the breakdown of measurements by type of sample (comment – in liquid scintillation method in a single location two samples were taken, this is why 54 samples mean 27 measurements).[10]

Table 6. Breakdown of measurements by type of sample

Type of sample	Samples	Results if > 2 Bq/l
Tap water - Warsaw	20	-
Tap water – outside Warsaw (Konstancin, Zgorzała, Zamienie, Gdańsk, Żyrardów, Valencia)	20	3.1 ± 1.1 (Zgorzała) 3.3 ± 1.1 (Zgorzała) 2.6 ± 0.9 (Gdańsk) 2.9 ± 0.9 (Turze Rogi)

6 https://inis.iaea.org/collection/NCLCollectionStore/_Public/40/096/40096464.pdf

7 https://www.sciencedirect.com/science/article/abs/pii/S0969806X01003693

8 https://www.pgi.gov.pl/dokumenty-pig-pib-all/publikacje-2/przeglad-geologiczny/2023/2-luty-3/9678-potencjalnie-lecznicze-wody-radonowe-wschodniej-czesci-wysokiego-grzbietu-gor-izerskich-sudety-o-najwiekszej-zawartosci-radonu-w-polsce/file.html

9 https://repo.pw.edu.pl/info/bachelor/WUTfea7f71569194b3f8b9a202a14d4c2e7?r=supervisedwork&ps=20&tab=&title=Szczeg%25C3%25B3%25C5%2582y%2Brekordu%2B%25E2%2580%2593%2BPrace%2Bin%25C5%25BCynierskie%2B%2B%2Blicencjackie%2B%25E2%2580%2593%2BPolitechnika%2BWarszawska&lang=pl

10 For the results of individual detectors please refer to the Appendix that combines readout reports obtained from the laboratory.

Type of sample	Samples	Results if > 2 Bq/l
Oligocen well water	8	4.4 ± 1.5 (OW1) 4.2 ± 1.4 (OW1) 13.0 ± 4.0 (OW2) 12.2 ± 3.7 (OW2) 30.0 ± 9.1 (OW3) 35.4 ± 10.7 (OW3)
Underground source	2	-
Depleted uranium mine	1	472 ± 30 (Kowary)
Lost/Stored	4	
Total	55	

- **2 soil air measurements**

Soil measurements using EcoTrack passive detectors done in a schoolyard were confusing – we need to investigate further the geology of the neighbourhood, as we learned that years ago this district was a marshland. This resulted in water being present in our drills, interfering with the radon exhalation from the ground.

As one detector was incorrectly displaced (it drowned in water present in the pipe) we obtained the result only from the second one, which was (according to the laboratory report in Appendix) below 80 Bq/m^3, surprisingly low. As mentioned above, further investigation will be conducted regarding this issue.

- **Active measurements in 10 locations**

We bought seven active monitors, six EcoCubes from Ecosence and one Spirit from Radonova Laboratories. For the initial test, detectors were placed at school and in two physics teachers' houses, what is depicted in the print screen below as AHS (school), Chamber (sealed chamber in the school yard), GP (dr Giovanni Peralta), DA (Dariusz Aksamit). Later on, detectors were circulating among students, changing location every few weeks. One was placed by the teacher (GP) in his son's primary school (BSP), some were taken for private holiday trips or official school trips, to measure various locations for a few days. As most of the results from EcoCube did not show elevated radon levels, the data was archived but not processed further. **Figure 4** shows print screens of mobile applications.

Most of the results were around the average for Poland, only in Old Town in Warsaw we found indoor radon concentrations above 150 Bq/m^3. We also used active detectors to check radon concentration in a sealed chamber with a radium clock (exceeded 4000 Bq/m^3).

Figure 4. Print screens of EcoCube application by Ecosense, showing time-series of different detectors.

The tests revealed that work with Spirit detector is more feasible than with EcoCubes, as the latter one seems to require continuous wi-fi connection, and does not store the data in the memory to transmit it when connection is established – it might be used at home but it's not feasible to be used outdoors. For this reason, in the sealed chamber located on the school premises but outdoors, where school wi-fi is poor or none, we placed Spirit. For this device, it was enough to store and transmit the data or bring it to the physics lab every few weeks to download the series of data.

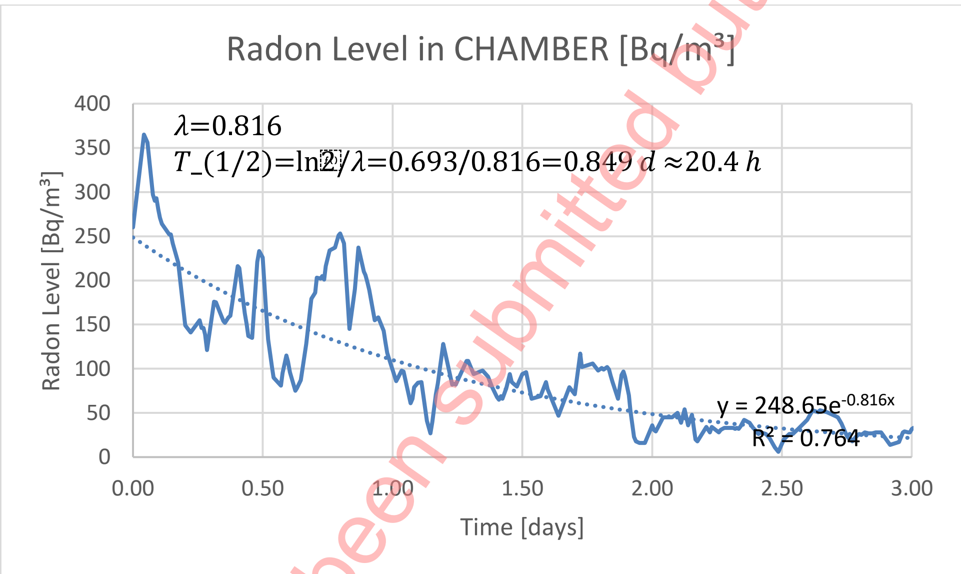
Figure 5 shows a print screen from Radonova online service, with results obtained by Spirit, including radon activity concentration, temperature, humidity and pressure. It's easy to observe daily patterns of temperature change (greenhouse effect, as the chamber was exposed to daily light) and change in concentration while we were placing a clock with radium paint inside (rising concentration) or removing it from the chamber.

Figure 5. Data obtained from Spirit logger placed inside radon chamber.

After downloading the data, basic analysis showed that the chamber is not sealed, as radon concentration is getting lower than expected, with a half-life of 20.4 h instead of 3.8 days (

Figure 6). From this, we concluded that after winter probably the rubber gloves need replacement.

Figure 6. Change in radon activity concentration inside radon chamber after removal of radon source.



As the radon chamber was not a part of an initial grant proposal, the abovementioned part is extracurricular. We were excited that thanks to the obtained equipment we could extend initial plan and obtain interesting materials for further studies with students.

To summarize measurements described in this section, including air and water samples, we inform that in none of the places, the reference levels were exceeded, therefore no action was required apart from follow-up measurement to double-check the results.

- **Social media activity**
  We set up TikTok account for this project (https://www.tiktok.com/@ahs_radon_hunt) which so far has 12 videos published with 14 360 total views, aside from using school social media channels to promote the project.

Novel or innovative approaches used

- The idea that we tested was to use a sealed chamber and radium clock as a source radon as a radon chamber – we proved with active detectors that there is a rise of radon inside a chamber. This could be the basis for other student projects, including making DIY calibration curve for CR39 detectors – if a chamber with active detectors serves as a reference radon activity concentration. We have a basis for further investigation to use radon exhaled from the soil as a source of radon in the chamber (for schools without radium source).

- The idea of using social media to bring attention to the project was also successful, as working with only ten students we were able to reach almost 2,5 thousand views of a single video about the project.

Other information which is relevant in project

- We cooperated with Atomic Forum Foundation (PL: Fundacja Forum Atomowe) for adding our results from schools to School Radon Map of Poland (Szkolna Radonowa Mapa Polski). Please note that this website is undergoing reconstruction before the next radon map campaign, which is scheduled to the second half of 2024.

  https://forumatomowe.org/szkolna-radonowa-mapa-polski/

- We collaborated for the first time with external laboratories as a school on radon-related project. Now we're working on including trips and measurements to our physics curriculum in the future.

4.3 Rationale and objectives of the CS project

Why the citizen science project?

Our main goal was to introduce citizen science as a pedagogical approach that builds students' agency and deepens their understanding of how science is created – the opposite of the traditional, textbook-based lecturing approach of well-established facts.

In regular teaching, focused on external exams, there is no more time for extracurricular activities than what is determined by subject specification. In the iGCSE physics textbook, radon is a very short topic, not even a separate lesson is dedicated to discussing health-related issues, nor the dosimetry techniques (for exams, students are expected to know only GM-counter) or differences in its activity concentration in various locations. Also, the local context is missing.

By running our own measurements, we were able not only to extend the knowledge and awareness but also to build the local context about this topic and a kind of emotional relation to the research (especially after field trips).

What were the objectives of the CS project?

Pedagogical objectives:

- To do research: plan measurements, place and collect detectors, collect samples, organize logistics of sample shipment, process the results, present the data
- To meet scientists and visit research laboratories
- To share gathered knowledge (build an active attitude)
- To build a deeper understanding of how science works

Dosimetric objectives:

- where we can find elevated levels of radon - what was reflected in the research question **"Where and to what extent is radon present in mining, drinking water, and indoor air in Poland?"**
- get acquainted with different measuring techniques: CR39, liquid scintillations, ionising chambers
- understand the difference between active and passive measurements

As described later, especially in section 5.1, all pedagogical objectives were achieved. As described earlier, in section 1 in "main results" subsection, where dosimetric results were presented, those objectives were achieved as well. Through use of variety of dosimetric techniques, both active and passive, and studying various aspects of radon presence (indoor air, soil air, tap water, underground locations) students gained a comprehensive overview of this topic.

We would like to stress, that in the school environment, with teenagers involved in the project, we found following approach the most feasible for maintaining students' interest and motivation: instead of focusing too much on one technique to maximize the number of obtained samples (therefore maximizing scientific value of output results), we decided purposefully to put diversity of techniques in the first place.

How would you classify your citizen science project?

Following **Table 1**, the level 3 "Participatory Science" and a bit of "Level 4. Extreme Citizen Science" applied to this project. The project was run by students, although it was initially framed by Dariusz Aksamit in a grant proposal before recruitment of those students. For legal reasons of working with minors, the teacher needed to take main initiative in logistics of trips or other formal arrangements.

4.4 Partners and roles

Core Team consisted of:

- **Dariusz Aksamit** – project initiation and coordination, leader
- **Dr Giovanni Peralta, Adam Markiewicz** – physics teachers, involved in framing the project, organizing the trips, discussing the results
- **Jakub Kałęcki, Sviatlana Volchak** – Lab Manager and Lab Technician, responsible for equipment purchase, maintenance, shipments and supported trips
- **Teams of ten Y10 students** (not listed by names here due to data protection) – core team running the measurements and attending field trips
- **Zuzanna Podgórska**, RadoNova Laboratories – external consultant as radiation protection officer, radon expert and main supplier of laboratory equipment

Additionally, we cooperated with:

- **Dr Michał Bończyk**, Śląskie Centrum Radiometrii Środowiskowej, GIG Katowice (member of RadoNorm consortium)
- **Leopold Stempowski**, Geodynamic Observatory of Polish Academy of Science (Książ Castle)
- **Łukasz Koszuk**, Faculty of Physics, Warsaw University of Technology and Atomic Forum Foundation

4.5 Citizen engagement

This section includes the main aspects related to citizen scientist's engagement.

4.5.1 Role of citizen scientists

Who were the main participants/citizen scientists?

As the project was incubated in a high school environment, the main participants were teachers and students. Ten Y10 students (ages 14-15) were running the project with the direct supervision of the project leader (physics teacher). The school community witnessed their work on various occasions (via social media, during assembly presentations and during the PDS fair, where the final video was displayed)

From which community / region / school, etc?

The school is located in Warsaw, Poland, Mazovia District, but some students placed detectors in their family houses outside the capitol (Turze Rogi), gave them to friends (Gdańsk and Mazury) or took them for a trip (Valencia).

What was their role? What did they have to do?

Their main role was to decide where to place detectors and from where to collect the samples. Prior to that, they needed to gain the knowledge needed to reach that goal – they took part in introductory sessions with the project leader and analysed selected materials disseminated by IAEA and WHO. Afterwards, we analysed the results together and decided on the next steps (where to redo measurements).

One of the core concepts was also to give them agency over the dissemination of projects in social media, namely to record and publish the videos about their work on TikTok (the platform of their choice). Due to initially unforeseen legal issues (no option for sharing access between different accounts). finally, the project leader was handling the account formally, publishing their content.

In which stages of the scientific process did they participate and how:

- **problem definition**

  This part was initially framed by the project leader prior to the start of the project

- **developing a research question**

  The idea of the "radon hunt" was to answer the question "where to find radon" – after initial theoretical introduction, they were given detectors and decided where to place them.

- **designing a research method**

  The dosimetric techniques were chosen by the project leader but applied by the students themselves

- **gathering data**

  Students were the main workforce for gathering data, collecting samples and organising results

- **analysing or interpreting data**

  We analysed obtained data together during weekly meetings

- **disseminating results**

  Students decided to run a TikTok account and they were solely responsible for delivering the content – recording and editing videos. 12 videos reached more than 14k views in total, with almost 2,5 thousand with the most popular video, https://www.tiktok.com/@ahs_radon_hunt

  The project leader presented the project to the school community (around 300 students) during the assembly together with the invitation to International Medical Physics Day and European Radon Day on 07.11.2023.

  Students were responsible for creating a stand, press release and presentation for the school's PDS Fair on 06.03.2024. The presentation was delivered to the school community, including students and teachers, with the following discussion facilitated by the group of teachers, including the school Headmaster. The final video was displayed, the same as the one posted on TikTok. The disseminated press releases can be found in Annexes.

  The project leader had the opportunity to:

  - Give an interview for the biggest news portal in Poland, regarding natural radiation (19.04.2024)

    https://zielony.onet.pl/przyroda/sprawdzilem-poziom-promieniowania-w-otoczeniu-pochodzi-ono-z-trzech-zrodel/4wnp6nm

  - Present the project at the annual conference of the Polish Medical Physics Society (Warsaw Chapter) (12.04.2024), scientists around Warsaw

- Relate to the project during a presentation in Copernicus Science Center (25.04.2024), around 250 adults across Poland
- Write an article with Sviatlana Volchak (lab technician who took part in the trip) article in the Belarusian language for the online magazine “Pamylka”, to be released in July.

4.6 Recruitment process

How were participants / citizen scientists recruited?

Participants were recruited from the school community – they were filling out the forms for various PDS projects and ten of them were assigned to this project based on their answers in the questionnaire.

Communication tools used for the recruitment process.

Direct meetings during the initial presentation of the project.

Number of participants / citizen scientists - how many participants were recruited, how many were involved from the beginning to the end of the project; any participants drop out and possible reasons.

Ten students, one teacher, and one external expert – this was the core team, plus the abovementioned four other faculty members supporting the project on a regular basis and an additional five teachers or external experts supporting the project occasionally.

Students involved also their families, former teachers, and colleagues – I would approximate that this was around an additional 20-30 people (with passive participation in the project, like placing detector).

4.7 Motivation of participants

Motivation of participants/citizen scientists – What motivated citizen scientists to join the project? What motivated scientists to launch this citizen science project?

In this setup, students needed to join one of the projects proposed by the school, so there is additional external motivation, but referring to Arazy & Anderson (2011) they focused on:

- Hedonistic/intrinsic motivation – as this project offered work with real equipment and participation in exciting trips it was perceived as a great adventure(!)
- Norm-related motivation – as high school students are aware of the highly competitive process of university applications some perceive projects as a way to strengthen their academic portfolio

The perspectives of scientists were partially overlapping:

- Hedonistic/intrinsic motivation – as this project offered a break in a routine, visiting interesting places, the ability to test ideas and hypotheses, joy of doing something new
- Based on reward (extrinsic) motivation – the perspective of writing journal articles, networking with scientists, building a professional portfolio that may help obtain other funding in future

4.8 Communication and engagement activities

With the core team, we held weekly meetings in person to discuss the progress and plan the next steps.

We set up also a separate group on MS Teams, where we shared materials and information and stayed in touch throughout the project. The channel “Introduction to Radon” was dedicated to presentations, journal articles and other materials to gain knowledge,

As stated above – we held weekly meetings in person and continuous communication via MS Team.

The main mode of communication to non-participants was via social media, with our new TikTok account in the first place.

School's social media were occasionally used to share our materials. Information about the project was also disseminated via school newsletters (with around 300 students this means around 1000 people (students, teachers, and parents). The Newsletter sent on 01.12.2023 summarized a trip to Katowice (see Appendix), the one sent on 01.02.2024 mentioned upcoming trip to Wałbrzych.

Aside of the abovementioned TikTok, the team took part in the PDS Fair, a full-day school festival where our group prepared a stand with press releases, the exhibition of equipment used, scientific papers related to the topic, and artefacts like uranium glass. Students also delivered a presentation in front of the whole 5th-form school community.

The project leader attended the Warsaw Chapter of the Polish Medical Physics Association local scientific conference on the 12th of April 2024 to describe the project and its findings.

The project leader presented the project on the RadoNorm webinar celebrating International Day of Medical Physics and European Radon Day on 7th November 2023.

The project leader gave an interview for the biggest news portal in Poland, regarding natural radiation (19.04.2024), related to the project during a presentation in Copernicus Science Center (25.04.2024) to around 250 adults across Poland. Additionally, the project leader wrote an article with Sviatlana Volchak (lab technician who took part in the trip) in Belarusian for the online magazine "Pamylka", to be released in July.

The project leader received an acceptance letter from the IRPA16 Congress in Orlando, in July 2024, for a poster about the project (though can't attend), an invitation to the RICOMET conference in June 2024 and acceptance from the 6th International Conference on Radioecology & Environmental Radioactivity (November 2024).

4.9 Results

4.9.1 Behavioural and socio-cultural impact

In the first place, for high school students, the hands-on exercises and showing science as a process was an eye-opening experience. A lot of things happened that were completely not expected by them (as textbooks presents rather outcome of scientific progress, not the struggle itself):

- One detector was stolen from public space (Oligocene well)
- One detector was confiscated at the airport (liquid scintillation vial)
- A few detectors were not sent back on time (some people forgot about them)
- Logistics of placing and collecting time-sensitive samples
- Because of misreading of the instructions, one detector was not operating
- Someone did not cut the plastic foil covering the passive detector
- Some data from active detectors were deleted (in Spirit – overwritten by new data, EcoQube – lost while reconnecting to different wi-fi)
- The number of a detector was incorrectly entered in the spreadsheet (…442… instead of …422…)

All of this triggered some frustration, but it was a valuable learning experience (especially when students got frustrated by their own previous mess in spreadsheets).

Additionally, in self-reflection questionnaire filled out in the end they stressed how important was teamwork and that they learned a lot about science, critical thinking and doing research.

4.9.2 Outputs

Results in terms of measurements / mitigation

The project revealed to participants that levels of radon in drinking water are below the measuring threshold for tap water in Warsaw but reached up to around 35 Bq/l in water from Oligocene wells in the city and around 3-4 Bq/l outside Warsaw where water comes from underground source. Regarding mines, we already have the results of radon in the water sample that we collected in Kowary-Podgórze, 472 Bq/l, from a flooded mining shaft where commercial deep diving is organized.

We also confirmed an assumption that in general, the concentration of radon indoors is low in modern buildings in the Mazovia district. However, we identified two elevated levels - one in the basement in the Old Town (around 150 Bq/m^3), where people gather for meetings and one in an underground pantry (350 Bq/m^3) close to a family house in a remote location (119 Bq/m^3). In places with elevated levels, we are continuing follow-up measurements.

The results from Książ Castel underground laboratory were a complete surprise for us, as from the literature we expected a level of a few hundred Bq/m^3, up to a thousand, while we obtained around 50 Bq/m^3. We need to repeat this measurement, but because of logistic (Wałbrzych is very remote from Warsaw), we plan to do this as a separate project.

Outputs from the project

The project leader prepared presentations described in the section referring to dissemination (Copernicus Science Center, Polish Medical Physics Society), apart from three presentations for online consortium meetings and one for European Radon Day.

For the project introduction, the project leader prepared this online presentation using Genially software:

https://view.genial.ly/651fcec125f5b700110ec476/dossier-radonhu

Raw data are used only internally, though outcomes were discussed publicly, including social media accounts.

As specified above – apart from RadoNorm/RICOMET meetings we issued abstracts for IRPA16 and ICRER2024.

We aim to publish the results, though the decision on which journal to submit to has not yet been made.

4.10 Evaluation of the citizen science project

All participants filled in an initial questionnaire (on paper) at the beginning of the project and the online survey at the end. In the middle of the project, they completed a self-assessment questionnaire (on paper) prepared by the project leader. At the end of the PDS, all students wrote self-reflection essays summarizing their perspectives.

4.11 Main conclusions and final reflections

The main conclusion is that “doing” science is way more interesting than listening about it – though it requires a lot of time and resources. External funding allowed us to set up a new path in our curriculum with regard to ionising radiation.

The main challenge in the beginning was to issue the formal agreement, as the law in Poland did not allow us to simply “take” the money without specifying all the details. Secondly, we initially overlooked that VAT needed to be paid and therefore our budget was overoptimistic (we thought it would be treated as a scientific grant, but as we were treated as a subcontractor and issued an invoice it looked like a service from the perspective of Polish law).

The internal challenge was to prepare a separate set of documents for students, carefully managing data protection issues with the use of social media accounts (with student's presence and ownership). Thanks to cooperation with the development and marketing department, we obtained a set of consents to be signed by parents.

The better the initial research, the more informed and interesting the actual research is – identifying crucial scientific publications and discussing original ideas with experts revealed a new possibility (don't waste too many detectors for samples that will be almost certainly "boring", while exploring the places that will probably be "interesting").

4.12 Way forward

The ideas that we need to follow up on, regardless of the ending of this project:

- Conduct follow-up measurements in places with elevated radon concentration
- Repeat measurements in Książ Castel
- Figure out what's the problem with soil measurements in our schoolyard
- Finish the measurements with a radon chamber and with soil exhalation (as a school DIY radon source)
- Use school microscopes and chemistry lab facility to etch passive detectors with students
- Maintain TikTok account for future activities referring to radioactivity (regardless if curricular or extracurricular)

The ideas that emerged because of the project:

- Idea to organize other field trips, like to a school in Lubelskie voivodship which was closed because of elevated radon levels (January 2024)
- Measurements of radon in underground facilities for sewage treatment, in underground tunnels, in caves with speleologists (results with discussions with different scientists)
- Side-idea to measure if the radon concentration in the watered mine shaft in Kowary mine is changing with depth (diving possibly with vials opened at different depths)
- Trip to Sudety mountains, as lately prof. Przylibski from Wroclaw University of Technology identified the most radioactive water stream in Poland there – hiking trips plus sample collections
- Plan to issue an Erasmus+ grant to continue radon testing and field measurements with more students and possibly other citizens

4.13 Resources

Table 7 shows the breakdown of the costs. As planned, the biggest part of the budget was spent on the Equipment category – six EcoCube active monitors, one Spirit active monitor (those two were covered 15% by grant and the rest from the school budget), 50 RadTracks passive indoor air detectors, 10 EcoTrack passive soil air detectors, 54 liquid scintillation vials for radon in water testing, sealed chamber. Additionally, the other category proved to be very important, as we could flexibly buy accessories like power banks for active devices, drills and pipes for soil measurements and cover shipping (which we overlooked in the initial plan) and also invested in some books about radon ("Radon: A Tracer for Geological, Geophysical and Geochemical Studies" by Mark Baskaran from Wayne State

University, Detroit, USA[11], "Podziemne trasy turystyczne Polski – kopalnie" (Underground tourist routs of Poland – mines) by Tomasz Rzeczycki[12], books about history of Książ Castel and Riese facility and history of mining in the region). From the Travel category, we were able to cover all costs for both trips (to Katowice and to Książ/Kowary), including lunches and overnight in the hotel.

The main deviation which was made in the budget – after obtaining confirmation via e-mail from the consortium – was to shift money from Travels and Staff to Other. The reason was that we initially planned to have a bit more students in the project and secondly, that one logistics of the first trip allowed us to skip staying overnight. Therefore, 1,900 EUR was shifted as stated above. Additionally, again after obtaining permission via e-mail from the consortium, the conference fee for ICRER is going to be covered by the grant, which we initially did not expect.

Disclaimer: most of the expenses were covered in PLN (staff, travel), and some were covered in EUR (part of the equipment ordered from international companies). In the period between issuing the proposal to issuing the final report exchange rates from EUR to PLN were varying from 4.66 to 4.25. For this reason, an additional few per cent discrepancies might occur between the planned and final budget.

Table 7. Breakdown of cost per budget category

Category	Planned	Final
staff	28.6%	20.6%
travel	30.6%	24.1%
equipment	36.7%	39.6%
other	4.1%	15.7%
subcontr.	0.0%	0.0%

4.14 Annexes

In this document, on following pages there are following annexes:

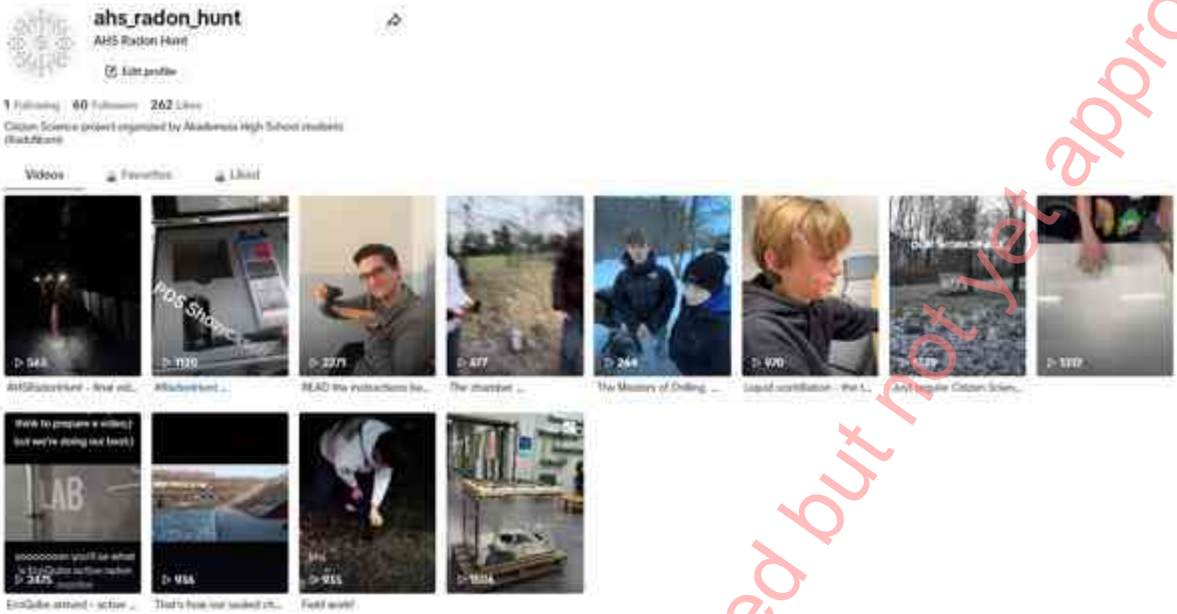
- Print screen from TikTok account
- Print screen from presentation for Polish Medical Physics Society, Warsaw Chapter:
- School Newsletter (December)

Attached to PDF version of this document there are additional annexes:

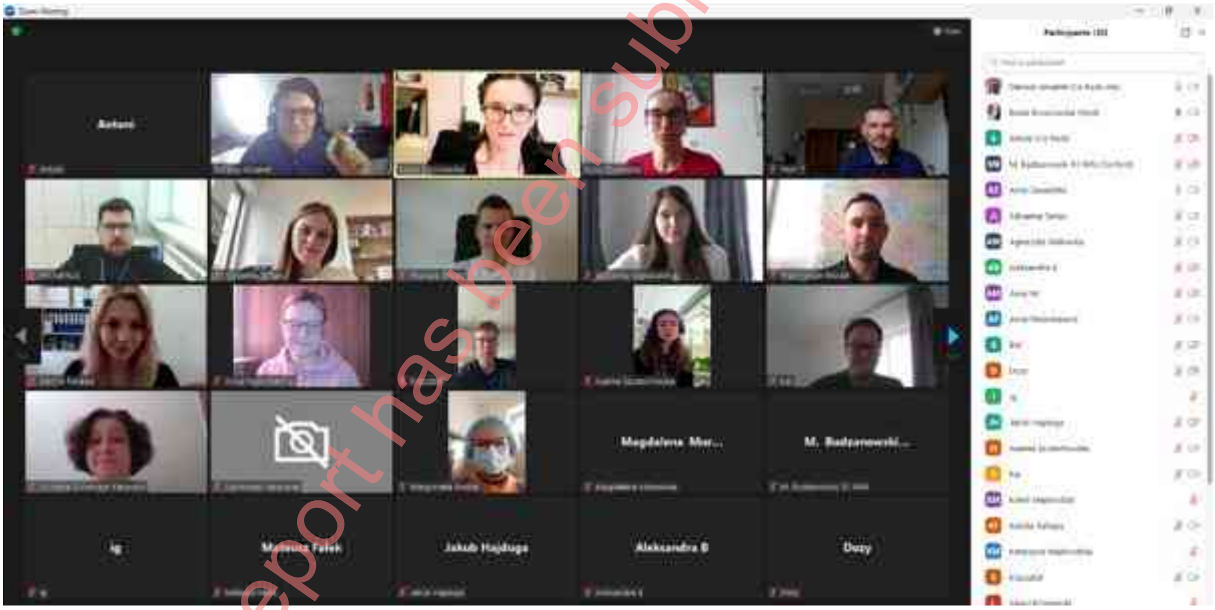
- Laboratory reports for passive measurements
- Initial PDS AHS Radon Hunt brief for students
- Radon Hunt Consent Forms
- RadonHunt-sefl-assesment-2024.01.21

[11] https://link.springer.com/book/10.1007/978-3-319-21329-3
[12] https://lubimyczytac.pl/ksiazka/248086/podziemne-trasy-turystyczne-polski-kopalnie

- Print screen from project TikTok account:



- Screenshot from presentation for Polish Medical Physics Society, Warsaw Chapter:



Appendix – school Newsletter

December at Akademeia High School | Newsletter

Akademeia High School <office@akademeia.edu.pl>
[illegible]
To: Dariusz Aksamit <dariusz.aksamit@akademeia.edu.pl>

December 2023
AKADEMEIA HIGH SCHOOL
Newsletter

Radon Hunt PDS Club
15.11.2023

Introducing the AHS Radon Hunt, our students' latest venture guided by Mr Aksamit from the Natural Sciences Department and funded by the RadoNorm consortium - a dynamic addition to our Personal Development Scheme in the 5th Form!

Our students are representing Poland in this programme alongside countries such as Italy, Hungary, Portugal, Slovakia, Slovenia, and Spain.

The primary goal of the AHS Radon Hunt is to evaluate the necessity of reducing radon concentrations in Warsaw and the Silesia region. Our students are conducting indoor radon assessments in school buildings, houses, underground mines, and tourist routes. Additionally, they're comparing radon levels in tap water across different regions with those in radon water sold for drinking in spa resorts. The project aims to revolutionise science curriculum in high schools by incorporating much-needed radon education.

Recently, our students explored Poland's largest radiometric laboratory, delving into gamma spectrometry, radiochemical preparations, and more. Their mission? To comprehend radon levels in Warsaw and Silesia.

Join us in following these PDS-powered scientists as they will be sharing their experiences in this remarkable journey! They will start their own social media channels very soon, stay tuned!

Learn more about this project

5 Portugal: RadAR students as key players on radon management

RadAR was a citizen science project that aimed to engage high school students in inland areas of Portugal, integrated in school science projects. This empowered students to create and implement a local communication strategy that conducted their community to measure their dwellings and to provide information about existing solutions, to help citizens to reduce indoor radon exposures in the cases where high concentrations levels were found.

The project was initiated in September 2023 and had its final event on May 21st, 2024. The timeframe was as followed:

- Onsite presentation by RadAR team about radon and project goals (**SEP 2023**)
- Definition of local survey (**OCT-NOV 2023**)
- Creation of dissemination materials (**OCT-NOV 2023**)
- Local events for community (**OCT-NOV 2023**)
- Distribution of detectors to community (**OCT-NOV 2023**)
- Retrieval of detectors and analysis (**FEB-MAR 2024**)
- Delivery of radon results (**APR 2024**)
- Data treatment (**APR 2024**)
- Presentation of results (**MAY 2024**)
- Final event at Lisbon (**MAY 2024**)
- Local events for community (**June 2024** – Only 2 schools due to school exams, etc.)
- Follow-up meeting (**SEP 2024**)

As main objectives, the project aimed:

- To increase the awareness about radon (students as the central tool to promote increased knowledge on radon);
- To foster radon measurements in a poorly characterized region in the country;
- And to promote a behavior change.

The key results were:

- A Radon survey in 300 dwellings at the district of Portalegre (Portugal);
- The creation of communication/dissemination materials about radon management;
- The increase of radon knowledge of high schools' students;
- The creation of guidelines about strategies for local awareness campaigns to maximize community engagement.
- Finally, presentation of mitigation methods for the severe cases found.

The RadAR team used an innovative approach to motivate the students:

- Gamification - Creation of a competition between schools for awards:
  - **100% RadAR -** For the school that achieves the higher rate of detectors recovery;
  - **Best communication material -** For the school that has created the best communication material based on originality and effectiveness to reach the citizens;
  - **Best presentation of RadAR results -** For the best presentation of RadAR results on the final event and/or to the local communities.

5.1 Rationale and objectives of the CS project

RadAR's research question was: Can a local awareness campaign designed and implemented by students promote action to reduce indoor radon exposure?

The idea of RadAR was innovative since it placed the students as the main driving force and central pillar of the strategy to create awareness in the population and to promote the behavioural change necessary to conduct citizens to take action to reduce radon levels in their dwellings (remediation).

With support and recommendations of the RadAR's team members, the students had the freedom to define strategies to communicate to both scholar and local communities, in order to maximise their participation in a radon survey. Within a school-project, they evaluated the results from the survey and communicated their assessment to the communities. The natural proximity between students and their communities was the key and differentiate factor for an effective communication with the populations, which enhanced their engagement within the different phases of the radon management process.

It must be noted that this particular region of the county was poorly characterised in terms of indoor radon measurements.

The objectives of our CS project were:

- Increase the characterization of radon levels in a region poorly characterized (this information will allow authorities and public bodies to act accordingly);
- Provide the assessment of radon levels of dwellings to citizens, along with additional information about remediation, which will allow them to act accordingly;
- Allow students to understand the importance of different disciplines to implement such a project, along with the role that a citizen can play in solving a scientific question;
- Create a set of materials, good practices and guidelines to maximize the success of future actions;
- Improve the understanding of radon management to the public, throughout the scholar community, and including all local community in the process.

The classification of our CS project based on the **Table 1** is of Level 1 for the volunteers and Level 4 for the students. We undoubtedly had a distribution of items – scientists designed the project, school students acted as scientists and even helped with basic interpretation of the radon data and members of the public contributed with data.

5.2 Partners and roles

Members of IST and APA composed RadAR team. IST members have a long experience on air quality and on design of awareness campaigns with students and citizens regarding air quality in different municipalities, including with the creation of school projects to involve the students as scientist citizens. APA members have expertise on radon, on conducting national surveys and is the institution in charge of implementing the National Radon Action Plan (NRAP), whose actions were closely related with the activities of RadAR. A third-party "Ciência Viva" also got involved towards the end of the project and promoted the final event in Lisbon. Ciência Viva is the National Agency for Scientific and Technological Culture, which seeks to bring the Portuguese society closer to science and scientists. (Radão: sim ou não? (pavconhecimento.pt))

Miguel Felizardo (coordinator) – Auxiliary researcher at IST, PhD in Astrophysics with experience on radiation topics and on implementation of scientific projects, even related with air quality and engagement of citizens. (Directly involved in the implementation; leader; dissemination of the project results and analysis);

Joana Lage (coordinator) – Junior Researcher at IST with PhD in Environmental Sciences and a strong experience on schools and student engagement toward different activities in European projects ClimACT and ECF4CLIM – H2020. (Directly involved in the implementation; leader; expert on citizen science; dissemination of the project, results and analysis);

Nuno Canha (ex-coordinator, (former IST)) – Auxiliary Researcher at IST with PhD in Environmental Sciences and expertise in indoor air quality (IAQ) and human exposure to air pollutants. N. Canha has extensive experience in awareness campaigns related to air quality and citizens engagement on science related projects. (Directly involved in the implementation; leader; expert on citizen science; dissemination of the project, results and analysis);

Sara Gonçalves - MSc student (IST) currently working in indoor air quality. Internship experience in air quality and microbiology areas. (Directly involved in the implementation and dissemination of the project);

Marta Almeida - Coordinator Researcher at IST with PhD in Environmental Sciences and vast expertise in indoor air quality (IAQ) and human exposure to air pollutants. She is also a Vice-President of IST (Involved in the implementation of the project);

Catarina Antunes – Senior Technical Officer at APA, working on environmental radioactivity, radon and its health effects. Strong experience in science communication and responsible for the NRAP's communication activities. (Directly involved in the implementation; expert on citizen science; dissemination of the project and results, analysis);

Inês Simão – Senior Technical Officer at APA, working on environmental radioactivity, radon and its health effects. (Directly involved in the implementation; dissemination of the project and results);

Heloisa Fonseca – Senior Technical Officer at APA, with experience in radon mitigation and prevention, radon science and construction technology, training development and guidance for radon service providers, radon communication to a range of stakeholders, from householders through to remediation contractors and building control professionals. (Involved in the implementation; analysis of results and comparison with Portuguese Radon Map);

Margarida Malta – Head of Division at APA, with experience on environmental radioactivity and radiation protection. (Involved in the implementation; dissemination of the project and results).

5.3 Citizen engagement

RadAR covered part of the Portalegre district (region of Alto Alentejo, interior of Portugal), by targeting two municipalities: Portalegre (22368 inhabitants) and Ponte de Sor (15249 inhabitants). These municipalities were chosen because they had a scarce characterization in terms of the number of indoor radon measurements and also represent different levels of radon susceptibility: low (Ponte de Sor) and high (Portalegre). Choosing areas with low and high risk of radon was beneficial to show differences in terms of measurements results and also how lifestyle and dwelling's characteristics may have influenced those levels.

5.3.1 *Role of citizen scientists*

The main participants/citizen scientists were the 60 students from the three schools selected from the municipalities of Ponte de Sor and Portalegre. The schools were: Escola Secundária de Ponte de Sor, Escola Secundária Mouzinho da Silveira and Escola Secundária São Lourenço.

They had the role as citizen scientists to plan and implement communication strategies, divided in 2 phases:

1st phase – to disseminate information about radon and engage the population to participate in the radon survey;

2nd phase – to provide an overall evaluation of indoor radon concentration results of their area and to create communication tools about radon remediation strategies.

The citizens (300 volunteers) of the municipalities were also active participants by:

1. Measuring radon levels in their dwellings (radon survey);

2. Participating in the events organized by RadAR where they were asked to participate in a questionnaire to assess their knowledge about radon and to take actions to reduce radon exposures in a most suitable way. They also participated in other questionnaires, for instance, the one from RadoNorm.

These CS students, besides the enormous effort of dissemination, participated in developing the research question via meetings and class sections, and in analyzing/interpreting the data from the results.

5.3.2 *Recruitment process*

The schools were selected as follows: to cover part of the Portalegre district (region of Alto Alentejo, interior of Portugal), by targeting two municipalities. Portalegre (22368 inhabitants) and Ponte de Sor (15249 inhabitants). These municipalities were chosen because they had a scarce characterization in terms of the number of indoor radon measurements and also represent different levels of radon risk: low (Ponte de Sor) and high (Portalegre). Choosing areas with low and high risk of radon is beneficial to show differences in terms of measurements results and how lifestyle and dwelling's characteristics may influence those levels. The RadAR team asked each school to implement a science project of each of the selected high schools (2 in Portalegre and 1 in Ponte de Sor) during a 9-month period.

The students created in their classrooms working groups and defined their own timeline and strategies.

They prepared presentations, instructions of the radon survey, flyers and posters, used social networks and local news in the school's webpage, news bulletins in local or regional Newspapers, had information at the municipalities webpages[13] and finally prepared public sessions.

Sixty students had the opportunity to participate. All of them maintained interest and stayed involved until the end. They managed to recruit volunteers through public assemblies and even via the creation of online forms (Microsoft Forms (office.com)) for volunteers to register and participate. In the survey, the passive detectors were distributed to 100 volunteers in Ponte de Sor (low susceptibility area) and 200 in Portalegre (high susceptibility area).

5.3.3 *Motivation of participants*

As the team members have a long experience on air quality and on design of awareness campaigns with students and citizens regarding air quality in different municipalities, the creation of school projects to involve the students as scientist citizens was the intrinsic driving force.

[13] Projetos Escolares Distinguidos Representam Ponte de Sor da Melhor Forma: https://www.cm-pontedesor.pt/projetos-escolares-distinguidos-representam-ponte-de-sor-da-melhor-forma/
Município de Ponte de Sor: https://www.cm-pontedesor.pt/projetos-escolares-distinguidos-representam-ponte-de-sor-da-melhor-forma/
https://www.facebook.com/story.php?story_fbid=739042514916713&id=100064329146535&rdid=96XIlSADd2068GiQ

The motivation of the participants was done by means of meetings with the students of the selected classes to explain the project. These presentations included information about radon (what it is, health effects, how it is measured and how we can reduce exposure to radon). Students were encouraged to create communication and monitoring campaigns at their schools and goals to school community and to the general public from their municipality. The creation of a competition between schools for awards turned out to be an incentive too, since these young scientists are highly competitive. At the beginning, it was more of a collective motivation and towards the end; the motivation was more of a Norm-related and reward enthusiasm.

5.3.4 Communication and engagement activities

The RadAR team participated actively in the different stages of the project, from meetings with stakeholders (e.g., municipalities) to organize the dissemination events to the community, by working closely with the students to help them to create their own communication strategies, by analysis of the results and presenting them, via the creation of research publications and lastly the RadAR website. This engagement was maintained throughout the entire timeframe of the project.

The approaches to communicate with the citizen scientists were meetings at the schools, online consultations using normal platforms and close online communications (Zoom meetings, WhatsApp short messages) with the teachers of each class.

The final events held at each municipality were opened to the communities. These events had the contributions of students to show their experiences and overall results, along with the RadAR team members.
Experts on radon remediation (from the RadAR team) participated on the event and presented what remediation techniques exists and that can be applied. These experts also analyzed the results and, where high levels appeared elaborated a set of remediation techniques that are suitable for each case. Besides a visit to the research laboratories at IST, a final event in Lisbon (Ciência Viva - associated partner) opened to the public took place.

As of now, the team has participated through RadoNorm webinars and conferences to disseminate the CS outcomes and results.

<u>Poster communications:</u>

1. **RadAR, Students as key players on radon management 9th international conference on Social Sciences and Humanities in Ionizing Radiation Research (RICOMET2023), Dessel, Belgium September 2023.**

   POSTER PITCH: Portugal, citizen science, high schools, radon measurement, local communities, radon mitigation. C. Antunes (Agência Portuguesa do Ambiente, APA, Portugal), N. Canha, M. Felizardo, J. Lage, S. Marta Almeida, M. Reis (Instituto Superior Técnico, Universidade de Lisboa, Portugal), M. Malta, H. Fonseca – (Agência Portuguesa do Ambiente, APA, Portugal)

2. **O potencial da ciência cidadã na consciencialização e redução da exposição ao radão IX Congresso de Proteção Contra Radiações da Comunidade dos Países de Língua Portuguesa, Coimbra, de 11 a 15 de dezembro de 2023.**

   Simão I., Canha N., Antunes C., Almeida S., Felizardo M., Fonseca H., Lage J., Malta M., Reis M.

<u>Oral communications:</u>

1. **RadoNorm Citizen Science Network in Radon Testing and Mitigation 9th international conference on Social Sciences and Humanities in Ionizing Radiation Research (RICOMET2023), Dessel, Belgium September 2023**.

   RadoNorm Citizen Science Network in Radon Testing and Mitigation. M. A. Hoedoafia (SCK CEN), M. Martell, (Merience SCP, Spain), D. Aksamit, G. Peralta, A. Markiewicz, Z. Podgórksa, K.

Wołoszczuk, (AHSRadon Hunt, Poland), N. Canha, M. Felizardo, M. Almeida, J. Lage, C. Antunes, M. Malta, H. Fonseca (RadAR, Portugal), F. Bianchini, L. Grassi, S. Sbrulli (OCRA, Italy), A. Ďurecová, F. Ďurec, R. Rabenseifer, M. Krajčík, M. Ponický (RadonGPS, Slovakia), L. Quindos, F. Sanz, F. Romero (RADOHOW, Spain); K. König, D. Kocman, J. Vaupotič, J. Board, N. Žagar (RadoNorm-SLO, Slovenia), T. Perko (SCK CEN, Belgium)

2. **RadAR, Students as key players on radon management RadoNorm citizen science webinar on 7th November 2023.**

C. Antunes, N. Canha, M. Felizardo, J. Lage, S. Marta Almeida, M. Reis, M. Malta, H. Fonseca

3. **RadAR project - Students as key players on radon management – A citizen science approach. C2TN Workshop on Earth Systems, Radioactivity and Cultural Heritage (ESRCH) – 30 November 2023 Bobadela.**

N. Canha, M. Felizardo, J. Lage, C. Antunes, S. Marta Almeida, M. Reis, M. Malta, H. Fonseca

4. **Students as key players on radon management – RadAr. IAEA Regional Training Course on prevention and mitigation methods for protection against radon exposure in buildings - 22 to 26 January 2024 at Faculdade de Ciências e Tecnologia da Universidade de Coimbra, Portugal.**

C. Antunes, N. Canha, M. Felizardo, J. Lage, I. Simão, S. Marta Almeida, M. Reis, M. Malta, H. Fonseca

5. **RadoNorm Citizen Science Network in Radon Testing and Mitigation 10th international conference on Social Sciences and Humanities in Ionizing Radiation Research (RICOMET2024), RadoNorm citizen science incubator meet the coordinators of 7 citizen science projects related to radon – 11TH June 2024 Ljubljana**

C. Antunes, M. Felizardo, J. Lage, S. Marta Almeida, M. Reis, M. Malta, H. Fonseca, N. Canha

6. **RadAR, Students as key players on radon management E³UDRES² International Citizen Science Conference JUNE 29TH / IPS, BARREIRO CAMPUS**

5.4 Results

5.4.1 *Behavioural and socio-cultural impact*

The impact on the community had a profound impression, raising collaborations, education, and empowerment. The project brought people together to achieve common goals. Community members actively participated in the research, nurturing a sense of belonging and purpose. The residents engaged in the project's goals and related to their environment and health. This involvement strengthened community ties. Via the students' deliverables, the public learned about their surroundings - radon. This knowledge encouraged environmental stewardship. As the data is available, the people can advocate for conservation, sustainable practices, and policy changes. The students gained scientific literacy, data analysis skills, and critical thinking abilities. Through the initial and final questionnaires, the students gained a clear awareness of the issue of radon.

The students' knowledge about radon issue was assessed in the first meeting and was continuously evaluated until the last event to understand the increment of their knowledge about radon with their involvement in this project. Seventy-six students participated as citizen scientists. The analysis of the answers given by the students in the survey is as follows: For questions Q1, Q2 and Q3 one can see from **Figure 7** that 67% of the students thought that radon could cause headaches and a third of them did not know that radon was linked to lung cancer. Only 7% of the students believed that radon was a radioactive liquid and 27% of the students assumed that radon had a strong odour. The majority (86%) new that radon is invisible.

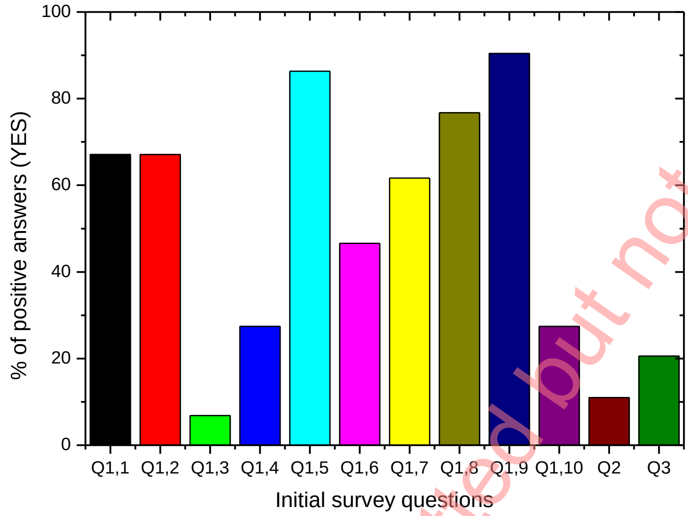


Figure 7. Percentage of "*yes"* answers to each question done in the students' survey.

Roughly, half of the students were convinced that the radon levels usually are higher in the attic than in the basement and 61% believed that testing is the only way to evaluate radon levels. Seventy-six percent new that radon can enter houses through cracks or crevices in walls and floors and a vast majority (90%) of the students new that the risks to radon are related to the exposure time. Almost 72% did not know what the units for radon concentrations were. To conclude, only a small portion (11%) of the students had participated in a research project and approximately 21% of the students were aware of the meaning of citizen science.

In question four (results revealed in **Figure 8**), the students identified which type of involvement they expected to have in the project.

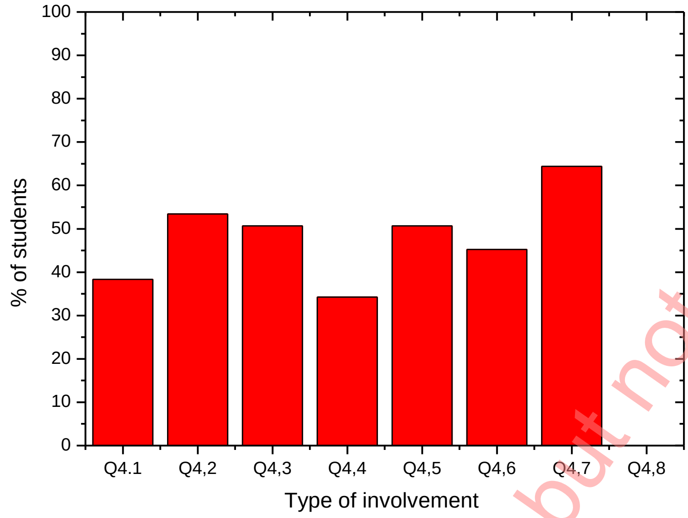


Figure 8. Students expected contributions in the project.

•

As shown, 40% expect to meet scientists to get more involved and half of the student population expect to measure the concentration of radon in their own homes. As presumed, half of the student population expected to have clear tasks throughout the project and two-thirds of the students, *a priori,* did not expect to be involved in disseminating the project's objectives and results to the community.

Part (~50%) of the student population expect to be educated in this subject and clearly expect to be bonding with others via the project. In conclusion, 65% of the students think that they would be helping people and contributing to the environment and as for the last query none responded with another type of involvement.

The responses contained by question 5, shown in **Figure 9**, display that half of the student population clearly expect to have some type of personal satisfaction, and hope to get access to the data, possibly their own data sets from their houses or families.

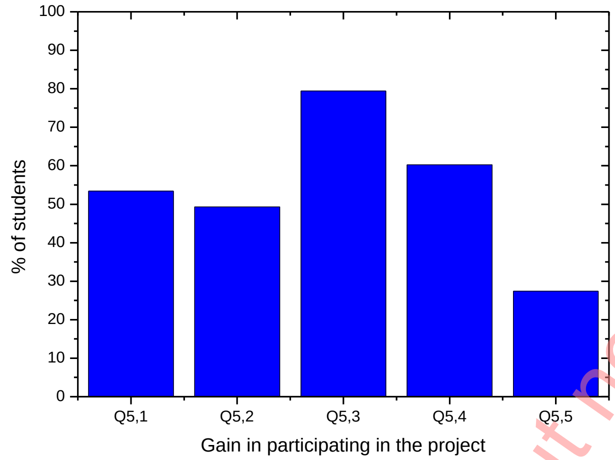


Figure 9. Gains foreseen in the project by the students.

Eighty percent have confidence in increasing their knowledge and skills and 60% are eager to contribute to the development of scientific work. Roughly 27% of the students, via these types of first steps in citizen scientist projects, ponder in becoming themselves scientists.

As for the last question, which was related to setbacks, 70% encounter the lack of time as the major barrier in their own involvement and therefore the development off this project. As shown in **Figure 10**, 35% of the students considered they would lose interest and have other priorities. One quarter of the students, state that due to educational difficulties they would be unable to fully understand the topic and as a result delaying the development of the project. An immense majority (90%) do not predict technical issues since they are more predestined to new technologies than other generations and only 25% deliberate that they would not have any type of response within the project scientist's group.

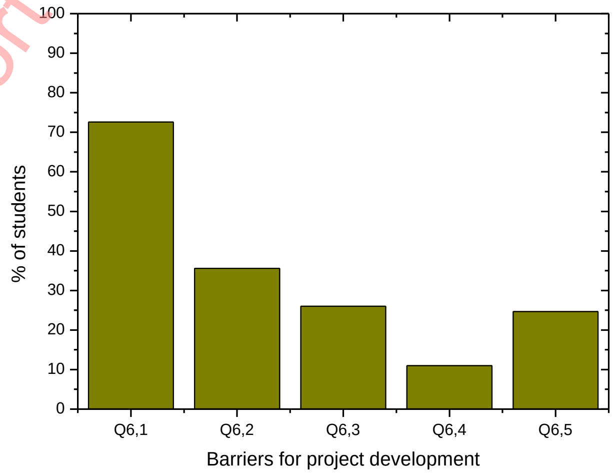


Figure 10. Barriers identified by the students that could hinder the development of the project.

As suspected, most students failed to have a correct or complete understanding of radon and the citizen science issue.

The final questionnaire with the same questions had obviously a complete understanding of all questions and top motivation.

An important result of the project was also the recovery of the devices. Detector recoveries achieved an overall 86% for the 3 schools (Escola Sec. São Lourenço 82%; Escola M. Silveira 81% and Escola de Ponte de Sor 95%). This is substantially higher than the detector recovery (68%) for the national susceptibility map done in 2020 by APA (private communication please see www.apambiente.pt/radao). As for the results in the low-risk area (Escola de Ponte de Sor) only 3 cases above 300 Bqm^{-3} as expected. The results from the high-risk areas of both schools of Portalegre show 30% above 300 Bqm^{-3}, roughly 50 dwellings in that area (**Figure 11**).

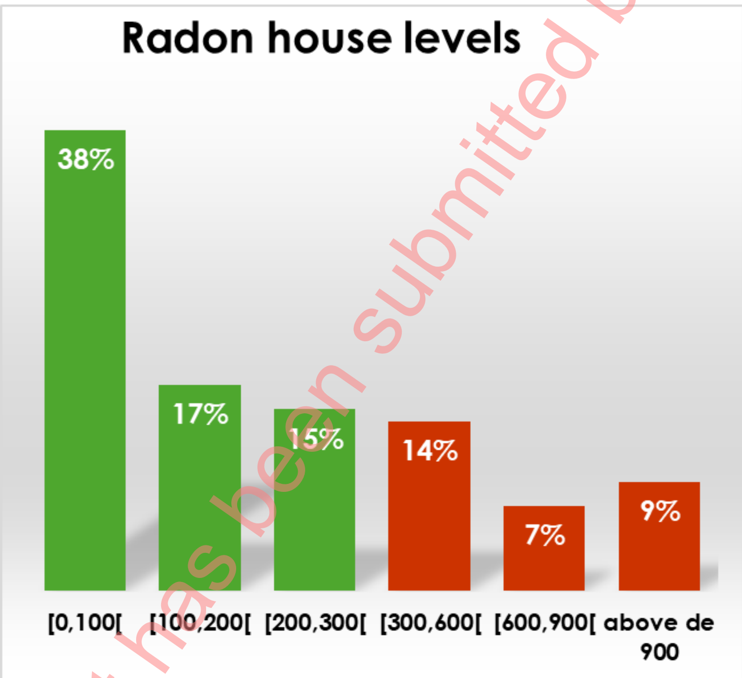


Figure 11. Percentage of radon levels in the high-risk area.

The analysis carried out has the geographical factor as expected to be dominant however, the study also can set some preliminary conclusions.

Approximately 76% of dwellings have only natural ventilation with radon concentrations above 1000 Bqm^{-3} recorded by some detectors, i.e. values about 3 times higher than the threshold.

It was concluded that the concentration of radon is, on average, higher on the ground floor, compared to the 1st floor (**Figure 12**). Only 11% of the total detectors placed on the first-floor recorded values above the reference threshold, while 35% of the total detectors placed on the ground floor recorded values above this threshold.

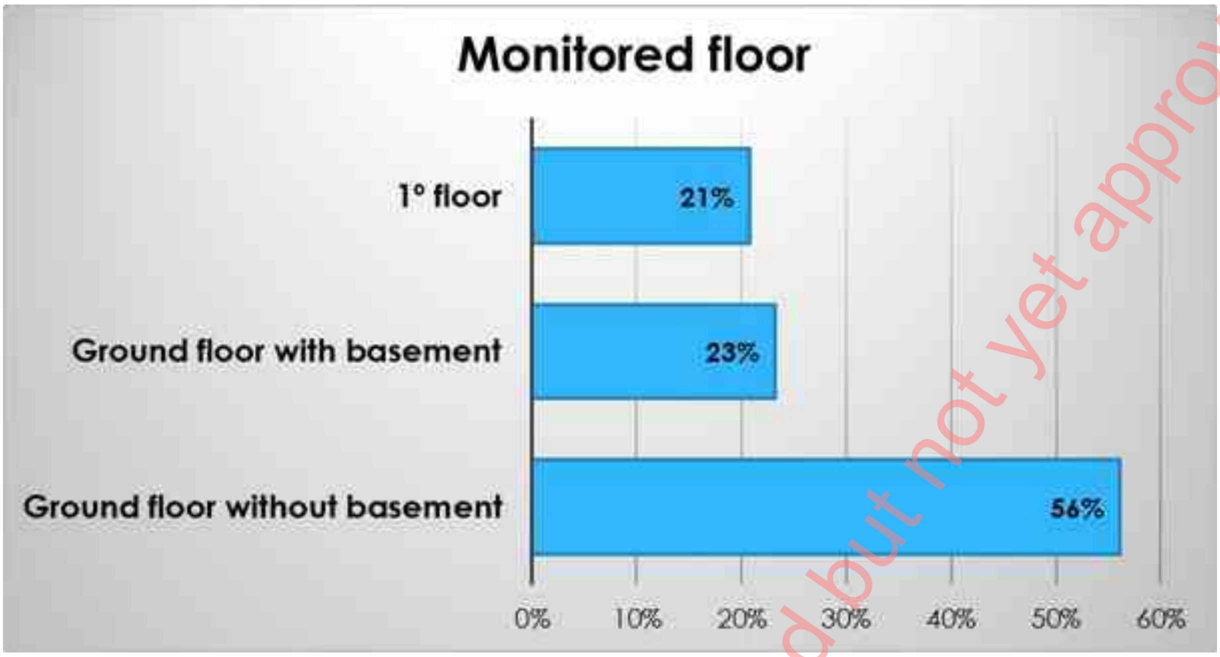


Figure 12. Percentage of detectors placed between the 1st floor and ground floor.

It was also observed that the radon concentration values obtained for houses with thermal insulation are higher than those obtained for houses without insulation. In this way, it was found that greater air circulation, promoted by less insulation of the house from the outside, favors the reduction of radon concentration inside the house.

As the people with cases above the reference levels receive their own report, they are encouraged to contact APA for advice on how to mitigate this issue. This is an arduous task since each case is probably unique.

As for the awards the results were:

- **100% RadAR -** Escola Secundária São Lourenço;
- **Best communication material –** Escola Secundária de Ponte de Sor;
- **Best presentation of RadAR results -** Escola Secundária M. Silveira.

5.4.2 *Outputs*

All of the gathered data will be openly available in a dedicated project page at Portuguese Environment Agency (APA) website during and after the lifetime of the project. Moreover, RadAR, together with the students, will adapt the tools provided by the RadoNorm toolkit to the Portuguese experience and language and all of these outputs will be available at RadAR webpage, which will be freely available at APA's website section after the lifetime of the project.

RadAR complied with GDPR in all phases of the project implementation and followed the best practices and the recommendations of the Ethics Committee of Instituto Superior Técnico - University of Lisbon. All volunteers expressed their willingness and provided their written consent in order to participate in the study before any action.

A scientific paper based on the RadAR project, entitled "The potential of citizen science in raising awareness for the reduction to radon exposure" will be submitted in the following weeks.

In the framework of the project, a science fellowship was funded for the period of 3 months (between November 2023 and February 2024). However, the project failed to have a MSc thesis regarding the RadAR implementation since the students decided to leave for another job opportunity.

It is foreseen the participation of one student in a side event related with the implementation of NRAPs in the 68th General Conference of the IAEA in September 2024 to show the students/schools perspectives about the participation in a citizen science project.

The citizen scientists from the different schools involved organized various public sessions within the community, where the public was informed about what radon is, how they can be exposed to this radioactive contaminant, and its health implications, as well as the final results of the project. The public had the opportunity to ask questions to the researchers and technicians involved in the project, who were present at some of these sessions.

There will be an improvement of the national radon risk map, by using results of the survey. This will be shortly available at the APA website.

The production of guidelines on how to implement a local communication strategy, to be used and/or adapted to other municipalities is being developed by APA. The project will be replicated in 3 other Portuguese districts: Guarda, Viseu and Coimbra. The project is set to start in September 2024. The project is promoted by Radosys Atlantic Lda and APA will collaborate in its implementation.

5.5 Evaluation of the citizen science project

The impact of citizen science projects plays a significant role in advancing scientific knowledge and encouraging collaboration between researchers and the public. Without this, a broad amplified data collection is normally much more challenging. Since the project involved a large number of participants, allowing for extensive data collection across diverse locations, timeframes and volunteers contributed to monitoring radon exposures and thus conducted a long-term study that would be problematic for small research teams, such as ours. Another fruitful aspect is that via the project people from various backgrounds participated in making bridges between professionals and the public.

One important aspect is that the participation in citizen science projects educates volunteers about scientific methods, data analysis, and critical thinking, thus performing a real science literacy, especially in these remote areas of the country. This engaged citizens to become advocates for conservation and environmental protection.

In summary, all of us: researchers, teachers, students and volunteers can state that citizen science empowers individuals, enriches scientific research, and nurtures a sense of shared responsibility. In fact, from the contact with the schools resulted the participation in other activities, showing that the involvement of schools and citizens can be beneficial to different scientific purposes. The CS project has not yet been evaluated internally by the team.

5.6 Main conclusions and final reflections

The sustainability of the project was assured by the associated partner APA, since the webpage dedicated to RadAR created within the website of APA (in the framework of radon section: apambiente.pt/radao) and all created materials will be kept available freely after the end of funding. This allows that the strategy adopted by RadAR can be replicated afterwards by interested parties (such as other municipalities).

The participation in RadoNorm allowed access to the different experiences and best practices in Europe regarding communication of radon management, including to contact with experts that can provide valuable inputs for future works. In fact, the activities offered the additional resources needed to upscale the project in terms of communication and information tools, but most important will be crucial to address needs of assistance by remediation experts to help providing the best remediation strategies to those who found high levels of indoor radon during the survey.

5.7 Way forward

The project was well received in the scholar communities and seen as very profitable to the communities by creating awareness to a subject not often known. By such, the project will be replicated in 3 other Portuguese districts: Guarda, Viseu and Coimbra. The project is set to start in September 2024 and is funded by a Portuguese fund specific for activities related with the environment and with the active involvement of citizens. The project is promoted by Radosys Atlantic Lda and APA will collaborate in its implementation.

5.8 Resources

The following sections present the categories where the project budget was invested:

Table 8. Breakdown of costs

Rubric	Amount [€]
University overheads	5,000
Research Fellowship	1,803.58
Missions	2,000
Laboratory material	3,038.10
Copy and print services	1,541
Schools Awards	1,500
Final event	3,305.49
Radon expert service	3,075
Implementation of mitigation measures	3,736
Total	**24,999.17**

Note: a 500€ voucher was given to each school. Schools had the opportunity to decide what and how to invest this money. They choose to invest the budget in a school trip for all the citizens' scientists who participate in the project. It is also foreseen to have a follow-up meeting with one of the schools (Escola Secundária São Lourenço) in Portalegre. These activities will occur in September 2024 and in 2025 (to be defined by the schools).

Annexes

- **Ethics commission from IST**

TÉCNICO LISBOA

Ethis Commission (CE-IST)

Ref. n.º 29/2023 (CE-IST)
Date: 12/11/2023

Name of IR: Inv Nuno Henrique Varela Canha

Name of the project: RadAR – Os estudantes como atores-chave na gestão do radão
Inv Nuno Henrique Varela Canha

The Ethics Committee of Instituto Superior Técnico (EC-IST) reviewed your application to obtain ethical assessment for the above mentioned project. The following documents have been reviewed:

Ref.	Documents	Version & date
1619170	Formulario_COMISSAO DE ETICA IST_2023-10-18_Projeto RadAR_revisto_signed.pdf Anexo II - RadAR_Campanha de monitorização de radão_documentação_versão revista II.pdf Download Anexo I - Consentimento participação no projeto RadAR_final.pdf RadAR_Support Letter_Escola Secundária de Ponte de Sor.pdf RadAR_Support Letter_Escola Secundária de São Lourenço.pdf RadAR_Support Letter_Escola Secundária Mouzinho da Silveira_Portalegre.pdf	18/10/2023

The following members of the EC-IST participated in the ethical assessment:

Name	Role in Ethics Committee	Qualification	Gender	Affiliation to IST (Yes/No)
Mário Gaspar da Silva	President	Professor	M	Y
Isabel Trancoso	Member	Professor	F	Y
Isabel Sá Correia	Member	Professor	F	Y
Fernando Borges Araújo	Member	Professor	M	N
Miguel Prazeres	Member	Professor	M	Y

This EC-IST is working accordance to ICH-GCP, Schedule Y and ICMR guidelines, the EC-IST regulation and other applicable regulation.

None of the researchers participating in this study took part in the decision making and voting procedure for this assessment.

Based on the review of the above mentioned documents, the EC-IST states a favourable ethical opinion about the request / trial as submitted.

The EC-IST expects to be informed about the progress of the study, any Serious Adverse Events occurring in the course of the study, any revision in the protocol and in the participants' information/informed consent, and requests to be provided a copy of the final report.

Prof. Mário Gaspar da Silva
President of Ethics Committee of
Instituto Superior Técnico (CE-IST)

Ethis Commission (EC-IST) - Instituto Superior Técnico - Avenida Rovisco Pais, 1, 1049-001 Lisboa, Portugal
comissaoetica@tecnico.ulisboa.pt

- **Letter to the volunteers and acceptance of their consent**

Caro(a) Proprietário(a),

O projeto RadAR vem desta forma convidá-lo(a) a participar na Campanha de Monitorização do Gás Radão que se encontra a decorrer no distrito de Portalegre. O projeto RadAR é desenvolvido pelo Instituto Superior Técnico (IST), em colaboração com a Agência Portuguesa do Ampiente (APA), sob a coordenação do investigador Nuno Canha. O projeto RadAR possui ainda o apoio da Ciência Viva. Este estudo teve a aprovação da comissão de ética do IST.

O projeto RadAR - **Os estudantes como atores-chave na gestão do radão** - é um projeto-escola de ciência cidadã dedicado à temática do radão e é implementado em três escolas secundárias do distrito de Portalegre. Este projeto tem como objetivo principal promover a consciencialização da população sobre os efeitos nocivos do radão na saúde humana e das questões principais relacionadas com a gestão do radão. Para além disso, a implementação do projeto RadAR pretende motivar os cidadãos a realizar medições da concentração de radão nas suas habitações e promover a sua remediação nos casos em que valores acima dos valores de referência do radão sejam registados.

A monitorização de radão é feita através de um detetor de radão que se coloca no interior da habitação, na divisão onde se passa mais tempo, durante um período de 3 meses (não se pode mover o detetor de local durante este período). Para participar e fazer o teste ao radão, basta seguir as instruções que se encontram nos documentos em anexo. Esta tarefa pode ser efetuada por qualquer pessoa.

Os detetores não têm custos associados, não necessitam de energia para funcionar e são de pequenas dimensões.

No fim do período de medição, o participante na campanha de monitorização deverá devolver o detetor e os formulários em anexo preenchidos aos responsáveis da campanha de monitorização (guardando-os no envelope). Os documentos em anexo necessários preencher são:

- Consentimento Informado

- Questionário sobre características da habitação

A análise ao seu detetor será realizada no Laboratório de Proteção e Segurança Radiológica do IST, de forma gratuita. Posteriormente, receberá um relatório com o resultado da concentração de radão na sua residência.

Todos os dados recolhidos no âmbito da campanha de monitorização irão ser tratados de forma confidencial. Para isso, os resultados do teste ao radão serão anonimizados (incluindo informação das residências) e só serão usados de forma anónima pelo alunos que participam no projeto. Os valores de concentração de radão obtidos serão analisados como um todo e nenhum participante poderá ser identificado.

Os dados pessoais serão tratados pelo IST e pela APA, não sendo transferidos para qualquer outra entidade. Não há lugar a decisões automatizadas e os dados não são tratados para outros fins. Mais se informa que o tratamento dos dados é feito no âmbito do Regulamento Geral de Proteção de

Dados. De acordo com o Regulamento Geral de Proteção de Dados (RGPD), os dados dos participantes serão destruídos assim que o tratamento dos dados esteja terminado.

Os resultados provenientes da campanha de monitorização poderão ser utilizados para produção científica pela equipa do projeto RadAR, em formato de publicação de artigos científicos ou apresentações em eventos nacionais ou internacionais. A informação apresentada nestas publicações não será individualizada, ou seja, será previamente tratada de forma a que não seja possível identificar a identidade dos participantes.

A sua participação é voluntária e pode retirar-se em qualquer fase do estudo sem explicações.

Caso tenha alguma dúvida não hesite em nos contactar através do email: radao@apambiente.pt ou através do telefone 214728262.

Para mais informações: apambiente.pt/radao

Desde já agradecemos a sua participação nesta campanha local de monitorização do gás radão.

Com os melhores cumprimentos,

A equipa do projeto RadAR

Documentos anexos:

1) Consentimento Informado
2) Questionário sobre características da habitação
3) Instruções de colocação de detetor

- **CONSENTIMENTO INFORMADO**

Caro Participante,

Leia por favor as seguintes declarações antes de consentir participar no estudo:

- **Li e compreendi a carta convite.**
- **Compreendo o objetivo do estudo, e para o que os resultados vão ser utilizados.**
- **Sei que a minha participação é voluntária e que posso retirar-me em qualquer fase do estudo sem explicações.**
- **Estou ciente de que as minhas informações e respostas serão mantidas confidenciais.**

Tendo lido as informações acima, concorda em participar neste estudo?

SIM ☐

NÃO ☐

Nome: ____

Data: ____/____/_______

- **Instruções para a colocação do detetor de radão – passo a passo**

Passo 1 – O detetor é entregue numa embalagem selada. Retire o detetor da embalagem e guarde a embalagem.

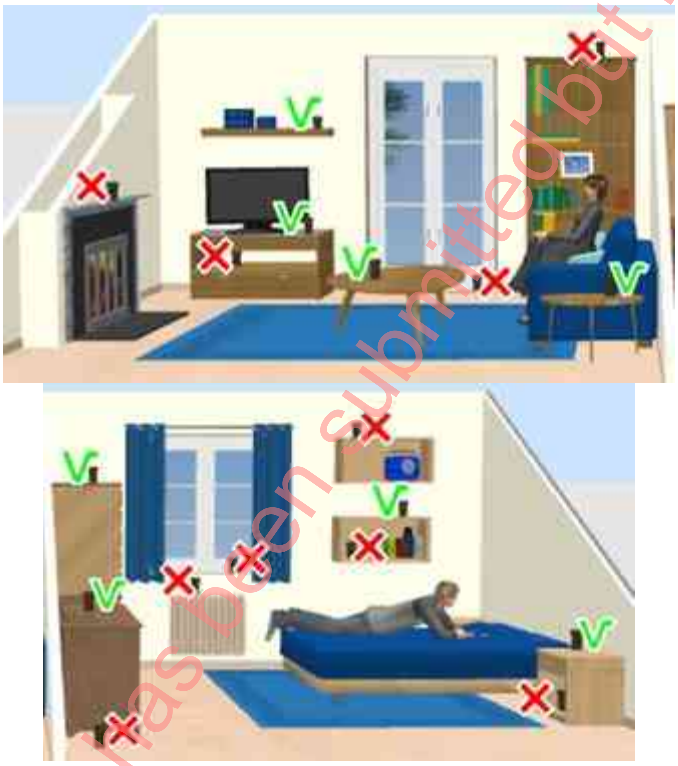
Passo 2 - O detetor deve ser colocado na divisão onde se permanece mais tempo, como a sala de estar ou o quarto de dormir.

A sua colocação deve ser feita **de acordo com as seguintes indicações**:

- deve ser colocado a cerca de 1 m a 2 m do pavimento, num espaço livre;
- deve estar afastado da parede;
- deve estar afastado de qualquer fonte de calor e da luz solar;
- não deve ser colocado em locais com poeiras ou humidade excessiva.

O **detetor tem de permanecer na mesma posição durante os 3 meses** em que decorrerá a medição. Deve colocá-lo afastado do bordo de móveis, bem como de objetos de manuseamento mais frequente.

Tome como exemplo as seguintes imagens:



Coloque o detetor logo que o receba para evitar invalidar os resultados.

Passo 3 – Preencha a ficha de identificação e de caracterização da habitação, registando de imediato a data de colocação do detetor (início). Preencha o Consentimento Informado também.

Passo 4 - Após os **3 meses de exposição**, guarde o detetor na embalagem e sele-a. Registe a data da recolha na ficha do passo 3, guarde todos os documentos e o detetor no envelope A5 (onde o detetor foi entregue) e devolva aos responsáveis da campanha de monitorização.

Para mais informações visite o website apambiente.pt/radao.

Caso tenha alguma dúvida não hesite em contactar-nos através do e-mail: radao@apambiente.pt ou através do telefone 21 472 82 62.

FICHA DE IDENTIFICAÇÃO E DE CARACTERIZAÇÃO DA HABAÇÃO
Ficha de identificação e de caracterização da habitação

PARTE 1

Identificação da habitação

Morada: ____

Localidade: ___________________________________

Código postal: __________ - ________

Localidade Postal (associada ao código postal): _____________________________________

Identificação do proprietário da habitação

Nome:

____

Telefone/telemóvel: ______________________

E-mail:____

Informações sobre o detetor

Código do Detetor (n.º): ________________________

Data da colocação (início) ____/____/________ **Data da recolha (fim)**____/____/________

Local de colocação: Sala ☐

Quarto ☐

Andar do local de colocação: Rés-do-Chão (sem andar por baixo) ☐

Rés-do Chão (com andar por baixo, p.ex. garagem, armazém, etc) ☐

1º Andar ☐

PARTE 2

Características da habitação

Tipo de habitação:
- Moradia unifamiliar ☐
- Moradia em banda ☐
- Apartamento (em prédio) ☐

Andares que constituem a habitação (assinale **todas** as opções que se verifiquem)**:**
- Cave (e subcaves) ☐
- Rés-do-Chão ☐
- 1.º andar ☐
- 2.º ou mais andares ☐

Tipo de paredes da habitação:
- Com isolamento térmico ☐
- Sem isolamento térmico ☐
- Misto (com ambos) ☐
- Não sei ☐

Ventilação existente na habitação:
- Apenas natural ☐
- Mecânica (centralizada, em toda a habitação) ☐
- Mecânica (cozinha e/ou casa de banho) ☐
- Não sei ☐

O pavimento da habitação:
- Está assente diretamente sobre o terreno ☐
- Tem caixa-de-ar subjacente (entre o pavimento e o terreno) ☐
- É misto ☐
- Não sei ☐

Tipo de janelas da habitação:
- Com vidros duplos ☐
- Sem vidros duplos ☐
- Misto (com ambos) ☐
- Não sei ☐

- **Questionnaire**

RadAR
projeto de ciência cidadã em Portalegre
da ESCOLA para a COMUNIDADE

QUESTIONÁRIO

Nº DE ALUNO:________

DATA DE NASCIMENTO (DD/MM/AAAA): __/__/____

1 - O que sabes sobre radão?

(Responde SIM ou NÃO às seguintes questões)

1.1. O radão causa dores de cabeça.
☐ Sim
☐ Não

1.2. A exposição ao radão está relacionada com o aparecimento de cancro do pulmão.
☐ Sim
☐ Não

1.3. O radão é um líquido radioativo.
☐ Sim
☐ Não

1.4. O radão tem um odor forte.
☐ Sim
☐ Não

1.5. O radão é invisível.
☐ Sim
☐ Não

1.6. Os níveis de radão costumam ser mais elevados no sótão do que na cave.
☐ Sim
☐ Não

1.7. Os testes são a única forma de determinar se uma casa tem um nível elevado de radão.
☐ Sim
☐ Não

1.8. O radão pode entrar nas casas através de fissuras ou fendas nas paredes e no chão.
☐ Sim
☐ Não

1.9. Os riscos da exposição ao radão aumentam, quanto maior for o tempo de exposição.
☐ Sim
☐ Não

1.10. As concentrações de radão no ar interior são expressas em Watt.
☐ Sim
☐ Não

2 – Já ouviste falar em ciência cidadã?
☐ Sim
☐ Não

Se respondeste **Sim**, descreve brevemente o que é para ti ciência cidadã.

____

____

____

4 - Que tipo de envolvimento tiveste neste projeto?

(escolhe as respostas que mais se adequam a ti)

☐ reuni regularmente com cientistas

☐ medi a concentração de radão em minha casa

☐ tive tarefas bem definidas e soube sempre qual o meu papel no projeto

☐ disseminei os objetivos e os resultados do projeto à comunidade

☐ relacionei-me com a comunidade escolar e local

☐ ajudei as pessoas e contribui para o ambiente

☐ outro tipo de envolvimento. Qual? ____

5 - O que consideras que ganhaste com a participação neste projeto?

(escolhe as respostas que mais se adequam a ti)

☐ satisfação pessoal (pela interação com outras pessoas e com cientistas)

☐ acesso a dados relacionados com riscos para a saúde, incluindo análise dos mesmos

☐ adquiri conhecimento e competências

☐ oportunidade de desenvolver trabalho científico

☐ adquiri formação

☐ outras coisas, como: ____

6 - Que tipo de barreiras consideras que podem ter dificultado o teu envolvimento neste projeto?

(escolhe as respostas que mais se adequam a ti)

☐ falta de tempo

☐ perda de interesse / outras prioridades

☐ questões educacionais (p.ex. muito difícil, não sou qualificado, ...)

☐ questões técnicas (p.ex. tecnologia disponível, usabilidade da tecnologia, ...)

☐ falta de comunicação com os cientistas / falta de feedback por parte dos cientistas

☐ outras, como: ____

Obrigada pela tua participação!

A tua opinião conta. Se tiveres **comentários ou sugestões**, podes deixá-los aqui:

____

____

____

1st session – Escola Secundária de Ponte de Sor

1st session – Escola Secundária Mouzinho da Silveira

•**1st session – Escola Secundária de São Lourenço**

Public Session for distribution of radon detectors – Escola Secundária de Ponte de Sor

Public Session for distribution of radon detectors – Escola Secundária Mouzinho da Silveira

Public Session for distribution of radon detectors – Escola Secundária de São Lourenço

Final session for presentation of the results to the community – Escola Secundária de Ponte de Sor

Final session for presentation of the results to the community – Escola Secundária Mouzinho da Silveira

RadAR final event – 21st May 2024 helded at IST and Pavilhão do Conhecimento.


RADÃO:
SIM OU NÃO?
21 maio


2


RADÃO:
SIM OU NÃO?
21 maio

Poster presented at RICOMET 2023

Poster presented at IX SPPCR

- **Some materials produced by the students:**


RadAR
da ESCOLA
para a COMUNIDADE
RADÃO
O que é o radão?
• Gás radioativo de origem natural.
• Uma das principais causas de cancro de pulmão.
Colabore Connosco!
INSCRIÇÕES
Se vive no Concelho de Ponte de Sor faça a medição do radão na sua habitação.
Contacte a sua Junta de Freguesia ou radar.sor@aeps.pt

Newspaper "Ecos do Sor" July 2024

(4) Ecos do Sor
2 de JULHO de 2024

Local

Projeto Ciência Cidadã - RadAR

Alunos de Ponte de Sor premiados com o galardão de melhor estratégia de comunicação

Turma B do 11.º Ano ESPS
[illegible]

O projeto de ciência cidadã RadAR, intitulado "Os estudantes como atores-chave na gestão do radão", foi lançado à turma B do 11.º ano da ESPS - Escola Secundária de Ponte de Sor, que formou a equipa RadAR. SOR. Este projeto é promovido pelo IST - Instituto Superior Técnico, em colaboração com a Agência Portuguesa do Ambiente, e conta com o apoio da Ciência Viva. Trata-se de um dos seis projetos de ciência cidadã selecionados na Europa no âmbito do Projeto Europeu RadoNORM, sendo o primeiro projeto de ciência cidadã sobre radão a ser implementado em escolas de Portugal. O radão, com o símbolo químico Rn, é um gás radioativo natural, incolor e inodoro, o que dificulta sua deteção. A única maneira de determinar a concentração de radão é através de medições específicas. Este gás resulta da decomposição do urânio, presente em rochas e solos, sendo liberado para a superfície e encontrando-se tanto no exterior quanto no interior dos edifícios. O radão entra nos edifícios através de fissuras no telhado e nas paredes, junções entre o telhado e as paredes, e pela canalização inadequada ou não isolada. O radão é prejudicial à saúde, pois gera partículas radioativas no ar que respiramos. Estas partículas ficam presas nas vias respiratórias e emitem radiação, causando lesões pulmonares que aumentam o risco de cancro do pulmão. Fumadores e ex-fumadores correm maior risco devido aos efeitos combinados do tabaco e do radão. Para medir a concentração de radão, utilizam-se detetores passivos de pequena dimensão, fáceis de usar e que não necessitam de energia para funcionar.

Alertar consciências e promover mudanças nos hábitos culturais e sociais

Um dos grandes desafios do projeto era monitorizar o radão em 100 habitações no concelho de Ponte de Sor. Após um extenso trabalho de divulgação, o projeto foi bem recebido pela comunidade, conseguindo 100 voluntários de todo o concelho. Estes voluntários instalaram os detetores passivos nas suas casas durante três meses para medir a concentração de radão. Dos 100 detetores distribuídos, 95 foram recolhidos e enviados para o Laboratório de Proteção e Segurança Radiológica do IST. Nem todos os detetores recolhidos reuniam as condições para serem analisados, mas conseguimos constatar que o NR - nível de referência de 300 Bq/m^3 (bequerel por metro cúbico) foi excedido apenas em três habitações, ou seja, em menos de 10% dos edifícios, confirmando que o concelho de Ponte de Sor é uma zona de baixa suscetibilidade ao radão. Os dados recolhidos e a estratégia de divulgação do projeto foram apresentados no Pavilhão do Conhecimento da Ciência Viva, na sessão "Radão: Sim ou Não?", no dia 21 de maio, juntamente com as duas escolas secundárias da cidade de Portalegre. O grupo de Ponte de Sor foi premiado com o galardão de melhor estratégia de comunicação. O encerramento do projeto ocorreu em junho com uma sessão aberta ao público na ESPS, onde os resultados da medição do radão nas habitações dos voluntários foram apresentados. Houve uma grande preocupação em informar os cidadãos sobre as medidas a implementar em caso de níveis elevados de radão. O projeto RadAR teve um impacto extremamente positivo, envolvendo ativamente todo o grupo nas atividades propostas, com grande interesse e empenho. Este envolvimento demonstrou a crescente importância de alertar consciências e promover mudanças nos hábitos culturais e sociais. O sucesso do RadAR sublinha o poder da educação e da ciência cidadã em criar uma comunidade mais consciente e proativa, transformando aprendizagens da escola em ações para a vida. Estão assim de parabéns os alunos da Turma B do 11º Ano ESPS e a professora responsável, Sílvia Veríssimo, pelo estudo efetuado e pelo galardão alcançado.

Magazine School group of Ponte-Sor

RadAR Projeto de Ciência Cidadã

RADÃO: SIM OU NÃO?

O projeto de ciência cidadã RadAR, intitulado "Os estudantes como atores-chave na gestão do radão", foi lançado à turma B do 11.º ano no início do ano letivo, que formou a equipa RadAR.SOR. Este projeto é promovido pelo Instituto Superior Técnico (IST), em colaboração com a Agência Portuguesa do Ambiente, e conta com o apoio da Ciência Viva. Trata-se de um dos seis projetos de ciência cidadã selecionados na Europa no âmbito do Projeto Europeu RadoNORM, sendo o primeiro projeto de ciência cidadã sobre radão a ser implementado em escolas de Portugal.

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entrada de radão nos edifícios

Análise dos dados

O radão é prejudicial à saúde, pois gera partículas radioativas no ar que respiramos. Estas partículas ficam presas nas vias respiratórias e emitem radiação, causando lesões pulmonares que aumentam o risco de cancro do pulmão. Fumantes e ex-fumantes correm maior risco devido aos efeitos combinados do tabaco e do radão.

Para medir a concentração de radão, utilizam-se detetores passivos de pequena dimensão, fáceis de usar e que não necessitam de energia para funcionar.

mapa de suscetibilidade radão

RadAR Projeto de Ciência Cidadã

RADÃO: SIM OU NÃO?

Um dos grandes desafios do projeto era monitorizar o radão em 100 habitações no concelho de Ponte de Sor. Após um extenso trabalho de divulgação, o projeto foi bem recebido pela comunidade, conseguindo 100 voluntários de todo o concelho. Estes voluntários instalaram os detetores passivos nas suas casas durante três meses para medir a concentração de radão. Dos 100 detetores distribuídos, 98 foram recolhidos e enviados para o Laboratório de Proteção e Segurança Radiológica do IST. Nem todos os detetores recolhidos reuniam as condições para serem analisados, mas conseguimos constatar que o nível de referência (NR) de 300 Bq/m³ (becquerel por metro cúbico) foi excedido apenas em três habitações, ou seja, em menos de 10% dos edifícios, confirmando que o **concelho de Ponte de Sor é uma zona de baixa suscetibilidade ao radão.**

Os dados recolhidos e a estratégia de divulgação do projeto foram apresentados no Pavilhão do Conhecimento da Ciência Viva, na sessão "Radão: Sim ou Não?", no dia 21 de maio, juntamente com as duas escolas secundárias da cidade de Portalegre. O grupo de Ponte de Sor foi premiado com o galardão de melhor estratégia de comunicação.

O encerramento do projeto ocorreu no dia 4 de junho com uma sessão aberta ao público, onde os resultados da medição do radão nas habitações dos voluntários foram apresentados. Houve uma grande preocupação em informar os cidadãos sobre as medidas a implementar em caso de níveis elevados de radão.

A sessão contou também com a presença da equipa ETXIS, da turma A do 12.º ano, que apresentou o seu projeto "Bastidores do Vinho", vencedor da 6.ª Edição dos "Detetives do Clima", promovido pela ...

O projeto RadAR teve um impacto extremamente positivo, envolvendo ativamente todo o grupo nas atividades propostas, com grande interesse e empenho. Este envolvimento demonstrou a crescente importância de alertar consciências e promover mudanças nos hábitos culturais e sociais. O sucesso da RadAR sublinha o poder da educação e da ciência cidadã em criar uma comunidade mais consciente e proativa, transformando aprendizagens da escola em ações para a vida.

Equipa RadAR.Sor no Pavilhão do Conhecimento

Turma B do 11.º Ano
Professora responsável: Sílvia Veríssimo

6 Slovakia: RadonGPS - How future building professionals can help remove barriers for citizens to take radon remedial measures in the Slovak Republic

The CS RadonGPS project "How future building professionals can help remove barriers for citizens to take radon remedial measures" was selected for funding by RadoNorm project in 2023.

The main aim of the CS RadonGPS project was to compare short-term (about 2 weeks by active radon detector) and long-term (3 month by passive radon detectors) indoor radon measurements in family houses in the municipalities around the town of Banská Bystrica in the Slovak Republic and to engage students of secondary construction school (as future building professionals) to design tailor-made remediation projects for owners of the family houses. The basic idea was to foster communication between different stakeholders interested in the radon issue within the town of Banská Bystrica. Students of secondary construction school in Banská Bystrica (as future building professionals) had opportunity to work with citizen scientists and designed tailor-made radon remediation projects in cooperation with experts from the Faculty of Civil Engineering at the Slovak University of Technology in Bratislava. Students designed 14 tailor-made radon remediation projects (13 remedial measures and 1 preventive measure). About 50 citizen scientists were engaged in distribution of passive radon detector and/or active radon detectors, gathering data from measurements, data analysis and in the FAQ collection.

Flowchart of the activities of the CS project RadonGPS is shown in Figure 13.

The CS RadonGPS project was divided into the following 4 phases

1. 1st Phase - preparation of starting materials and purchase of radon detectors
2. 2nd Phase – kick-off meetings, recruitment of citizens scientists and distribution of radon detectors, recruitment of students to design tailor-made radon remediation projects
3. 3rd Phase – data analysis and final meetings, distribution of results
4. 4th Phase – rewarding of students, results made available on the web interface of non-governmental organization NatuRadon

Figure 13. Flowchart of the activities of the CS project RadonGPS

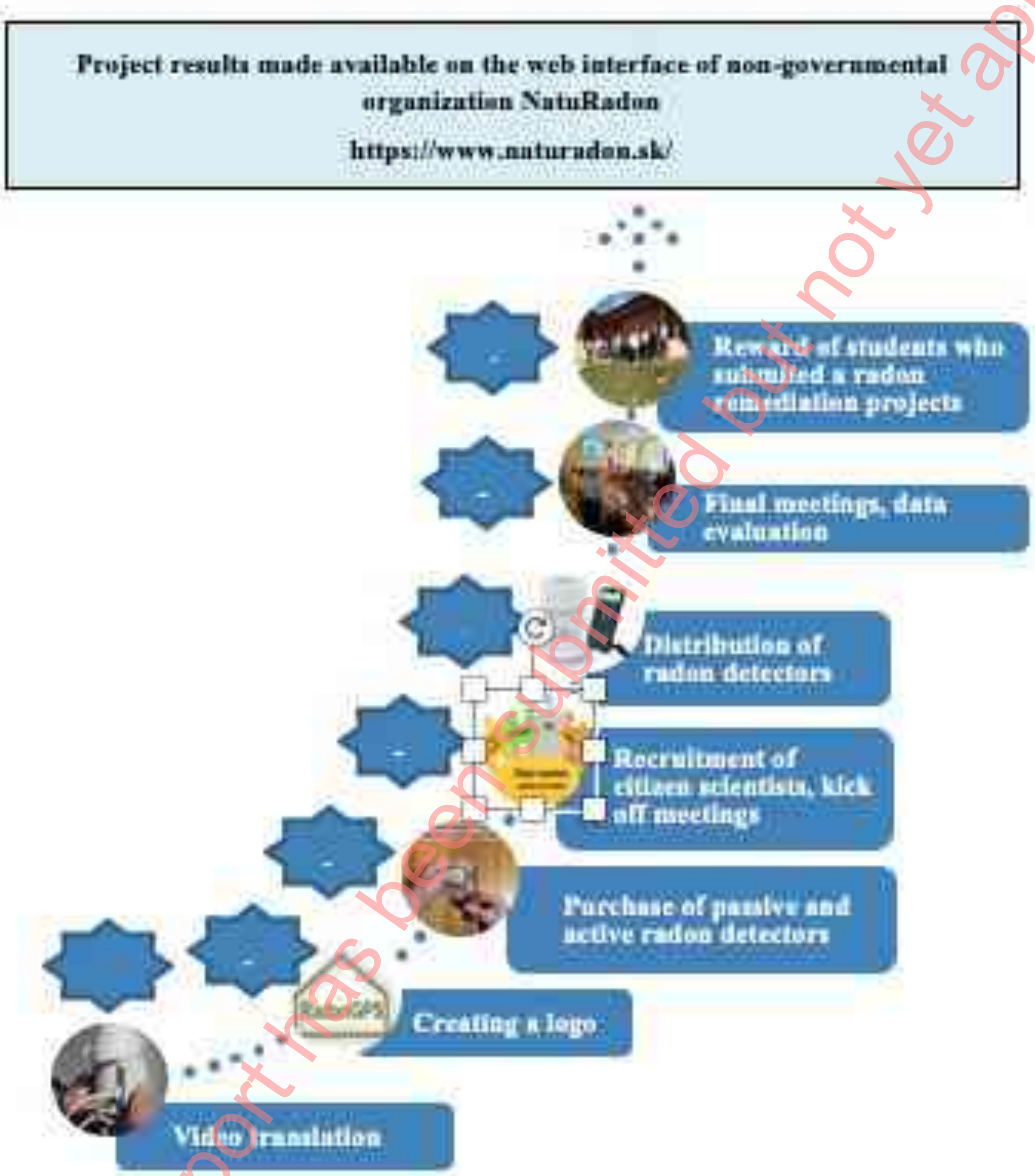

Table 9. Main objectives of the project and overview of the basic activities

Phase	Dates	Activities	Objectives
1	May–September 2023	Creation of leaflets, roll up banners and other relevant documents (Annexes 1 to 10) Purchase of the radon detectors and ensuring the traceability of active radon detectors to AlphaGuard. Translation of Radon EPA video into Slovak Setting tasks for stakeholders Dissemination of the project - 26.09. First meeting with students, 29.09. European researchers' night	Increasing radon awareness of the stakeholders Development of communication strategies between different stakeholders regarding the radon issue
2	October 2023-April 2024	Kick off meetings (recruitment of citizen scientists and students, distribution of the radon detectors) - 14.10. Ponická Lehôtka, 23.10. Secondary construction school, 24.10. Ponická Huta 24.10. Online webinar about the CS projects (CVTI, Bratislava) 20.03.-23.03. The CS RadonGPS project at an exhibition CONECO RACIOENERGY 2024 in Bratislava 22.03. The competion of secondary school professional activity within the Banská Bystrica self governing region. Student´s project „Radon in the family house" took 2nd place and advanced to the national round where it took 6th place Several face to face and remote meetings with the citizens, experts, students, teachers of the Secondary construction school were managed	
3	April-May 2024	Final meetings, distribution of results, students' rewards (Annex 11 to 13) – 08.04. Secondary construction school, 26.04. Ponická Huta	Comparison of short-term and long-term indoor radon measurements in family houses. Evaluation and collection of students´s tailor-made radon remediation projects / measurement projects in family houses
4	May-July 2024	05.06. Student´s excursion for the demonstration of the blower door test joined with radon activity concentration measurement in a new wooden house The FAQ collection (Annex 14). Results and student´s projects made available on the web interface of non-governmental organization NatuRadon	Creation of freely accessible database of student´s tailor-made radon remediation projects in family houses on the web interface of non-

			governmental organization NatuRadon.

The CS RadonGPS project generated results from the indoor radon measurements in family houses, a significant amount of input from the citizen scientists, a number of frequently asked questions from all parties involved, i. e. the citizen scientists and stakeholders, 14 tailor-made radon remediation projects for family houses, various types of record forms (Annex 9 and Annex 10), etc. Answers to the frequently asked questions were developed by our experts from either non-governmental organization NatuRadon or Faculty of Civil Engineering at the Slovak University of Technology in Bratislava (Annex 14).

The basic results from indoor radon activity concentration measurements by passive radon detectors Radonova Radtrak are shown in **Table 10**. We purchased 100 pieces of passive radon detectors Radonova Radtrak, of which 91 pieces were evaluated in 47 family houses.

Table 10. Data from indoor radon activity concentration measurements

Statistical data	**Bq/m^3**
Minimum (Min)	16
Maximum (Max)	850
Median	137
Aritmetic Mean (AM)	177
Geometric Mean (GM)	137

In 34 family houses with 126 rooms, the citizen scientists measured the concentration of radon activity in the interior using active Radon Eye radon detectors. These measurements turned out to be the most interesting for the citizen scientists because they saw changes in the radon concentration over time, for example, when closing the rooms of the house for the weekend and then opening the windows. A total of 6 Radon Eye active detectors circulated between the citizen scientists.

The minimum value of radon activity concentration measured by active detectors was 4 Bq/m^3 and the maximum value was 1485 Bq/m^3.

The strength and novelty of the CS RadonGPS project was that students of the Secondary construction school, as future building professionals, designed tailor-made radon remediation projects for family houses in cooperation with experts from the Faculty of Civil Engineering at the Slovak University of Technology in Bratislava.

The novelty of the CS RadonGPS project was that it was the first CS project in Slovak Republic focused on radon issues in family houses. The citizen scientists also appreciated the possibility of communication with experts on the radon issue.

Citizen scientists have welcomed student projects to be freely available online on the web interface of the non-governmental organization NatuRadon.

We were surprised that we had to approach communication strategies very carefully and change them very often according to the situation. The basic communication strategies between stakeholders that needed to be engaged are shown in **Figure 14**.

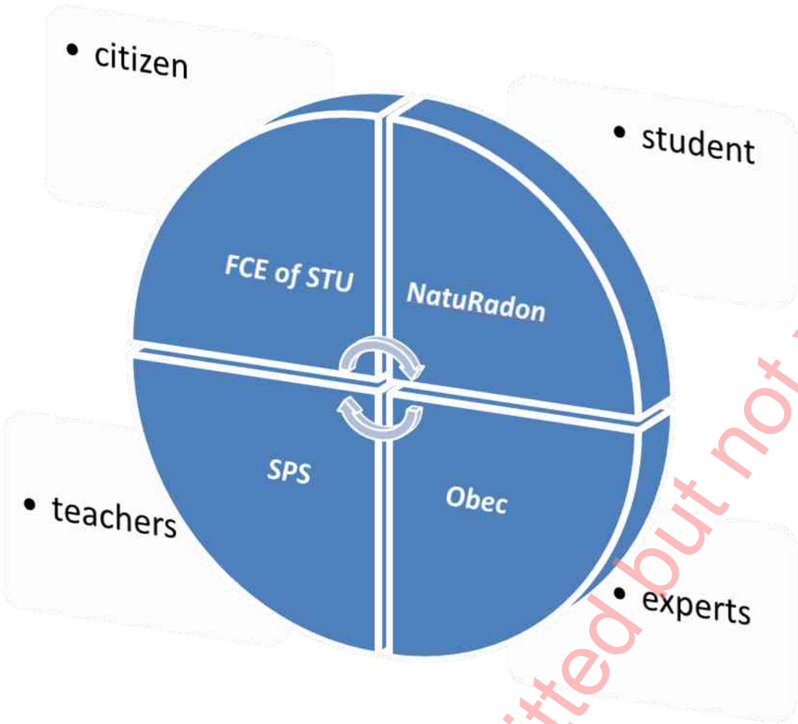

Figure 14. Communication strategies between stakeholders and citizen scientists

Stakeholders involved in the RadonGPS project were as follows:

a. NatuRadon – non-governmental organization, key stakeholder
b. FCE of STU - Faculty of Civil Engineering at the Slovak University of Technology in Bratislava
c. SPS - Secondary construction school in Banská Bystrica
d. Obec - Representatives of local municipalities (Poniky, Ponická Huta)

6.1 Rationale and objectives of the CS project

The Slovak Republic does not have established criteria for identifying radon prone area although it belongs to the countries with highest indoor radon activity concentration in Europe (equilibrium radon activity concentration is 86 Bq/m^3 based on measurements in the 1990s).

The CS project is a way how to engage citizens to the radon awareness by their active participation in the indoor radon measurements and evaluation of the data. Participation of students of the Secondary construction school on the CS project as citizen scientists and a person who designed tailor-made radon remediation projects for family houses help increased also radon awareness of their family members.

Objectives of the CS RadonGPS project were to compare short-term (approximately 2 weeks) and long term (3 month) indoor radon activity concentration measurements in family houses in the municipalities around the town of Banská Bystrica in the Slovak Republic and to engage students of Secondary construction school in Banská Bystrica (as future building professionals) to design tailor-made radon remediation projects for family houses. The idea was to foster cooperation between citizens interested in indoor radon activity concentration measurement in their family houses, experts and future building professionals (students) in radon issue and in creation of a freely accessible database of tailor-made radon remediation projects on web interface of non-governmental organization NatuRadon. One of the objectives was to collect frequently asked questions from all stakeholders and citizen scientists regarding the radon issue and increased their awareness of radon. To achieve these objectives of the CS RadonGPS project, about 50 citizen scientists were engaged to active participation in gathering data from measurements, data analysis, and in the design of tailor-made radon remediation projects in cooperation with experts from non-governmental organization NatuRadon and the Faculty of Civil Engineering at the Slovak University of Technology in Bratislava.

According the **Table 1**, RadonGPS project was Level 2 "Distributed intelligence". Our first idea was to realize the project as Level 3 "Participatory science", but due to lack of time we had to change to Level 2.

6.2 Partners and roles

We started the CS RadonGPS project with 5 members of the core team. In the course of implementation, we gradually added three more members to the core team. In the end, we had 8 members of the core team, each of whom had a specific role in fulfilling the main objectives of the project. None of the key team members had previous personal experience in participating in or managing CS projects. The following members of the core team participated in the implementation of the project:

- Alžbeta Ďurecová
    - representative of the key involved stakeholder non-governmental organization NatuRadon
    - has more than 30 years of experience in the field of radon measurement, data analysis of naturally occurring radionuclides in various components of the environment, including radon in workplaces and family houses, dissemination and insights of radon questionnaires
    - was the project counter-part for the Slovak Republic in two IAEA radon projects and is a co-author of the National Radon Action Plan of the Slovak Republic, which was approved by the government in 2022
    - role in the CS RadonGPS project as a representative of the key involved stakeholder non-governmental organization NatuRadon was coordination, promotion, dissemination of the project, expert advice, preparation of ppt presentations, distribution of passive or active radon detectors together with questionnaires plus instruction on the placement of detectors in family homes, analyses of results, proposals for report formats for radon measurements with active and passive detectors, updating of communication strategies in relation to the citizen scientists and stakeholders, collecting frequently asked questions and preparing answers to them.
- František Ďurec
    - representative of the key involved stakeholder non-governmental organization NatuRadon
    - has more than 25 years of experience in the field of radon measurement, data analysis of naturally occurring radionuclides in various components of the environment, including radon in workplaces and family houses, dissemination and insights of radon questionnaires
    - actively participated in several IAEA radon workshops
    - role in the CS RadonGPS project as a representative of the key involved stakeholder non-governmental organization NatuRadon was mainly administration of web interface of the non-governmental organization NatuRadon (basic information about the project, work plan, data collection from all parties involved, demonstration of downloading data from active radon detectors, etc.), distribution of passive or active radon detectors together with questionnaires plus instruction on the placement of detectors in family homes, distribution of informed consents and cooperation agreements,
    - role in the CS RadonGPS project was also analyses of all collecting data, preparation of ppt presentations, management of cooperation to the Secondary construction school in Banská Bystrica, dissemination of the project results and financial management of the project
- Roman Rabenseifer
    - representative of Faculty of Civil Engineering at the Slovak University of Technology in Bratislava, the CS RadonGPS project stakeholder
    - associated professor at Department of Building Construction, Faculty of Civil Engineering at the Slovak University of Technology in Bratislava
    - actively participated in two IAEA radon workshops focusing on the radon remedial measures
    - role in the CS RadonGPS project was to lead the students of the Secondary School of Construction in Banská Bystrica in designing tailor-made radon remediation projects and evaluating these projects, active participation in the dissemination of the project results and the preparation of research publications from the project's conclusions
    - role in the CS RadonGPS project was also analyses of all collecting data as an expert, preparation of ppt presentations to the students and teachers of the Secondary construction school in Banská Bystrica
- Matúš Krajčík
    - representative of Faculty of Civil Engineering at the Slovak University of Technology in Bratislava as one of the stakeholders involved in the project

  - PhD student at Department of Building Construction, Faculty of Civil Engineering at the Slovak University of Technology in Bratislava, title of PhD thesis "Effect of heat recovery ventilation on reducing indoor radon concentration"
  - actively participated in IAEA radon workshop focusing on the radon remedial measures
  - role in the CS RadonGPS project was to lead the students of the Secondary School of Construction in Banská Bystrica in designing tailor-made radon remediation projects and evaluating these projects, active participation in the dissemination of the project results and the preparation of research publications from the project's conclusions
  - role in the CS RadonGPS project was also analyses of all collecting data as an expert, preparation of ppt presentations to the students and teachers of the Secondary construction school in Banská Bystrica
- Milan Ponický
  - representative of the Secondary construction school in Banská Bystrica as one of the stakeholders involved in the project
  - teacher and principal of the Secondary construction school in Banská Bystrica
  - had no experience with radon at the beginning of the project
  - role in the CS RadonGPS project was recruitment of students and the management of other involved teachers, dissemination of the project results
- Katarína Puskailerová
  - representative of the Secondary construction school in Banská Bystrica as one of the stakeholders involved in the project
  - teacher at the Secondary construction school in Banská Bystrica
  - had no experience with radon at the beginning of the project
  - role in the CS RadonGPS project was recruitment and engagement of students as citizen scientists and/or as designer of tailor-made radon remediation projects in family houses, guidance of students during preparation of tailor-made radon remediation projects in family houses, organization and coordination of meetings, dissemination of the project results
  - had to learn how to design tailor-made radon remediation projects in cooperation with both experts from Department of Building Construction, Faculty of Civil Engineering at the Slovak University of Technology in Bratislava
- Igor Šalko
  - representative of citizen scientists and local municipalities as one of the stakeholders involved in the project
  - had no experience with radon at the beginning of the project
  - role in the CS RadonGPS project was recruitment and engagement of citizen scientists, organization of meetings, evaluation of data from radon activity concentration measurements in cooperation with experts from non-governmental organization NatuRadon, dissemination of the project results
- Martina Šalková
  - representative of citizen scientists and local municipalities as one of the stakeholders involved in the project
  - had no experience with radon at the beginning of the project
  - role in the CS RadonGPS project was recruitment and engagement of citizen scientists, organization of meetings, evaluation of data from radon activity concentration measurements in cooperation with experts from non-governmental organization NatuRadon, dissemination of the project results

6.3 Citizen engagement

All members of the core team were helpful to citizen scientist’s engagement.

6.3.1 *Role of citizen scientists*

The main participants of the project were citizen scientists from the municipalities around the town of Banská Bystrica and students of Secondary construction school in Banská Bystrica.

Citizen scientists from the municipalities around the town of Banská Bystrica were involved in the distribution of detectors, evaluation of data from measurements by active detectors by their own decision, evaluation of data from measurements by passive detectors, cooperation with students of Secondary construction school in Banská Bystrica during the design of tailor-made radon remediation projects for the property, communicating their questions with experts.

The CS RadonGPS project was managed as “Distributed intelligence” and citizen scientist on gathering all data from the project (Annex 5 to 10) and analysing data during personal communication not only with experts by also between members of their community. For us, as key stakeholders, it was very interesting to watch how citizen scientists advise each other when using student projects, for example, how to properly ventilate (remediate) the house (remediate) when the floor covering in the house is being replaced. Citizen scientists among the students will continue to disseminate the results of the project in their future careers as professionals in the field of construction.

6.3.2 *Recruitment process*

We started disseminating information about the project in September 2023 by actively participating in the European Night of Researchers in the town of Banská Bystrica. Two roll up banners (Annex 1 and Annex 2) and demonstration of the radon measurement by active detectors were presented. **Figure 15** shows the program of all moderated lectures on the stage of the European Night of Researchers in the city of Banská Bystrica. The scientific stand of the CS RadonGPS project at the European Night of Researchers in Banská Bystrica in September 2023 is shown in **Figure 16**.

Before we organized the kick-off meetings, we had several meetings with the mayor of Poniky and also with representatives of Secondary construction school in Banská Bystrica.

After the meetings, we prepared leaflets, invitations to kick-off meetings (Annex 3 Annex 4), the mayor of the village of Poniky helped us by distributing invitations in the village of Poniky, Ponická Lehôtka and Ponická Huta. The mayor of the village of Poniky also invited citizens to the kick-off meetings through the local public address system. Despite the mentioned activities, we had little response from the citizens and therefore we started inviting citizens personally kick-off meeting. **Figure 17** captures the presentation of the CS RadoGPS project during the meeting at Ponická Lehôtka.

The recruitment of students from the Secondary Construction School in Banská Bystrica required a different approach. We understood that first we have to convince the teachers of the school about the meaning of the project. We had to explain the radon issue to the teachers and that they too can benefit from participating in the project and not only the students. **Figure 18** captures a presentation from student recruitment.

In the end, we managed to get 50 citizen scientists, of which 14 were students. Most of them persevered from beginning to end, i.e. 47. One student withdrew from the project because the father ultimately disagreed. This student was from a divorced family and communication with her parents was problematic from the beginning. One student returned passive detectors unpacked and was not interested in active ones. One citizen scientist, that was not a student, placed the detectors in inappropriate rooms.

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Figure 15. Program of presentations on stage during the European Night of Researchers in the town of Banská Bystrica

Figure 16. Scientific stand of the CS RadonGPS project at the European Night of Researchers in Banská Bystrica in September 2023

Figure 17. Presentation of the CS RadoGPS project during the meeting at Ponická Lehôtka.

Figure 18. Recruitment of students of the Secondary construction school in Banská Bystrica

6.3.3 Motivation of participants

A strong motivation for all citizen scientists was that they learned during the kick off meetings about the gas that is everywhere around us, is harmful to health and can increase the risk of lung cancer. They were most surprised that they definitely have radon in their house as well and that within the project they can provide measurements of the indoor radon activity concentration at their houses. At the beginning of the project, they did not take cooperation in the implementation of remedial radon measures very seriously.

The information that they will participate in a project financed by the European Union was also a strong motivation. They had never heard the term citizen science before and we had to explain to them what it is. The motivation for the citizens was also the fact that they would meet more and communicate with each other more.

It was a strong motivation for the students of Secondary construction school in Banská Bystrica that their teachers promised them that their tailor-made radon remediation projects for a family house would be accepted as a final project at school.

The citizen scientists were engaged throughout the project by maintaining new information about the progress of the project on the web interface of non-governmental organization NatuRadon, e.g. the date of publication of videos on YouTube, current results from measuring the concentration of indoor activity with active radon detectors.

We also created a Facebook profile for the project, but without a response.

For citizen scientists, face-to-face communication, communication via mobile phones was very important. The citizen scientists appreciated that the experts were willing to communicate with them even in the afternoon after their working hours.

The teachers of Secondary construction school in Banská Bystrica also appreciated that the experts were willing to explain the radon issue in ad doc communications and via SLIDO. SLIDO is an online interaction platform that helps engage participants with live polls and quizzes, collect feedback from meeting participants, and instantly visualize and analyse the results.

Students of the Secondary School of Construction in Banská Bystrica participated with their tailor-made radon remediation projects “Radon in family house” in the competition of Secondary Schools within the Banská Bystrica self-governing region, where they took 2nd place and advanced to the national round. In the national round they took 6th place (**Figure 19**). We also presented the project during the online webinar about citizen science projects on 24.10.2023 that was organized by CVTI in the town of Bratislava, at the student conference ENERGOINFO 30.11.2023 in Banská Bystrica, at CONECO RACIOENERGY 20.04.-23.04.2024 in Bratislava (**Figure 20**).

Figure 19. Completion of Secondary School within the Banská Bystrica self-governing region

Figure 20. The CS RadonGPS project at an exhibition CONECO RACIOENERGY 2024 in Bratislava

6.4 Results

6.4.1 *Behavioural and socio-cultural impact*

All stakeholders, citizen scientists, students, teachers of Secondary construction school in Banská Bystrica as well as citizens of the participating municipalities profiled either from direct participation in the project or from observing their fellow citizens who directly participated in the project.

Citizen scientists greatly appreciated that they could measure radon themselves using active detectors and that measuring and evaluating the data from these measurements is useful for them because they could observe how the concentration of radon in the indoor air of buildings changes quickly, for example, one participant said that she changed her behaviour and started to ventilate their bedroom more intensively every morning and evening, the second participants were surprised how quickly their radon concentration increased during the weekend when their house was closed and after the abbot's return it quickly decreased with intensive ventilation.

During the final meeting in Ponická Huta, the citizen scientists appreciated that the student projects along with the calculation of the costs of radon remedial measures will be available on the web interface of non-governmental organization NatuRadon. Right after the meeting, one citizen scientist borrowed an active radon detector because he is going to remodel the bathroom and wants to do it in such a way that he does not needlessly increase the indoor radon activity concentration in the house.

Thanks to our idea of handing over the results of indoor radon measurements to citizen scientists during the final meetings in blue envelopes decorated with pearl white ribbon, we managed to raise awareness about lung cancer in this way as well. **Figure 21** shows the handover of the results of indoor radon measurements to citizen scientists at Secondary construction school in Banská Bystrica.

Figure 21. Handing over the results of indoor radon measurements to students at the final meeting at the Secondary construction school in Banská Bystrica

During the implementation of the project in relation to the students who designed a tailor-made project, after consultation with all stakeholders in the project, we decided not to organize a competition for the students, but to reward them in such a way that we are able to apply the principles of an inclusive society, i.e. all pupils were equally rewarded in the form of a voucher for a free purchase of their choice in the shopping centre.

On June 5, 2024, with the help of a colleague from the Faculty of Wood Sciences and Technology at Technical University in Zvolen, we organized a demonstration of a blower door test together with indoor radon measurement in a newly built wooden house in the village of Pitelová for students of Secondary construction school in Banská Bystrica and their teachers that were involved in CS RadonGPS project.[14] It was the first experience with such a test for both the students and their teachers.

6.4.2 Outputs

The outputs of the project are available on the web interface of non-governmental organization NatuRadon[15] where it is possible to find the results of indoor radon measurements with passive and active detectors in family houses in an anonymized form and also all tailor-made radon remediation projects along with the calculation of the costs of radon remedial measures

Example of indoor radon measurements with active radon detector in house no. 3 is shown in **Figure 22**. Results of indoor radon measurements with passive radon detectors in all family houses are shown in **Figure 23**.

[14] https://df.tuzvo.sk/sk/meranie-radonu-v-drevostavbach
[15] https://www.naturadon.sk

Indoor radon measurements were done in family houses within the Banská Bystrica self-governing region (**Figure 24**). Example of the tailor-made radon remediation project is shown in **Figure 25**. All data are openly available on the web interface of non-governmental organization NatuRadon.

We have got positive feedback from all citizen sciences.

IAs for mitigating radon, several of the citizen scientists involved in the project intend to do so on their own using tailor-made radon remediation projects along with the calculation of the costs of radon remedial measures.

Associate professor Rabenseifer from Faculty of Civil Engineering at the Slovak University of Technology in Bratislava in terms of research recommendations is intent to add results of the project to the basic education to his students.

We plan to disseminate results of the project in online magazines Eurostav and Drevársky magazín and through active participation in European Researcher´s night that will take place in the town of Banská Bystrica in September this year. All stakeholders who were involved in the project will prepare at least one current article on the results of the project.

We are going to produce at least one podcast about the results of the project and we have also been promised space on Regina radio. In addition to the above, we also want to offer the results of the project for the needs of the National Radon Action Plan of the Slovak Republic.

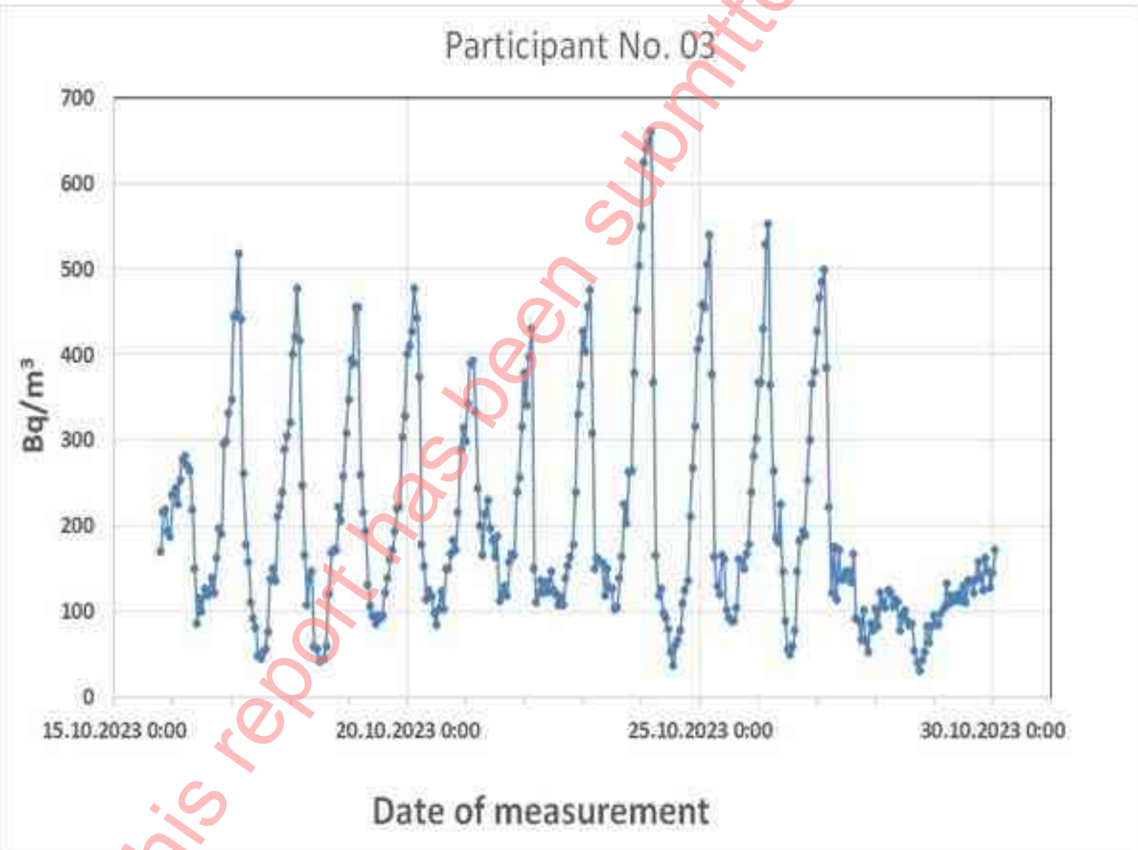


Figure 22. Example of indoor radon measurements with active radon detector in family house no. 3

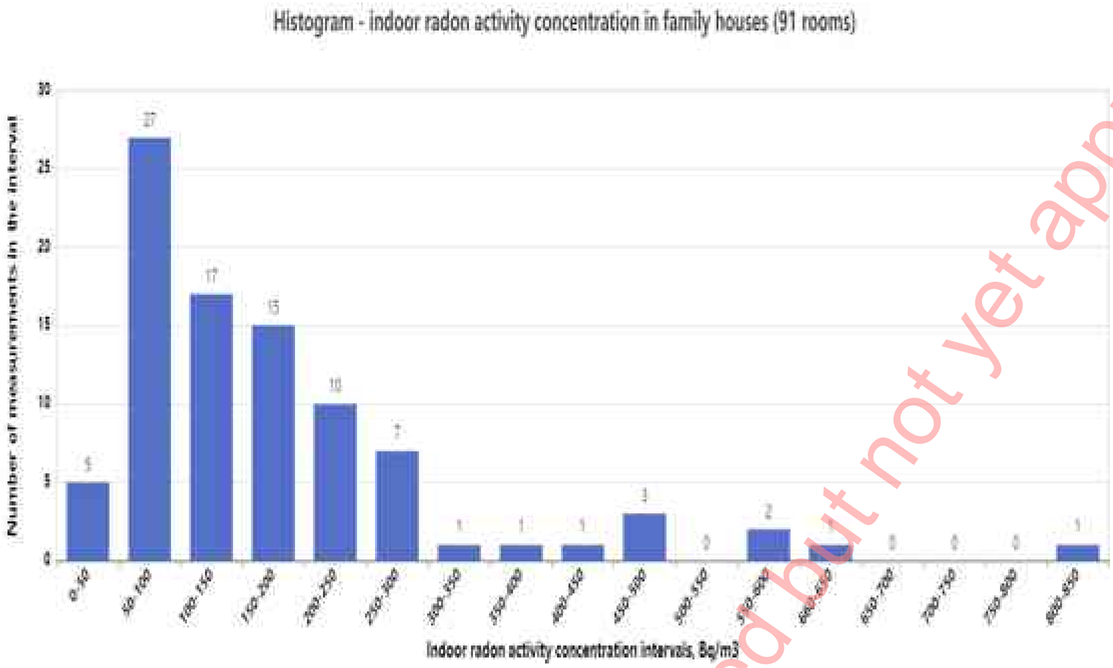


Figure 23. Results of indoor radon measurements with passive radon detectors in all family houses

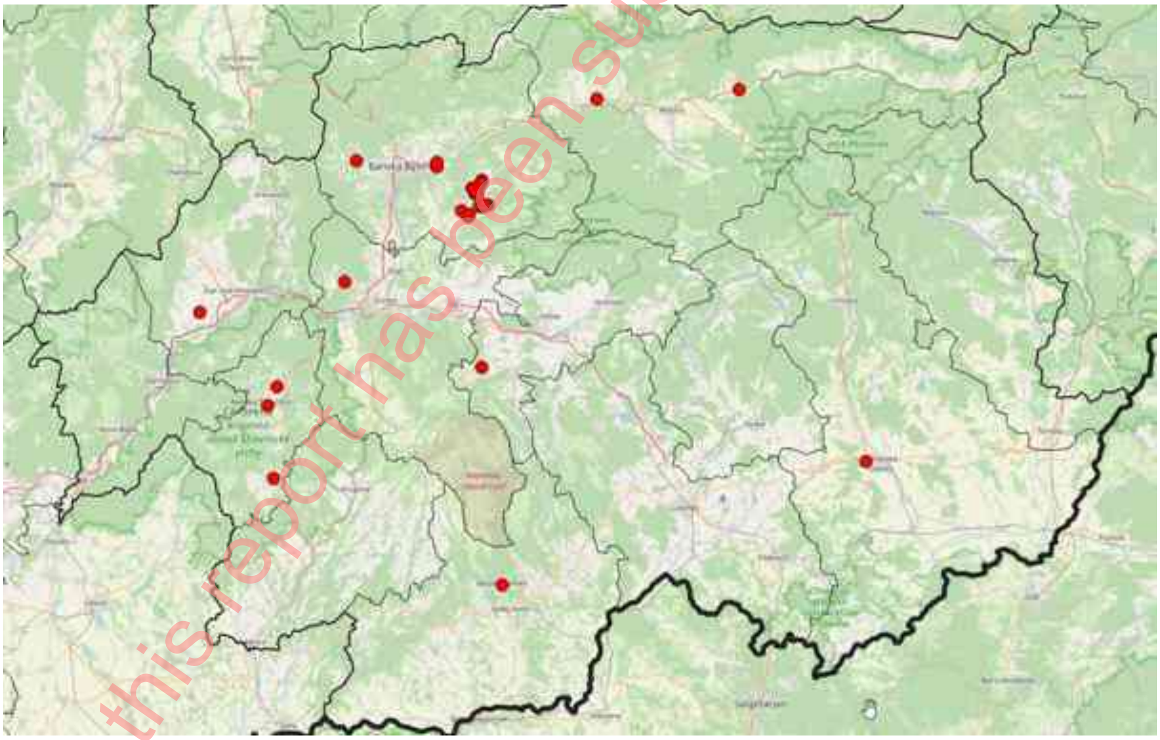


Figure 24. Distribution of indoor radon measurements in family houses within the territory of Banská Bystrica self-governing region

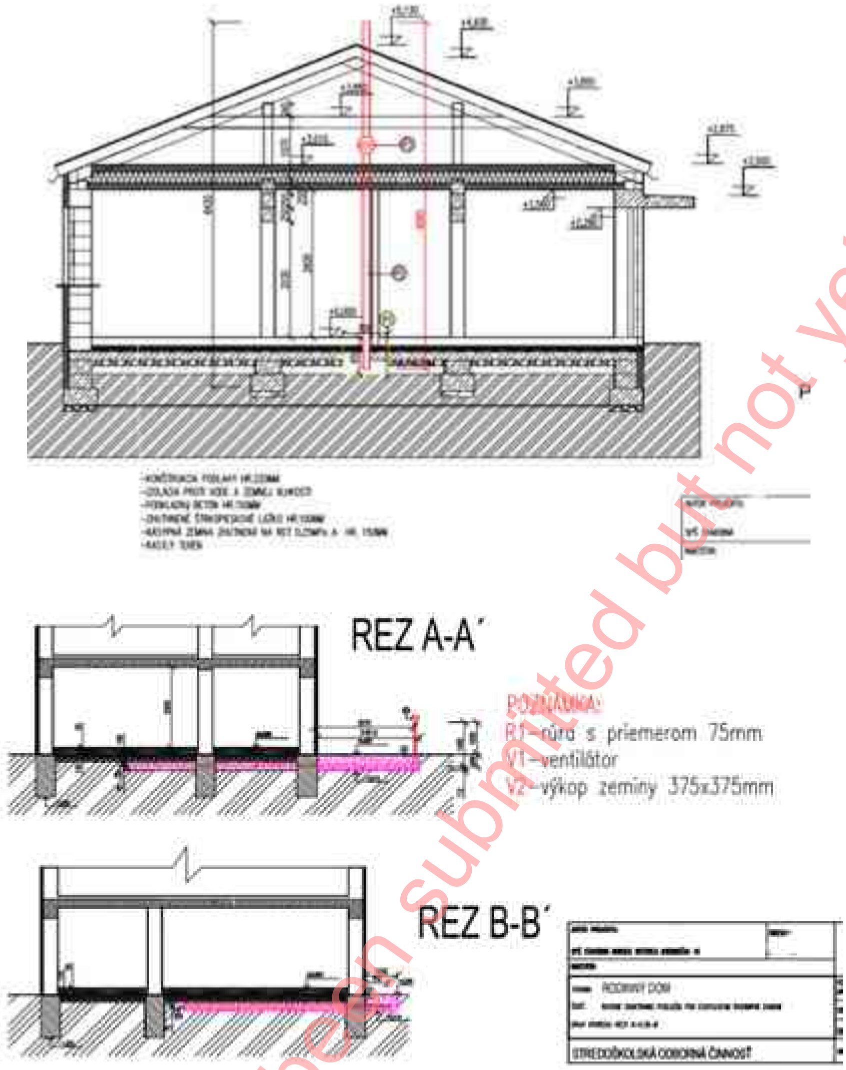


Figure 25. Example of the tailor-made radon remediation project

6.5 Evaluation of the citizen science project

Citizen scientists from the ranks of citizens and students of Secondary construction school in Banská Bystrica were involved in the CS RadonGPS project.

Citizen scientists among citizens appreciated that they could measure radon independently with active radon detectors and also that with the help of experts they were able to evaluate the radon situation at house. They also appreciated that they have up-to-date information about radon available on the web interface of non-governmental organization and that they have student projects available along with cost calculations for possible radon remedial measures. The majority of citizen scientists expressed that they are going to do radon remediation measures on their own in the houses they live in.

Citizen scientists among students of Secondary construction school in Banská Bystrica evaluated their participation as motivation for their further future at universities. One of the students commented that he told his father at home that he can already implement radon remedial measures in their house, he already has the project.

An expert from non-governmental organization NatuRadon as a key coordinator of the project concluded that the most complicated was the development and rapid updating of communication strategies towards other stakeholders and citizen scientists involved in the project.

6.6 Main conclusions and final reflections

All results of the project are available on web interface of the key stakeholder NatuRadon. NatuRadon will offer all the results of the project to the National Radon Action Plan of the Slovak Republic. All openly available data of the CS RadonGPS project will be shared with representatives of local/regional and national authorities such as local governments and Regional Public Health Offices of the Slovak Republic during the implementation of the National Radon Action Plan of the Slovak Republic.

The main financial resources of non-governmental organization NatuRadon are membership contributions, donations, crowdfunding, grants, which are used in accordance with the statutes of the NatuRadon, i.e. for the promotion of radon issues in the Slovak Republic.

The planned duration of the project for 6 months was very short, therefore we recommend to plan the duration of the project for at least 1 year when implementing other similar projects.

Updating the web interface with the results of the project was also a big challenge for the non-governmental organization NatuRadon.

6.7 Way forward

Excluding emergency radiation exposure and those received in radiation therapy the largest and most variable component of dose to the public is due to exposure to the naturally occurring radioactive gas radon and its progeny in their homes.

We plan to disseminate results of the project in online magazines Eurostav and Drevársky magazín and through active participation in European Researcher´s night that will take place in the town of Banská Bystrica in September this year. All stakeholders who were involved in the project will prepare at least one current article on the results of the project.

As mentioned above, some citizen scientists intend to implement radon remediation measures in their homes themselves using the students projects now available on the web interface of non-governmental organization NatuRadon.

6.8 Resources

The RadonGPS project proposal included the budget shown in **Table 11** and the main financial expenditures are shown in **Table 12.**

Table 11. RadonGPS project proposal budget

Cost category	Cost over 6 months (euros)	Overhead (25%) (euros)	Total in euros
Personnel	4000,-	1000,-	5000,-
Travel	8000,-	2000,-	10000,-
Equipment	0,-	0,-	0,-
Other goods and services	8000,-	2000,-	10000,-
Subcontracting	0,-	n/a	0,-
		Grand total in euro	25000,-

Table 12. RadonGPS main financial expenditures

Cost category	Description of the main expenditure	Total in euros
Personnel	Reward to experts and project coordinators	5000,-
Travel	Core team members travel reimbursement, experts travel reimbursement, transport costs for student excursion	5220,-
Equipment	N/A	0,-
Other goods and services	Pasive and active detectors	4143,-
	Printing, photocopying, amenities etc.	1062,-
	Refreshments for the meetings, room rental	497,-
	Students project awards (a gifts in kind)	950,-
	Consultancy services for data evaluation and their presentations on web	5070,-
	Medical advisory and lecturing services OrtopediBB NGO	2000,-
	Video editing services	1000,-
Subcontracting	N/A	0,-
Grand total in euro		**24942,-**

In the project proposal, we considered an excursion for students to the Czech Republic, where they would learn about the practical implementation of radon remedial measures in the kindergarten building. At the student recruitment stage, the students' parents expressed their disapproval of the foreign excursion. Unused funds for travel were therefore used for consultancy services for data evaluation and their presentations on the web interface. It turned out that the value of these auxiliary services was underestimated in the original budget.

6.9 References

Mc Laughlin, J. Risk Communication as a Strategic Tool to Raise Awareness of Radon Health Effects and to Reduce Exposures of the Public, Radiation Emergency Medicine 2012, Vol. 1 No. 1-2, s-6

Cori, L.;Curzio,O.;Donzelli.G.;Bustafa,E.;Bianchi.,F.; A Systematic Review of Radon Risk Perception, Awareness and Knowledge Risk Communication Options, Sustainability 2022, 14, 10505

Tsapalov, A.; Kovler, K; Studying temporal variations of indoor radon as a vital step towards rational and harmonized international regulation, Environmental Challenges 4 (2021) https://doi.org/10.1016/j.envc.2021.100204

Tsapalov, A.; Kovler, K; Short- versus long-term tests of indoor radon for risk assessment by Monte-Carlo method towards effective measurement strategy, Indoor Air. 2022; 32:e13166 https://doi.org/10.1111/ina.13166

Web interface of Faculty of Civil Engineering at the Slovak University of Technology in Bratislava https://www.svf.stuba.sk/sk/zivot-na-fakulte/aktuality/spolupraca-so-strednymi-skolami-na-projekte-horizon.html?page_id=9940 (in Slovak)

Web interface of Faculty of Wood Sciences and Technology at Technical University in Zvolen https://df.tuzvo.sk/sk/meranie-radonu-v-drevostavbach (in Slovak)

Web interface of Secondary construction school in Banská Bystrica https://stavebnabb.edupage.org/news/ (in Slovak)

Web interface of non-governmental organization NatuRadon https://www.naturadon.sk/ (in the Slovak language and the measurement results also in the English language)

6.10 Annexes

In the framework of the development of the CS project RadonGPS in the Slovak Republic, a number of documents have been created. These documents are listed below as Annexes in the order in which they were created.

Annex 1 Roll up banner Basic information about radon (in Slovak)

Annex 2 Roll up banner Basic information about the CS project RadonGPS (in Slovak)

Annex 3 Leaflet for the kick off meeting at Poniky (in Slovak)

Annex 4 Leaflet for the kick off meeting at Ponická Huta (in Slovak)

Annex 5 Informed consent to the processing of personal data of the property owner (citizen)

Annex 6 Annex 6 Cooperation agreement (citizen)

Annex 7 Informed consent of the student´s legal representative to the processing of the student´s personal data

Annex 8 Informed consent of the student´s legal representative on the student´s participation in the RadonGPS project

Annex 9 Record form for measurement with active radon detector RadonEye

Annex 10 Record form on the location of Radonová's passive radon detectors and Record form of the character and use of the house

Annex 11 Example of indoor radon measurement results using passive radon detectors and/or active radon detector sent to a participant of the CS project RadonGPS (in Slovak)

Annex 12 Certificate for students about their active participation in the CS project RadonGPS (in Slovak)

Annex 13 Letter of thanks from the dean of the Faculty of Civil Engineering at the Slovak University of Technology in Bratislava to the director of the Secondary construction school in Banská Bystrica for active participation in the CS project RadonGPS (in Slovak)

Annex 14 Frequently asked questions with answers

Annex 15 One of the ppt presentations that was presented at the final meetings of the CS RadonGPS project (in Slovak)

6.10.1 Annex 1 Roll up banner Basic information about radon (in Slovak)

Annex 2 Roll up banner Basic information about the CS project RadonGPS (in Slovak)

6.10.2 Annex 3 Leaflet for the kick off meeting at Ponická Lehôtka (in Slovak)


RadoNorm
NatuRadon
RadonGPS
Pozvánka
OZ NatuRadon v spolupráci s obecným úradom Poniky Vás pozývajú na stretnutie k zlepšeniu Vášho bývania
14.10.2023 od 17:00 hod.
v kultúrnom dome v Ponickej Lehôtke.
Program:
• Čo je zdraviu škodlivý rádioaktívny plyn radón.
• Ako a odkiaľ sa dostáva do domov.
• Ako ho doma zmerať.
• Nápravné opatrenia proti radónu.
• Projekt RadonGPS - pomôžem sebe aj žiakom.
Počas stretnutia bude k dispozícii malé občerstvenie.
SvF, STU Bratislava
NatuRadon, občianske združenie
SPŠs
Obec
Občania
(Poniky, Ponická Huta, Ponická Lehôtka)
Žiaci Spojenej školy Kremnička BB
This project has received funding from the Euratom research and training programme 2019-2020 under grant agreement No 900009.

6.10.3 Annex 4 Leaflet for the kick off meeting at Ponická Huta (in Slovak)

RadoNorm NatuRadon RadonGPS

Pozvánka

OZ NatuRadon v spolupráci s obecným úradom Poniky Vás pozývajú na stretnutie spojené s bezplatnou distribúciou detektorov na meranie radónu

24.10.2023 od 18:00 hod.

v „Hutníckej krčme" v Ponickej Hute

Program:

- Čo je zdraviu škodlivý rádioaktívny plyn radón
- Ako a odkiaľ sa dostáva do domov
- Ako ho doma zmerať
- Nápravné opatrenia proti radónu
- Projekt RadonGPS - pomôžem sebe aj žiakom

This project has received funding from the Euratom research and training programme 2019-2020 under grant agreement No 900009.

6.10.4 Annex 5 Informed consent to the processing of personal data of the property owner (citizen)

Informed consent to the processing of personal data of the property owner

within the meaning of Article 6(1)(a) of Regulation (EU) 2016/679 of the European Parliament and of the Council on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC (General Data Protection Regulation) (hereinafter referred to as the "GDPR") and Act No. 18/2018 Coll. on the Protection of Personal Data and on Amendments to Certain Acts (hereinafter referred to as Act No. 18/2018 Coll.).

The undersigned, hereinafter referred to as the "Data Subject", hereby grants to non-governmental organization NatuRadon (hereinafter referred to as the "Operator"), Jazmínová 26, 974 04 Banská Bystrica, ID No. 54 257 697 in accordance with Article 19 of Act No. 18/2018 Coll.

Voluntary consent to the collection and processing of personal data

in the scope:

name ______________________________

surname ______________________________________

address ____

telephone ______________________________

email ______________________________

for the purpose of: the implementation of the RadonGPS project – " How future building professionals can help remove barriers for citizens to take radon remedial measures ".

Duration of consent: The consent in question is granted for the duration of the purpose, i.e. October 2023 to March 2024. According to Section 14 of Act No. 18/2018 Coll., the data subject has the option to revoke it at any time in writing and/or electronically. The consent in question will be kept with Operator in paper form for a period of five years from the completion of the project.

Operator's declaration:

Operator declares that it will not publish, disclose or provide the personal data of the data subject to third parties, except in cases of waiver of confidentiality pursuant to Section 79 (3) of Act No. 18/2018 Coll. Personal data will not be transferred to other countries outside the European Union and also outside the territory of the Slovak Republic. Documents with personal data will be disposed of after the end of the purpose of processing, with the exception of those that must continue to be stored in accordance with the applicable legislation of the Slovak Republic.

Mandatory information:

The processing of personal data is governed by the GDPR and Act No. 18/2018 Coll. I am aware of my rights, which are listed in Articles 12 to 23 of the GDPR and in Articles 14, 21 to 24 and 100 of Act No. 18/2018 Coll., which regulate or specify the obligations of the controller in exercising the rights of data subjects.

In ....

Date .... signature of the person concerned

Annex 6 Cooperation agreement (citizen)

Cooperation agreement

concluded according to Article 51 of Act No. 40/1964 Coll., the Civil Code, as amended

Article I.

Parties to the agreement

Non-governmental organization:	NatuRadon,
Registered office:	Jazmínová 26, 974 04 Banská Bystrica
Represented by:	RNDr. František Ďurec, Statutory representative
Company ID:	54 257 697
Email:	info@naturadon.sk

(hereinafter referred to as the „NatuRadon“)

and

Name and surname:

Permanent residence:

Email:

(hereinafter referred to as the „Partner“)

agreed to cooperate with each other as follows:

Article II.

Subject of the agreement

1. With this agreement, NatuRadon and Partner regulate mutual rights and obligations for the purpose of implementing the RadonGPS project - "How future building professionals can help remove barriers for citizens to take radon remedial measures". The RadonGPS project is implemented as a CS project and its organizer is the non-governmental organization NatuRadon.

Article III.

Time and place of implementation

1. This Agreement shall be concluded for a fixed period for the period from October 2023 to March 2024.
2. The place of implementation of the subject of the agreement is a permanently inhabited property owned by the Partner.

Article IV.

Obligations and rights of the Partner

1. The Partner understands that participation in the project is unclaimable, exclusively voluntary, without coercion and at his/her own responsibility.
2. The Partner undertakes to carry out a measurement of the radon in their permanently inhabited property according to the recommendations and instructions of NatuRadon. The Partner will perform a measurement with passive radon detectors for three months and a measurement with an active radon detector for two weeks.
3. The Partner or his/her family member will carry out measurements independently according to NatuRadon instructions after training in the operation and placement of detectors. The training will be carried out by a member of NatuRadon or a person authorized by him.

4. The Partner has the right to consult with NatuRadon about radon measurement, its health effects and radon measures.
5. The Partner shall transmit the data from the measurements of radon by an active radon detectors to NatuRadon for further evaluation.
6. The Partner has the right to a copy of the data from the measurements with an active detector and their evaluation by their own means.
7. The Partner has the right to the results of measurements by passive radon detectors.
8. The Partner shall record the data necessary for the evaluation of the measurements and for their statistical processing in the form of a questionnaire provided by NatuRadon.
9. The Partner shall hand over the passive radon detectors to the NatuRadon representative without unjustified delay upon request or after three months from the receipt of the detectors.
10. The Partner shall hand over the active radon detector to NatuRadon representative without reasonable delay upon request or after two weeks from the receipt of the detector.
11. The Partner shall not hold the non-governmental organization NatuRadon liable for any risk associated with the publication of the measurement results in his/her property by a person who is not a member of NatuRadon.

Article V.

Relationship between the Partner and other participants in the RadonGPS project

The Partner voluntarily, without pressure and on his/her own responsibility, declares that:

1. agrees, disagrees (cross out what doesn´t fit) with the publication of the measurement results in an anonymized form without the possibility of identifying the property and its owner,
2. agrees with the development of a project of tailor-made radon remediation projects for the property owned by the students of the Spojená škola, Kremnička 10, Banská Bystrica (future construction experts) in cooperation with experts from the Department of Building Construction, Faculty of Civil Engineering at the Slovak University of Technology in Bratislava.
3. provides, does not provide (cross out what doesn´t fit) for the development of a tailor-made radon remediation projects for the property in his/her possession the project documentation of the situation of the floor(s) in contact with the subsoil,
4. allows, doesn´t allow (cross out what doesn´t fit) for the development of a tailor-made radon remediation projects for the property in his possession to measure the situation of the floor(s) in contact with the subsoil to the representative of NatuRadon,
5. agrees, disagrees (cross out what doesn´t fit) with the publication of tailor-made radon remediation projects for the property in his/her possession in an anonymized form without the possibility of identifying the property and its owner.

Article VI.

NatuRadon obligations and rights

1. NatuRadon undertakes to provide the Partner with passive radon detectors and an active radon detector for radon measurement in their property free of charge in the form of a loan. In doing so, it takes into account the efficiency of the use of detectors and reserves the right not to provide detectors in justified cases.
2. NatuRadon will not hold the Partner responsible for unintentional damage to the detectors or failure of the detectors.
3. NatuRadon undertakes to train the Partner to operate the detectors and acquaints the Partner with the principles of detector placement.
4. NatuRadon undertakes to provide the Partner with expert consultations on radon measurement, its health effects and radon measures upon request.
5. NatuRadon shall immediately inform the Partner of the results of its measurements with passive radon detectors after receiving them from the company that analyzes the detectors.
6. NatuRadon undertakes to publish the results of measurements and tailor-made radon remediation projects only in anonymized form without the possibility of identifying the property and its owner.

Article VII.

Final provisions

1. The Agreement shall be drawn up in duplicate and each Participant shall receive one copy.
2. The Agreement may be amended only on the basis of a convention between NatuRadon and the Partner, in the form of a written amendment.
3. This Agreement shall enter into force on the day following the date of its signature by the Parties.
4. Personal data of data subjects are processed in accordance with Regulation 2016/679 of the European Parliament and of the Council on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, repealing Directive 95/46/EC (General Data Protection Regulation) and Act No. 18/2018 Coll. on the protection of personal data and amending certain acts.
5. The Contracting Parties declare that they concluded the Agreement voluntarily, that it was not concluded in distress under unfavourable conditions, that they have read the Agreement, that they have understood its content and, as a sign of agreement with its content, they shall sign it in their own hands.

In .... Date ....

....

NatuRadon Partner

6.10.5 Annex 7 Informed consent of the student´s legal representative to the processing of the student´s personal data

Informed consent of the student's legal representative to the processing of the student's personal data

within the meaning of Article 6(1)(a) of Regulation (EU) 2016/679 of the European Parliament and of the Council on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, repealing Directive 95/46/EC (General Data Protection Regulation) (hereinafter referred to as the "GDPR") and Act No. 18/2018 Coll. on the protection of personal data and on amendments to certain acts (hereinafter referred to as Act No. 18/2018 Coll.).

I, the legal representative (name and surname)*

Father:

Mother: ______________________________

the person concerned – the student (name, surname, date of birth, email, telephone number)

____

I hereby grant to non-governmental organization NatuRadon (hereinafter referred to as Operator), Jazmínová 26, 97404 Banská Bystrica, ID No. 54 257 697 in accordance with Section 19 of Act No. 18/2018 Coll.

Voluntary consent to the collection and processing of personal data of the data subject-student

in the scope of: name, surname, date of birth, email, telephone number

for the purpose of: implementing the RadonGPS project – " How future building professionals can help remove barriers for citizens to take radon remedial measures "

Duration of consent:

The consent in question is granted for the duration of the purpose, i.e. October 2023 to March 2024. According to Article 14 of Act No. 18/2018 Coll., the legal representative of the affected person-student has the option to dismiss him or her at any time in writing and/or electronically. The consent in question will be kept with Operator for a period of five years from the end of the project.

Operator's declaration:

Operator declares that it will not publish, disclose or provide the personal data of the data subject to third parties, except in cases of waiver of confidentiality pursuant to Article 79 (3) of Act No. 18/2018 Coll. Personal data will not be transferred to other countries outside the European Union and also outside the territory of the Slovak Republic. Documents with personal data will be disposed of after the end of the purpose of processing, with the exception of those that must continue to be stored in accordance with the applicable legislation of the Slovak Republic.

Consent to the preparation and publication of image documentation:

I agree I do not agree (cross out what doesn´t fit) with the creation of visual documentation from collective activities with the participation of the student during the implementation of the RadonGPS project.

I agree I do not agree (cross out what doesn´t fit) with the publication of image documentation from collective activities with the participation of the student during the implementation of the RadonGPS project for the purpose of promoting the RadonGPS project.

Mandatory information:

The processing of personal data is governed by the GDPR and Act No. 18/2018 Coll.

I am aware of my rights, which are listed in Articles 12 to 23 of the GDPR and in Articles 14, 21 to 24 and 100 of Act No. 18/2018 Coll., which regulate or specify the obligations of the controller in exercising the rights of data subjects.

In ______________________________ ____

Date ___________________________ ____

Signatures of legal representatives*

*In the case of one legal representative of the student, only one is required.

6.10.6 Annex 8 Informed consent of the student´s legal representative on the student´s participation in the RadonGPS project

Informed consent of the student's legal representative on the student's participation in the RadonGPS project

"How future building professionals can help remove barriers for citizens to take radon remedial measures"

October 2023 – March 2024

The student's parent or another his/her legal representative provided this consent on behalf of the student as a condition for the student's participation in the RadonGPS project, which is organized by non-governmental organization NatuRadon, with its registered office at Jazmínová 26, 974 04 Banská Bystrica, ID No. 54 257 697, registered in the list of non-governmental organizations maintained by the Ministry of the Interior of the Slovak Republic under the number: VVS/1-900/90-62795. References to the term "NatuRadon" in this agreement mean the NatuRadon non-governmental organization and all its members, employees, representatives, consultants, advisors and authorized persons.

About the project

The RadonGPS project " How future building professionals can help remove barriers for citizens to take radon remedial measures " is a CS project focused on measuring radon concentrations in the indoor air of family houses and on tailor-made radon remediation projects to citizens in cooperation with non-governmental organization NatuRadon, students and teachers of the Spojená škola, Kremnička 10, Banská Bystrica (hereinafter "Secondary School Kremnička"), employees of the Faculty of Civil Engineering at the Slovak University of Technology in Bratislava and citizens from the vicinity of Banská Bystrica. The task of the students of the Secondary School Kremnička is to measure the concentration of radon in their family houses or in the houses of their family members using passive and active radon detectors, which are purchased from the RadonGPS project. In addition to measuring and analysing the results, the student´s' task will also be to help find answers to questions related to the perception and awareness of radon risk and related to the obstacles that prevent the implementation of radon measures in family houses.For students of the Secondary School Kremnička as future experts in the field of construction, a call for proposals for tailor-made radon remediation projects in family houses will be announced during October 2023. The students will work on the projects under the guidance of teachers of the Secondary School Kremnička , employees of the Faculty of Civil Engineering at the Slovak University of Technology in Bratislava and representatives of NatuRadon. Students who participate in the RadonGPS project will be rewarded and a visit to a company that implements radon measures in buildings. The RadonGPS project will be implemented from October 2023 to the end of March 2024.

Project financing

The RadonGPS project is funded through the RadoNorm project (https://www.radonorm.eu/activities/radonorm-citizen-science), which received funding from the Euratom Research and Education Programme 2019-2020 under grant agreement No. 900009. The purchase of radon detectors for the implementation of the RadonGPS project will be paid from the funds allocated for the implementation of the RadonGPS project through non-governmental organization NatuRadon. Travel costs related to the implementation of the RadonGPS project will be covered from the funds allocated for the implementation of the RadonGPS project through non-governmental organization NatuRadon.

Conditions of participation

The student's legal representative and the student understands that participation in the project is exclusively voluntary, without pressure and at their own risk.

The student's legal representative agrees that the student will follow the instructions of NatuRadon when handling radon detectors borowed from NatuRadon.

NatuRadon Commitments

NatuRadon will provide students with passive and active radon detectors to measure radon in their family members' properties free of charge in the form of a loan. In doing so, it takes into account the efficiency of the use of detectors and reserves the right not to provide detectors in justified cases.

NatuRadon will not provide radon detectors for measurements in real estate from whose owners it will not have consent to perform measurements, use of the obtained results and information for the implementation of the project, consent to the publication of results in anonymized form and consent to the processing of personal data within the meaning of Article 6(1)(a) of Regulation (EU) 2016/679 of the European Parliament and of the Council on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, repealing Directive 95/46/EC (General Data Protection Regulation) (hereinafter referred to as the "GDPR") and Act No. 18/2018 Coll. on the Protection of Personal Data and on Amendments to Certain Acts (hereinafter referred to as Act No. 18/2018 Coll.").

NatuRadon is aware of the risks associated with renting detectors and will not hold the student responsible for unintentional damage to the detectors or failure of the detectors.

NatuRadon will train the project participant to operate the detectors and familiarize the project participant with the principles of detector placement.

NatuRadon will provide expert consultations for project participants in the field of radon measures and in the field of health protection against radon.

NatuRadon undertakes to process the personal data obtained from this informed consent in accordance with the requirements of the GDPR and Act No. 18/2018 Coll., and this informed consent will be stored by NatuRadon for a period of five years from the end of the project.

NatuRadon undertakes not to make and publish video and audio documentation with the student's personal data during the implementation of the project.

Contact details for additional information

NatuRadon, Jazmínová 26, 974 04 Banská Bystrica

RNDr. František Ďurec

E-mail: info@naturadon.sk

tel.: 0944 676 324

I, the legal representative (name and surname)*

Father: ___________________________

Mother: ___________________________

Student (name, surname, date of birth, email)

Name and surname: _______________________________________

Date of Birth: _________________

Email: ___________________________

I declare that I have been clearly informed of the above terms and conditions of the RadonGPS project and I agree that my child will participate in the RadonGPS project.

In _____________________ __________________________________

Date Signatures of legal representatives*

*In the case of one legal representative, only one is required.

6.10.7 Annex 9 Record form for measurement with active radon detector RadonEye

Dear Citizen,

Based on your interest and cooperation agreement, the non-governmental organization NatuRadon lends you an active radon detector for radon measurement in your house for about 2 weeks free of charge

The active radon detector allows you to examine the presence of radon in your home in more detail.

For one week , leave the active radon detector in one of the rooms where you also placed the passive radon detector. Preferably near it.

In the following days, use the active radon detector to explore the other rooms of the house at your discretion. Prefer rooms in contact with the subsoil (ground). We recommend measuring approximately 1 day in one room. Short measurements lasting up to 2 hours do not provide sufficiently reliable values and are often influenced by previous measurements. We recommend not ventilating rooms before and during the measurements.

The active radon detector must be positioned so that it is not near a window, heat source, water source, and more than 20 cm away from a TV, microwave, computer, and other electrical appliances. Place the active radon detector at a distance of more than 20 cm from the wall or floor. The ideal location of the active radon detector is at a height of one to two meters above the floor of the room. It can also be a lower in the bedroom, at the level of the head of a lying person.

Do not move, clean, or cover the active radon detector during measurement. The exception is the display, the light of which can be distructing at night.

The results will be used in accordance with the cooperation agreement for the needs of the CS project RadonGPS, which is funded by the European Commision through the RadoNorm project (https://www.radonorm.eu/activities/radonorm-citizen-science/).

In connection with the measurements and statistical evaluation of the measurements, we would like to ask you to fill in a short record of the measurements.

If you have any further questions, we will be happy to answer them.

Email: info@naturadon.sk

Thank you for your cooperation and for filling in the record.

More information can also be found on the web interface of the non-governmental organization NatuRadon (https://naturadon.sk/radongps/).

A. Record form for measurement with active radon detector RadonEye

We recommend that you carry out a continuous weekly measurement in one of the rooms where the passive radon detectors is located.

In other rooms, we recommend measuring for about 1 day.

Short measurements lasting up to 2 hours do not provide sufficiently reliable values and are often influenced by previous measurements.

The address of the measured house:

Name and surname of the contact person:

Room name	Start of measurement (hh:mm dd.mm.yyyy)	End of measurement (hh:mm dd.mm.yyyy)	Use of room (approx. hours/day)	Is there a Radonova detector in the room?	Are the floors and walls in contact with the subsoil?	Does this room have forced ventilation?
				Yes No *	Yes No *	Yes No *
				Yes No *	Yes No *	Yes No *
				Yes No *	Yes No *	Yes No *

				Yes No *	Yes No *	Yes No *
				Yes No *	Yes No *	Yes No *
				Yes No *	Yes No *	Yes No *
				Yes No *	Yes No *	Yes No *
				Yes No *	Yes No *	Yes No *
				Yes No *	Yes No *	Yes No *

* (cross out what doesn´t fit)

6.10.8 Annex 10 Record form on the location of Radonová's passive radon detectors and Record form of the character and use of the house

Dear Citizen,

Based on your interest and cooperation agreement, the non-governmental organization NatuRadon sends you passive radon detectors for radon measurement in your house.

Place passive radon detectors in the rooms where you spend most of your time (usually the bedroom, living room, children´s room, etc.). Passive radon detectors are harmless, which only served to passively record radon.

Passive radon detector must be positioned so that it is not near a window, heat source, water source, and more than 20 cm away from a TV, microwave, computer, and other electrical appliances. Place passive radon detector at a distance of more than 20 cm from the wall or floor. The ideal location of the passive radon detector is at a height of one to two meters above the floor of the room. If possible, place passive detectors in the middle of the room, e. g. hung on a chandelier. It can also be a lower in the bedroom, at the level of the head of a lying person.

Do not move or clean the detectors during the entire measurement period.

The detectors will be placed with you for approximately 3 months. After the measurement is finished, non-governmental organization NatuRadon sends the detectors to the detector manufacturer for evaluation.

After evaluating the detectors the results of the measurements will be delivered to you by non-governmental organization NatuRadon.

The results will be used in accordance with the cooperation agreement for the needs of the CS project RadonGPS, which is funded by the European Commission through the RadoNorm project (https://www.radonorm.eu/activities/radonorm-citizen-science/).

During the measurement with passive detectors, non-governmental organization NatuRadon will lends you an active radon detector for approximately 2 weeks, which allow you to examine the presence of radon in your home in more detail.

In connection with the measurements and statistical evaluation of the measurements, we would like to ask you to fill in a short questionnaire.

If you have any further questions, we will be happy to answer them.

Email: info@naturadon.sk

Thank you for your cooperation and for filling in the questionnaire.

More information can also be found on the web interface of the non-governmental organization NatuRadon (https://naturadon.sk/radongps/).

A. Record form on the location of Radonová's passive radon detectors

Name and surname of the person mentioned in the cooperation agreement:

1st room

Name of the room (e.g. living room, bedroom,...)		
Detector number		
Measurement start date (dd.mm.yyyy)		
Measurement end date (dd.mm.yyyy)		
Description of the detector´s placement in the room(e.g. cabinet, hanging on a chandelier, bedside table, etc.)		
Use of theroom by residents (approximately hours/day)		
Is the floor of the room or wall in contact with the subsoil(ground)?	Yes	No *
What materila are the walls of the room made of		
What material is the floor of the room made of		
Is the room ventilated in a forced way? (central ventilation, recuperation, etc.)	Yes	No *

* (cross out what doesn´t fit)

2nd room

Name of the room (e.g. living room, bedroom,...)		
Detector number		
Measurement start date (dd.mm.yyyy)		
Measurement end date (dd.mm.yyyy)		
Description of the detector´s placement in the room(e.g. cabinet, hanging on a chandelier, bedside table, etc.)		
Use of theroom by residents (approximately hours/day)		
Is the floor of the room or wall in contact with the subsoil(ground)?	Yes	No *
What materila are the walls of the room made of		
What material is the floor of the room made of		
Is the room ventilated in a forced way? (central ventilation, recuperation, etc.)	Yes	No *

* (cross out what doesn´t fit)

B. Record form of the character and use of the house

Village	
District	
Total number of household members	
Is the house built before 1992?	Yes No *
Does your house have a basement?	Yes No *
How many floors does your house have?	
What building materials are the walls of your house made of?	Bricks ☐ Blocks ☐ Wood ☐ Other:
Has your house been substantially renovated?	Yes No *
Has the windows been replaced on the house?	Yes No *
Do you have a central forced ventilation system installed in your house?	Yes No *
Has radon been measured in your house in the past? If you know, provide a numerical value	Yes No * Value:

* (cross out what doesn´t fit)

Thank you for your willingness and cooperation.

6.10.9 Annex 11 Example of indoor radon measurement results using passive radon detectors and/or active radon detector sent to a participant of the CS project RadonGPS (in Slovak)

NatuRadon RadonGPS

www.naturadon.sk *projekt občianskej vedy*

Výsledky meraní objemovej aktivity radónu v ovzduší

Miesto merania: *Identifikácia miesta*

Identifikácia na stránke www.naturadon.sk : ***Budova-18***

A. Výsledky merania pasívnymi detektormi (dlhodobé merania)

Miestnosť	a_{Rn} (Bq.m^{-3})	U_{Rn} (Bq.m^{-3})	**č. detektora**
spálňa	353	46	101081339
obývačka	83	14	101565349

a_{Rn} – priemerná objemová aktivita radónu v ovzduší, U_{Rn} - rozšírená neistota pre koeficient rozšírenia k = 2.

Na merania boli použité pasívne detektory stôp Radtrak[3] od firmy Radonova Laboratories (Švédsko).

Trvanie ožiarenia bolo cca 3 mesiace v zimnom období.

B. Výsledky merania aktívnymi detektormi (krátkodobé merania)

Miestnosť		a_{Rn} (Bq.m^{-3})	$a_{Rn,min}$ (Bq.m^{-3})	$a_{Rn,max}$ (Bq.m^{-3})
M01	spálňa	338,7	40	1003
M02	obývačka	354,8	35	982

a_{Rn} – priemerná objemová aktivita radónu v ovzduší, $a_{Rn,min}$ – minimálna objemová aktivita radónu, $a_{Rn,max}$ – maximálna objemová aktivita radónu

Na meranie bol použitý aktívny detektor radónu RadonEye od firmy FTLab (Kórea). Detektor zaznamenáva priemerné hodinové objemové aktivity radónu v ovzduší.

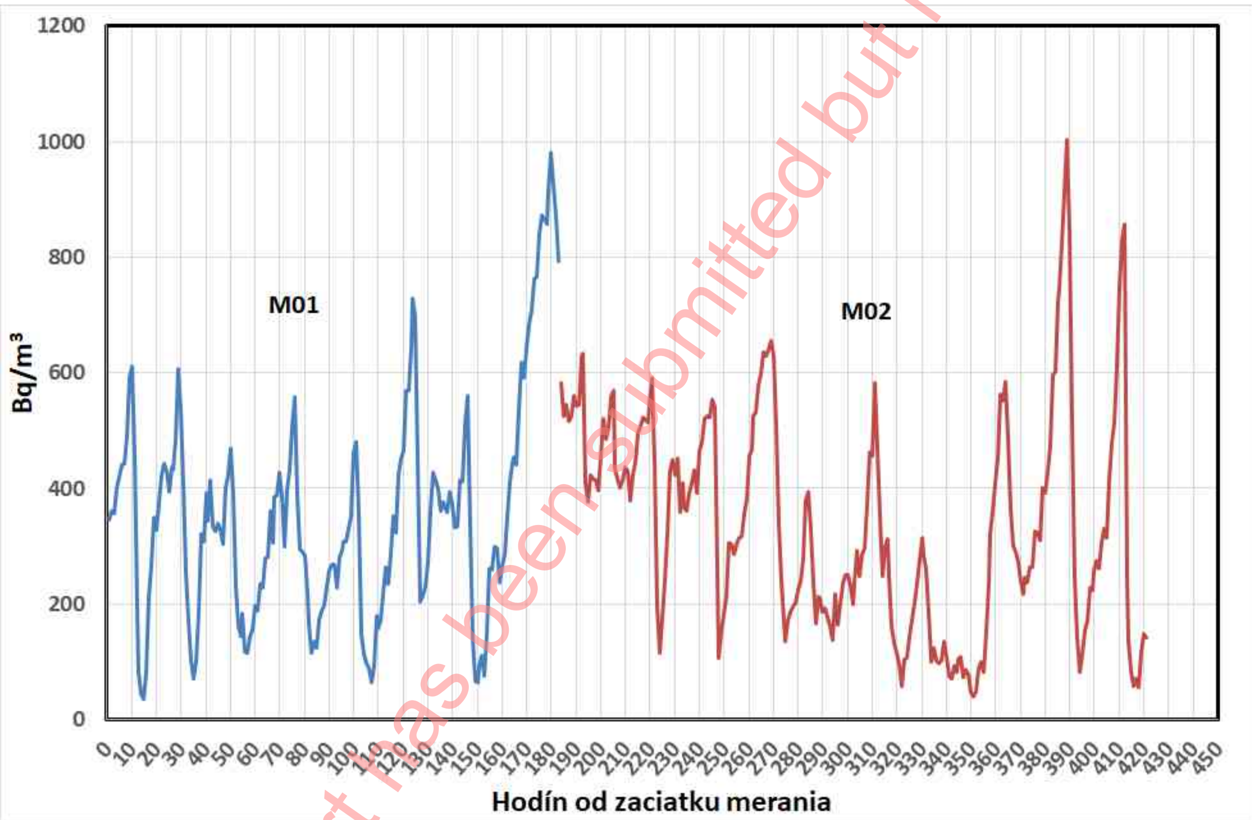
Zhodnotenie:

Podľa platnej legislatívy SR (zákon č. 87/2018 o radiačnej ochrane a o zmene a doplnení niektorých zákonov v znení neskorších predpisov) je **referenčná úroveň** pre objemovú aktivitu radónu a_{Rn} vo vnútornom ovzduší budovy počas pobytu osôb **v priemere za kalendárny rok 300 Bq.m^{-3}**. Referenčná úroveň je ustanovená za predpokladu, že priemerný občan sa doma zdržiava 7000 hodín ročne.

Z výsledkov dlhodobého merania pomocou pasívnych detektorov (v trvaní 3 mesiace v zimnom období) **sa nedá vylúčiť**, že priemerná celoročná objemová aktivita radónu a_{Rn} **v miestnosti spálňa** neprekročí referenčnú úroveň 300 Bq.m^{-3}. **Odporúčame** zvýšiť intenzitu vetrania v uvedenej miestnosti v čase pobytu obyvateľov, minimálne však na začiatku prítomnosti obyvateľov v miestnosti. Odporúčame tiež vykonať celoročné meranie v trvaní 12 mesiacov a stanoviť priemer objemovej aktivity za kalendárny rok a na základe výsledkov zvážiť ďalšie protiradónové opatrenia.

Merania objemovej aktivity radónu a_{Rn} pomocou aktívneho detektoru dokumentujú variabilitu objemovej aktivity radónu v meranej miestnosti, ktorá je závislá najmä od intenzity vetrania miestnosti. Merania pomocou aktívneho detektoru v trvaní cca 1 až 2 týždne nezohľadňujú dlhodobejšie zmeny a_{Rn} , ktoré sú ovplyvnené hlavne meteorologickými vplyvmi, ako napríklad zmenami vonkajšieho tlaku a teploty, zrážkami, vetrom a pod. Vzhľadom k týmto skutočnostiam je porovnanie referenčnej úrovne 300 Bq.m^{-3} s výsledkami meraní pomocou aktívneho detektoru spojené s rizikom nesprávnej interpretácie.

Priebeh nameraných objemových aktivít radónu v ovzduší



RadonGPS – projekt občianskej vedy

Cieľom projektu je podporiť spoluprácu medzi občanmi, ktorí sa zaujímajú o meranie radónu vo vnútornom ovzduší svojich rodinných domov a s pomocou budúcich stavebných odborníkov (žiakov a študentov) hľadať riešenia týkajúce sa nápravných protiradónových opatrení a vytvoriť voľne prístupnú databázu projektov zameraných na nápravné protiradónové opatrenia, ktorá bude k dispozícii na webovom rozhraní občianskeho združenia NatuRadon.

Projekt RadonGPS získal finančnú podporu z programu EURATOM Horizon 2020 pre výskum a odbornú prípravu prostredníctvom grantu č. 900009 s názvom RadoNorm.

Súvisiaca legislatíva:

Zákon č. 87/2018 Z. z. o radiačnej ochrane a o zmene a doplnení niektorých zákonov v znení neskorších predpisov.

Vyhláška MZ SR č. 57/2024 Z. z. o obmedzovaní ožiarenia pracovníkov a obyvateľov z prírodných zdrojov ionizujúceho žiarenia.

This project has received funding from the Euratom research and training programme 2019-2020 under grant agreement No 900009.

V Banskej Bystrici 24.04.2024

6.10.10 Annex 12 Certificate for students about their active participation in the CS project RadonGPS (in Slovak)


NatuRadon
STU SvF SLOVENSKÁ TECHNICKÁ UNIVERZITA V BRATISLAVE STAVEBNÁ FAKULTA
RadonGPS

CERTIFIKÁT

Žiak Spojenej školy, Kremnička 10, Banská Bystrica

Name Surname

sa aktívne podieľal návrhom protiradónových stavebných opatrení a meraniami radónu na riešení projektu občianskej vedy „RadonGPS"

doc. Ing. Peter Makýš, PhD
prodekan pre vzdelávanie a vnútorný systém kvality SvF STU

RNDr. František Ďurec
predseda občianskeho združenia NatuRadon

25.03.2024

6.10.11 Annex 13 Letter of thanks from the dean of the Faculty of Civil Engineering at the Slovak University of Technology in Bratislava to the director of the Secondary construction school in Banská Bystrica for active participation in the CS project RadonGPS (in Slovak)

SLOVENSKÁ REPUBLIKA
SLOVENSKÁ TECHNICKÁ UNIVERZITA V BRATISLAVE
STAVEBNÁ FAKULTA

ĎAKOVNÝ LIST

Vážený pán riaditeľ,

Dovoľujeme si Vám aspoň touto cestou vyjadriť našu vďačnosť za podporu projektu občianskej vedy s tematikou ochrany pred radónom. Spolupráca s Vašou Spojenou školou - Strednou priemyselnou školou stavebnou a Strednou odbornou školou stavebnou a SvF STU ako partnerom občianskeho združenia NatuRadon v rámci projektu RadonGPS bola pre nás veľmi cenná.
Zároveň by sme sa tiež chceli poďakovať nasledovným študentom Vašej spojenej školy za ich aktívnu účasť na projekte, na ktorom sa podieľali návrhom protiradónových stavebných opatrení a meraním radónu:

Bánik Matúš	Hrnčiarová Sára	Maliniak Lukáš
Dobšovičová Ľubica	Jelža Filip	Melicherčíková Lara
Fašková Ema	Katreniak Tomáš	Šimon Roman
Gnotová Kristína	Kružlicová Nikola	Slávíková Natália
Halama Pavol	Kubincová Ema	Trubianska Laura
	Kutliak Alan	

Vaša podpora nám umožnila realizovať tento dôležitý projekt, ktorý prispieva k informovanosti verejnosti o rizikách spojených s radónom a krokoch, ktoré môžeme podniknúť na jeho minimalizáciu. Veríme, že spoločne môžeme prispieť nielen k zlepšeniu životného prostredia a zdravia našich občanov, ale aj k výchove budúcich odborníkov v stavebníctve.

Ešte raz veľmi pekne ďakujeme za Vašu podporu a tešíme sa na ďalšiu spoluprácu.

doc. Ing. Peter Makýš, PhD.
prodekan pre vzdelávanie a vnútorný systém kvality

prof. Ing. Stanislav Unčík, PhD.
dekan

Vážený pán
PaedDr. Milan Ponický
Riaditeľ Spojenej školy
Kremnička 10
97405 Banská Bystrica

6.10.12 Annex 14 Frequently asked questions with answers

What is radon?

Radon is a tasteless, colorless, and odorless gas found all around us.

It is formed in the soil and rocks, from where it is released through cracks and leaks in the foundations of buildings and through openings around pipes into the indoor air. Radon can also be found in some building materials and groundwater.

Radon is one of the pollutants of indoor air in buildings.

Why is radon dangerous?

Prolonged exposure to radon may increase the risk of developing lung cancer.

There is always some amount of radon in the interior of your house. Radon is a major risk factor for lung cancer in people who have never smoked and the second most important risk factor for smokers.

The risk of developing lung cancer from radon can range from about 3% to 14%, depending on the average radon exposure in your home.

Where can I expect radon?

I can expect radon in all houses. The dominant source of radon in the Slovak Republic is the subsoil on which your house is built, and therefore you can expect a higher amount of radon in the underground spaces of your house or in areas that are in contact with the subsoil.

How do I know how much radon I have in my house?

The only way to find out how much radon you have in your home is to measure it.

Measuring radon in your home takes place by placing small passive radon detectors in the living room, bedroom, children's room, office for at least three months and then sending the detectors for evaluation. Such a service is provided by organizations that have a valid registration from the relevant regional public health authority.

Can I measure radon myself?

Yes, you can measure radon yourself with active radon detectors, which you can buy for just a few hundred euros. When choosing a suitable active radon detector, you can consult with various experts, such as members of the non-governmental organization NatuRadon (info@naturadon.sk).

How can I reduce the amount of radon in my house?

Before the construction of the building, preventive measures are carried out, the task of which is to prevent radon from penetrating into the indoor air.

In the existing building, corrective measures are being carried out to prevent radon from penetrating into the indoor air.

The basic measures to prevent the penetration of radon into the indoor air of buildings are radon barriers located in the foundations of the building, sufficient ventilation of the subsoil under the building, sealing of the part of the building that is in contact with the ground, creation of a vacuum in the soil and in the subsoil under the building.

Opening windows is only considered a temporary solution, as it is an ineffective solution for reducing the amount of radon in the house in the long run.

Both preventive and corrective measures are designed and implemented by experts in the field of construction.

I'm building a house, how do I prevent radon from entering my future house?

We recommend contacting an expert in the field of construction.

Do I have radon at work?

Yes, there is a certain amount of radon in every indoor air of a building as well as in the outdoor air. If he works in a building or your workplace is located underground, your employer is obliged to ensure the measurement of radon and the evaluation of the measurement results.

How are wooden houses doing?

The amount of radon in wooden houses also needs to be measured in order to take appropriate measures.

Is radon also in the school where my child attends?

Radon measurements in schools and kindergartens are required to be provided by the owner of the building.

Does radon affect my pet?

Yes, it has an impact. Several studies have been published that have demonstrated the effect of an increased risk of lung cancer in cats and dogs in areas where higher amount of radon have been measured in the indoor air of buildings.

What does the legislation of the Slovak Republic require?

The legislation of the Slovak Republic requires designers to propose such preventive measures so that the amount of radon in the indoor air of a building does not exceed the reference level of 300 $Bq.m^{-3}$ on average per calendar year.

The owner of an apartment building that has an underground floor or the first above-ground floor is obliged to ensure that radon is measured in indoor air within one year of the start of use of the building.

How are we doing in the European Union?

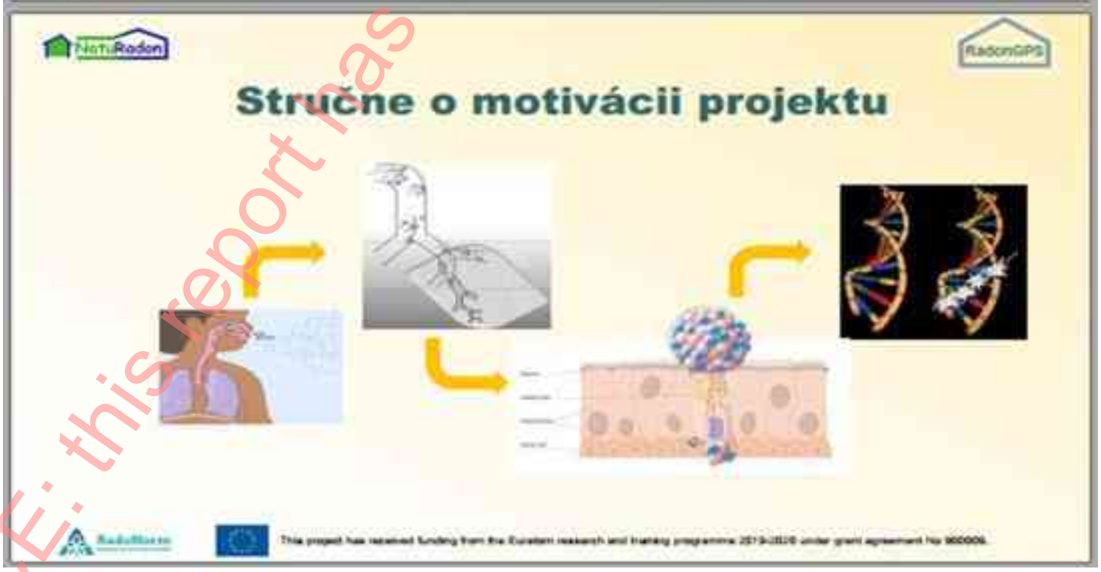
In European countries, malignant tumors are among the main public health problems.

In 2020, 2.7 million people were diagnosed with cancer in the European Union, and another 1.3 million, including more than 2000 young people, lost their lives as a result of one of these diseases. If no action is taken, the number of cancer cases will increase by 24% by 2035 and will be the leading cause of death in the European Union. About 40% of tumors are preventable. Prevention can prevent disease, save lives and reduce suffering.

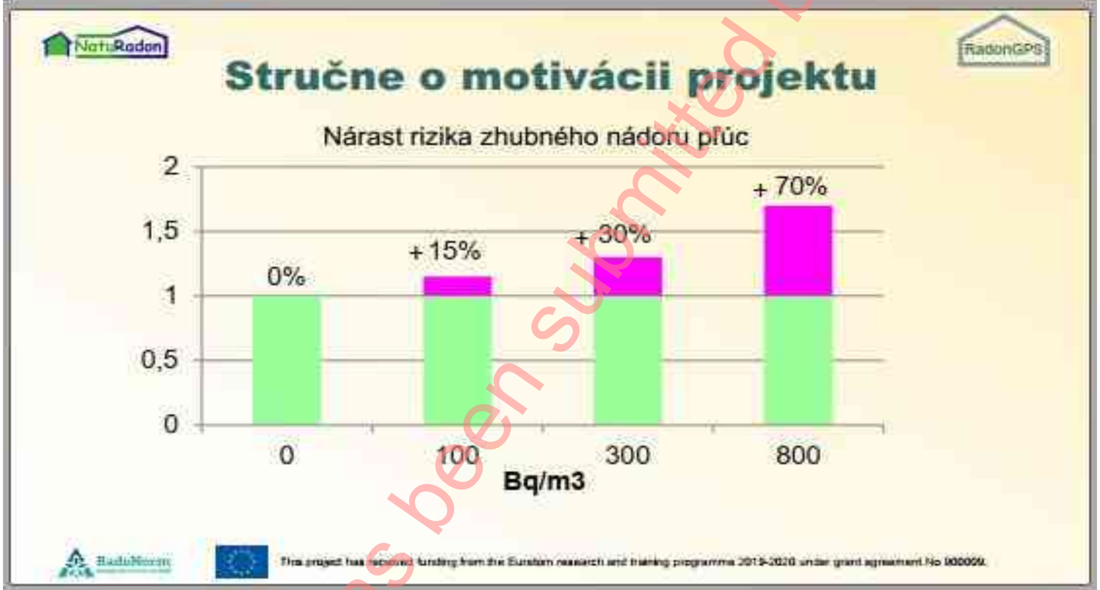
Annex 15 One of the ppt presentations that was presented at the final meetings of the CS RadonGPS project (In Slovak)


NaturRadon
RadonGPS
Zhodnotenie výsledkov projektu občianskej vedy RadonGPS
Ponická Huta 26.04.2024
RadoNorm


NaturRadon
RadonGPS
Stručne o motivácii projektu
Potraviny
12 %
Vonkajšie ožiarenie
20 %
Kozmické žiarenie
16 %
Radón
52 %
Ra
Rn
At
Po
Bi
Po
Pb
Pb
Tl
RadoNorm

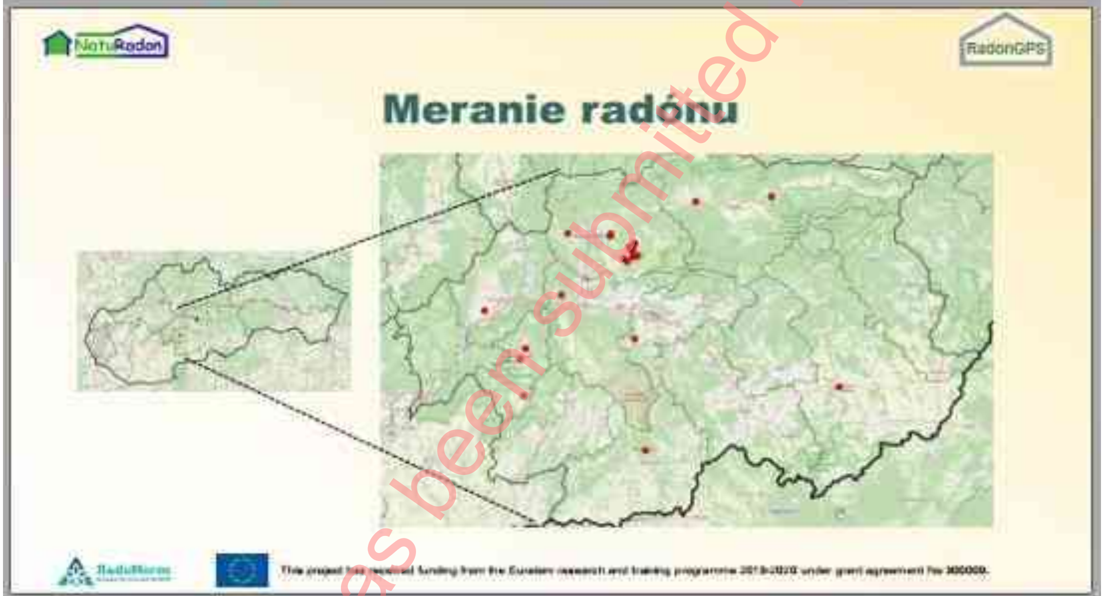

NaturRadon
RadonGPS
Stručne o motivácii projektu
RadoNorm


NatuRadon
RadonGPS
Stručne o motivácii projektu
Zdroje:
• Pôda
• Voda
• Stavebný materiál
RadoNorm
This project has received funding from the Euratom research and training programme 2019-2020 under grant agreement No 900009.


NatuRadon
RadonGPS
Stručne o motivácii projektu
Nárast rizika zhubného nádoru pľúc
2
1,5
1
0,5
0
0%
+ 15%
+ 30%
+ 70%
0
100
300
800
Bq/m3
RadoNorm
This project has received funding from the Euratom research and training programme 2019-2020 under grant agreement No 900009.


NatuRadon
RadonGPS
Ciele projektu
• Informovať o radóne
• Meranie radónu
• Vzdelávať budúcich stavbárov cez návrh protiradónových opatrení
SvF STU
NatuRadon
Škola
SŠ-SPŠ
Obec
Občianski vedci
žiaci a občania
RadoNorm
This project has received funding from the Euratom research and training programme 2019-2020 under grant agreement No 900009.

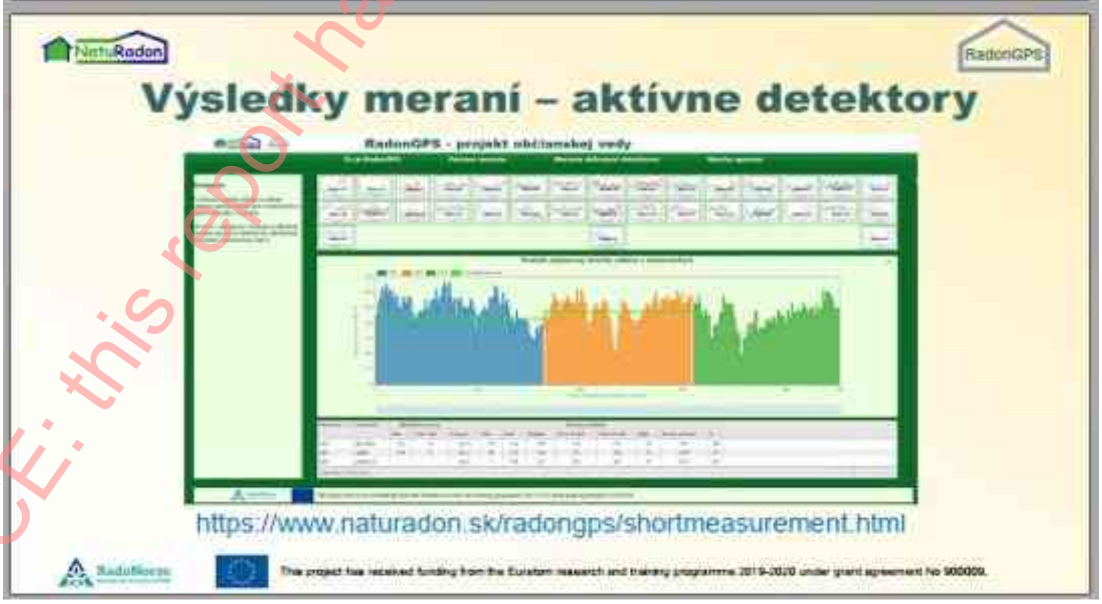

NatuRadon
RadonGPS
Meranie radónu
Aktívne detektory
(meranie cca 2 týždne)
Pasívne detektory
(meranie cca 3 mesiace)


NatuRadon
RadonGPS
Meranie radónu


NatuRadon
RadonGPS
Výsledky meraní – pasívne detektory
Zakúpených 100 ks detektorov Radtrak³ od Radonova
• 93 vyhodnotených, 91 v pobytových miestnostiach
• merania v 47 rodinných domoch
• 11 % miestností nad referenčnou úrovňou 300 Bq/m³
Minimum 16 Bq/m³
Maximum 850 Bq/m³
Priemer 177 Bq/m³


NatuRadon
RadonGPS
Výsledky meraní – pasívne detektory
RadonGPS - projekt občianskej vedy
https://www.naturadon.sk/radongps/pasivmeasurement.html
RadoNorm
The project has received funding from the Euratom research and training programme 2019-2020 under grant agreement No 900009.


NatuRadon
RadonGPS
Výsledky meraní – aktívne detektory
Krátkodobé merania (cca 2 týždne) detektorom RadonEye
• Meranie v 34 rodinných domoch
• Zmeraných 126 miestností
Minimum 4 Bq/m³
Maximum 1485 Bq/m³
RadoNorm
The project has received funding from the Euratom research and training programme 2019-2020 under grant agreement No 900009.


NatuRadon
RadonGPS
Výsledky meraní – aktívne detektory
RadonGPS - projekt občianskej vedy
https://www.naturadon.sk/radongps/shortmeasurement.html
RadoNorm
The project has received funding from the Euratom research and training programme 2019-2020 under grant agreement No 900009.

NatuRadon RadonGPS

Výsledky – návrhy opatrení

Realizovali žiaci Spojenej školy – SPŠ, Kremnička 10

Cieľ: Zvýšiť vzdelanosť budúcich stavbárov v problematike radónu

Odovzdaných 14 projektov protiradónových opatrení spolu s rozpočtom

- **13 pre existujúce stavby**
- **1 novostavba**

Jeden z projektov - 2. miesto v krajskom kole SOČ

This project has received funding from the Euratom research and training programme 2019-2020 under grant agreement No 900009.

NatuRadon RadonGPS

Výsledky – návrhy opatrení

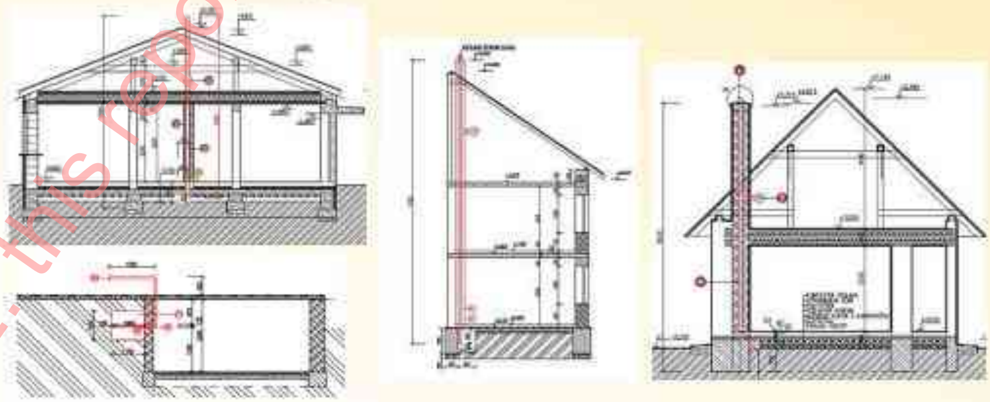
Vytvorenie odvetrávacej dutiny pod stavbou	5 prác	800 – 2100 €
Centrálna rekuperácia	2 práce	8000 – 11000 €
Odvetranie suterénu	2 práce	400 – 2100 €
Vytvorenie odvetrávanej medzivrstvy	1 práca	2300 €
Odvetranie podvŕtaním stavby	2 práce	1700 – 3000 €
Lokálne rekuperácie do miestnosti	1 práca	1700 €
Novostavba – odvetranie pod stavbu	1 práca	6000 €

V cenách nie sú náklady na elektroinštalácie

This project has received funding from the Euratom research and training programme 2019-2020 under grant agreement No 900009.

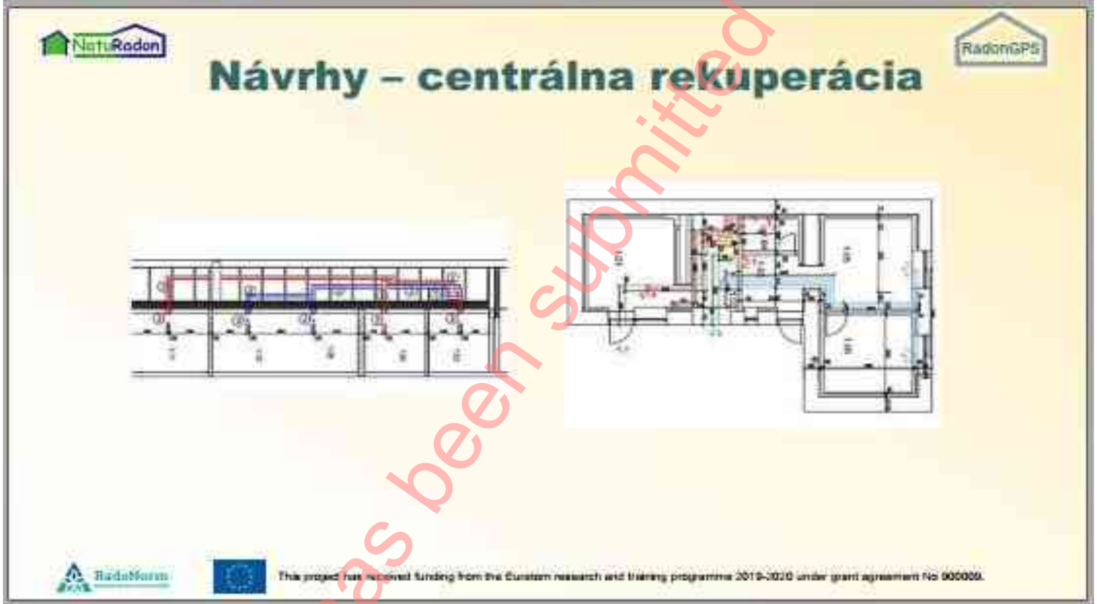
NatuRadon RadonGPS

Návrhy – odvetrávacia dutina

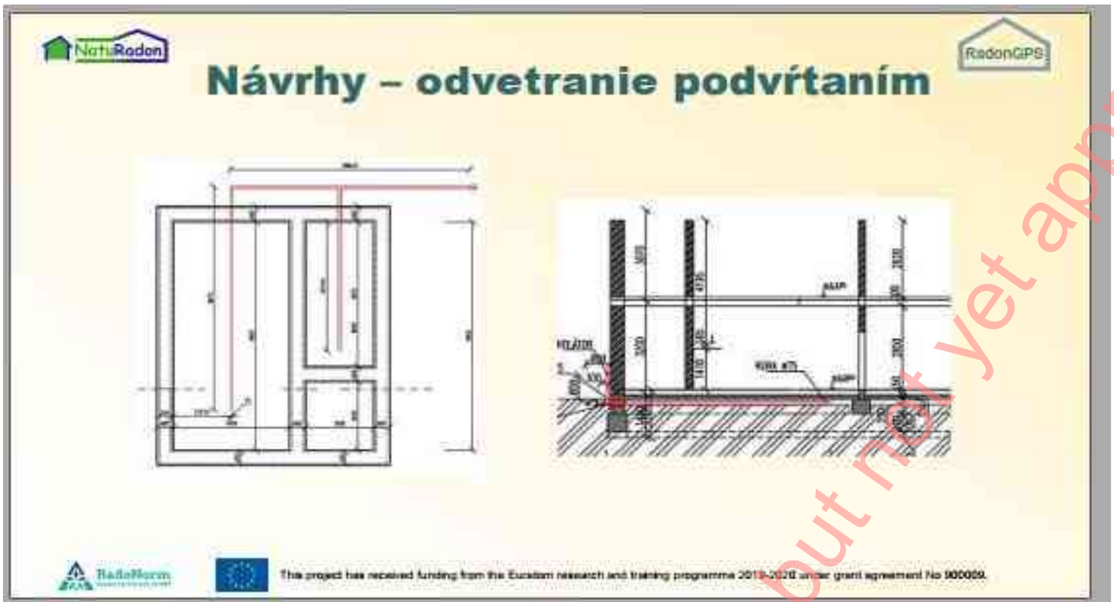


This project has received funding from the Euratom research and training programme 2019-2020 under grant agreement No 900009.


NatuRadon
RadonGPS
Návrhy – odvetránie suterénu
RadoNorm
This project has received funding from the Euratom research and training programme 2019-2020 under grant agreement No 900009.


NatuRadon
RadonGPS
Návrhy – centrálna rekuperácia
RadoNorm
This project has received funding from the Euratom research and training programme 2019-2020 under grant agreement No 900009.


NatuRadon
RadonGPS
Návrhy – odvetrávaná medzivrstva
RadoNorm
This project has received funding from the Euratom research and training programme 2019-2020 under grant agreement No 900009.


NatuRadon
RadonGPS
Návrhy – odvetranie podvŕtaním
This project has received funding from the Euratom research and training programme 2019-2020 under grant agreement No 900009.


NatuRadon
RadonGPS
Návrhy – lokálna rekuperácia
This project has received funding from the Euratom research and training programme 2019-2020 under grant agreement No 900009.


NatuRadon
RadonGPS
Návrhy – novostavba
ilustračný obrázok
This project has received funding from the Euratom research and training programme 2019-2020 under grant agreement No 900009.


NatuRadon
RadonGPS
Ďakujem za pozornosť
... utekáme pred radónom
RadoNorm

7 Slovenia: RadoNorm-SLO: Citizen Science as support to increasing radon testing and mitigation in Bela Krajina

The RadoNorm-SLO project was conducted between October 2023 and April 2024 in the Bela krajina region of Slovenia. As part of the larger RadoNorm initiative funded by the Euratom research and training program under grant agreement No. 900009, the project aimed to explore public perception and behavior related to radon measurement and mitigation. Specifically, it sought to understand why people are reluctant to measure radon levels in their homes and take mitigation actions, despite radon being a known health risk in certain regions of Slovenia, such as Bela krajina.

The project actively involved 90 citizen scientists from Bela krajina and neighboring areas, from which 35 take part in the mitigation workshop and 20 at the societal and health influences, organized in the last week of the project. These participants contributed to both passive and active radon measurements, helping to gather valuable data on radon concentrations in local homes. During the project, 73 passive measurements and 56 active measurements were conducted using radon detectors and monitors. The digital radon monitors were provided by the Slovenian Radiation Protection Administration (URSVS) and the Jožef Stefan Institute (JSI). Passive measurement campaigns mainly took place over two distinct periods, ensuring a comprehensive assessment of radon levels in participating households.

In addition to the measurement campaigns, the project facilitated educational workshops focused on characteristics of radon in indoor living environments, the role and potential of citizen science, and radon mitigation strategies. These workshops empowered participants with the knowledge needed to address elevated radon levels, should they be detected in their homes. The workshops culminated in the mitigation of three homes: two through the installation of active sub-slab depressurization systems and one through a heat recovery ventilation system. Moreover, seven additional homes were assessed for potential mitigation solutions, and discussions with the homeowners explored various mitigation strategies.

The project's citizen science approach was one of its key innovations. By directly involving citizens in the research process, the project not only gathered valuable scientific data but also fostered a greater sense of responsibility and awareness among participants. While many participants remained engaged throughout the project, it was noted that motivation declined for those whose homes had low radon levels. This trend highlighted the importance of extrinsic motivation, as the free radon measurements initially served as a strong incentive for participation.

Despite the six-month duration of the project, RadoNorm-SLO achieved significant results in raising radon awareness within the community. It provided key insights into why many people hesitate to measure radon concentration and take mitigation actions.

7.1 Rationale and objectives of the CS project

In Slovenia, the management of radon-related risks is still in the developmental stages. In 2018, European regulations regarding radon were transposed into Slovenian legislation, leading to the establishment of a national radon program. The reference level for radon concentrations was set at 300 Bq/m³, and systematic radon monitoring in residential environments was initiated. As part of this program, the Slovenian Radiation Protection Administration (URSVS) finances approximately 480 radon measurements for citizens annually, focusing primarily on municipalities identified as high-risk areas.

One of the key roles of URSVS and the national radon program is to raise public awareness about radon-related risks. Initially, public awareness in Slovenia was low, especially when compared to Scandinavian and Western European countries. During the first year of the program, it was difficult to recruit citizens willing to participate in radon measurements. However, interest in the issue grew significantly in subsequent years, partly due to well-targeted advertising efforts. Despite this, interested citizens are often still unwilling to purchase passive radon detectors, even at a low cost, preferring instead to remain on the priority list for the next measurement campaign.

The Bela krajina region remains a less developed area, heavily burdened by radon exposure, and is classified as one of the highest-risk regions. The local Adult Education Center in Črnomelj (ZIK Črnomelj) took on the initiative to address this issue by organizing a public lecture on radon in 2023 (13.02.2023, Katja König, Radioaktivni plin radon doma in na delovnem mestu - zdaj je čas za ukrepanje!). In 2023, as part of the national URSVS program, radon levels were measured in approximately 50 homes and apartments in the Bela krajina region (**Figure 26** shows a map of radon measurements in residential environments in 2023). Citizens with elevated radon levels were invited to participate in the RadoNorm-SLO project.

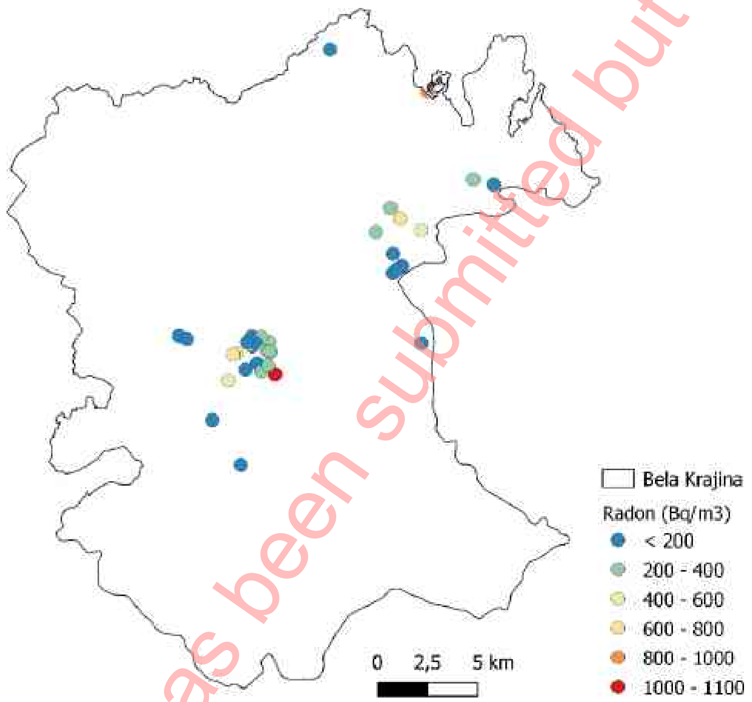


Figure 26. Results of the radon measurements in the living environment of the Bela krajina region performed in the national program in 2023.

7.1.1 Why the Citizen Science Project?

The RadoNorm-SLO project was initiated to address the persistent lack of public engagement and action regarding the health risks posed by radon in the Bela krajina region of Slovenia. Despite the introduction of European radon regulations into Slovenian legislation in 2018 and the implementation of the national radon program, public awareness and participation in radon mitigation have remained low. Even though interest in radon measurement has grown significantly in recent years, many citizens are still reluctant to invest in affordable passive radon detectors, preferring instead to rely on the government-provided measurements through URSVS, which are limited to 480 measurements per year.

The Bela krajina region, classified as a high-risk area for radon exposure, has seen limited progress in mitigating these risks. As a less developed region, Bela krajina faces economic challenges that may further hinder citizen participation in radon mitigation efforts. To address these issues, the local Adult Education Center in Črnomelj (ZIK Črnomelj) has taken the lead by organizing public lectures and engaging the community in discussions about radon. However, more direct and active citizen involvement is necessary to effectively increase radon testing and mitigation rates in the region.

The RadoNorm-SLO project aimed to overcome these barriers by involving citizens not only as participants in radon measurement campaigns but also as active collaborators in the research process. Through citizen science, the project sought to raise awareness, foster a deeper understanding of radon risks, and empower individuals to take action to reduce radon exposure in their homes.

7.1.2 2.2. Objectives of the Citizen Science Project

The primary objectives of the RadoNorm-SLO project were:

- To engage citizens from the Bela krajina region in co-creating radon-related research activities, focusing on both radon measurement and the social and psychological aspects of radon risk perception.
- To analyze data on radon levels, ventilation efficiency (via measurements of CO_2, $PM_{2.5}$, PM_{10} concentrations), and citizens' attitudes toward radon testing and mitigation, with the goal of developing targeted communication strategies.
- To increase the rate of radon testing and mitigation by empowering citizens to take an active role in the measurement process and by addressing their reluctance to invest in radon detectors.
- To collaborate with local stakeholders, such as family physicians and educational centers, to raise awareness and promote radon mitigation actions.
- To disseminate project findings to national authorities and propose actionable steps to improve radon awareness and mitigation strategies across Slovenia.

7.1.3 Classification of the Citizen Science Project

While the RadoNorm-SLO project aimed for a high level of citizen engagement, in practice, it fell between Level 1: Crowdsourcing and Level 2: Distributed Intelligence according to Haklay's (2013) classification in **Table 1**.

The majority of participants contributed by conducting radon measurements in their homes, but their involvement in the scientific process was limited. Most participants followed predefined protocols for data collection, though some had difficulty understanding or implementing the instructions provided by the project coordinators. The instructions, in some cases, were perceived as confusing, which led to variability in the quality of the data collected.

Although there were exceptions where some participants showed a deeper interest and ability to engage with the radon data and its interpretation, these were not representative of the broader group. Some older participants, in particular, faced challenges with the technical aspects of the project. While the project succeeded in involving citizens in basic radon measurements, there was limited contribution to the analysis or scientific refinement of the data. As such, the project more closely aligns with a blend of crowdsourcing (Level 1) and distributed intelligence (Level 2), rather than full participatory science or extreme citizen science.

7.2 Partners and roles

The RadoNorm-SLO project was implemented by a collaborative team of experts from various fields, each playing a critical role in ensuring the success of the citizen science initiative. Below is a detailed description of the core team members, their relevant experience, and their specific roles in the project.

7.2.1 1. Dr. Katja König (KK)

Role: Project Coordinator and Radon Measurement Expert

Dr. Katja König, with her extensive background in radon measurement, was the central coordinator of the RadoNorm-SLO project. Her responsibilities included the overall coordination of the project, ensuring timely reporting to the project's sponsor, SCK CEN, and maintaining citizen engagement throughout the project.

Key roles and responsibilities:

- Coordination of the project and on-time reporting to SCK CEN.
- Active engagement with citizens, ensuring their involvement in various stages of the project.
- Organization and moderation of meetings with citizen scientists.
- Preparation and distribution of questionnaires to gather data from participants.
- Facilitating discussions with citizen scientists about their experiences and concerns regarding radon.
- Overseeing both passive and active radon measurement activities.
- Analysis of questionnaire responses to assess citizen involvement and understanding.
- Preparing the final project results for dissemination to Slovenian authorities and members of the Slovenian Adult Education Centre network.

7.2.2 2. Jožef Stefan Institute (JSI)

Role: Scientific and Technical Support

The Jožef Stefan Institute (JSI) team (Dr. David Kocman, Dr. Rok Novak, Maria Alejandra Rubio Rojas, PhD Student, Prof. Dr. Janja Vaupotič), led by Dr. David Kocman, provided critical financial, technical, and scientific support for the project. Their expertise was instrumental in ensuring that the project's data collection and analysis met scientific standards, and they managed the technological infrastructure for citizen data collection.

Key roles and responsibilities:

- Handling the financial distributions for the project.
- Assisting with the preparation of questionnaires and analysis of citizen responses.
- Organizing active indoor radon and other indoor air quality measurements (CO_2, $PM_{2.5}$, and PM_{10}).
- Collecting and analyzing radon and air quality data from citizens' homes and securely storing it in a cloud-based system.
- Producing a regional map of radon measurement data, which was used to identify high-risk areas in Bela krajina.

7.2.3 ZIK Črnomelj (Adult Education Center Črnomelj)

Role: Community Engagement and Local Coordination

ZIK Črnomelj, under the leadership of Mag. Nada Žagar, played a key role in engaging the local community in Bela krajina. ZIK was responsible for raising awareness about the project, organizing local logistics, and supporting communication between the project team and participants.

Key roles and responsibilities:

- Engaging citizens and encouraging their participation in the project through local outreach.
- Distributing and collecting questionnaires from participants.

- Preparing and disseminating advertising materials to raise awareness about the project and radon risks.
- Providing meeting rooms, materials, and logistical support for workshops and community events.

7.2.4 UK Radon Ltd. (UK-R, Jerry Board)

Role: Radon Mitigation Expert

UK Radon Ltd., led by Jerry Board, brought practical expertise in radon mitigation to the project. His experience in fieldwork and hands-on demonstrations was crucial in educating participants about effective radon mitigation strategies.

Key roles and responsibilities:

- Presenting various radon mitigation measures to participants and discussing the pros and cons of different approaches.
- Conducting fieldwork, including the demonstration of corrective radon measures, to provide participants with a practical understanding of mitigation techniques.

7.3 Citizen engagement

7.3.1 Role of citizen scientists

The primary participants in the RadoNorm-SLO project were citizens from the Bela krajina region, with a smaller group coming from neighboring areas. These participants, referred to as citizen scientists, played an essential role in the project by contributing to the data collection process. The participants came from a range of age groups: 40% were over 60 years old, 30% were between 45 and 60 years old, and 30% were between 26 and 45 years old.

The main responsibility of the citizen scientists was to perform both passive and active radon measurements in the air of their homes. They collected data on indoor radon concentrations using passive solid-state nuclear track detectors (SSNTDs), active radon and indoor air quality monitoring devices that measured CO_2, $PM_{2.5}$, and PM_{10} levels continuously to provide additional insights into indoor air quality. This data collection formed the backbone of the project and contributed to understanding the radon exposure in the region.

While the citizen scientists participated in discussions regarding the results at project events, their role in the scientific process was mostly centered around data gathering. They were involved in some discussions about radon perception, though their contributions to the scientific analysis and interpretation of the data - apart from a workshop devoted to showcasing citizens not experienced in data analyzing how data gathered are visualized and interpreted - were limited. Their participation did not extend to shaping the research methodology or actively analyzing data in a structured, scientific way, as this was out of the scope of the project, given time and budget constraints.

7.3.2 Recruitment process

The citizen scientists were recruited through multiple channels, allowing for a diverse group of participants. The first recruitment process was linked to the national radon measuring campaign, which took place between February and October 2023. 43 radon measurements were performed in the Bela krajina region during this campaign. Participants who recorded elevated radon levels were directly informed about the upcoming citizen science project and invited to participate. The results of these radon measurements were displayed on a map of Bela krajina, which was presented during the first project event where citizen scientists were formally onboarded.

The second recruitment channel was the information e-board of ZIK Črnomelj, where the project was publicly announced. The third recruitment method involved individuals attending various courses at ZIK, who were also invited to join the project. These participants received detailed project invitations and completed questionnaires at the beginning of the project to gather baseline information.

7.3.2.1 Communication Tools for Recruitment

The project used a combination of direct communication, public announcements, and digital tools to recruit participants. Invitations and information about the project were distributed through the ZIK information e-board, as well as personal communications from the national radon measuring campaign. Additionally, participants attending educational courses at ZIK were approached in person and through official project correspondence.

7.3.2.2 Participant Numbers and Dropout Rates

At the start of the project, 105 citizens from Bela krajina completed the entry questionnaires. Of these, 90 citizens attended the first project event, officially joining the project as citizen scientists. However, as the project progressed, the number of active participants gradually decreased. By the time of the radon mitigation strategies workshop, there were 35 participants remaining. At the final event, which focused on the societal and health influences of radon, only 20 participants were present. **Figure 27** shows the number of citizen scientists participating in the different project meetings. Nevertheless, 54 RadoNorm questionnaires were filled out by Slovenian citizen scientists at the end of the project.

The primary reason for this participant drop-off was likely related to the radon levels measured in their homes. Many participants recorded low radon levels using the detectors and monitors provided by the project, and this led to a decline in motivation for further involvement. To address this issue in future projects, extrinsic motivation could be introduced, such as encouraging participants to help friends or family members with high radon levels.

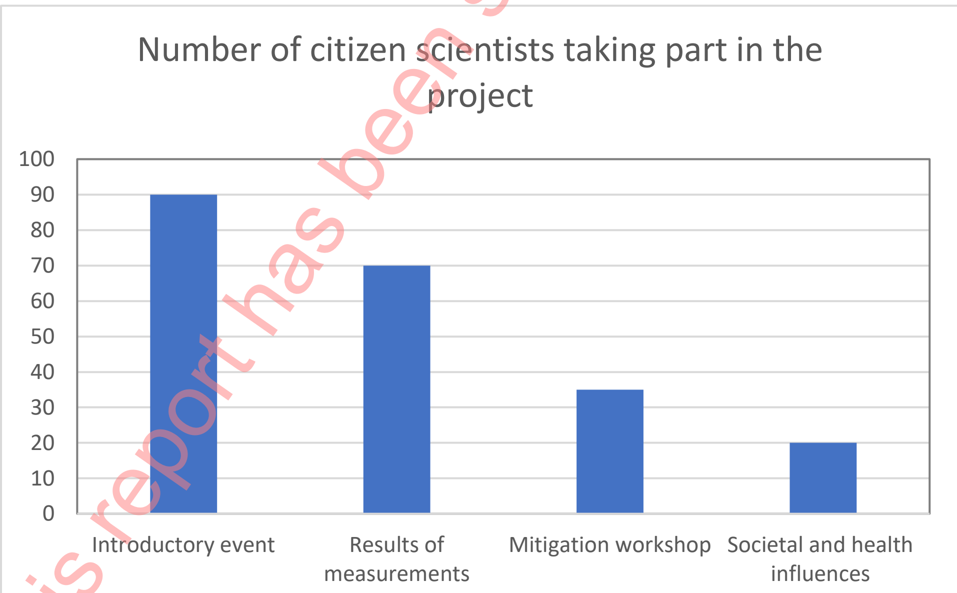


Figure 27. Number of citizen scientists attending each of the main project events.

7.3.3 Motivation of participants

The motivation behind the participation of citizen scientists in the RadoNorm-SLO project was predominantly extrinsic, driven by the opportunity to measure radon concentrations in their homes free of charge. Many participants were interested in determining whether their households were exposed to high radon levels, as radon is a known health risk, which was also acknowledged and confirmed by the participants. The ability to access this information at no cost provided a clear benefit, aligning with the reward-based motivation described by Arazy & Anderson (2011). This is further evidenced by the fact that many participants lost interest and dropped out of the project after discovering that their homes had low radon concentrations. For these individuals, once the primary benefit of measuring radon levels had been realized, their motivation to remain involved in the project diminished.

A smaller group of participants, however, showed more intrinsic motivation. These individuals were particularly interested in learning more about radon and the ways to mitigate high radon concentrations in their homes. They remained engaged throughout the project, actively participating in discussions about radon perception and attending workshops on radon mitigation strategies. Their ongoing involvement suggests a desire to not only measure radon concentrations but also to take concrete actions to address the issue.

The scientists behind the project were motivated by a combination of factors. One of the key motivations for launching the RadoNorm-SLO project was the need to gather more extensive radon data from the Bela krajina region, a high-risk area for radon exposure. In addition, the project aimed to improve public awareness about radon and encourage greater participation in radon testing and mitigation efforts. Through the citizen science approach, the project team hoped to directly involve citizens in the scientific process, thus fostering a more community-driven effort to address radon risks. This aligns with the collective motivation described in Arazy & Anderson's framework, as the project's goals were seen as important for public health and safety.

While there were some indications of norm-related motivation, such as participants discussing radon concerns with their families and communities, the dominant motivation for most participants was clearly reward-based. The free radon measurement provided immediate tangible benefits, and for many, this was the primary reason for their involvement in the project.

7.3.4 Communication and engagement activities

7.3.4.1 Engagement Activities

The Introductory event for the RadoNorm-SLO project aimed to engage citizens in the Bela krajina region in radon measurement and mitigation efforts. Presentations included an overview of the project by Dr. Katja König, who discussed radon in indoor environments, relevant legislation, and project objectives. Dr. David Kocman introduced the concept of citizen science and its application in research, while Prof. Dr. Janja Vaupotič highlighted the importance of continuous radon measurements and ventilation. Additionally, a local family physician shared her experiences regarding health risks associated with exposure to various health risk factors, emphasizing the potential impact on public health.

The citizen scientists were engaged progressively throughout the RadoNorm-SLO project through a structured measurement protocol. In the initial phase, participants conducted passive radon measurements in the air of their homes. This first step allowed them to assess radon levels and identify whether their homes were exposed to potentially harmful concentrations. In the second phase of the project, active radon measurements were introduced for buildings where elevated radon levels had been detected in the passive measurements. They were supported by air quality measurements (CO_2, $PM_{2.5}$, and PM_{10}), allowing participants to track ventilation's effects.

Participants who had already completed passive radon measurements before the official start of the RadoNorm-SLO project were able to begin active measurements earlier, during the first third of the project. Those who carried out passive measurements in the early stages of the project proceeded to active measurements during the second third. This step-by-step approach ensured continuous engagement and a clear progression of tasks for the participants.

The results of both passive and active radon measurements were presented and discussed at project events, which took place toward the end of the second phase of the project. These discussions allowed citizen scientists to reflect on the findings and share their experiences. In the final stage, seminars were held, featuring experts on radon mitigation strategies and the health and societal impacts of radon exposure. These seminars equipped participants with the knowledge necessary to understand and address elevated radon levels, should they encounter them in their own homes or communities.

However, despite the structured engagement process, the level of participation gradually decreased throughout the course of the project. This decline was primarily attributed to a loss of motivation among participants who recorded low radon levels in their homes, leading them to feel less invested in continuing their involvement. Nevertheless, even those who disengaged acknowledged the importance of the radon issue, which had initially motivated them to join the project. We believe that they gained enough information to take appropriate actions if faced with elevated radon levels in the future or to pass on the relevant knowledge to someone else experiencing radon issues.

7.3.4.2 Communication with Citizen Scientists

The RadoNorm-SLO project employed several modes of communication to keep citizen scientists informed and engaged throughout the project. Invitations to project events and updates were posted on the ZIK Črnomelj webpage, and participants were contacted directly via email and phone calls. For participants performing active radon measurements—particularly those with elevated radon levels—personal communication was emphasized. This included one-on-one discussions, phone calls, and, in some cases, home visits, to provide tailored guidance and support.

7.3.4.3 Communication with Non-Participants

To reach the wider public and non-participants, the project mainly relied on flyers and informational posts on the ZIK Črnomelj webpage. These materials provided general information about the project and radon awareness to the broader community, helping to raise awareness even among those not directly involved in the project.

The results of the RadoNorm-SLO project were disseminated through multiple channels to reach both the participants and the broader public. Below is a summary of the key dissemination activities:

- Project Website: The results were published on the ZIK Črnomelj webpage, providing easy access for participants and the public to review the findings and project updates.
- Radio Coverage: News about the initial project event was featured on Radio Odeon, a local radio station, helping to raise awareness about the project. Additionally, an article on radon mitigation strategies featuring Jerry Board was also published by Radio Odeon. The article can be found at Zmanjšajmo vrednosti radona v svojem domu.
- Local Newsletter: An interview and article about the project were published in Belokranjec**,** a local newsletter, providing further insights into the project's activities and its relevance to the local community (see Appendix 4).
- Scientific Paper: Two scientific papers are currently in preparation, focusing on (i) evaluation and showcasing citizen-science potential in radon mitigations, and (ii) new insights into indoor radon characteristics and ventilation regimes in radon-prone areas, based on data gathered using participatory approaches. Both papers will contribute to the broader scientific understanding of radon-related issues and mitigation strategies.
- Video Release: A video summarizing the project results and key findings is currently in preparation, with a predicted release in November 2024. This video aims to further disseminate the project outcomes and raise public awareness about radon risks and mitigation strategies.

7.4 Results

7.4.1 Behavioral and socio-cultural impact

The RadoNorm-SLO project provided several benefits to the citizen scientists who took part, particularly in terms of knowledge acquisition and changes in perception. Although the primary goal of the project was not to provide free radon measurements, this proved to be the most significant benefit and motivation for many participants. This conclusion is supported by the observation that participation rates dropped once the radon concentration results for individual homes were made available.

Questionnaire Analysis (105 participants)

At the start of the project, 105 questionnaires were completed, providing insight into the participants' knowledge and perceptions of radon. The key findings are summarized as follows:

1. Motivation to Join:

Of the 105 responses, 54% expressed interest in joining the project, with roughly 60% stating a specific interest in measuring radon levels in their homes. However, 34% were not interested in participating, and 11% left the question unanswered. These figures suggest that some participants joined the project despite not initially expressing strong interest, indicating a low level of motivation and a primarily extrinsic reason for their involvement.

2. Awareness of Radon:

50% of respondents knew that radon could be a potential air pollutant in their homes, though only 4% had previously measured it. This highlights a general awareness of radon, but a lack of understanding regarding its behavior, health effects, and the importance of measuring it. This gap in knowledge likely contributed to the limited action taken by participants before the project.

3. Radon Knowledge Breakdown:

Four related questions explored participants' knowledge of radon in more detail:

- 88% had heard of radon.
- 54% knew what radon is.
- 35% were aware of its health effects.
- 20% knew how to reduce radon levels.

The relatively high figure of 20% for radon mitigation knowledge is likely inflated by the fact that many participants consider basic room ventilation (through windows) to be a sufficient radon mitigation measure.

4. Interest in Measuring Radon:

60% of participants expressed a desire to measure radon levels in their homes, while 12% did not want to conduct radon measurements, 9% were undecided, 17% were uncertain, and 2% provided no answer. Interestingly, the reluctance or indecision to measure radon was more prevalent in younger age groups, possibly due to the increasing concern for personal health as individuals age.

5. Indifference to Radon Risks:

12% of respondents indicated they had no interest in measuring radon levels, which aligns with the 9% who said they would not be afraid for their health if radon was present (3% did not answer) and the 5% who said they would not take any action if elevated radon levels were detected (7% did not answer). The reasons behind this indifference to radon risks remain unclear.

6. Interest in Radon Mitigation Strategies:

71% of participants expressed an interest in learning more about radon mitigation strategies. This figure is higher than the percentage of those interested in measuring radon in their homes, indicating a curiosity about mitigation methods, even among those who might not currently feel the need to test for radon. This finding suggests that while the public may lack detailed knowledge about radon mitigation, there is a strong desire to learn more about how to reduce radon exposure.

While we do not have data on the final responses to the RadoNorm questionnaire at the end of the project, we believe that participants gained substantial knowledge about radon through their involvement. This assumption is based on their active engagement during seminars and discussions, and we expect that they are now better equipped to understand radon-related risks and mitigation strategies.

7.4.2 Outputs

Measurement and Mitigation Results

During the course of the RadoNorm-SLO project, citizen scientists performed 73 passive radon measurements (with SSNTD) and 56 active radon measurements. The active measurements were conducted using 20 Airthings Home instruments, which were provided free of charge by the Slovenian Ministry of Health's Radiation Protection Administration (URSVS), as well as instruments owned by the Jožef Stefan Institute (JSI), including three Radon Scout, four Radon Scout Professional devices (provided to the JSI within the operation 'Development of research infrastructure for the international competitiveness of the Slovenian RRI space–RI-SI-EPOS', co-financed by the Republic of Slovenia, the Ministry of Education, Science and Sport, and the European Union from the European Regional Development Fund), and four uHoo Smart Air Monitors. Passive measurement campaigns mainly took place over two periods: November–January and February–April.
The results of passive radon (Rn) measurements (obtained with SSNTD) are presented in **Table 13**. Altogether, 73 measurements were made, including 2 measurements following the mitigation actions in two dwellings (to be conducted in the period November–December 2024).

Table 13. Results of the passive radon measurements performed in the RadoNorm-SLO project

#	Postal code	City	Dwelling type	Room	Rn conc. [Bq/m³]	Uncertainty [Bq/m³]	Start time	Stop time	Floor
1	8340	Črnomelj	Family house	kitchen	487	64	2023-10-23	2023-12-23	basement
2	8344	Vinica	Family house	bedroom	171	24	2023-10-20	2024-01-03	first floor
3	8344	Vinica	Family house	bedroom	3800	680	2023-11-02	2024-01-03	ground floor
4	8330	Metlika	Family house	kitchen	529	68	2023-09-27	2024-01-04	ground floor
5	8344	Vinica	Family house	information not provided	62	12	2023-10-20	2024-01-04	information not provided
6	8340	Črnomelj	Family house	living room	211	30	2023-10-20	2024-01-04	first floor
7	8340	Črnomelj	Family house	bedroom	319	44	2023-10-21	2024-01-04	first floor
8	8340	Črnomelj	Family house	living room	222	32	2023-10-21	2024-01-04	ground floor

#	Postal code	City	Dwelling type	Room	Rn conc. [Bq/m³]	Uncertainty [Bq/m³]	Start time	Stop time	Floor
9	8340	Črnomelj	Family house	room	568	74	2023-10-19	2024-01-05	first floor
10	8340	Črnomelj	Flat	living room	130	20	2023-10-19	2024-01-05	information not provided
11	8344	Vinica	Family house	living room	1800	270	2023-10-20	2024-01-05	ground floor
12	8333	Semič	Family house	living room	255	34	2023-10-20	2024-01-05	ground floor
13	8340	Črnomelj	Family house	living room	240	32	2023-10-20	2024-01-05	ground floor
14	8340	Črnomelj	Family house	living room	265	36	2023-10-20	2024-01-05	first floor
15	8340	Črnomelj	Family house	living room	428	56	2023-10-20	2024-01-05	ground floor
16	8340	Črnomelj	Family house	hallway	172	24	2023-10-20	2024-01-05	first floor
17	8340	Črnomelj	Flat	living room	141	20	2023-10-20	2024-01-05	second floor
18	8340	Črnomelj	Family house	room	1280	190	2023-10-21	2024-01-05	basement
19	8340	Črnomelj	Family house	living room	114	18	2023-10-22	2024-01-05	first floor
20	8340	Črnomelj	Family house	living room	441	60	2023-10-23	2024-01-05	elevated ground floor
21	8344	Vinica	Family house	living room	168	26	2023-10-25	2024-01-05	first floor
22	8340	Črnomelj	Family house	living room	180	26	2023-10-27	2024-01-05	first floor
23	8340	Črnomelj	Family house	dining room	407	56	2023-10-29	2024-01-05	ground floor
24	8333	Semič	Family house	bedroom	698	92	2023-11-03	2024-01-05	first floor
25	8333	Semič	Family house	living room	300	42	2023-11-06	2024-01-05	ground floor
26	8340	Črnomelj	Family house	kitchen	91	14	2023-10-09	2024-01-08	first floor
27	8333	Semič	Family house	kitchen	462	62	2023-10-20	2024-01-11	ground floor
28	8340	Črnomelj	Family house	living room	900	120	2023-10-20	2024-01-11	second floor
29	8340	Črnomelj	Family house	living room	184	28	2023-10-20	2024-01-11	basement
30	8340	Črnomelj	Family house	bedroom	870	110	2023-10-20	2024-01-11	first floor
31	8340	Črnomelj	Family house	living room	586	78	2023-10-20	2024-01-11	ground floor

#	Postal code	City	Dwelling type	Room	Rn conc. [Bq/m³]	Uncertainty [Bq/m³]	Start time	Stop time	Floor
32	8340	Črnomelj	Family house	living room	242	34	2023-10-20	2024-01-11	basement
33	8340	Črnomelj	Family house	bedroom	563	74	2023-10-19	2024-01-12	ground floor
34	8340	Črnomelj	Flat	bedroom	211	30	2023-10-19	2024-01-12	first floor
35	8340	Črnomelj	Flat	living room	150	22	2023-11-01	2024-01-15	ground floor
36	8343	Dragatuš	Flat	bedroom	412	56	2023-10-31	2024-01-16	first floor
37	8343	Dragatuš	Flat	bedroom	463	62	2023-10-31	2024-01-16	ground floor
38	8340	Črnomelj	Family house	living room	273	40	2023-11-22	2024-01-29	first floor
39	8340	Črnomelj	Family house	living room	262	38	2023-12-01	2024-02-01	first floor
40	8340	Črnomelj	Flat	information not provided	123	20	2023-12-07	2024-02-01	information not provided
41	8330	Metlika	Family house	living room	292	44	2023-12-10	2024-02-01	ground floor
42	8340	Črnomelj	Family house	bedroom	269	40	2023-12-13	2024-02-01	first floor
43	8340	Črnomelj	Family house	living room	177	24	2023-11-14	2024-02-15	ground floor
44	8340	Črnomelj	Flat	kitchen	139	22	2023-11-14	2024-02-15	forth floor
45	8340	Črnomelj	Family house	gym room	2140	320	2023-12-16	2024-02-15	basement
46	8340	Črnomelj	Family house	boiler room	544	68	2023-12-18	2024-02-20	basement
47	8340	Črnomelj	Family house	living room	345	48	2023-12-24	2024-02-21	ground floor
48	8340	Črnomelj	Family house	living room	603	80	2023-12-05	2024-02-22	basement
49	8340	Črnomelj	Family house	utility	654	86	2023-12-06	2024-02-22	basement
50	3260	Kozje	Family house	living room	223	30	2023-11-24	2024-02-25	ground floor
51	3260	Kozje	Family house	living room	290	38	2023-11-24	2024-02-25	attic
52	8382	Koprivnica	Family house	living room	186	26	2023-11-24	2024-02-25	information not provided
53	8341	Adlešiči	Family house	utility	258	36	2023-12-21	2024-03-06	first floor
54	8341	Adlešiči	Family house	living room	285	38	2023-12-21	2024-03-06	first floor

#	Postal code	City	Dwelling type	Room	Rn conc. [Bq/m³]	Uncertainty [Bq/m³]	Start time	Stop time	Floor
55	8330	Metlika	Family house	cellar	370	52	2024-01-03	2024-03-06	elevated ground floor
56	8340	Črnomelj	Family house	living room	514	70	2024-01-14	2024-03-10	first floor
57	8330	Metlika	Family house	room	434	60	2024-01-09	2024-03-11	information not provided
58	8330	Metlika	Family house	kitchen	344	48	2024-01-09	2024-03-11	information not provided
59	8330	Metlika	Family house	bedroom	193	26	2023-12-13	2024-03-12	information not provided
60	8340	Črnomelj	Family house	bedroom	410	56	2024-01-07	2024-03-12	information not provided
61	8330	Metlika	Family house	kitchen	1760	230	2024-02-03	2024-03-12	information not provided
62	8330	Metlika	Family house	living room	211	34	2024-01-03	2024-03-13	information not provided
63	8330	Metlika	Family house	living room	595	78	2024-01-12	2024-03-18	ground floor
64	8340	Črnomelj	Family house	room	393	54	2024-01-05	2024-03-19	second floor
65	8340	Črnomelj	Family house	bedroom	194	30	2024-01-05	2024-03-19	first floor
66	8312	Podbočje	Flat	bedroom	123	18	2023-12-23	2024-03-23	ground floor
67	8332	Gradac	Family house	room	387	52	2024-01-04	2024-03-27	ground floor
68	8330	Metlika	Family house	living room	266	36	2023-12-18	2024-03-28	ground floor
69	8340	Črnomelj	Family house	living room	1440	220	2024-02-01	2024-04-15	ground floor
70	8344	Vinica	Family house	living room	191	28	2024-01-13	2024-04-16	ground floor
71	8344	Vinica	Family house	living room	391	52	2024-01-13	2024-04-16	ground floor

An example of the results collected by a citizen scientist of active radon measurements (obtained with an Airthings Home instrument) is shown in **Figure 28**.

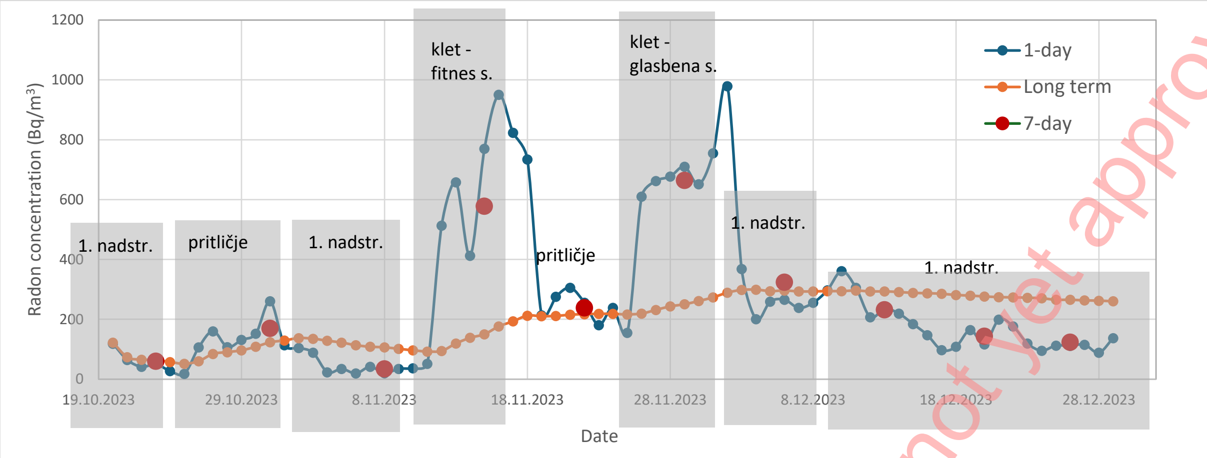


Figure 28. Radon concentrations obtained with active measurements (Airthings Home instrument), conducted by a citizen scientist, with analysis and explanations provided by the project coordinator.

Active indoor radon measurements that continuously record Rn concentration (Radon Scout) or Rn and CO_2 concentration (Radon Scout Professional) were conducted in sixteen homes. Each measurement lasted two to three weeks, with a sampling frequency of 60 minutes, between December 18, 2023, and April 15, 2024. In eleven homes (69%), average Rn concentrations, calculated from continuous monitoring, exceeded the national reference value of 300 Bq/m³. An example of such continuous Rn monitoring for one week in a house with increased radon concentration is shown in **Figure 29**.

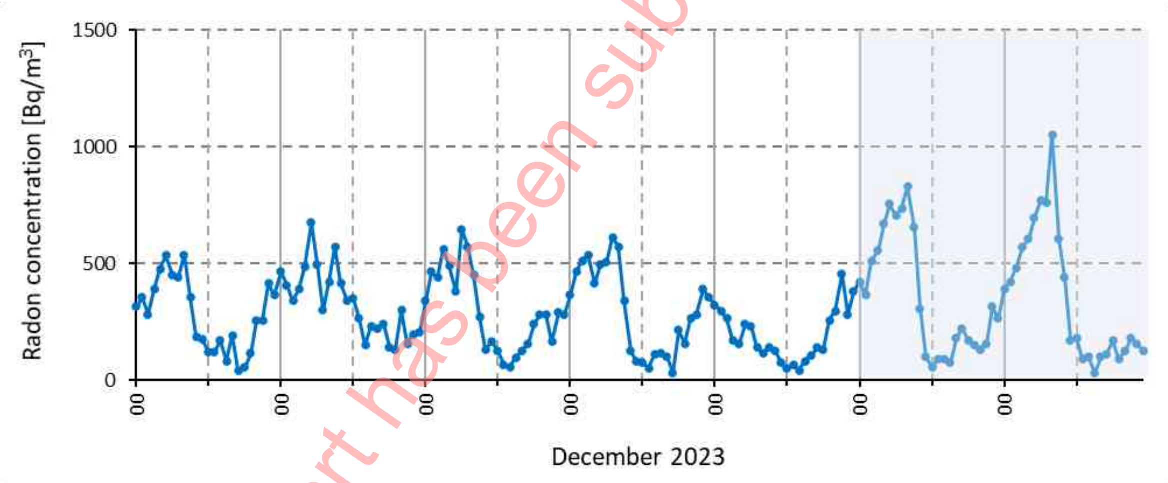


Figure 29. The diurnal variation of Rn concentration obtained with active measurements (Radon Scout) during one week of monitoring (00 indicates midnight, and shading indicates the weekend).

Indoor air quality measurements, which include CO_2, $PM_{2.5}$, and PM_{10} concentrations and meteorological parameters, were performed in seven homes, mainly together with active radon monitors. These measurements allowed insight into the behavior of other measured pollutants and the influence of meteorological parameters and ventilation on their concentrations. The data from the air quality measurements were automatically uploaded to a cloud-based system managed by JSI. However, despite instructions being provided at the introductory event, most citizen scientists did not actively utilize this functionality. This was largely because many participants were not accustomed to using digital platforms for data access and analysis.

Figure 30. Radon mitigation presentation and fieldwork conducted as part of the project.

At a workshop focused on radon mitigation strategies, two houses were equipped with an active sub-slab depressurization system (**Figure 30**). The success of these mitigation efforts was evaluated through active radon measurements in the April–May period, and final confirmation will be obtained through passive radon measurements conducted in November–December 2024. In addition, seven other houses were visited with radon mitigation specialist Jerry Board, where potential solutions were discussed directly with the homeowners. Furthermore, one dwelling was mitigated by a citizen scientist using mechanical ventilation with a small overpressure. Moreover, the comparison to increased natural ventilation, with a large energetical/heating impact, was made. The citizen scientist will make the control measurement with his own digital radon monitor.

Figure 31 shows the indoor radon situation before and after the mitigation in one of the two houses equipped with an active sub-slab depressurization system. After optimizing the system, the radon concentration dropped below 100 Bq/m^3.

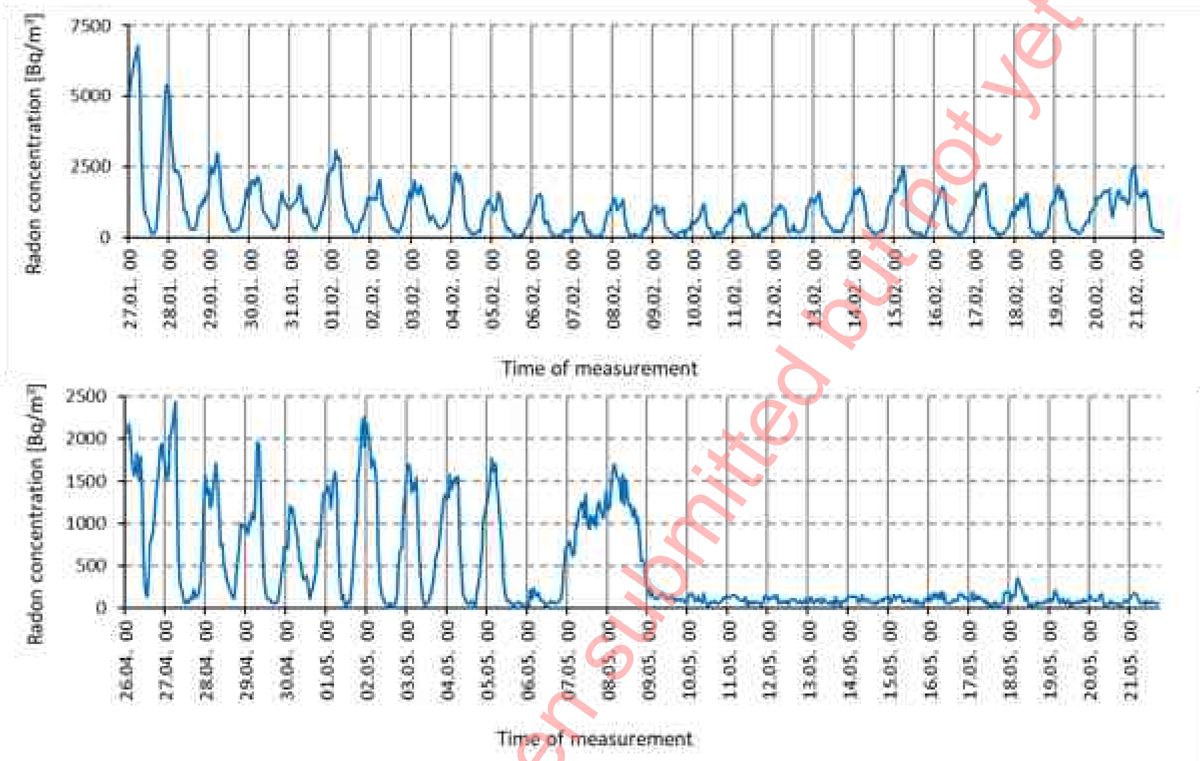


Figure 31. The diurnal variation of Rn concentration a) before (January 27–February 21, 2024) and b) after (April 26–May 21, 2024) mitigation.

The societal and health aspects of radon were presented at the final project workshop by dr. Nadja Železnik from Elektroinštitut Milan Vidmar (a partner in RadoNorm project) in a presentation entitled Ionizing radiation and people: how do we think about radon (*Ionizirajoče sevanje in ljudje: kako razmišljamo o radonu).*

Additional Outputs

- Presentations on radon risks and mitigation strategies were given during project workshops.
- Policy recommendations and research suggestions were prepared and shared with national authorities.
- Ongoing scientific publications and papers related to the project are currently in preparation.
- Data collected through the passive and active measurements will be available in anonymized form, presented on a mute map for public access, helping to further scientific research and awareness of radon levels in the region.
- Informed consent was conveyed during the introductory presentation and was deemed accepted by participants upon their enrollment in the project. This covered the use of personal data for communication and the inclusion of anonymized measurement data for research purposes, with all ethical requirements duly observed.

Collaborations

The project fostered significant collaboration with the Slovenian Radiation Protection Administration (URSVS), which provided 20 radon monitors free of charge.

Key recommendations to authorities prepared by the project include:

- The importance of providing free radon measurements, though these alone are insufficient to address the issue.
- The need to increase public awareness of radon, its health risks, and the mitigation options available.
- Encouraging radon prevention in new buildings and ensuring that the public is well-informed about radon safety requirements in the workplace.
- Expanding radon awareness presentations at least in radon-prone regions across Slovenia across through 53 Slovenian Third Age University organizations (offering additional educational opportunities across Slovenia) and 21 People's Universities (part of a national network providing educational courses for adults).
- A focus on educating the younger population about radon, integrating this knowledge with other health risks such as alcohol, smoking, and sugar consumption.

Adoption of Results

- Policy Adoption: The timeframe of the project has been too short to see full policy adoption at the local or national level.
- Technology Development: The project has not yet led to the development of new technologies.
- Theses or Dissertations: Due to the short duration of the project, no student dissertations or theses have emerged from the project.
- Economic Benefits: There has been no significant increase in economic benefits, such as the sale of radon detectors or mitigation kits, attributable to the project thus far.
- Public Debate: We are not aware of any public or political debates on radon and its management outside of project-related events.

While several outputs were anticipated as potential long-term impacts of the RadoNorm-SLO project, they were not achieved within the project timeframe. This can largely be attributed to the relatively short duration of the project, which was insufficient to detect these effects. For example:

- Adoption by Policy-makers: Although the project generated recommendations for policy-makers, the time frame was too short to observe any concrete policy changes at the local or national level.
- Development of New Technologies: The project has not yet led to the creation or commercialization of new radon-related technologies due to the limited project duration.
- Theses or Dissertations: The project did not result in any student theses or dissertations, as six months was too brief for students to complete such work.
- Economic Impact: While an increase in the sale of radon detectors or mitigation kits was expected, no significant economic benefits have been observed within this short period.
- Public or Political Debate: There has been no widespread public or political debate outside of project-related events, as these discussions typically take more time to develop.

Evaluation of the citizen science project

The RadoNorm-SLO project was successfully conducted in the Bela krajina region from 19 October 2023 to 15 April 2024. A total of 90 participants joined the project, exceeding the originally anticipated number of around 50 citizen scientists. However, as the project progressed, the number of participants gradually declined. This decrease was primarily due to the loss of motivation among participants who measured low radon levels in their homes. Despite this reduction, many citizen scientists remained engaged, performing active radon measurements and participating in discussions to better understand their results and plan further measurements.

By the time of the radon mitigation strategies workshop, 35 citizen scientists were still actively involved. These participants are now well-informed about radon-related risks and mitigation options. They have acquired the knowledge necessary to address high radon levels, should they encounter such a problem. Additionally, two volunteers carried out mitigation actions in their own homes, and potential mitigation solutions were discussed with several other homeowners. Unfortunately, due to the limited budget and the 6-month timeframe of the project, it was not possible to monitor whether additional homes were mitigated based on the information provided through the RadoNorm-SLO project.

The project also achieved significant dissemination efforts. It was publicized through various channels, including an interview in a local newsletter, an article on a local radio station, and postings on the ZIK Črnomelj webpage. One of the mitigation actions was recorded, and a 3-minute video summarizing the key steps to mitigate radon risks is currently being prepared. This video will provide a clear and accessible overview of the essential actions to tackle radon dangers.

7.5 Main conclusions and final reflections

The RadoNorm-SLO project successfully raised awareness of radon risks in the Bela krajina region, involving 90 citizen scientists in both passive and active radon measurements. While the project achieved its immediate goals of educating participants and facilitating radon measurements, the sustainability of the project remains a challenge due to a lack of additional funding. The project partners do not currently have the resources to continue or expand these activities without external support.

The next logical step in extending the project's impact would be to present the outcomes to a broader audience, specifically at the 21 People's Universities and 53 Slovenian Third Age University centers across Slovenia. Such a campaign would provide much-needed support to the national URSVS program, helping to significantly increase radon awareness and encourage greater participation in radon measurement and mitigation efforts. This approach would extend the project's reach to other radon-prone regions, empowering more communities to take action against radon exposure.

Challenges and Limitations

The most significant limitations of the RadoNorm-SLO project were the short project duration (just 6 months) and the limited budget. The brief timeframe did not allow for extensive follow-up with participants or a comprehensive evaluation of the long-term impact of the project. Ideally, future projects should span at least 1.5 years, covering two winter seasons, when indoor radon levels tend to be highest. This extended period would allow for more thorough monitoring and the potential to engage participants more deeply over time.

A larger budget would also be essential to improve the sustainability and effectiveness of the project. It could help cover:

- Partial compensation for the time and effort of the most enthusiastic citizen scientists.

- Costs related to mitigation equipment and labor, enabling more homeowners to take concrete mitigation actions.
- Increased scientist involvement, allowing more time for one-on-one engagement with citizen scientists, providing guidance on data collection, interpretation, and mitigation strategies.

These measures would ensure a more personalized and effective approach to engaging citizens, especially if younger participants could be attracted to the project, which would ease the use of modern technologies and data interpretation.

These recommendations are particularly relevant for regions where radon awareness and radon mitigation industries are not well developed, such as Slovenia. For such areas, more targeted support is needed to foster both public awareness and action on radon risks.

Advice for Future Citizen Science Projects on Radon

Future citizen science projects focused on radon should consider the following recommendations:

1. Longer project timelines are critical. A period of 1.5 to 2 years allows for deeper engagement, more comprehensive follow-up, and thorough monitoring of both radon levels and the effects of mitigation.
2. Adequate funding should be allocated to cover equipment, mitigation efforts, and the time contributions of citizen scientists. Offering incentives or compensation can sustain participant engagement and ensure more meaningful results.
3. Education and outreach efforts should target younger generations alongside the elderly, as younger participants may be more adept at using technology and could contribute more actively to data collection and analysis.
4. Strong collaborations with national authorities, such as URSVS in Slovenia, are essential for providing the necessary tools and support to citizens and ensuring that project outcomes feed into national radon awareness campaigns.

Consider mitigation-focused workshops or field visits where participants can see firsthand how mitigation strategies are implemented. This can bridge the gap between measurement and action, encouraging citizens to take the next step beyond simply measuring radon levels.

To achieve higher levels of citizen engagement, such as Level 3 (Participatory Science) and Level 4 (Extreme Citizen Science), several additional factors would be necessary:

- Extended project timelines: Longer durations would allow for deeper involvement of citizen scientists, giving them more time to refine research questions, contribute to data collection and interpretation, and fully engage with the scientific process.
- Increased resources: Access to more powerful instruments and funding would enable citizen scientists to contribute meaningfully to more advanced data collection and analysis, particularly for those willing to engage at higher levels.
- Larger pool of participants: Expanding the number of citizen scientists would increase the likelihood of finding participants capable and motivated to engage at these higher levels of involvement, such as shaping research methodologies or conducting independent data analysis.
- Incentivizing long-term engagement: Offering compensation or other incentives could help sustain participant interest and enable citizens to commit to the deeper involvement required for Level 3 and Level 4 engagement.

RadoNorm-SLO project has laid a strong foundation for increasing radon awareness and community action in the Bela krajina region. With the right resources and extended timeline, similar projects could make a substantial impact on public health by promoting radon mitigation strategies across Slovenia and other radon-prone areas in Europe.

7.6 Way forward

The next logical step to amplify the impact of the RadoNorm-SLO project would be to disseminate the project results across the 21 People's Universities and 53 Slovenian Third Age University centers. A short presentation should be developed to cover all key aspects of the radon topic, including:

1. Health risks associated with radon exposure.
2. Measurement protocols, explaining the significance of radon levels.
3. Mitigation strategies for existing buildings.
4. Radon prevention protocols for new constructions.

This educational campaign would align with the national URSVS efforts to increase radon awareness in Slovenia, particularly in radon-prone regions. However, the project team would need to secure funding to execute these dissemination activities. Many adult education centers, especially those in high-risk areas, are expected to be interested in hosting radon-related events, but without financial support, such a campaign would not be feasible.

Regarding the citizen scientists, the project team is not currently aware of any ongoing activities initiated by them following the end of the RadoNorm-SLO project.

Looking forward, we believe that future citizen science projects on radon would benefit significantly from an extended project duration of at least 1.5 years, covering two cold periods. This extended timeline would enable the following improvements:

- Measurement campaigns could be completed in the first cold period, with enough time for comprehensive data collection and follow-up.
- After initial measurements, some participants—particularly those with lower motivation—may disengage without negatively impacting the overall project. This would allow the remaining, more committed participants to continue with extended measurements and analysis.
- More thorough support from project partners, including one-on-one interactions with citizen scientists, would be possible in the second part, increasing the quality and depth of both the data collected and the engagement of participants. Such collaborations would yield scientifically valuable data on radon concentrations in buildings and insights into personal and social perceptions of radon risks.

As for future activities, the project team remains open and interested in participating in more citizen science projects related to radon, both within Slovenia and as part of broader European initiatives like the RadoNorm network. If a suitable funding call is released, the project team would be keen to apply and continue their efforts in radon awareness and mitigation.

7.7 Resources

The funding provided by the RadoNorm project was essential for the successful implementation of the RadoNorm-SLO project. Resources were distributed across several key areas to ensure that the project objectives were met. Below is a breakdown of the primary costs and how the resources were allocated **Table 14**).

Main Costs

1. Personnel costs

The personnel costs primarily encompassed the time invested by the project team in various essential tasks. These included preparing presentations, collecting and analyzing data, supporting the development and implementation of measurement protocols, and facilitating discussions with citizen scientists. Additionally, significant effort was dedicated to communication with participants, such as managing emails and phone calls, ensuring continuous engagement and addressing any questions or issues that arose during the project. These activities played a crucial role in the overall execution and success of the project.

2. Passive Radon Detectors:

A total of 73 passive radon detectors were needed, which cost €25 each (including postal shipments), amounting to a total expenditure of more than €1,800. This was a crucial cost, as the detectors were necessary to collect baseline data on radon levels in participants' homes. The cost of passive detectors increases with the number of participants, making this a significant expenditure, particularly given the higher-than-expected participant turnout.

3. Active Radon Monitors:

Active radon measurements were performed using 20 commercial radon monitors, provided by the Slovenian Radiation Protection Administration (URSVS) and professional instruments provided by the Jožef Stefan Institute (JSI). This collaboration was critical, as the project could not have been conducted without access to these monitors and instruments. The availability of these devices throughout the lifespan of the project represented a significant in-kind contribution by URSVS and JSI, offsetting what would have been a substantial cost.

4. Mitigation Costs:

Persuading participants to contribute to the costs of radon mitigation proved challenging. In fact, the two mitigation actions carried out were only possible due to the generosity of a local company, which donated part of the equipment, and contributions from the project coordinator's budget. This highlights the need for external financial support when encouraging citizens to engage in mitigation activities.

5. Overhead Costs:

Another significant expenditure was the overhead costs at the research institution. These costs covered administrative and institutional support, but they reduced the overall budget available for direct project activities.

Table 14. Informative table with distribution of the costs

	Cost over 6 months (euros)	Overhead (25%)	Total in euros
Personnel	KK: 5085 € JSI: 4700 € ZIK: 4000 € UK-R: 3510 €	KK: 200 € JSI: 1300 € ZIK: 500 €	19,295 €
Travel	UK-R: 1490 € KK: 890 € JSI: 500 €		2,880 €
Equipment	/	/	
Other goods and services	KK: 2325 € (Rn-detectors + craftsman work) ZIK: 500 €		2,825 €
Total			25,000 €

Limitations

One of the major limitations of the project was the short timeframe. While the project was successfully completed within the 6-month period, tracking the long-term impact would require at least one more year. This would allow for a more in-depth evaluation of the effects of radon awareness and mitigation actions.

The project's budget proved to be limiting in several ways:

- Covering the cost of passive radon detectors and active radon monitors was a significant expense, which increased as more participants joined the project. Without the 20 monitors provided by URSVS, the project could not have been conducted as planned.
- The difficulty of getting participants to cover any part of the mitigation costs was a significant challenge. The two mitigation actions that were carried out were made possible through external contributions and the coordinator's personal budget. This highlights the need for funding to support mitigation actions in future projects.

Deviation from the Original Plan

The most significant deviation from the original plan was the decision to forgo the closing survey. The RadoNorm project had prepared a comprehensive questionnaire for all participants in the cascade-funded projects that was filled out by 54 participants of the RadoNorm-SLO project. Since the results of this survey have not been shared with us, we have been unable to draw any further conclusions regarding the behavioral changes of the participants.

Due to budget constraints, some planned activities were canceled, including the presentation of the project's results at the ROOMS conference. Nevertheless, there remains the possibility of showcasing the findings at other conferences attended by Dr. Janja Vaupotič and Dr. David Kocman from JSI.

An online lecture on mitigation strategies, originally set for February, was also omitted. It was determined that language barriers would limit the majority of participants' ability to fully understand and benefit from the session. As planned, these strategies were thoroughly presented within the mitigation workshop held on April 11, 2024.

Presenting the RadoNorm-SLO results and conclusions at 21 People's Universities and 53 Third Age University centers across Slovenia is seen as a viable path to ensuring the project's sustainability. This approach was considered due to the limited financial support available from these institutions, which could only cover minimal travel expenses. Despite this we are investigating in what form the results could be presented to the decision makers at the Slovenian centers for education of adults and how could our activities be financed.

In the proposal, we anticipated that seminars and workshops would be available online via the ZIK webpage and recorded for later viewing. However, this plan was adjusted based on practical considerations. To ensure meaningful interaction, citizen scientists were required to attend the Introductory event in person to officially join the project. During this event, it was determined that online access was unnecessary, given that most participants were from nearby cities and part of an older demographic less familiar with remote communication tools.

Additionally, the recordings were unsuitable for publication due to the interactive nature of discussions with participants, which contained personal contributions that could not be shared publicly. Presenting only the slides without the full content would not be beneficial. Instead, a video summarizing the project outcomes is to be published, which will convey the main message: to measure radon levels and take action if the results exceed recommended limits.

7.8 References

1. https://www.zik-crnomelj.eu/sl/dogodki/radioaktivni-plin-radon-doma-in-na-delovnem-mestu-zdaj-je-cas-za-ukrepanje/

7.9 Annexes

Annex 1. Invitation to the first event

Annex 2. Presentation at the introductory event (first of the three parts)

Annex 3. Entry questionnaire

Annex 4. An interview and article about the project published in a local newsletter Belokranjec

Annex 5. An example of a report of a citizen scientist performing active measurements

Annex 6. Draft presentation for 21 People's Universities and 53 Slovenian Third Age University centers.

Annex 1

Flyer:

Invitation text:

RadoNorm-SLO: Skupaj raziskujmo radon v Beli krajini, predavanje o radonu, merjenju in ukrepanju

Z uvodno delavnico projekta RadoNorm-SLO, ki se bo naslednjih šest mesecev odvijal v Beli krajini, želimo povabiti občane k sodelovanju.

Projekt naslavlja problem povišanih koncentracij radona v bivalnih prostorih in je namenjen vsem občanom, ki bi se želeli aktivno vključiti v merjenje radona v njihovih bivališčih in se seznaniti z različnimi protiradonskimi ukrepi.

Na delavnici bo dr. Katja König najprej predstavila nekaj splošnih dejstev o radonu v bivalnem okolju, ter zakonodajo in priporočila na tem področju. Nato bo predstavila cilje in predviden potek projekta RadoNorm-SLO, ter kako se bodo občani lahko vključili v aktivnosti projekta. V okviru projekta bodo občani lahko izmerili koncentracijo radona v njihovih domovih z različnimi merilnimi metodami, ter izmerili tudi splošno kakovost zraka v njihovih domovih. Občani, aktivno vključeni v projekt, bodo lahko predstavili njihovo videnje problematike radona. Partner projekta je tudi Institut Jožef Stefan, s katerega se bosta delavnice udeležila dr. David Kocman in dr. Janja Vaupotič. David Kocman bo predstavil koncept občanske znanosti, ki v raziskave vključuje siršo skupnost. Janja Vaupotič pa bo predstavila pomen kontinuirnih meritev koncentracije radona (kot dopolnilne tehnike k detektorjem jedrskih sledi) in prezračevanja ter problem prevelike tesnosti stavbnega ovoja. Cilj projekta je izboljšanje ozaveščenosti občanov na področju radona in povečanje stopnje protiradonskih ukrepov.

Prispevki:

dr. Katja König: Projekt RadoNorm-SLO

dr. David Kocman: Občanska znanost – novi pristopi znanstvenoraziskovalnega dela na podlagi primerov dobrih praks dr. Janja Vaupotič: Kontinuirne meritve koncentracije radona in prezračevanja stavb

Annex 2


RadoNorm
Managing risks from radon and NORM
RadoNorm-SLO
RadoNorm-SLO: Občanska znanost kot podpora merjenju radona in protiradonski sanaciji v Beli krajini
Uvodni dogodek: Skupaj raziskujmo radon v Beli krajini
Katja König
Črnomelj, 19. Oktober 2023
Ta projekt je prejel sredstva iz programa Euratom za raziskave in usposabljanje 2019–2020 v okviru sporazuma o dodelitvi sredstev št. 900009.
1

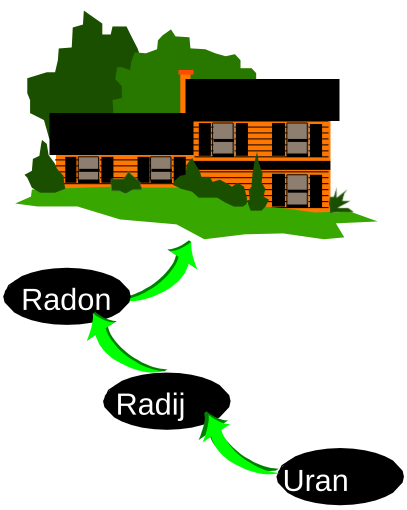

Naša projektna ekipa
RADON REŠITVE
ZIK ZAVOD ZA IZOBRAŽEVANJE IN KULTURO ČRNOMELJ
Jožef Stefan Institute
UKRadonLtd
Katja König s.p., distributer pasivnih detektorjev radona pooblaščenega podjetja Radonova Laboratories AB v Sloveniji, dr. Katja König
Zavod za izobraževanje in kulturo Črnomelj, (ZIK Črnomelj), Bela krajina, mag. Nada Žagar
Institut Jožef Stefan, Odsek za znanosti o okolju:
Center za radon, prof.dr. Janja Vaupotič
Okoljska informatika, dr. David Kocman
UK Radon Ltd, proti-radonski ukrepi v stavbah s povišano koncentracijo radona, Jerry Board
2

Splošno o radonu

3

Kaj je radon?

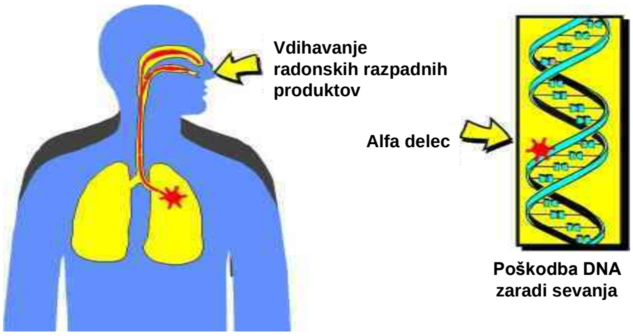
- Radon je radioaktivni plin.
- Nenehno nastaja z razpadom urana, ki je prisoten v tleh in kamninah.
- Ko nastane plin radon, izhaja iz tal v atmosfero, kjer se razredči, razen če pride v zgradbo ali zaprt prostor, kjer lahko njegova koncentracija močno naraste.



4

-

Zakaj nas radon skrbi?



- Radon je znan povzročitelj pljučnega raka (Razred 1*)
- Radon je odgovoren za skoraj polovico celotne doze ionizirajočega sevanja, ki jo vsako leto prejme prebivalstvo.
- Tveganje za zdravje zaradi radona je pri kadilcih 25-krat večje

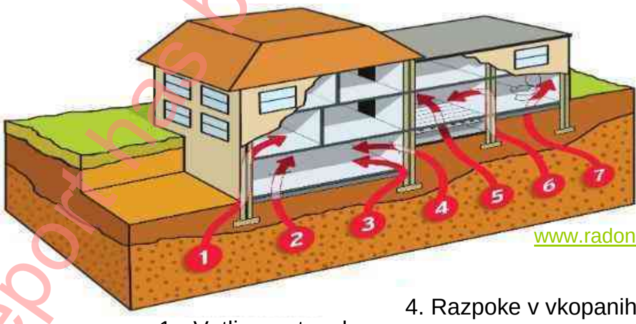
Pri vdihavanju plina radona delci alfa iz produktov razpada radona poškodujejo biološko tkivo v pljučih (DNK), kar lahko povzroči nastanek rakavega obolenja.

Po vsem svetu radon predstavlja 3 % do 16 % vseh smrti zaradi pljučnega raka, odvisno od povprečne koncentracije radona v državi (WHO Handbook on Radon, 2009).

** Mednarodna agencija za raziskave raka*

5

Kako radon vstopa v zgradbe?

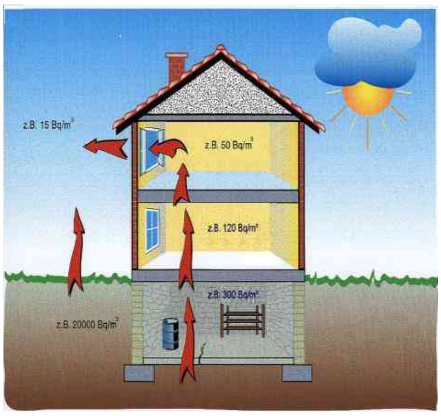


www.radon.ie

1. Votline v stenah
2. **Razpoke v tleh**
3. **Dilatacije**
4. Razpoke v vkopanih stenah
5. Montažne talne konstrukcije
6. Razpoke v stenah
7. **Reže/vrzeli ob napeljavah**

6

Raven radona v stavbah



BfS Nemčija

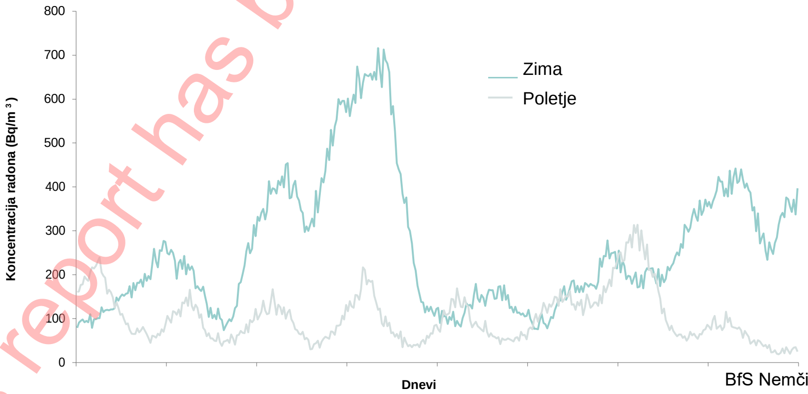
Na raven radona v zaprtih prostorih vpliva:

- Koncentracija radona v zraku v tleh
- Prepustnost tal
- Razpoke in vrzeli v strukturi
- Raven in vrsta ogrevanja/prezračevanja
- Etaža
- Uporaba stavbe vključno z navadami stanovalcev
- Letni čas in vreme

7

8

Časovne spremembe koncentracije radona v zaprtih prostorih – poletje/zima



BfS Nemčija

8

Slovenska zakonodaja o radonu

- Zakon o varstvu pred ionizirajočimi sevanji in jedrski varnosti
- Uredba o nacionalnem radonskem programu
- Pravilnik o zahtevah za novogradnje, posege v obstoječe stavbe in sanacijo obstoječih stavb zaradi varovanja zdravja ljudi pred škodljivimi učinki radona
- Tehnična smernica za graditev glede zaščite pred radonom v stavbah

Letna referenčna raven radona v zaprtih prostorih za stanovanja in delovna mesta v Sloveniji je **300 Bq/m³**.

WHO priporočilo za bivalno okolje je 100 Bq/m³.

9

Cilji in predviden potek projekta RadoNorm-SLO

10

Bela krajina

občine Črnomelj, Metlika in Semič; 596 km^2
~ 3 % ozemlja; 27.000 preb.

11

Cilji

- vključiti občane z različnimi pogledi in znanjem o radonu,
- skupaj z občani analizirati razloge za nizko stopnjo protiradonskih sanacij stavb preko participativne znanosti, kjer bodo občani vključeni v vse faze projekta in bomo spremljali njihov odnos do radona,
- oceniti, kako bi dejavna udeležba pri merjenju in poznavanje protiradonskih ukrepov lahko spremenila vedenje udeležencev in povečala stopnjo sanacij v primeru povišanih ravni radona v zaprtih prostorih.

12

Koristi za občane

- Izvedba pasivnih in aktivnih meritev radona

60 dni, en prostor
povprečna vrednost

4–6 tednov, več prostorov
beleženje rezultatov

- Merjenje kakovosti zraka v zaprtih prostorih CO_2, $PM_{2.5,\ 5,\ 10}$
- Seminarji o zdravstvenih tveganjih, strategijah protiradonskih ukrepov
- Delavnica o protiradonski sanaciji in terensko delo
- Aktivno sodelovanje z deljenjem svojih meritev, mnenj in predlogov

13

Meritve radona za občane

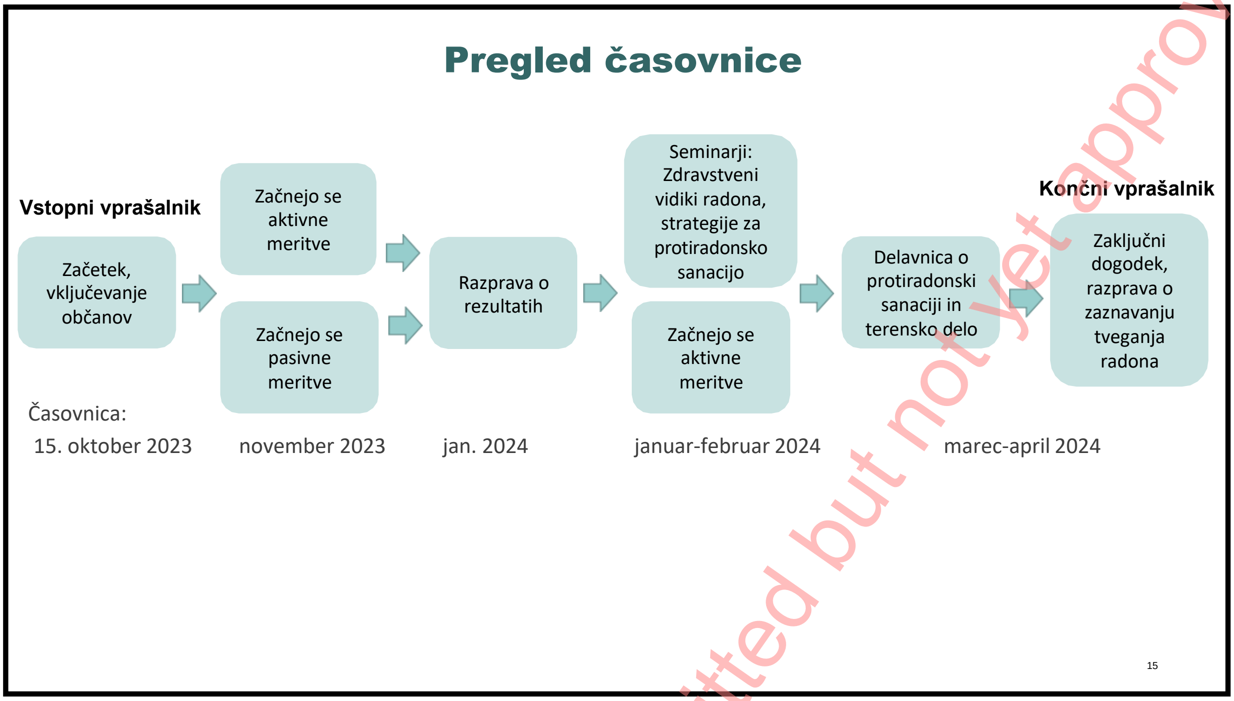
Poročilo iz laboratorija

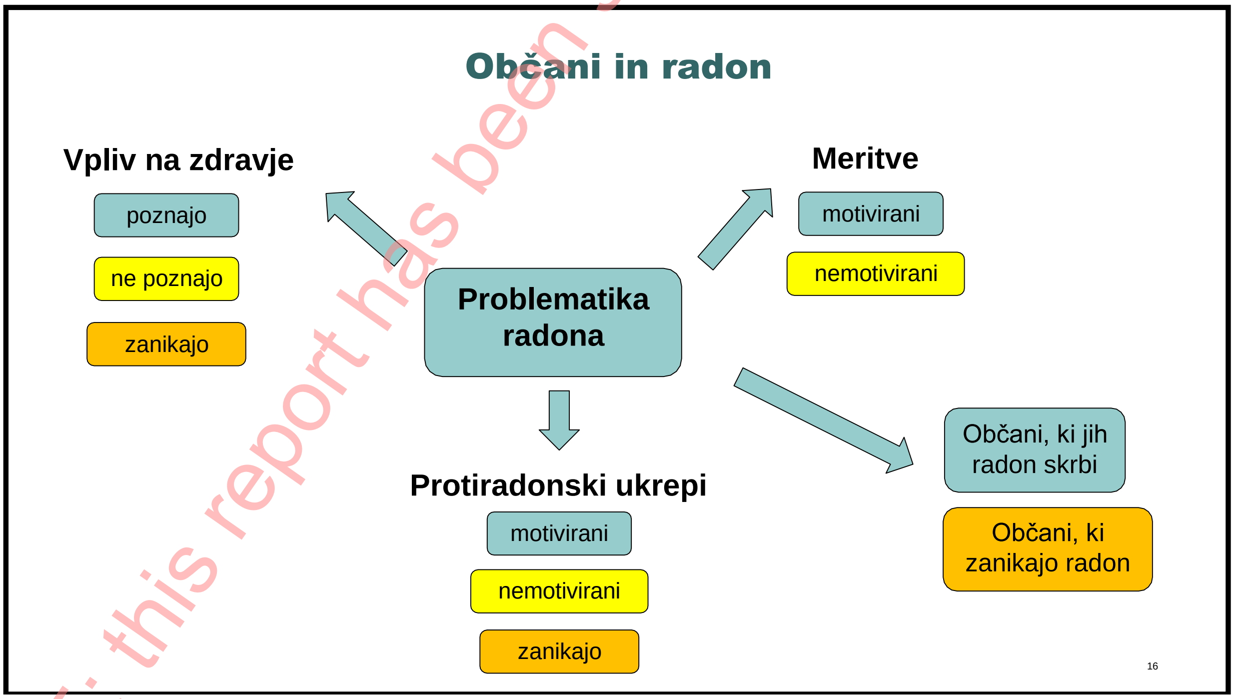
Dve skupini občanov:

- 1. SKUPINA: radon še ni bil izmerjen
  - Ta skupina bo začela s pasivnimi meritvami na začetku projekta (v začetku novembra)
  - Nadaljevanje z aktivnimi meritvami (januar–februar 2024)
- 2. SKUPINA: že izmerili radon na svojih domovih (sami, v množični akciji) in imajo povišano koncentracijo radona
  - Ta skupina bo začela z aktivnimi meritvami na začetku projekta

Beleženje rezultatov in deljenje v oblaku

14


Pregled časovnice
Vstopni vprašalnik
Začetek, vključevanje občanov
Začnejo se aktivne meritve
Začnejo se pasivne meritve
Razprava o rezultatih
Seminarji: Zdravstveni vidiki radona, strategije za protiradonsko sanacijo
Začnejo se aktivne meritve
Delavnica o protiradonski sanaciji in terensko delo
Končni vprašalnik
Zaključni dogodek, razprava o zaznavanju tveganja radona
Časovnica:
15. oktober 2023
november 2023
jan. 2024
januar-februar 2024
marec-april 2024
15


Občani in radon
Vpliv na zdravje
poznajo
ne poznajo
zanikajo
Meritve
motivirani
nemotivirani
Problematika radona
Protiradonski ukrepi
motivirani
nemotivirani
zanikajo
Občani, ki jih radon skrbi
Občani, ki zanikajo radon
16

Aktualni rezultati merjenja ravni radona v Beli krajini

Meritve radona v bivalnem okolju 2023 (URSVS), meritve radona v obdobju februar – junij 2023 (detektorji Radonova Laboratories AB)

Predstavitev o radonu v ZIK Črnomelj, februar 2023

17

Pričakovani rezultati in trajnost

- Povezava med ozaveščenostjo, aktivnim izvajanjem meritev in izvedbo protiradonskih ukrepov
- Priprava predlogov za spodbujanje ljudi k merjenju radona (RadoNorm, URSVS)
- Opolnomočiti ljudi za ukrepanje proti visokim ravnem radona v zaprtih prostorih (izvedba protiradonskih ukrepov)

Trajnost:

- razširjanje rezultatov projekta v 21 drugih Ljudskih univerzah in 53 organizacij Slovenske univerze za tretje življenjsko obdobje po vsej Sloveniji
- Spletna stran z rezultati projekta

18

“Naredi si sam” komplet za ublažitev vpliva radona in izvedbe z različnimi ventilatorji

“Naredi si sam” komplet za izvedbo sistema za ustvarjanje podtlaka pod temeljno ploščo objekta (UKRadon Ltd.)

19

Sponzorja

- Akrapovič d.d., Malo Hudo 8A, 1295 Ivančna Gorica

AKRAPOVIĆ

- Uprava Republike Slovenije za varstvo pred sevanji (URSVS)

Uprava Republike Slovenije za varstvo pred sevanji
MINISTRSTVO ZA ZDRAVJE

REPUBLIKA SLOVENIJA
GOV.SI

20

Naslednji dogodek

V novembru na ZIC Črnomelj:

- Pregled in diskusija rezultatov vstopnih vprašalnikov
- Odnos do problematike radona (diskusija)
- Skrb za kvaliteten zrak v bivalnem okolju (diskusija)
- Pregled in diskusija prvih rezultatov aktivnih meritev
- Razdelitev in postavitev merilnikov CO_2 in PM delcev

Navodila za izvedbo meritev (ZIK Črnomelj, kontakt: Irena Bohte)

- Pasivni detektor
- Digitalni merilnik (Excel tabela, cloud)

21

Kontakt

Katja König
Tel: 031 35 20 20
Email: info@radon-restive.si

Naslov za vračilo pasivnih detektorjev:
Katja König
Lepi pot 6
1000 Ljubljana

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7.9.1 Annex 3

VSTOPNI VRPAŠALNIK

1. Katere od navedenih onesnaževal zraka v domovih poznate (ustrezno obkrožite):
    a. Vlaga
    b. Plesni
    c. Ogljikov dioksid (CO2)
    d. Ogljikov monoksid (CO)
    e. Hlapne organske snovi (VOC)
    f. Radon

2. Kako ocenjujete kvaliteto zraka v vašem domu?
    a. Dobra
    b. Slaba
    c. Nekaj vmesnega
    d. Ne vem

3. Ali ste v vašem domu izmerili katero od onesnaževal iz točke 1? DA/NE
   Katero? ____________________

4. Kako v hladnem delu leta zračite vaše prostore (obkrožite en najustreznejši odgovor):
    a. Ne zračimo
    b. Včasih odpremo okno za krajši čas.
    c. Okno odpremo na kip.
    d. Redno zračimo z odpiranjem oken na stežaj (dvakrat ali večkrat dnevno).
    e. Imamo lokalno mehansko prezračevanje z ali brez rekuperacije toplote.
    f. Imamo centralni prezračevalni sistem z rekuperacijo toplote.

5. Ali vas zanima, kakšna je kvaliteta zraka v vašem domu? DA/NE

6. Ali vas skrbi za kvaliteto zraka v vašem domu? DA/NE

7. Katero od naštetih onesnaževal bi radi izmerili? _________________

8. Ali ste že slišali za radon? DA/NE

9. Ali veste kaj je radon? DA/NE

10. Ali poznate učinke radona na zdravje? DA/NE

11. Kje (v katerih objektih ali prostorih) so po vašem zadržuje radon (obkrožite le en najprimernejši odgovor)?
    a. V kleteh.
    b. V starih hišah/objektih.
    c. V šolah.
    d. V zaprtih/notranjih prostorih, še posebej na kraškem terenu.

12. Ali ste v vašem domu že izmerili koncentracijo radona? DA/NE Je bila vrednost povišana (višja od 300 Bq/m^3)? DA/NE/Nisem prebral poročila.

13. Ali bi v vašem domu radi izmerili koncentracijo radona? DA/NE

14. Če je bila/bi bila izmerjena vrednost povišana, ali bi vas skrbelo za vaše zdravje? DA/NE

15. Če je bila/bi bila izmerjena vrednost povišana, veste kako lahko koncentracijo znižate? DA/NE

16. Če je bila/bi bila izmerjena vrednost povišana, kaj ste/bi storili (obkrožite en odgovor):
    a. Nič.
    b. Več bi zračili.
    c. Zelo bi nas skrbelo in bi se pozanimali o možnih proti-radonskih ukrepih. Ukrepe bi izvedli in opravili kontrolno meritev.

17. Ali bi radi izvedeli več o radonu in proti-radonskih ukrepih? DA/NE

18. Bi vas zanimalo sodelovanje v projektu RadoNorm-SLO (oktober 2023–april 2024), ki na območju Bele krajine z udeležbo občanov raziskuje relacije med meritvami radona in izvedbo proti-radonskih ukrepov? V okviru projekta bodo za aktivne udeležence na voljo meritve radona s pasivnimi detektorji in aktivnimi merilniki kot tudi merilniki CO_2 in VOC. DA/NE

7.9.2

Annex 4

BUDNO OKO

Raziskujemo

RADIOAKTIVNI RADON

RADON JE RADIOAKTIVEN PLIN, KI JE NAVZOČ V VSEH OBJEKTIH: POSLOVNIH IN STANOVANJSKIH. BELA KRAJINA, ZLASTI ČRNOMELJ IN SEMIČ, STA PREPOZNANA KOT OBMOČJI Z VEČ RADONA. ZATO JE POMEMBNO, DA Z MERITVAMI UGOTOVIMO NJEGOVO KONCENTRACIJO IN UKREPAMO, ČE JE TO POTREBNO. V OKVIRU PROJEKTA RADONORM-SLO SO PRIČELI BELOKRANJCI MERITI KONCENTRACIJO RADONA V SVOJIH DOMOVIH. PROJEKT JE PREJEL SREDSTVA IZ PROGRAMA EURATOM ZA RAZISKAVE IN USPOSABLJANJE 2019-2020 V OKVIRU SPORAZUMA O DODELITVI SREDSTEV ŠT. 900009. NA SREČANJIH S STROKOVNJAKI SO UDELEŽENCI ŽE PREVZELI MERILNIKE RADONA IN SE TAKO PODALI V RAZISKOVALNE VODE.

KDO JE POLEG VAS V STROKOVNI EKIPI, KI PRIHAJA V BELO KRAJINO?

KOLIKO ČASA STE ŽE V BELI KRAJINI? NA KAKŠEN NAČIN POTEKAJO MERITVE?

STE ZADOVOLJNI Z ODZIVOM PREBIVALSTVA?

KAJ KAŽEJO DOSEDANJE MERITVE NA OBMOČJU BELE KRAJINE?

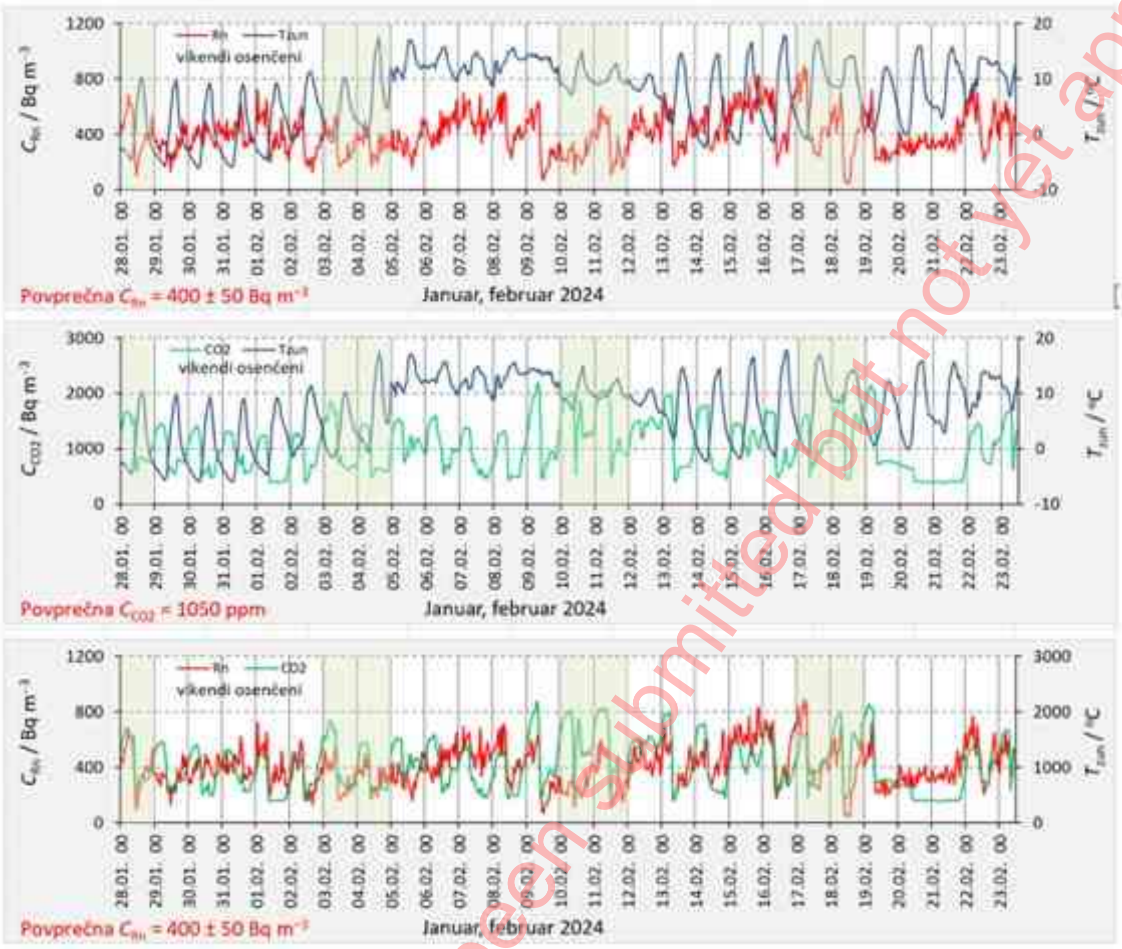
KAJ SVETUJETE LJUDEM, KI ŽIVIJO NA OBMOČJIH, KJER ZAZNAVATE POVIŠANO KONCENTRACIJO RADONA V ZRAKU?

KAKO BO V BELI KRAJINI POTEKALO VAŠE NADALJNJE DELOVANJE?

RUDI VLAŠIĆ

7.9.3 Annex 5

Poročilo Radon



*Slika 1; Spalnica, ugotavljanje stanja

Ugotovitev stanja Rn v spalnici v 1. nadstropju, kjer se največ zadržujemo v tekočem dnevu.

Vrata v spalnici so stalno odprta. Vrata na stopnišče se veliko odpirajo ali pa so odprta. Raven Rn je previsoka.

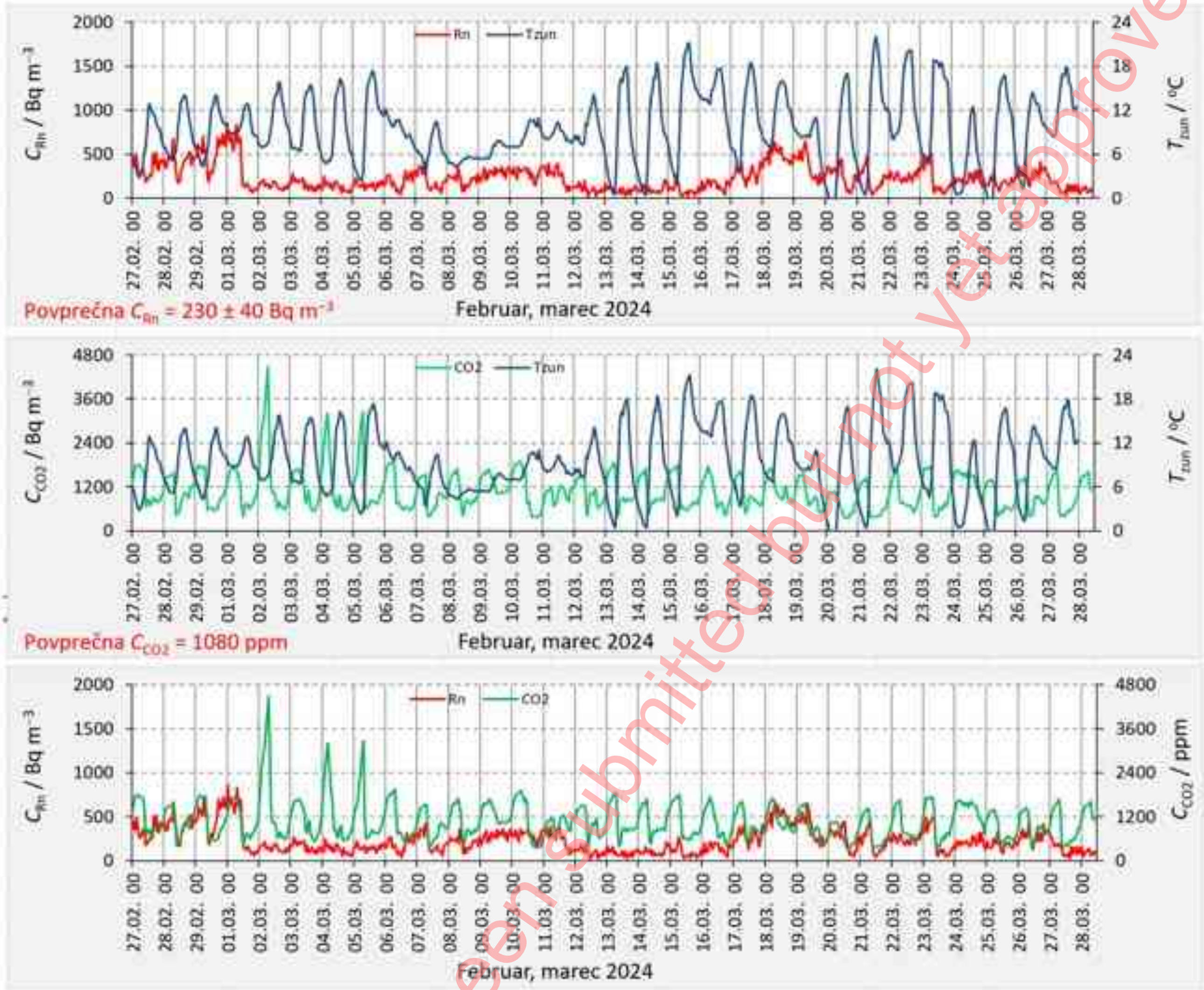
Ves čas od 28. 01.24 do 19.02 24 smo bili doma.

Od 19. 02. 24 do 22. 02. 24 nas ni bilo doma.

Vrata na stopnišče so bila ves čas zaprta.

Ugotovitev :Raven Rn je konstantno nizka in stabilna.

Predpostavljam, da prihaja Rn iz stopnišča, kjer je kanalizacijski jašek. Pokrov je iz Rf pločevine in oljno tesnjen.



*Slika 2; Spalnica

Meritev Rn v spalnici, ko sem spreminjal prezračevanje na stopnišču.

02.03. 24 – 08.03. 24--- Odprto okno na kiper v pritličju in vrhu stopnišča. Stalen prepih močno zniža raven Rn.

08.03.24 –12.03.24 ---Okno v pritličju in vrhu stopnišča zaprem in vključim na novo vgrajen rekuperator spodaj na stopnišču. Dela z polovično močjo. Raven Rn se je nekoliko povišala, vendar še v normalnih mejah.

12.03.24-- 17.03.24---Vklopljen rekuperator in odprta oba okna na kiper. (v pritličju in vrhu stopnišča)

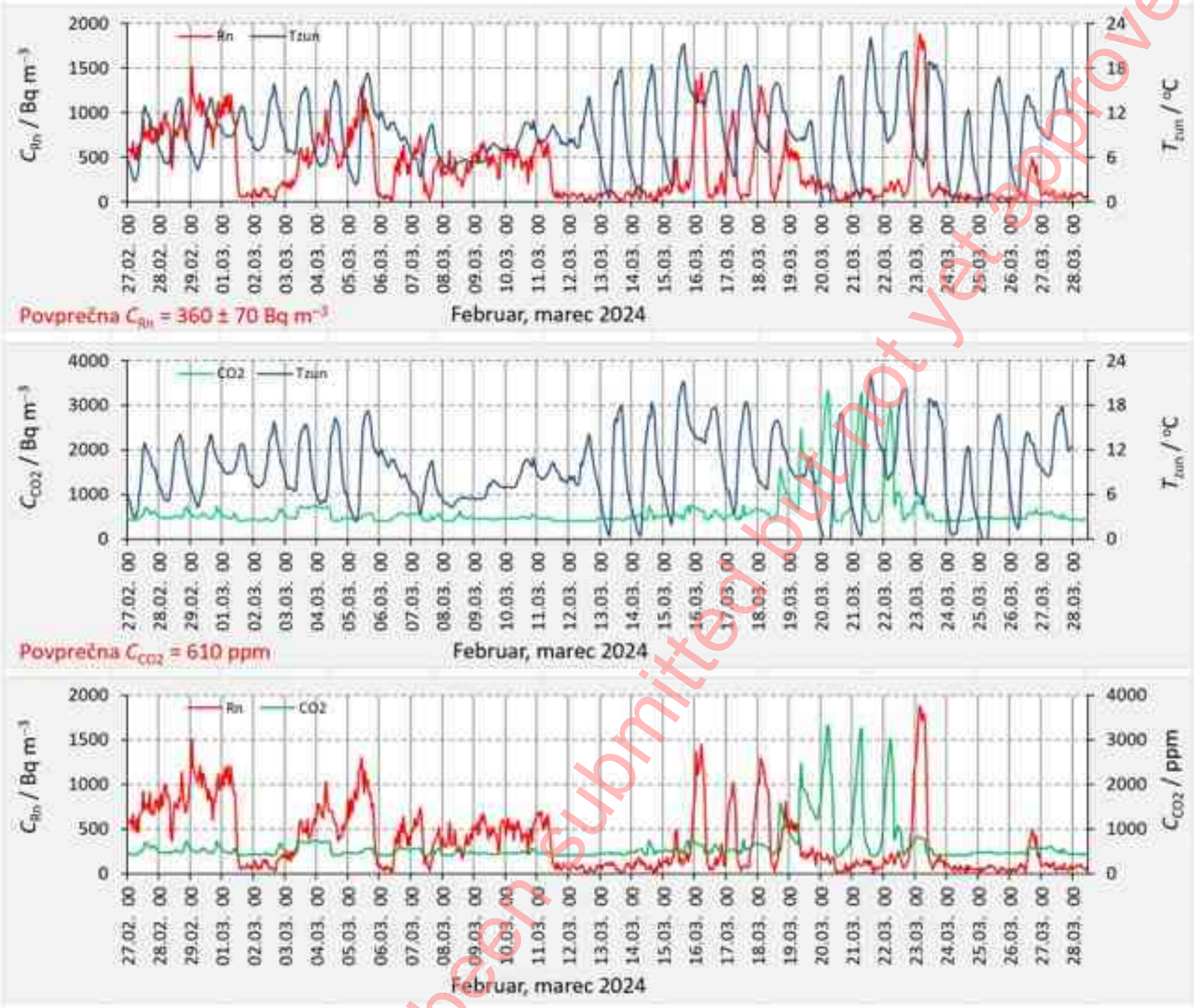
Rn padel na minimalno vrednost.

17.03.24—20.03.24—Vklopljen rekuperator na pol moči, oba okna zaprem. Rn se zopet poveča.

V zimskem času bom uporabljal polno moč rekuperatorja.

20.03.24—28.03.24---Rekuperator na polovico moči, oba okna na kiper. Rn v dovoljenih mejah.

Vgrajen rekuperator PRANA 150 SILENT, ki istočasno stalno dovaja cca 10% več zraka kot ga odvaja in s tem ustvarja v prostoru nekoliko višji tlak kot je zunaj.



*Slika 3; Stopnišče

27.02.2024 Okna na stopnišču in pritličju zaprta.

02.03.24---08.03.24 Odprto okno na kiper v pritličju in vrhu stopnišča.

08.03.24---12.03.24 Okno v pritličju in vrhu stopnišča zaprem in vključim rekuperator.

12.03.24---16.03.24 Vključen rekuperator in oba okna na kiper. Zelo nizka vrednost Rn.

16.03.24--- 23.03.24 Posodim instrument g. ________, ki meri v drugi hiši.

23.03.24---26.03.24 Posodim instrument g. ________, ki meri Rn v novi hiši zgrajeni na 20 cm. debeli temeljni plošči z izolacijo brez kanalizacijskega jaška v kleti. Raven Rn zelo nizka.

7.9.4 Annex 6

Problematika radona v Sloveniji

Dr. Katja König
Strokovne in tehnične dejavnosti
www.radon.si

Mesto, Datum

1

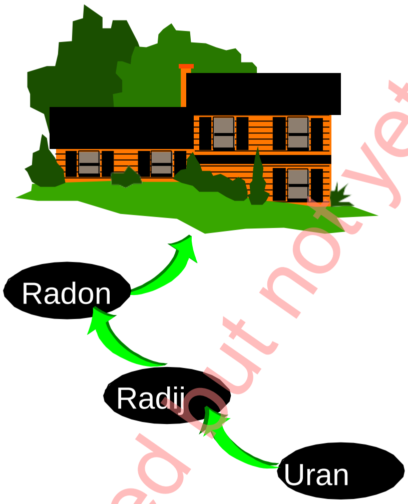
Vsebina predavanja

- Splošno o radonu
- Predstavitev rezultatov projekta RadoNorm-SLO
- Slovenska zakonodaja o radonu
- Merjenje radona
- Zaščita pred radonom

2

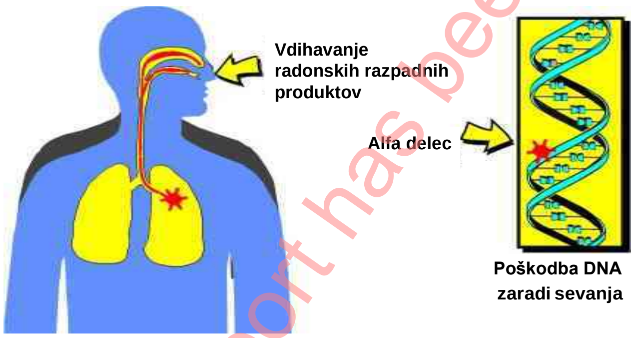
Kaj je radon?

- Radon je radioaktivni plin.
- Nenehno nastaja z razpadom urana, ki je prisoten v tleh in kamninah.
- Ko nastane plin radon, izhaja iz tal v atmosfero, kjer se razredči, razen če pride v zgradbo ali zaprt prostor, kjer lahko njegova koncentracija močno naraste.



3

Zakaj nas radon skrbi?



- Radon je znan povzročitelj pljučnega raka (Razred 1*)
- Radon je odgovoren za več kot polovico celotne doze ionizirajočega sevanja, ki jo vsako leto prejme prebivalstvo.
- Tveganje za zdravje zaradi radona je pri kadilcih 25-krat večje

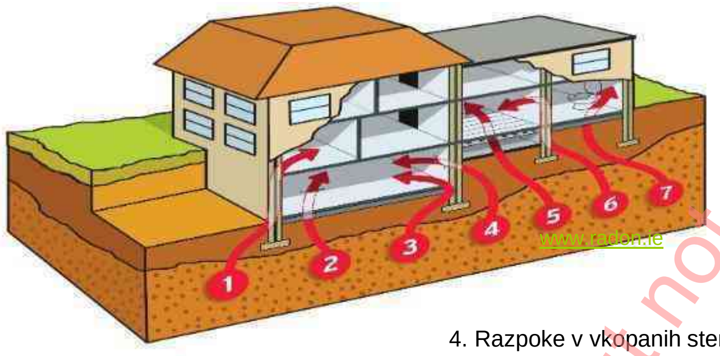
Pri vdihavanju plina radona delci alfa iz produktov razpada radona poškodujejo biološko tkivo v pljučih (DNK), kar lahko povzroči nastanek rakavega obolenja.

Po vsem svetu radon predstavlja 3 % do 16 % vseh smrti zaradi pljučnega raka, odvisno od povprečne koncentracije radona v državi (WHO Handbook on Radon, 2009).

** Mednarodna agencija za raziskave raka*

4

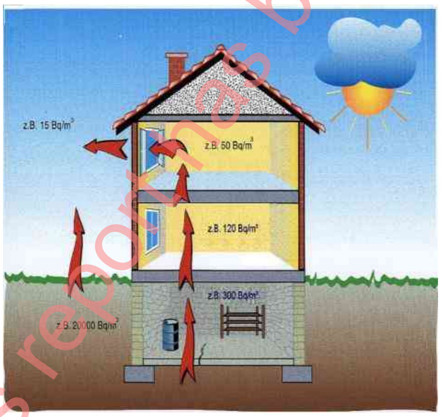
Kako radon vstopa v zgradbe?



1. Votline v stenah
2. **Razpoke v tleh**
3. **Dilatacije**
4. Razpoke v vkopanih stenah
5. Montažne talne konstrukcije
6. Razpoke v stenah
7. **Reže/vrzeli ob napeljavah**

5

Raven radona v stavbah



BfS Nemčija

Na raven radona v zaprtih prostorih vpliva:

- Koncentracija radona v zraku v tleh
- Prepustnost tal
- Razpoke in vrzeli v strukturi
- Raven in vrsta ogrevanja/prezračevanja
- Etaža
- Uporaba stavbe vključno z navadami stanovalcev
- Letni čas in vreme

6

Časovne spremembe koncentracije radona v zaprtih prostorih

- Koncentracija radona zelo niha zaradi vpliva vremena (temperatura, zračni tlak, veter), časa (noč/dan) zračenja
- Meritev povprečane koncentracije radona v daljšem časovnem obdobju (60-90 dni)
- Najvišje vrednosti v zimskem času ⟹ primeren čas za prvo ali kontrolno meritev

BfS Nemčija

7

RadoNorm
Managing risks from radon and NORM

RadoNorm-SLO

RadoNorm-SLO: Občanska znanost kot podpora merjenju radona in protiradonski sanaciji v Beli krajini

Partnerji:

RADON REŠITVE | ZIK ZAVOD ZA IZOBRAŽEVANJE IN KULTURO ČRNOMELJ | Jožef Stefan Institute | UKRadonLtd

Oktober 2023 – April 2024

Ta projekt je prejel sredstva iz programa Euratom za raziskave in usposabljanje 2019–2020 v okviru sporazuma o dodelitvi sredstev št. 900009.

8

Cilji

- vključiti občane z različnimi pogledi in znanjem o radonu,
- skupaj z občani analizirati razloge za nizko stopnjo protiradonskih sanacij stavb preko participativne znanosti, kjer bodo občani vključeni v vse faze projekta in bomo spremljali njihov odnos do radona,
- oceniti, kako bi dejavna udeležba pri merjenju in poznavanje protiradonskih ukrepov lahko spremenila vedenje udeležencev in povečala stopnjo sanacij v primeru povišanih ravni radona v zaprtih prostorih.

9

Aktivnosti

- Izvedba pasivnih in aktivnih meritev radona

60 dni, en prostor
povprečna vrednost

4–6 tednov, več prostorov
beleženje rezultatov

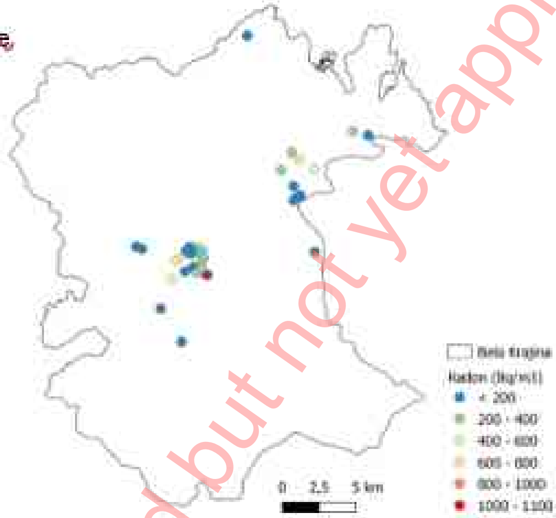
- Merjenje kakovosti zraka v zaprtih prostorih CO_2, $PM_{2.5,\ 5,\ 10}$
- Seminarji o zdravstvenih tveganjih, strategijah protiradonskih ukrepov
- Delavnica o protiradonski sanaciji in terensko delo
- Aktivno sodelovanje občanov z deljenjem svojih meritev, mnenj in predlogov

10

Aktualni rezultati merjenja ravni radona v Beli krajini

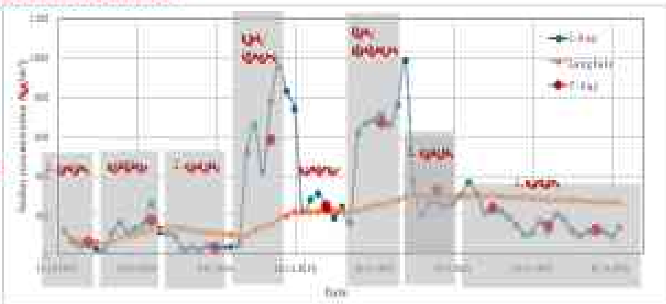
Meritve radona v bivalnem okolju 2023 (URSVS), meritve radona v obdobju februar – junij 2023 (detektorji Radonova Laboratories AB)

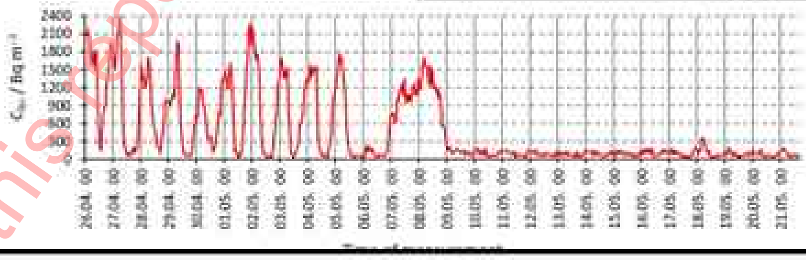
Predstavitev o radonu v ZIK Črnomelj, februar 2023



Rezultati

- 71 pasivnih meritev in 52 aktivnih meritev radona





Rezultati

- 73 pasivnih meritev in 54 aktivnih meritev radona
- 7 meritev kakovosti zraka v domovih občanov (CO_2, PM10, PM2.5)
- Povezava med ozaveščenostjo, aktivnim izvajanjem meritev in izvedbo protiradonskih ukrepov
- Priprava predlogov za spodbujanje ljudi k merjenju radona (RadoNorm, URSVS)
- Opolnomočiti ljudi za ukrepanje proti visokim ravnem radona v zaprtih prostorih (izvedba protiradonskih ukrepov)

13

Rezultati

- Povezava med ozaveščenostjo, aktivnim izvajanjem meritev in izvedbo protiradonskih ukrepov
- Priprava predlogov za spodbujanje ljudi k merjenju radona (RadoNorm, URSVS)
- Opolnomočiti ljudi za ukrepanje proti visokim ravnem radona v zaprtih prostorih (izvedba protiradonskih ukrepov)

Trajnost:

- razširjanje rezultatov projekta v 21 drugih Ljudskih univerzah in 53 organizacij Slovenske univerze za tretje življenjsko obdobje po vsej Sloveniji
- Spletna stran z rezultati projekta

14

Delavnica o protiradonski sanaciji in terensko delo

- Predstavitev različnih možnosti za znižanje koncentracije radona v obstoječih stavbah

Komplet za izvedbo sistema (UKRadon Ltd.)

Zaključki

- Poznavanje problematike radona je pomanjkljivo, večina je slišala za radon, zelo malo jih pozna rešitve
- Z izmerjeno nizko koncentracijo radona pade motivacija za boljše poznavanje problematike radona
- Z izmerjeno povišano koncentracijo radona se poveča motivacija za aktivne meritve
- Negotovost pri ukrepih: zračevanje ni zadosten ukrep, negotovost pred naprednimi tehnikami protiradonskih ukrepov
  - Nepoznavanje principa in delovanje
  - Cena
- Opolnomočiti ljudi za ukrepanje proti visokim ravnem radona v zaprtih prostorih (izvedba protiradonskih ukrepov)

16

Sponzorja

- Akrapovič d.d., Malo Hudo 8A, 1295 Ivančna Gorica

AKRAPOVIČ

- Uprava Republike Slovenije za varstvo pred sevanji (URSVS)

Uprava Republike Slovenije za varstvo pred sevanji
MINISTRSTVO ZA ZDRAVJE

REPUBLIKA SLOVENIJA
GOV.SI

17

Slovenska zakonodaja o radonu

- Zakon o varstvu pred ionizirajočimi sevanji in jedrski varnosti
- Uredba o nacionalnem radonskem programu
- Pravilnik o zahtevah za novogradnje, posege v obstoječe stavbe in sanacijo obstoječih stavb zaradi varovanja zdravja ljudi pred škodljivimi učinki radona
- Tehnična smernica za graditev glede zaščite pred radonom v stavbah

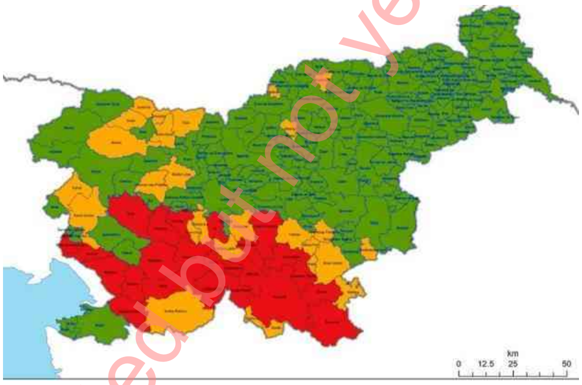
Letna referenčna raven radona v zaprtih prostorih za stanovanja in delovna mesta v Sloveniji je **300 Bq/m³**.

WHO priporočilo za bivalno okolje je <100 Bq/m³.

18

Slovenska zakonodaja o radonu

- Zakon o varstvu pred ionizirajočimi sevanji in jedrski varnosti (2018)
- Uredba o nacionalnem radonskem program (2018)
  - Razdelitev na tri območja tveganja
  - Letna referenčna vrednost 300 Bq/m^3
  - Obveznost merjenja na delovnih mestih



- Pravilnik o zahtevah za novogradnje, posege v obstoječe stavbe in sanacija obstoječih stavb zaradi varovanja zdravja ljudi pred škodljivimi učinki radona (2022)

19

Meritve radona

- Pasivni detektorji jedrskih sledi

60 dni, en prostor
povprečna vrednost

- Aktivni monitorji radona

4–6 tednov, več prostorov
beleženje rezultatov

- **Negotovost pri reševanju problema povišanih koncentracij radona**:
  Za noben ukrep ne moremo z gotovostjo trditi, v kolikšni meri bo deloval, zato moramo po posegih izvesti **kontrolno meritev v hladnem delu leta**.

20

Zaščita pred radonom

- 1. korak: meritev v bivalnem prostoru
- 2. korak: prepoznava tveganja za zdravje
    - Priporočena….pod 100 Bq/m3
    - Sprejemljiva….100-200 Bq/m3 (redno zračenje v zimskem času)
    - Povišana….200-400 Bq/m3 (mehansko prezračevanje – POZOR niso primerni vsi sistemi)
    - Visoka….400-900 Bq/m3 (ventilacija pod temeljno ploščo)
    - Zelo visoka….900-2000 Bq/m3 (ventilacija pod temeljno ploščo + ustrezno mehansko prezračevanje)
    - Ekstremna….nad 2000 Bq/m3 (identifikacija in sanacija večjih virov + ventilacija pod temeljno ploščo + ustrezno mehansko prezračevanje)
- 3. korak: odločitev za izvedbo protiradonskih ukrepov
    - Identifikacija večjih virov radona in tesnjenje
    - Mehansko prezračevanje
    - Sistem za odvajanje zraka izpod temeljne plošče
- 4. korak: kontrolna meritev

21

Zaključek

- Radon je zdravlju škodljiv plin, ki se lahko kopiči v domovih
- Detektorji in merilniki radona so dostopni
- Meritev se opravi v hladnem delu leta (60-90 dni) v bivalnem prostoru, kjer se največ zadržujemo
- Priporočeno ukrepanje, če je zimska vrednost nad 300 Bq/m^3
- Občasno prezračevanje ne zadostuje
- Izvedba mehanskega prezračevanja (zmerno povišane vrednosti)
- Sistem za ustvarjanje podtlaka pod temeljno ploščo (najučinkovitejši ukrep)
- Kontrolna meritev v hladnem delu leta
- Preventiva v novogradnjah je zelo enstavna in učinkovita

22

8 Spain: RadoHOW: radon doses in homes vs workplaces

The Citizen Science (CS) initiatives of the Spanish project RAdon DOses in HOmes vs Workplaces (RadoHOW; **Figure 32**) mainly began in September 2023 and continued until March 11, 2024, culminating in the final event. However, the project design started earlier, in June 2023, and the final analysis and closure extended until July 2024.

Figure 32. Logo of the CS Spanish project RadoHOW: radon doses in homes vs workplaces.

RadoHOW's main objective is to compare the levels of radon exposure that citizen scientists experience at work versus at home, across various geographical, geological, and building environments in Spain. Additionally, the project aims to raise awareness about the potential health effects, emphasising that these two doses are received continuously, as individuals spend most of their time in these two locations.

During the development of the project, it was determined that residents in the provinces of Galicia, Cantabria, Zaragoza and Madrid are exposed to radon gas doses at both their homes and workplaces that do not pose a health hazard and do not require severe mitigation measures. However, there are some nuances, as Zaragoza's residents experience the lowest radon exposure, followed by those in Madrid. The homes of Galician participants and the workplaces of Cantabrians are the closest to this value, suggesting perhaps two points where mitigation through simple ventilation should be carried out more continuously.

On the other hand, residents in the province of Salamanca are exposed to higher radon gas doses at their workplaces and, especially, in their homes. In these instances, the application of more significant mitigation measures is required to prevent long-term health hazards. Some locations where measurements have been taken had already implemented mitigation measures before this project. However, RadoHOW will continue with them, to study and monitor each case.

8.1 Rationale and objectives of the CS project

A vast number of studies have already explored radon exposure in homes, while only a few have investigated this matter in workplaces and, in some cases, the dose received in the latter can be significantly higher. This project addresses, for the first time, a pilot study that allows for the comparison of both environments. Therefore, in case one person develops health problems that could be related to radioactivity or radon gas, this project's results will be useful for discerning whether the problem is, if at home or at the workplace. It not only advances scientific knowledge about radon but also raises public awareness of the effects of radioactivity.

The **objectives of RadoHOW** were:

1) To compare the levels of radon exposure that citizen scientists experience at their home and at their workplaces.
2) To co-determine the measurement methodology together with the key stakeholders and feasible citizen scientists.

3) To assess differences between results from various geographical, geological, and building environments in Spain.
4) To use CR39 trace detectors and continuous measurement equipment for the assessment of doses.
5) To boost participation of citizen scientists in the communication and dissemination plan of the project.
6) To co-define with citizen scientists' basic strategies for both remediation of radon doses and communication of the methodology.
7) To increase citizen scientists' knowledge on how to interpret the results and provide them tools for continuing measuring after the project ends.
8) To raise awareness about the potential health effects, emphasising that these two doses are received continuously, as individuals spend most of their time in these two locations.

Due to all of the above, an extreme CS methodology has been applied in RadoHOW. Citizen scientists have been engaged from the very beginning of the initiatives, co-determining the measurement methodology alongside key stakeholders and the project team. Their skills have been developed to interpret their results and communicate the outcomes, allowing them to take a more active role during and after the project. Consequently, they have participated in various stages of the scientific process in RadoHOW, together with researchers: defining the research question, collecting data, interpreting the data, and disseminating the methodology. The dissemination of results will occur in the coming months, once certain results have been thoroughly monitored, in the form of scientific papers that will include and acknowledge the contributions of citizen scientists.

8.2 Partners and roles

1) Luis Quindos:

- Experience: Professor at the Environmental Radioactivity Laboratory of the University of Cantabria (LaRUC), in the research areas of naturally occurring radioactivity, especially radon gas, microenvironmental control in conservation settings and educational programs in environmental health. As the head of the Radon Group at the University of Cantabria, he has delivered over 100 talks at town halls across the country. Since 1989, he has participated in various European projects such as ERRICCA I and II, RADPAR, METRORADON, TRACERADON, and more than 15 projects funded by the Nuclear Safety Council and the National Government Science Programme.
- Role: leader, principal investigator, research scientist, data analyst and dissemination coordinator.

2) Alba Peiro:

- Experience: PhD in Geology from the University of Zaragoza with experience in CS focused on historical memory. Since 2023, a researcher on CS at the Ibercivis Foundation, mainly coordinating and participating in projects aimed at soil literacy and soil preservation against climate change at both national and European levels. Possesses extensive experience in delivering conference talks, group discussions, participating in dissemination events and writing academic papers.
- Role: project manager, CS and communication coordinator.

3) Francisco Sanz:

- Experience: Executive director of the Ibercivis Foundation, a national non-for-profit foundation devoted to CS in Spain. Ibercivis has deployed more than 70 experiments on CS in collaboration with several research groups reaching over 60.000 citizen scientists. He has coordinated two European CS projects: Socientize (in which the White Paper for CS in Europe was written) & D-Noses and participated in many other European projects related to CS. Ibercivis is a member of the European Citizen Science Association (ECSA) and is the main developer of the EU-Citizen.Science platform.

- Role: CS specialist, ethics advisor and Data Protection Officer (DPO).

4) Judith Bielsa:

- Experience: Social researcher at the Ibercivis Foundation since 2023. Graduate in Political Science specialising in Public and Social Policy, with experience in the study of qualitative and quantitative social indicators related to the Welfare State. Currently working in the field of CS, participatory methodologies and the analysis of environmental public policies.
- Role: CS and communication advisor and facilitator.

5) Enrique Fernandez:

- Experience: Laboratory technician, specialised in measuring radon gas. He has been working in the radon laboratory at the University of Cantabria for more than fifteen years. He is responsible for the quality control of continuous measurement equipment. Hired as a researcher, he has been coauthor of several articles related to radon gas.
- Role: Quality control of continuous radon monitors

8.3 Citizen engagement

8.3.1 Role of citizen scientists

A total of **20 citizen scientists** participated in RadoHOW, representing diverse target groups including researchers, residents, volunteer networks, local municipalities, nuclear industry workers, civil protection workers and public agencies, among others. They came from **5 different provinces** from Spain, with 4 participants from each (**Figure 33**):

- Galicia: Radon prone area in Spain.
- Cantabria: Karst zone in Spain,
- Salamanca: Uranium mining area,
- Zaragoza: Low potential radon area,
- Madrid: Radon prone area with high population.

Figure 33. Location of the RadoHOW citizen scientists according to the simplified map of potential radon gas zones from the Nuclear Safety Council (CSN - Consejo de Seguridad Nuclear, Spain).

An **initial questionnaire** allowed to determine the general profile of the citizen scientists at the beginning of their participation in RadoHOW (administered in September 2023; see Annex 1 for details). It was found that 92% of the citizen scientists had prior knowledge of the subject, but only 33% had previous experience with CS projects, compared to 50% who had participated in previous radon gas projects. Responses from this questionnaire allowed us to draw conclusions about their prior knowledge of radon gas issues (an average of 58% chose the correct answers, 22% neutral answers, and 20% incorrect answers) and their understanding of the detectors used (an average of 96% chose the correct answers, 4% neutral answers, and 0% incorrect answers). It is worth noting that they expressed uncertainties regarding the reference value for the maximum concentration of radon gas established by European authorities for all European Union countries. However, they were well aware of the measures to minimise the presence of radon gas as outlined in the Technical Building Code in Spain.

Therefore, participants started the project well-informed about CS but not highly experienced in it. Their main motivations indicated a high interest in CS projects, with a mix of individuals both unaware of whether they had radon gas issues in their homes or workplaces and those well-experienced and informed in this aspect. Additionally, participants demonstrated an intermediate knowledge of radon gas and a high understanding of the types of detectors to be used. The latter was high because the questionnaire was administered after the RadoHOW's final methodology and detectors had been explained.

The **citizen scientific role** within RadoHOW consisted in placing 2 containers containing 2 CR39 detectors at home, and other 2 containers containing 2 CR39 detectors at the workplace. Together with them, they also placed 1 continuous measurement equipment at home, and 1 continuous measurement equipment at the workplace (Fig. 3). They manipulated them for measuring during an approximate period of 3 months.

Figure 34. Examples from one citizen scientist of their jars containing CR39 detectors and their continuous measurement equipment at their workplace.

The procedure for using the pairs of **CR39 detectors** involved exposing one detector continuously by keeping its container open for the entire 3-month measurement period (see the "abierto" container in **Figure 34**). The other detector was systematically opened only during the participant's time at home or work, and was closed the rest of the time (see Annex 2 for details). Since trace detectors measure exposure, the respective exposures were determined by the difference between the two detectors. However, because these detectors measure the average radon concentration over the time they are exposed, citizen scientists also filled out a tracking calendar with the specific daily hours when each container was opened (Annex 3). There was no need for participants to manipulate the **continuous measurement equipment** (Annex 2), as it arrived already activated and measuring, and was returned in the same state.

It is important to highlight that continuous radon measurements equipment in both homes and workplaces were originally planned to be conducted over a two-week period (as shown in Annex 2). Initially, it was estimated that 10 continuous measurement devices would be sufficient for the five provinces, using a relay approach. Citizen scientists would measure for two weeks with two devices and then pass them to the next closest participant. However, the research team concluded that this period was too short to effectively control the CR39 detectors' results over the full three-month measurement period, significantly impacting the project's results. Therefore, the RadoHOW team agreed to increase the number of continuous measurement devices to 40, allowing the entire community to measure for the full three months. While the available budget permitted the acquisition of only a small number of these devices, an important number of the continuous measurement equipment was sourced from the RadoHOW's team or voluntarily provided by participants. As explained in the next section, this decision influenced the selection of some participants to a minor extent.

8.3.2 Recruitment process

Citizen scientists were recruited during summer 2023, starting by spreading the word on the "Citizen Science for radiation measurement" day celebrated by the Nuclear Safety Council (CSN - Consejo de Seguridad Nuclear) the 8th of June of 2023 (https://www.csn.es/-/un-grupo-de-expertos -expone-en-el-csn-las-aplicaciones-y-el-potencial-de-la-ciencia-ciudadana-para-la-medicion-de-radiaciones). In June, a specific section was created within the research group's website as well for this purpose (https://elradon.com/proyecto-de-ciencia-ciudadana-radohow-dosis-de-radon-en-el-hogar-vs- trabajo/). Another important channel of recruitment was direct communication with key stakeholders. The radon research group (LaRUC) has operated for almost 50 years and has an extensive list of varied collaborators of more than 500 people. This channel was leveraged to ensure the project's visibility, with communication by email or a direct approach with them.

A total of **20 citizen scientists** were finally selected to participate in RadoHOW, according to 4 types of home/work buildings (

Table 15). The majority of applicants, 18 of them, reached the project out by the abovementioned channels, and a minimum number of 2 applicants were chosen when they were able to provide a continuous measurement equipment. The total number of 20 participants were involved from the beginning to the end of the project.

Table 15. Hypothetical radon concentrations for homes and workplaces of each participant in five locations estimated by the research group

Initially radon concentration estimated at:	
HOME	WORKPLACE
Low	Low
High	Low
Low	High
High	High

8.3.3 Motivation of participants

Motivation of citizen scientists was one of the questions from the initial questionnaire administered at the beginning of their participation in RadoHOW (administered in September 2023; see Annex 1 for details). Their main motivations for participating in this project were their general interest in CS projects, even without knowing if they had radon gas issues in their locations (50%, **Figure 35**), and the possibility of delving deeper into the radon gas problems they already knew they had (16,7%). Collaboration with CS or the research group was an important aspect too.

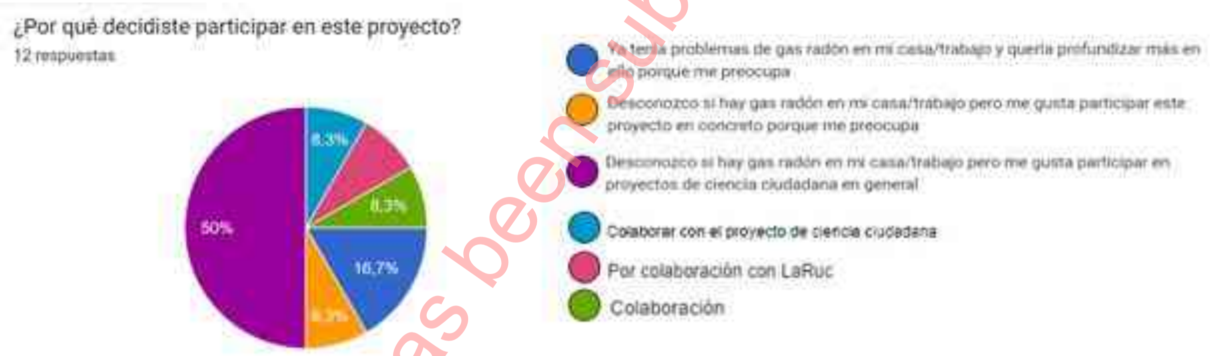


Figure 35. Question from the initial questionnaire regarding motivation of citizen scientists.

Translation into English: (question) Why did you decide to participate in this project?, (dark blue answer) I already had radon gas problems at home/workplace and I wanted to delve deeper in it because it worries me, (orange answer) I don't know if I have radon gas problems at home/workplace but I like to participate in this project in particular because this matter worries me, (purple answer) I don't know if I have radon gas problems at home/workplace but I like to participate in CS project in general, (blue answer) Collaboration with this CS project, (pink answer) Collaboration with LaRuc, (green answer) Collaboration.

Based on observations and questions raised prior to and during the initial meetings of RadoHOW, citizen scientists demonstrated a mixture of motivations. According to Arazy & Anderson (2011), these motivations can be mainly classified as collective, as participants expressed genuine concern about radon gas issues and the low visibility of this problem in society, especially as conveyed by those already affected. They indicated that dissemination and outreach activities are believed to be the most effective path forward. Furthermore, their participation was driven by both extrinsic and intrinsic motivations. Extrinsically, they gained tangible benefits such as continuous measurements, in-depth analysis and knowledge for ongoing monitoring. Intrinsically, they found participation enjoyable. Some citizen scientists already had extensive experience in dissemination and outreach activities, including talks, forums, magazines, and local radio. One participant, an engineer, is voluntarily designing a low-cost radon gas measurement device as part of The Things Network (https://www.thethingsnetwork.org/).

Motivation of the project's team to launch RadoHOW resides in its scientific novelty and the idea of creating a solid collaborative community around radon gas measurements. This project addresses, for the first time, a pilot study that allows for the comparison of both environments. It collected information that could be useful, in case one person develops health problems that could be related to radioactivity or radon gas, for discerning whether the problem is, if at home or at the workplace. For example: our approach would help a non-smoker individual who works in a nuclear plant, where all the security measures are properly followed, and develops lung cancer, and the radon gas dose at home is being analysed, because our approach would help to discern if the real problem is at their work or at home. The possible cause in the eyes of the society will be the nuclear plant, but the situation with radon gas at their house must be a priority.

To allow joint collaboration between participants with extensive experience in radon gas issues and individuals who were completely unfamiliar with it was also a motivation. It was interesting for radon science, as it meant that the unfamiliar participants had never measured before, so this collaboration has allowed collecting completely new data. And engaging participants with experience mainly meant that they had previously measured before, so the project allowed them to continue monitoring certain strategic places. Moreover, during our meetings, experienced participants could also guide the others, especially on the basic knowledge and advice for mitigation. For citizen science, this situation of putting together participants with extensive experience and individuals who were completely unfamiliar has contributed positively to one of the main objectives of citizen science, which is to create a diverse community and to foster literacy regarding one certain topic, in this case, radon gas. The experienced citizen scientists have participated in the transfer of knowledge, so this has not only been done by the project but also by participants themselves. And also, citizens have posed questions to the rest that were original and valuable, and that weren't raised in the scientific context.

8.3.4 Communication and engagement activities

The RadoHOW's citizen scientists started being engaged on the "Citizen Science for radiation measurement" day celebrated by the CSN, and during summer 2023. The communication plan has focused on both traditional and social media, with the help of citizen scientists, and has guaranteed a continuous communication between citizen scientists and researchers of the project. Their **engagement** was maintained through individual direct interactions with participants, sending circular emails (besides keeping track and reminders, see Annex 4 for details) and setting regular online general meetings (besides individual meetings):

- 1st circular - 28th August 2023: material and final guidelines (see Annex 5 for details), detectors distribution and meeting setting.
- 2nd circular - 29th September 2023: keeping track and meeting setting.
- Special announcements - 27 October 2023: European Radon Day activities.
- 3rd circular - 27th November 2023: keeping track and detectors picking-up.
- 4th circular - 30th January 2024: individual meetings and final event setting.
- Special announcements - 7th March: RadoHOW final event and RadoNorm final survey

The following **general online meetings** (besides minor individual meetings or direct interactions) were set with citizen scientists for the development of the project:

- 1st general meeting - 4th of September (**Figure 36**a): material, final guidelines and detectors distribution.
- 2nd general meeting - 5th of October: keeping track.

- Individual meetings - 19th to 23rd of February (**Figure 36**b): to discuss specific results that are anonymous for the rest of participants. First check and refining of the results, learning about their analysis, brainstorming of next-steps.
- 3rd general meeting / final event - 11th of March: To have a discussion about the simplified final results obtained in each province, learn about specific cases, co-create strategies and next steps, continue working with participants and the continuation of the project. Five infographics with the main conclusions of the project (see Annex 6 for details) were shown to participants, and they were invited to share them on their social media. We could also preview and discuss an interesting potential upcoming change in legislation concerning radon gas in workplaces.

a) b)

Figure 36. Examples of a general online meeting (a) and of the individual meetings (b).

The following **in-person activities** were organised to involve the RadoHOW's citizen scientists, citizens and/or the public, and to disseminate the results (see Annex 8 for photographs):

Event 1 - 8th June 2023: "Jornada Ciencia Ciudadana" at CSN. "El radón y la ciencia ciudadana".
Event 2 - 7th November 2023: Radon Day in Torrelodones.
Event 3 - 14th November 2023: Presentation at a speleology seminar in Motril.
Event 4 - 17th November 2023: Presentation at the University of Valencia.
Event 5 - 24th November 2023: Presentation at Enusa Industrias Avanzadas.
Event 6 - 1st December 2023: Presentation at the University of Cantabria, Faculty of Medicine.

The following activities have occurred or are about to take place to **disseminate the results**:

- In social media: the five infographics with the main aspects and conclusions of the project (see Annex 6 for details) have been delivered to participants and repeatedly shared in the Ibercivis social media accounts (Instagram's stories and Twitter) and website.
- Meetings with key stakeholders - 2024 (pending date): to communicate the results and discuss the impact of our results for them and for possible benefits related to the application of the regulations to workplaces (see section 6 for more information).
- Event 7 - 2024 (pending date): Presentation of the results at the IV National Radon Congress (Spain), which has already held three editions (see the third edition here: https://vivesinradon.org/iii-congreso-nacional-de-radon-ponencias/)
- Event 8 - 11th to 13th of November: Presentation of the results at the Workshop I+D+i about Radon (Spain), organised by the Canfranc Underground Laboratory (Laboratorio Subterráneo de Canfranc, LSC) with the participation of the CSN and the Spanish Society of Radiological Protection. Results will be presented at the "Social studies, communication, training, and Citizen Science" section of the workshop.

8.4 Results

8.4.1 Behavioural and socio-cultural impact

The RadoHOW citizen science project has had a substantial impact on the behavioural and socio-cultural landscape of its participants. One of the most significant impacts observed was the substantial **increase in participants' knowledge** about radon gas and its associated health risks. Prior to the project, many participants had only a superficial understanding of radon, with some completely unaware of its potential dangers. Throughout the project's duration, participants received comprehensive training and education, significantly deepening their understanding of radon science, measurement techniques, and mitigation strategies. This enhanced knowledge was not merely academic. Participants reported feeling more empowered to take proactive measures to monitor and mitigate radon levels in their environments. This empowerment was particularly evident in those who previously had no experience with radon issues. The hands-on nature of the project, combined with the updates and detailed discussions of the findings, fostered a learning environment.

The project also instigated notable **behavioural changes** among participants. Armed with new knowledge, the participants have received recommendations and information about the steps to be followed to mitigate radon exposure in their homes and workplaces. These measures included improving ventilation, sealing cracks in floors and walls, and in some cases repeating the measurements and contacting professionals. Proactive behaviours identified among the participants indicate a heightened sense of responsibility concerning their health. Moreover, the project encouraged participants to adopt a more scientific approach to problem-solving in their daily lives. The process of data collection and interpretation required a methodical and analytical mindset. This shift towards a more evidence-based approach to decision-making is a testament to the project's broader impact on participants' behavioural patterns.

Socio-cultural impact of RadoHOW extended beyond individual knowledge and behaviour. The project fostered a **sense of community** among participants, bridging the gap between experienced citizen scientists and novices. This integration was facilitated through the general and individual meetings, collaborative data analysis sessions, and shared dissemination activities. Experienced participants played a crucial role in mentoring newcomers, creating a supportive environment conducive to learning and collaboration. In order to clarify the information for the participants and to take into account their personal concerns and possible doubts, individual meetings were held. In these meetings, strategies for dissemination of the results at local and community level were co-created, showing the willingness of the participants to share the knowledge and experience gained in the field of radon with their circles and nearby communities.

Participants' perceptions and attitudes towards scientific research were also influenced by the project. Initially, some participants were sceptical about the relevance and impact of citizen science. However, as they engaged with the project and witnessed first-hand the tangible outcomes of their contributions, their perceptions shifted positively. Participants began to appreciate the value of citizen science in addressing real-world problems and contributing to scientific knowledge. Additionally, the project raised awareness about the broader implications of radon exposure, prompting participants to advocate for increased public awareness and policy changes. Through enhanced knowledge, behavioural changes, community building, and shifts in perceptions, citizen scientists have not only contributed to the scientific understanding of radon gas but have also experienced personal growth and societal engagement.

8.4.2 Outputs

8.4.2.1 Results from CR39 detectors and the continuous measurement equipment

As outlined in the proposal, four citizen scientists were chosen from each of the selected areas: Galicia, Salamanca, Madrid, Zaragoza, and Cantabria, corresponding to the scheme in

Table 15. **Table 16** to **Table 20** summarise the findings, with detailed information provided in Annex 9. To maintain the anonymity of the participants, both in terms of personal data and the locations of their residences and workplaces, we assigned codes: G1, G2, G3, and G4 for those in Galicia; C1, C2, C3, and C4 for Cantabria; Z1, Z2, Z3, and Z4 for Zaragoza; M1, M2, M3, and M4 for Madrid; and V1, LRN, CRF, and S1 for Salamanca.

In this section, we provide the individual results of the CR39, as well as the collective results of the continuous measurements in each province. The individual results of the continuous measurements for both participants' homes and workplaces are shown in Annex 10.

It is important to note that, as described in the proposal, one of the containers was permanently open, resulting in approximately 2000 hours of exposure. The other container was open only when the participant was at home and/or work and closed when they were not there. Regarding workplace measurements, the exposure was approximately 400 hours. Home exposure was more variable, with an average of about 1400 hours, which corresponds to a time spent at home of 70% of total living time. This is slightly lower than the average for other European Union countries, which is 80%. Each participant received a template (attached in Annex 3) to record the time spent at home and at the workplace, which assisted in the analysis and interpretation of the results.

8.4.2.1.1 GALICIA AREA

Table 16. Concentration (Bq/m³) obtained from detectors CR39 in Galicia

Types of container: always opened (AO) and opened/closed (O/C).

		HOME	WORKPLACE
	Type of jar	Concentration	Concentration
G1	AO	27.8	27.6
	O/C	64.0	102.7
G2	AO	328.7	203.8
	O/C	392.7	350.0
G3	AO	225.5	55.8
	O/C	219.1	137.0
G4	AO	65.8	61.8
	O/C	144.1	226.2

As shown in **Table 16**, participant G1 presents low levels of radon both at home and at work. G3 has lower radon levels at work than at home, but both are below the 300 Bq/m³ threshold specified in Spanish Royal Decree 1029/56 of 20 December 2022, which transposes Council Directive 2013/59/EURATOM into national law. G4 exhibits a very similar situation to G3. Regarding G2, their workplace and home present average values higher than those established by the Royal Decree 1029/56 of 20 December. However, it is noteworthy that the hours spent at home and in the workplace are significantly lower than the established average. In this situation, it would be necessary to implement remedial measures to reduce the concentration of radon gas by increasing natural ventilation.

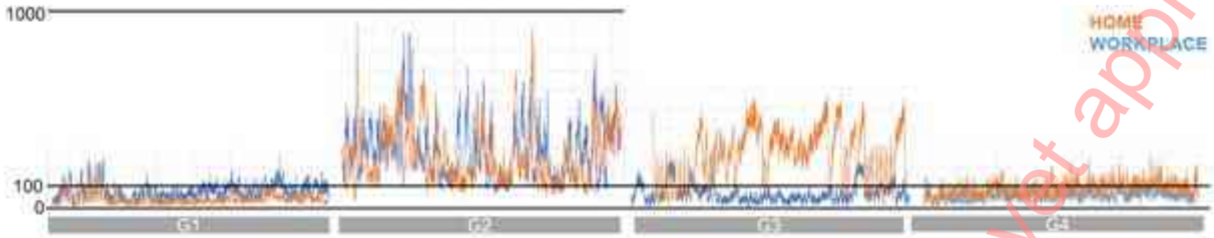


Figure 37. Results of the continuous measurements in Galicia

CANTABRIA AREA

Table 17. Concentration (Bq/m³) obtained from detectors CR39 in Cantabria.

:
Types of container: always opened (AO) and opened/closed (O/C).
(*) CR39 results that present the problem of "decay" and have been corrected using the average concentration of continuous measurements considering the hours provided by participants (see Annex 11) .

		HOME	WORKPLACE
	Type of jar	Concentration	Concentration
C1	AO	24.5	24.6
	O/C	164.0	184.4
C2	AO	191.7	583.7
	O/C	146.5	656.2
C3	AO	32.9	4211.0
	O/C	62.3	14897.8 (*)
C4	AO	106.3	93.1
	O/C	175.4	453.6

Participant C1 presents normal radon values at both home and workplace. For C2, an anomaly is observed: the open detector at the workplace shows an average concentration of 584 Bq/m³, while the detector that opens and closes shows a slightly higher value of 656 Bq/m³ (**Table 16**). This same circumstance occurs for participant C4. In both cases, the workplace values for C2 and C4 exceed the 300 Bq/m³ limit recommended in Royal Decree 1029/56 of 20 December 2022, necessitating increased ventilation to reduce these values.

Participant C3 presents a particularly interesting situation: both trace detectors at the workplace have nearly the same exposure (Annex 9). However, due to very different integration times, it appears that the average concentration for the open detector is high (4211 Bq/m³; **Fehler! Verweisquelle konnte nicht gefunden werden.**), but the concentration for the detector that opens and closes is much higher (14898 Bq/m³). The data from the continuous measurement monitor selecting the concentrations at the times collected show us that the first of the data is the most adjusted to the time of 340 hours, finding a value of 5423 Bq/m³. As shown in Annex 11, the explanation for this phenomenon may lie in the fact that when the detector is closed in the glass, and the concentration in the place is high, the radon's decay continues inside it, making the exposure very high. If this pattern repeats, the overall exposure will be similar to that of the open detector, but the shorter exposure time results in a very high concentration (Annex 9 and **Fehler! Verweisquelle konnte nicht gefunden werden.**). This working hypothesis, which is repeated in other cases and areas, opens a significant field of research into the study of worker doses using trace detectors and their associated uncertainties. In any case, remedial actions are absolutely necessary to reduce radon concentration values.

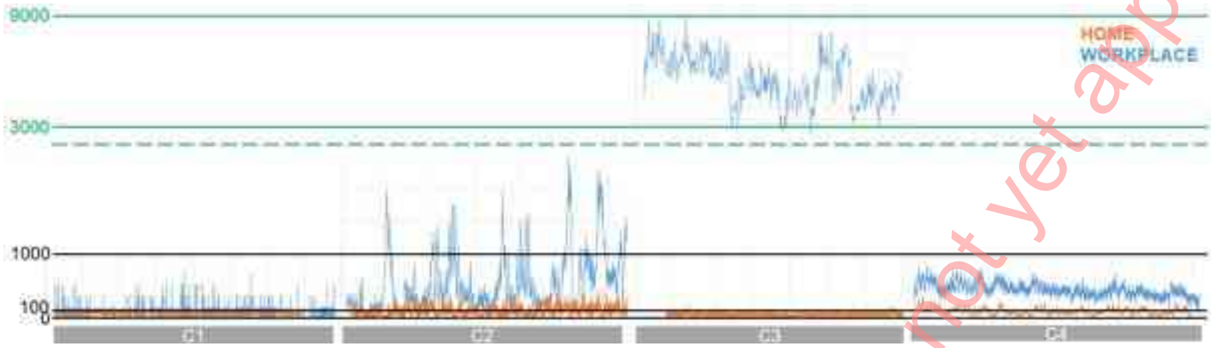


Figure 38. Results of the continuous measurements in Cantabria.

8.4.2.1.2 ZARAGOZA AREA

Table 18. Concentration (Bq/m³) obtained from detectors CR39 in Zaragoza.

Types of container: always opened (AO) and opened/closed (O/C).

		HOME	WORKPLACE
	Type of jar	Concentration	Concentration
Z1	AO	27.9	27.5
	O/C	45.6	116.6
Z2	AO	23.6	23.9
	O/C	29.9	107.8
Z3	AO	27.2	37.4
	O/C	36.3	139.7
Z4	AO	41.0	25.5
	O/C	29.6	161.3

The Zaragoza area is classified on the radon potential map of Spain as an area with low radon content. This classification is confirmed by the data obtained from the four locations where measurements were conducted. Both in homes and workplaces, the radon levels found are very low (**Table 18**).

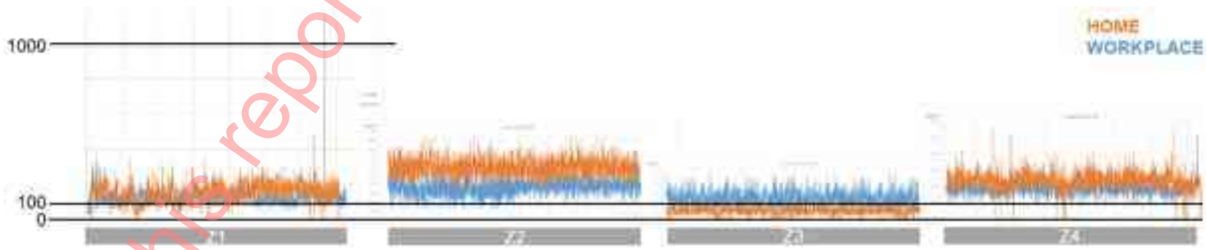


Figure 39. Results of the continuous measurements in Zaragoza.

8.4.2.1.3 MADRID AREA

Table 19. Concentration (Bq/m³) obtained from detectors CR39 in Madrid.

Types of container: always opened (AO) and opened/closed (O/C).

		HOME	WORKPLACE
	Type of jar	Concentration	Concentration
M1	AO	23.5	207.6
	O/C	67.9	349.6
M2	AO	47.9	52.8
	O/C	55.0	114.2
M3	AO	23.6	373.7
	O/C	38.1	1165.3
M4	AO	132.1	144.0
	O/C	113.1	235.2

The values found were normal for situations M1, M2, and M4. In the case of M3, the values in the workplace were slightly higher (374 Bq/m³), than those included in the legislation (300 Bq/m³), but where again, and thanks to the measurements provided by the continuous monitor, it is observed that the opening and closing container has been closed for longer than the indicated 287 hours, which has resulted in a higher concentration of 1165 Bq/m³. Once again, the importance of the continuous average is evident. It will be verified by contacting the person involved to see if this event has taken place, and if it is true, a new trace detector will be placed in the workplace. However, as prevention, it would be necessary to proceed with remedial measures to reduce the concentration of radon gas by increasing natural ventilation.

The values found were normal for situations M1, M2, and M4. In the case of M3, the workplace values were slightly higher (374 Bq/m³; **Table 19**) than the legislative limit (300 Bq/m³). However, thanks to the continuous monitor measurements, it was observed that the opening and closing container had been closed for longer than the indicated 287 hours, resulting in a higher concentration of 1165 Bq/m³. This once again highlights the importance of the continuous average measurement. We will verify this by contacting the person involved to confirm if this occurred, and if so, a new trace detector will be placed in the workplace. Nevertheless, as a precaution, remedial measures to reduce the concentration of radon gas by increasing natural ventilation are necessary.

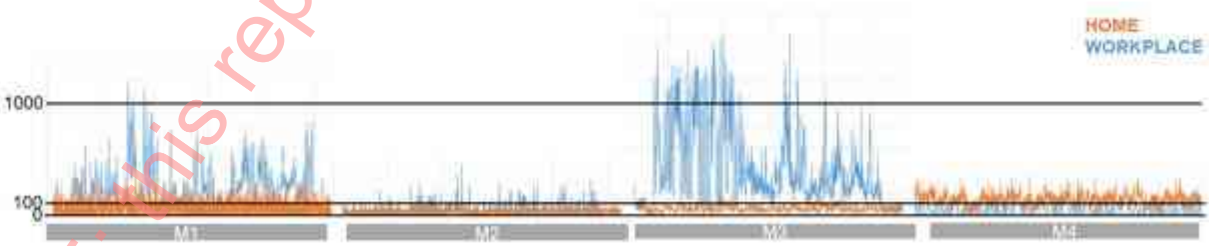


Figure 40. Results of the continuous measurements in Madrid.

8.4.2.1.4 SALAMANCA AREA

Table 20. Concentration (Bq/m³) obtained from detectors CR39 in Galicia.

Types of container: always opened (AO) and opened/closed (O/C).
(*) CR39 results that present the problem of "decay" and have been corrected using the average concentration of continuous measurements considering the hours provided by participants (see Annex 11).

		HOME	WORKPLACE
	Type of jar	Concentration	Concentration
V1	AO	1211.8	1158.7
	O/C	1443.6	13614.8 (*)
LRN	AO	1225.7	8695.6
	O/C	1453.7 (*)	17463.1 (*)
CRF	AO	48.3	267.6
	O/C	79.1	278.4 (*)
S1	AO	630.2	2956.6
	O/C	834.5	12080.1 (*)

Without a doubt, this has been the most interesting area. It is classified as a high-risk area in the Spanish Nuclear Safety Council's radon potential document, and the results have confirmed this classification. In all four situations, high concentration values were observed. Notably, the effect of radon accumulation in the container that is opened and closed was confirmed again, resulting in additional traces and consequently very high concentrations. These were corrected when analysing the continuous measurement results, as shown in Annex 11.

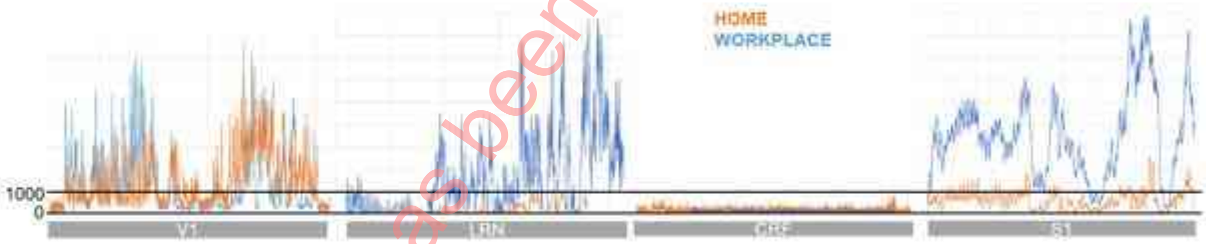


Figure 41. Results of the continuous measurements in Salamanca.

8.4.2.2 Overall results from the continuous measurement equipment

Collective results in each province are compared in **Figure 42** and the previous sections (**Figure 37** to **Figure 41**). **Figure 42** allows us to visually compare the overall values obtained for all provinces and verify which ones have a higher risk, such as Salamanca.

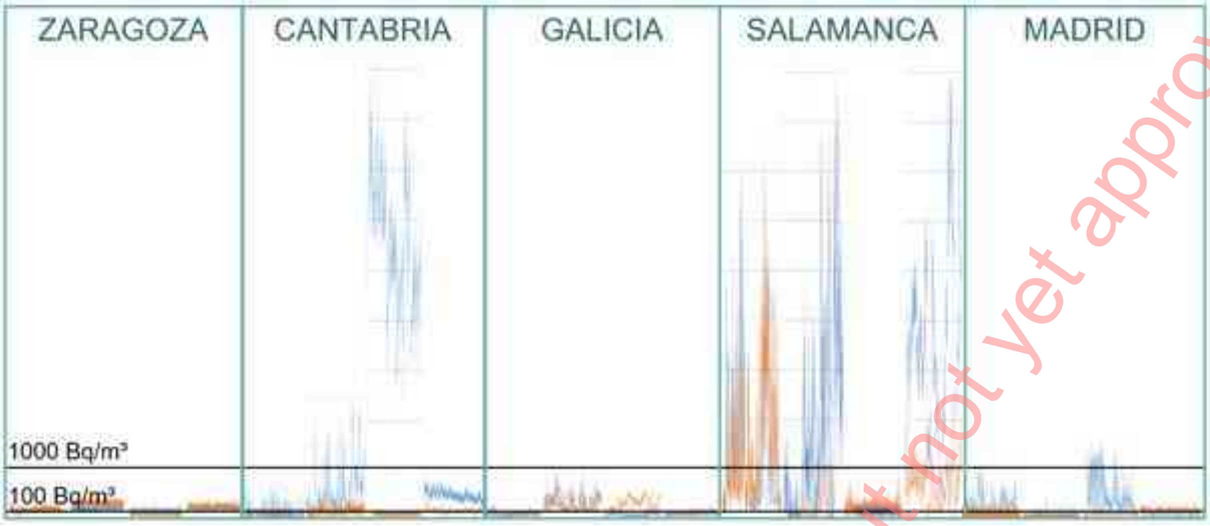


Figure 42. Simplified results of the continuous measurements in the five pilots (orange is home and blue is workplace)

8.4.2.3 Comparison between results from the CR39 detectors and the continuous measurement equipment

Table 21 shows the results from the CR39 detectors compared to the average continuous measurements and the initial estimations of concentrations. Figures 12 and 13 graphically compare the values obtained by both detectors at homes and workplaces, respectively. The relationship between the radon gas concentration we initially estimated for each type of structure in their homes and workplaces changed with the final results in almost 50% of the cases (**Figure 37** and **Table 21**). Finally, the accuracy of the CR39 detectors appears to decline when concentrations are high, around or above 300 Bq/m³, and especially above 600 Bq/m³ (**Figure 43** and **Figure 44**).

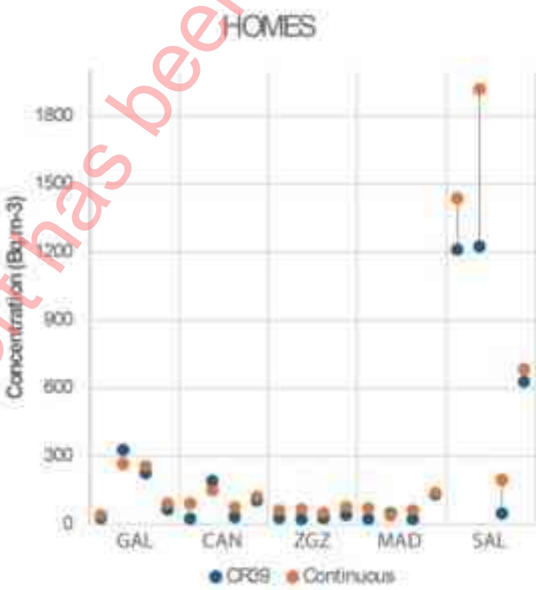


Figure 43. Concentration (Bq/m³) obtained from the always opened (AO) detectors CR39 compared to the average of the continuous measurements at homes.

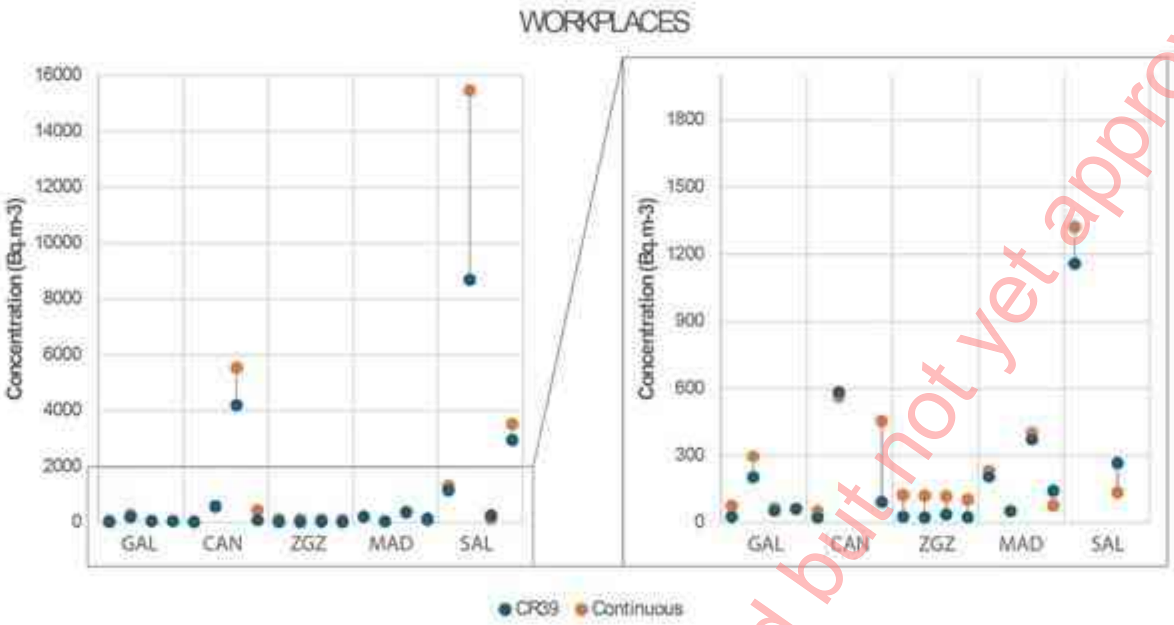


Figure 44. Concentration (Bq/m³) obtained from the always opened (AO) detectors CR39 compared to the average of the continuous measurements at workplaces.

Table 21. Concentration (Bq/m^3) obtained from detectors CR39 compared to the average of the continuous measurements, and the initial estimations of concentrations

Types of container: always opened (AO) and opened/closed (O/C).

	HOME					WORKPLACE			
	INITIAL ESTIMATION	CR39		Continuous	FINAL RESULTS	INITIAL ESTIMATION	CR39	Continuous	FINAL RESULTS
		Type of jar	Concentration	Average concentration			Concentration	Average concentration	
G1	LOW	AO	27.8	40,2	LOW	LOW	27.6	76,6	LOW
		O/C	64.0				102.7		
G2	HIGH	AO	328.7	266,7	HIGH	HIGH	203.8	294,5	LOW-HIGH
		O/C	392.7				350.0		
G3	HIGH	AO	225.5	256,1	LOW	LOW	55.8	66,2	LOW
		O/C	219.1				137.0		
G4	LOW	AO	65.8	91,1	LOW	HIGH	61.8	60,7	LOW
		O/C	144.1				226.2		
C1	LOW	AO	24.5	92,5	LOW	LOW	24.6	52,7	LOW
		O/C	164.0				184.4		
C2	HIGH	AO	191.7	149,9	LOW	HIGH	583.7	563,3	HIGH
		O/C	146.5				656.2		
C3	LOW	AO	32.9	75,2	LOW	HIGH	4211.0	5549,6	HIGH
		O/C	62.3				14897.8 (*)	5423 (‡)	
C4	HIGH	AO	106.3	121,8	LOW	LOW	93.1	454,8	LOW-HIGH
		O/C	175.4				453.6		
Z1	LOW	AO	27.9	61	LOW	LOW	27.5	124,8	LOW
		O/C	45.6				116.6		
Z2	LOW	AO	23.6	66	LOW	HIGH	23.9	122	LOW
		O/C	29.9				107.8		
Z3	HIGH	AO	27.2	49,6	LOW	HIGH	37.4	118,8	LOW
		O/C	36.3				139.7		
Z4	HIGH	AO	41.0	75	LOW	LOW	25.5	104	LOW
		O/C	29.6				161.3		
M1	HIGH	AO	23.5	70,5	LOW	HIGH	207.6	231,6	LOW-HIGH
		O/C	67.9				349.6		
M2	LOW	AO	47.9	39,7	LOW	LOW	52.8	51,4	LOW
		O/C	55.0				114.2		
M3	LOW	AO	23.6	61,1	LOW	HIGH	373.7	401,2	HIGH
		O/C	38.1				1165.3		
M4	HIGH	AO	132.1	138,8	LOW	LOW	144.0	78,2	LOW
		O/C	113.1				235.2		
V1	LOW	AO	1211.8	1437,6	HIGH	LOW	1158.7	1322,8	HIGH
		O/C	1443.6				13614.8 (*)	1541 (‡)	
LRN	HIGH	AO	1225.7	1920	HIGH	HIGH	8695.6	15477,4	HIGH
		O/C	1453.7 (*)	1927 (‡)			17463.1 (*)	10828 (‡)	
CRF	LOW	AO	48.3	196,2	LOW	HIGH	267.6	136,3	LOW
		O/C	79.1				278.4 (*)	186 (‡)	
S1	HIGH	AO	630.2	683,4	HIGH	LOW	2956.6	3526,5	HIGH
		O/C	834.5				12080.1 (*)	3700 (‡)	

(*) CR39 results that present the problem of "decay" (see Annex 11) and have been corrected using the average concentration of continuous measurements considering the hours provided by participants (‡).

8.4.2.4 Other outputs

Outputs from the project result in research and policy recommendations that can be summarised in the need for more comprehensive radon measurements in both homes and workplaces. This will support the upcoming changes in legislation concerning radon gas in workplaces, for example. The results of RadoHOW could ultimately have a significant impact on society through local policy adaptations, potential corrective measures, enhanced safety measures or outreach activities. However, this final impact cannot be assessed until the most problematic cases are further monitored by the research group in the coming months, especially in Salamanca. At this point, the anonymised data will be openly available on the research group's website to allow for open access.

Results will be disseminated at least at the IV National Radon Congress (Spain), and specially at the Workshop I+D+i about Radon (Spain), organised by the LSC, with the participation of the CSN and the Spanish Society of Radiological Protection (Sociedad Española de Protección Radiológica, SEPR). Scientific publications are also being drafted at this moment for publication in the *Journal of the European Radon Association* (JERA), *Revista RADIOPROTECCIÓN* (of the SEPR) and/or *Revista Alfa* (of the CSN).

8.5 Evaluation of the citizen science project

Based on verbal observations and conclusions mainly raised and drawn during the final event of RadoHOW, **citizen scientists** evaluate the project positively. After the project team expressed their gratitude to all participants for their involvement, participants reciprocated with their thanks for the project, voicing their satisfaction with the knowledge gained and the activities conducted. Participants highlighted the creation of a strong community within the project, which they can consult for sharing information, asking questions about future legislation, or getting support for continuing to monitor their homes and workplaces, in cases of higher levels of radon. The evaluation of RadoHOW through surveys, from the participants' perspective, was not conducted by the project team itself, as they filled out the final RadoNorm survey. Therefore, we cannot make a direct comparison with the results obtained from the initial questionnaire to achieve a quantitative evaluation.

The **RadoHOW coordinators** highlight the following challenges related to the project evaluation:

CS aspects:

- Coordinating in-person activities was difficult, as participants came from five different provinces in Spain, especially for distributing detectors and organising recurring meetings. This was addressed by conducting more online activities and directly distributing the detectors manually, person by person.
- It has been very beneficial for the project to see individuals with no prior knowledge of radon become informed and active contributors to scientific research. It was also encouraging to see how the community learned to analyse and interpret data together with us, so now they have the necessary tools.
- It was very enriching to be able to receive input and work with both newcomers to the radon issue and participants who are experts on the subject. Both have provided different views of the process and have enriched us with their interpretations.
- Maintaining participant engagement over the long term was a challenge, but we definitely overcame it. People were interested in knowing their results, learning how to interpret them, and discussing findings, so they stayed with us until the end of the project. Some of them will continue collaborating with the research group.

Scientific Aspects:

- Guaranteeing accurate data collection with the CR39 detectors required participants to open and close the containers correctly. We tackled this by creating detailed guides and holding follow-up sessions to address any questions or issues that arose during the data collection process.

- Ensuring the proper preservation of the continuous equipment, which is very expensive, was another challenge. We provided participants with clear instructions on handling and storing the equipment safely and conducted regular checks to ensure compliance.
- The relationship between the radon gas concentration we originally estimated for each type of structure in their homes and workplaces did not prove as relevant once the final results were analysed, so we could not draw conclusions in this regard.

It should be noted that the evaluation of the obtained results will also be carried out by the five **key stakeholders** indicated in the original proposal (CSN, Public Authorities from Galicia, Salamanca, Zaragoza and Madrid, Workplaces in which radon exposure is higher and Communities and associations of citizens affected or concerned by radon exposure). However, as said before, this final evaluation and project impact cannot be developed until the most problematic cases are further monitored by the research group in the coming months.

8.6 Main conclusions and final reflections

The most important conclusion of RadoHOW lies not only in the citizen participation, which underscores the interest in radon measurement, but also in the data analysis, which reveals a previously unknown aspect related to the use of trace detectors for evaluating high concentrations of radon gas.

The key conclusions of the RadoHOW project are summarised below:

- The levels of radon exposure that citizen scientists experience at their home and at their workplaces have been successfully assessed and compared, by using both CR39 trace detectors and continuous measurement equipment.
- The data analysis reveals a previously unknown aspect related to the use of CR39 trace detectors in evaluating radon gas concentrations. When concentrations are high, they are not accurate enough when compared to the use of the continuous equipment. CR39 can lead to high doses, taking into account that they are calculated from them considering the Spanish conversion factors are 5 mSv/WLM lower by a factor of two than those proposed by ICRP 137. Therefore, interpretation of data from CR39 detectors alone should be done with caution.
- These measurements emphasise the importance of using continuous measurements when radon gas concentrations are high, as they will allow for a more precise dose evaluation compared to conventional trace detectors.
- Despite the small number of participants, the results have allowed us to assess differences between results from various geographical, geological, and building environments in Spain. Residents in the provinces of Galicia, Cantabria, Zaragoza and Madrid are exposed to radon gas doses at both their homes and workplaces that do not pose a health hazard and do not require severe mitigation measures (always below 1 mSv). Zaragoza's residents experience the lowest radon exposure, followed by those in Madrid. The homes of Galician participants and the workplaces of Cantabrians are the closest to that value. On the other hand, residents in the province of Salamanca are exposed to higher radon gas doses at their workplaces and, especially, in their homes (in both cases, above 6 mSv). These results confirm the accuracy of the Radon Potential Map prepared by the Spanish Nuclear Safety Council, with active participation from the University of Cantabria.
- Radon gas literacy has been fostered within the community by increasing their knowledge and co-defining strategies. RadoHOW demonstrates that interest in measuring radon gas through citizen science projects is growing, especially in "radon-prone areas." This is crucial for raising awareness about its potential health effects and the importance of knowing radon concentrations and, if necessary, reducing them. It also underscores the responsibility of

workplace managers to inform their workers about the doses received due to radon gas exposure.

The project is completely sustainable, as the structure and community are already established, and the participants are familiar with the methodology and data interpretation. Moreover, the project is planned to continue in the coming months, especially in Salamanca.

The next steps are to continue monitoring these strategic points, draw more solid conclusions and discuss all RadoHOW results with the key stakeholders. At that point, tailored recommendations can be made to the participants, as well as local or regional recommendations to the authorities. So far, only simple mitigation recommendations have been made during the project's activities.

We want to thank the European project RadoNorm for their invaluable coordination of our project and of all the CS projects they have hosted. The joint activities conducted in the online meetings, the in-person RICOMET meeting, and the annual meeting in Slovenia have been very beneficial and are the result of great effort.

8.7 Resources

Distribution of resources was done as shown in **Table 22**. As it has been already mentioned, the main limitation and deviation from the original proposal is the number of continuous radon measurements equipment. This number was increased from 10 to 40, so that the entire community could measure for the full three months. While the available budget permitted the acquisition of only a small number of these devices, an important number of the continuous measurement equipment were sourced from the RadoHOW's team or voluntarily provided by participants.

Table 22. Final distribution of resources

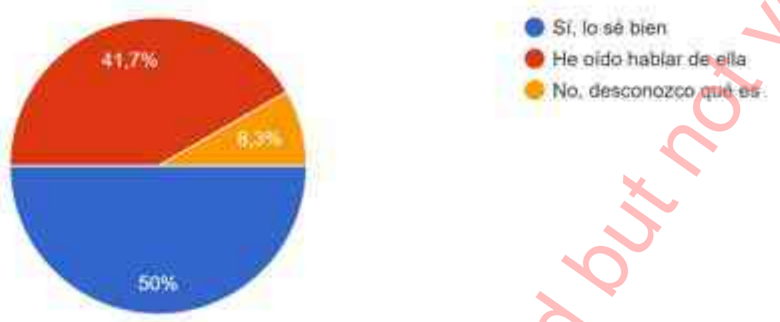
	IBERCIVIS	**UC**
Personnel	7,400€	
Travel	1,060,13 €	1,443€
RadoNORM remboursement	- 1,060,13 €	
Equipment		9,300 €
Equipment reparation		1,725€
Other goods and services		107€
Indirect costs	1,850€	3,144€
Total	**9,250 €**	**15,718.75 €**
	24,968.75 €	

8.8 Annexes

8.8.1 ANNEX 1. Responses of citizen scientists to the initial questionnaire that assess their previous knowledge and experience with CS and radon gas.

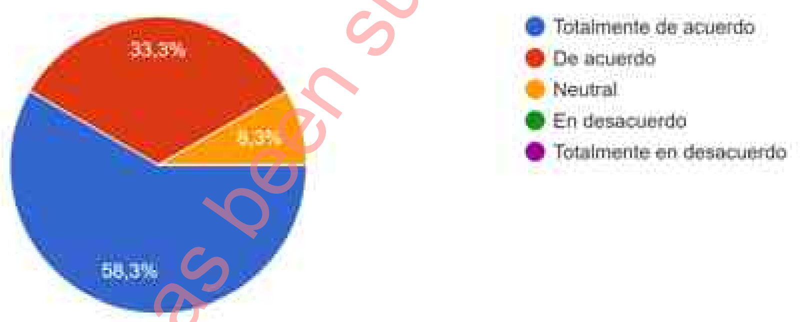
¿Sabes qué es la ciencia ciudadana?

12 respuestas

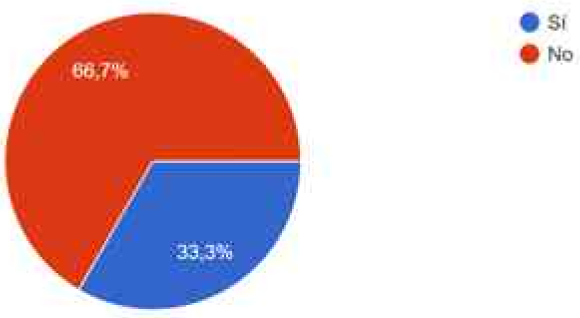


Los proyectos de ciencia ciudadana pueden contribuir significativamente al conocimiento general y a la toma de decisiones en la sociedad

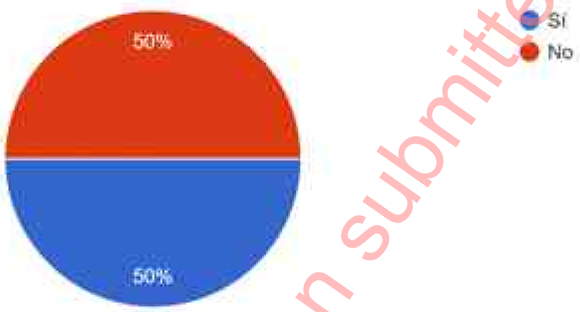
12 respuestas



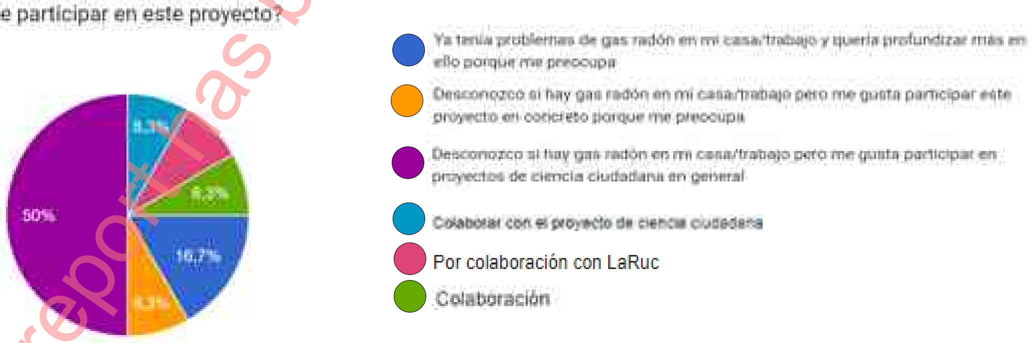
¿Has participado anteriormente en algún proyecto de ciencia ciudadana?
12 respuestas

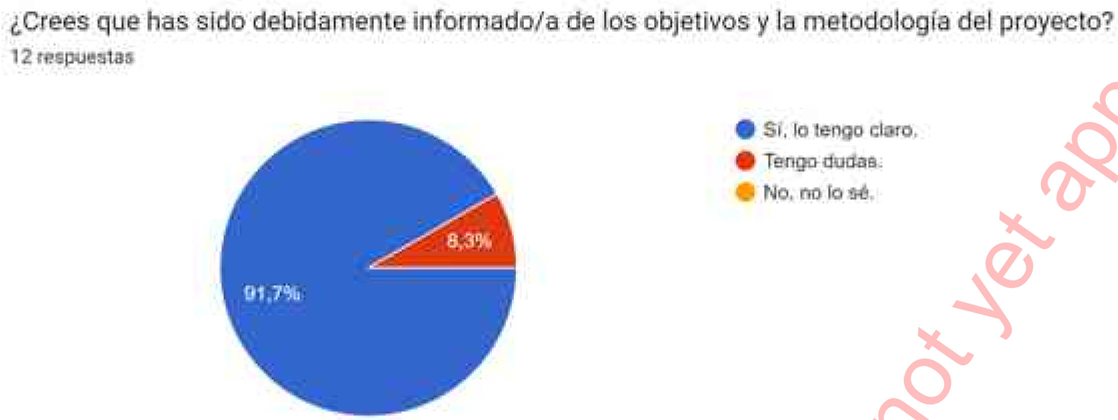


¿Y en algún proyecto de medición del gas radón?
12 respuestas



¿Por qué decidiste participar en este proyecto?
12 respuestas

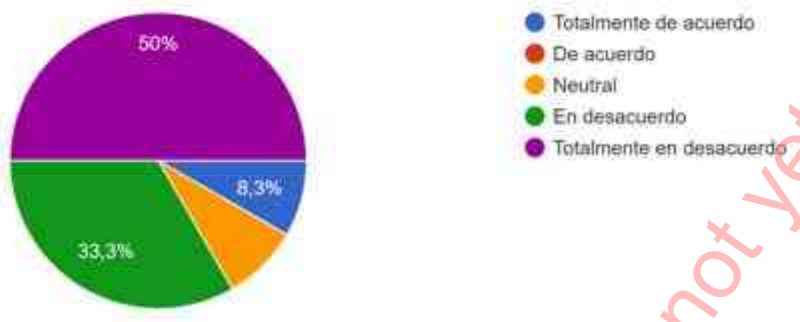



¿Crees que has sido debidamente informado/a de los objetivos y la metodología del proyecto?
12 respuestas
Sí, lo tengo claro.
Tengo dudas.
No, no lo sé.
8,3%
91,7%

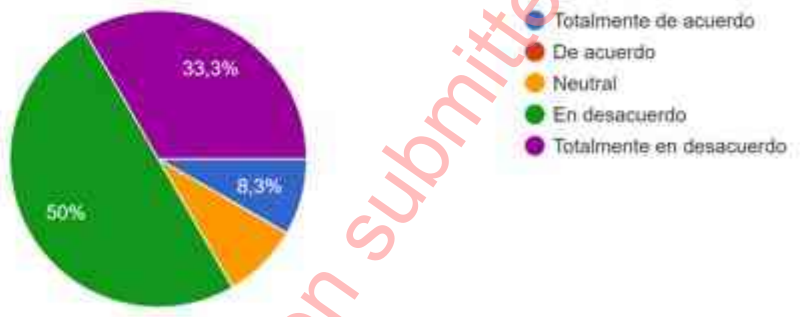

¿Cuánto tiempo estás dispuesto a dedicar diariamente al proyecto?
12 respuestas
Menos de 5 minutos
Entre 5 y 15 minutos
Más de 15 minutos
50%
8,3%
41,7%


Por favor, señala tu grado de acuerdo o desacuerdo con las siguientes afirmaciones: La concentración de gas radón siempre es mayor en mi puesto de trabajo respecto a mi casa.
12 respuestas
Totalmente de acuerdo
De acuerdo
Neutral
En desacuerdo
Totalmente en desacuerdo
8,3%
16,7%
50%
16,7%
8,3%

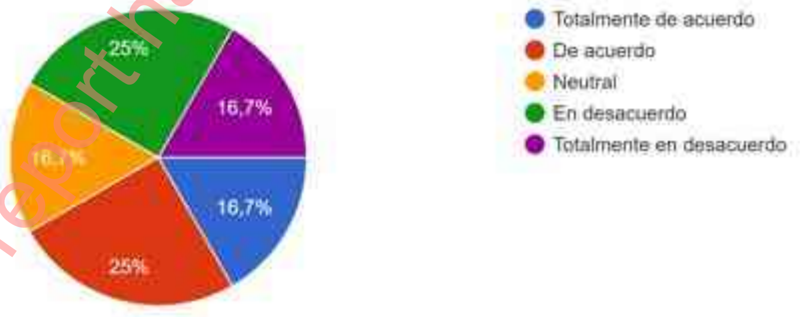
Los niveles de radón son similares en todos los tipos de casas.
12 respuestas



Las casas sin sótano no tienen radón.
12 respuestas

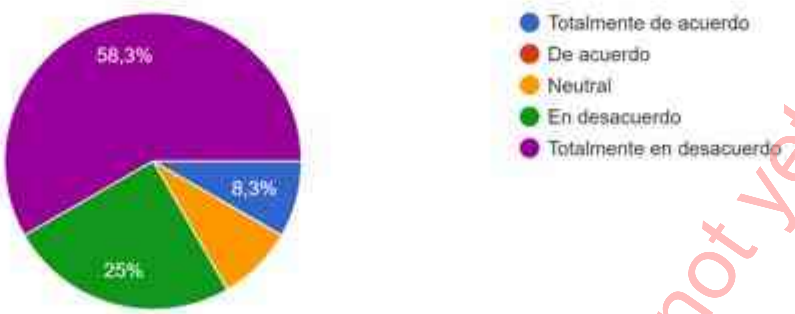


La presencia de radón en las casas no depende de la Comunidad Autónoma en la que se localizan.
12 respuestas



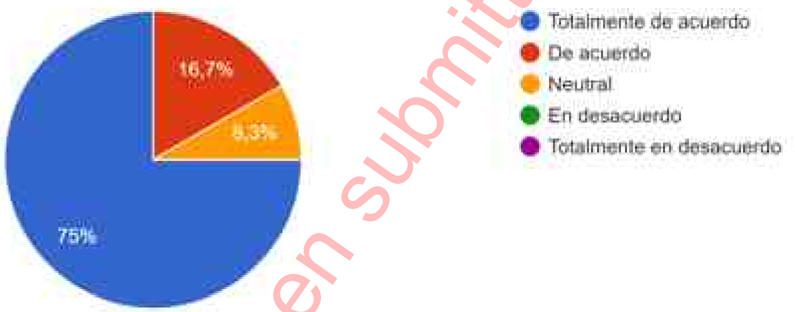
El radón solamente está en puestos de trabajo de centrales nucleares y minas de uranio.

12 respuestas



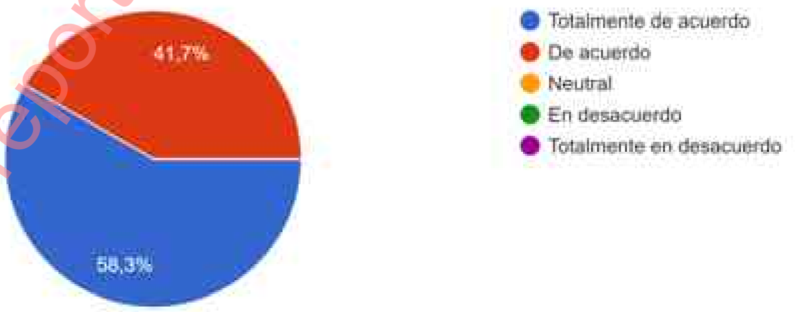
Los detectores de radón integrados miden la concentración de radón promedio durante el tiempo que han estado expuestos.

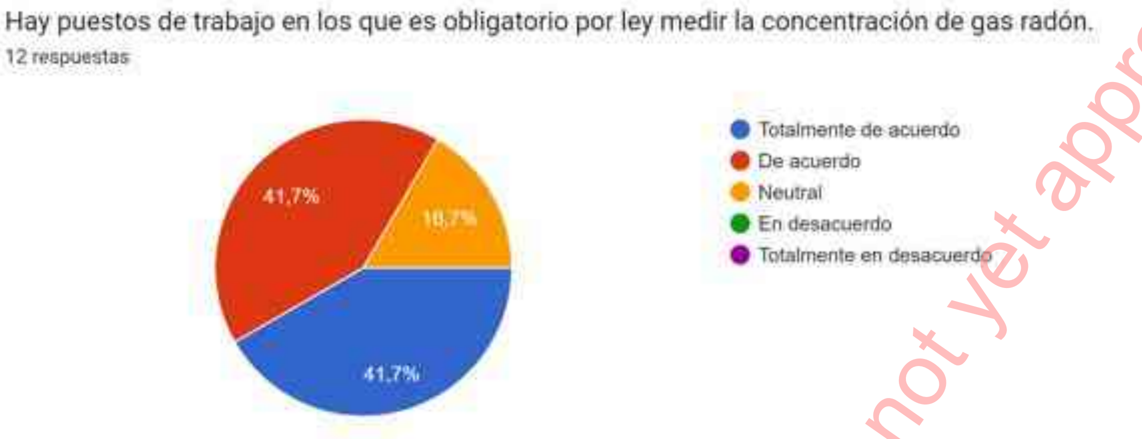
12 respuestas



Los detectores de radón en continuo nos permiten saber la evolución de su concentración, y a partir de ella evaluar la dosis recibida.

12 respuestas

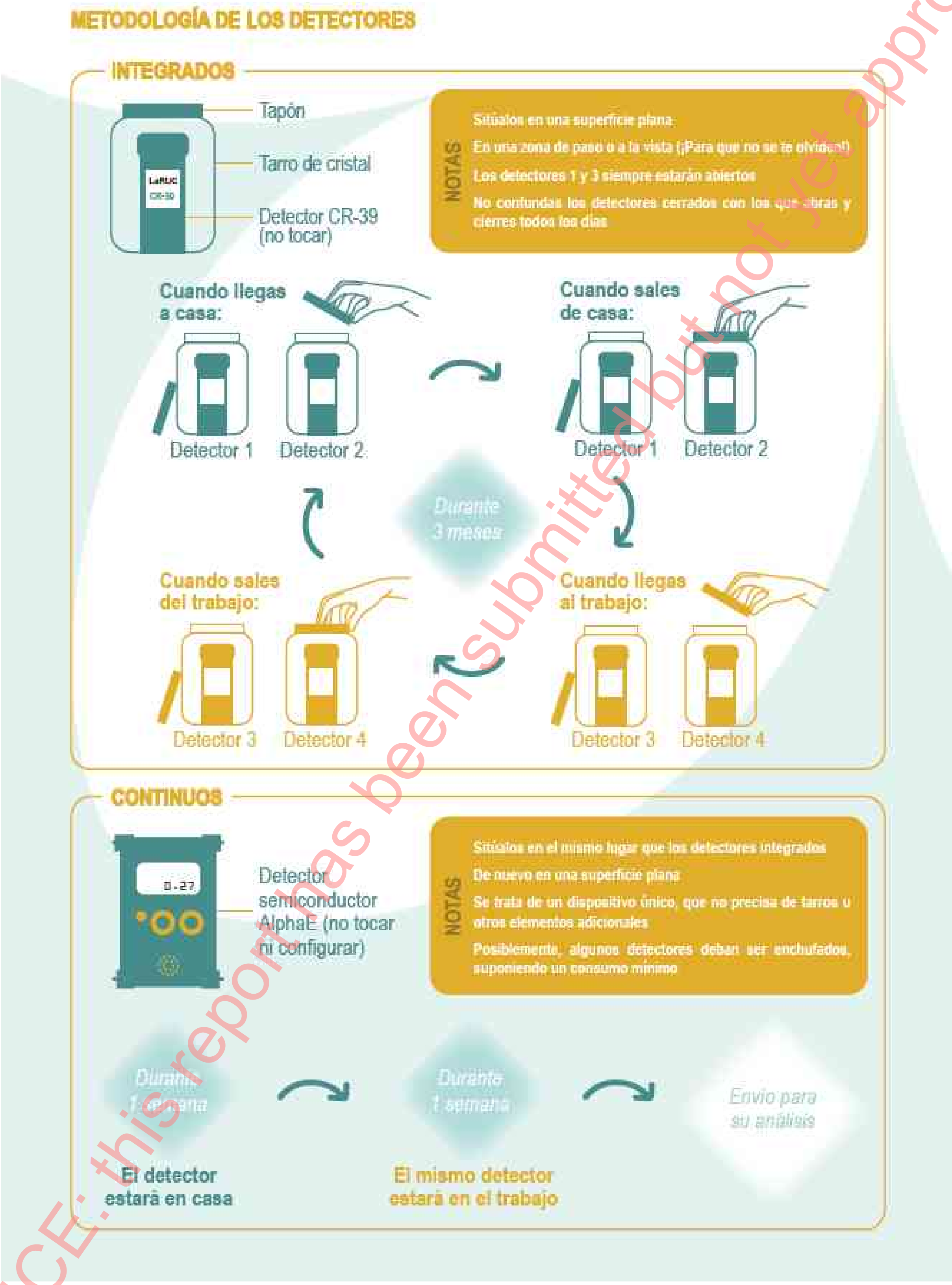



Hay puestos de trabajo en los que es obligatorio por ley medir la concentración de gas radón.
12 respuestas
41,7%
16,7%
41,7%
Totalmente de acuerdo
De acuerdo
Neutral
En desacuerdo
Totalmente en desacuerdo

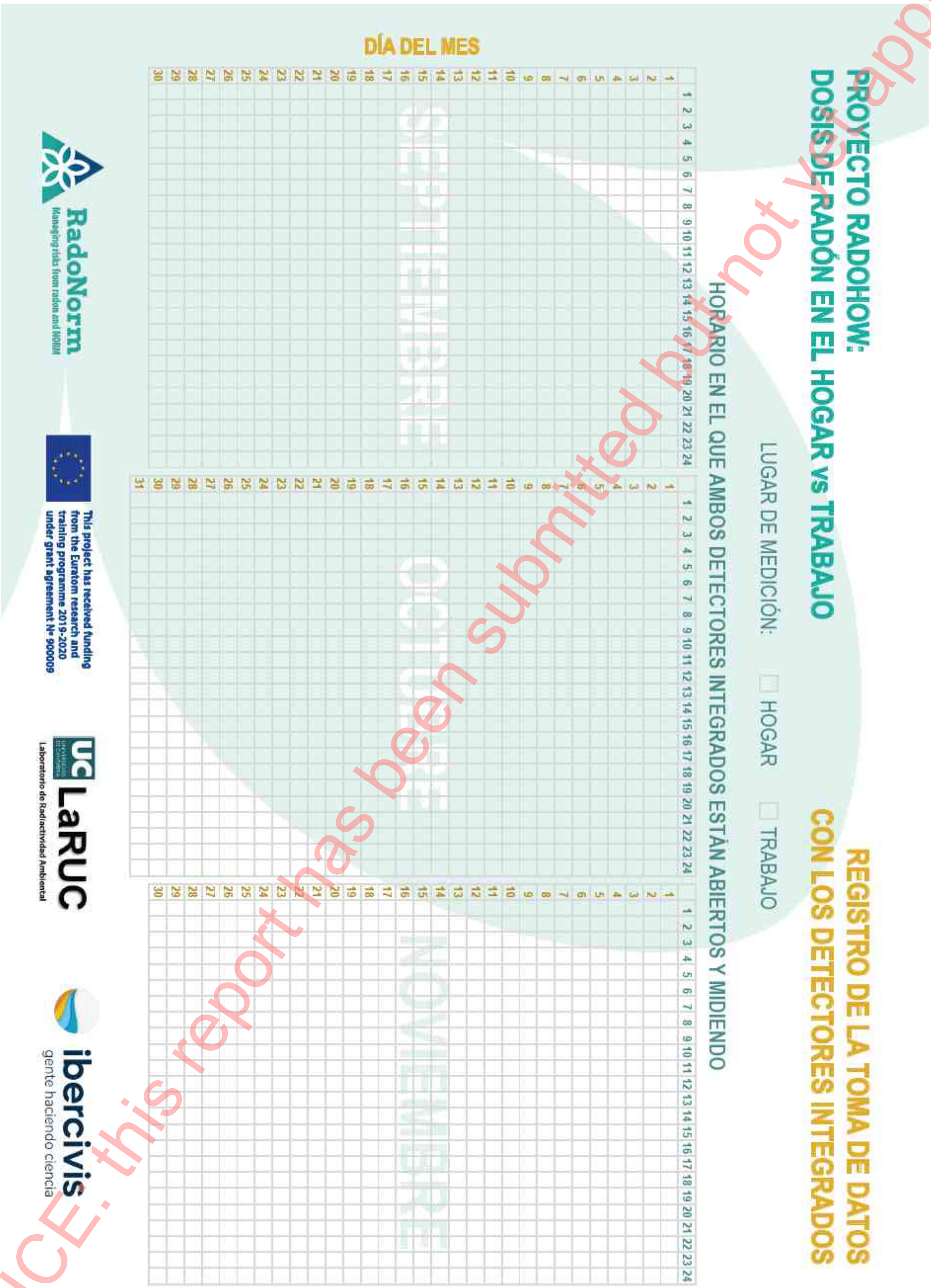

El valor de referencia de máxima concentración de gas radón en una casa/trabajo establecido por las autoridades europeas para todos los países de la Unión Europea es de 200 Bq/m3
12 respuestas
16,7%
25%
25%
16,7%
16,7%
Totalmente de acuerdo
De acuerdo
Neutral
En desacuerdo
Totalmente en desacuerdo


El Código Técnico de la Edificación obliga a que los proyectos de casas de obra nueva y rehabilitaciones reúnan las medidas necesarias par...inimizar la presencia de gas radón en las mismas.
12 respuestas
58,3%
16,7%
25%
Totalmente de acuerdo
De acuerdo
Neutral
En desacuerdo
Totalmente en desacuerdo

8.8.2 ANNEX 2. Guidelines for the radon gas measurement in RadoHOW provided to citizen scientists


METODOLOGÍA DE LOS DETECTORES
INTEGRADOS
Tapón
Tarro de cristal
Detector CR-39 (no tocar)
NOTAS
Sitúalos en una superficie plana
En una zona de paso o a la vista (¡Para que no se te olvide!)
Los detectores 1 y 3 siempre estarán abiertos
No confundas los detectores cerrados con los que abras y cierres todos los días
Cuando llegas a casa:
Detector 1
Detector 2
Cuando sales de casa:
Detector 1
Detector 2
Durante 3 meses
Cuando sales del trabajo:
Detector 3
Detector 4
Cuando llegas al trabajo:
Detector 3
Detector 4
CONTINUOS
Detector semiconductor AlphaE (no tocar ni configurar)
NOTAS
Sitúalos en el mismo lugar que los detectores integrados
De nuevo en una superficie plana
Se trata de un dispositivo único, que no precisa de tarros u otros elementos adicionales
Posiblemente, algunos detectores deban ser enchufados, suponiendo un consumo mínimo
Durante 1 semana
Durante 1 semana
Envío para su análisis
El detector estará en casa
El mismo detector estará en el trabajo

8.8.3 ANNEX 3. Tracking calendar with the specific daily hours when each container was opened



8.8.4 ANNEX 4. Circular emails and special announcements.

Proyecto RADOHOW - 1ª circular

[redacted]

lun, 28 ago 2023, 9:22

Buenos días a todos y todas.

Os escribimos con relación al proyecto de ciencia ciudadana "**RadoHow: dosis de radón en el hogar vs trabajo**", coordinado por el Laboratorio de Radiactividad Ambiental (LaRUC) de la Universidad de Cantabria, y la Fundación Ibercivis.

En primer lugar, nos gustaría agradeceros vuestra participación en este proyecto nacional, el primero que estudiará y comparará la concentración de este gas radiactivo a la que nos exponemos en ambos ambientes, y que forma parte del proyecto europeo RadoNorm. En este último, ya están participando cientos de personas pertenecientes a todos los rincones de Europa.

En segundo lugar, queríamos haceros llegar la 1ª circular con información relevante sobre varios puntos del proyecto:
- Os adjuntamos el **cartel del proyecto**, que contiene información general sobre el mismo, y un panfleto con información más específica del procedimiento. Éstos os darán una idea de la importancia del proyecto y de su organización.
- Con la idea de conoceros, contaros un poco más y resolver posibles dudas del proyecto, os invitamos a una **breve reunión online el lunes 4 de septiembre a las 10h**. Llegado el momento, podéis acceder a ella pinchando en este enlace de Zoom. Esta sesión se grabará para poder enviársela de manera individual a las personas que no hayan podido asistir.
- Próximamente, os pediremos que rellenéis un sencillo **cuestionario inicial** que nos permitirá tener un primer control de la participación.
- Os informamos también de que, siguiendo la planificación del proyecto, el envío y la recepción de la **caja contenedora de los detectores** se efectuará entre el **10 y el 14 de septiembre**. Para ello, os pedimos que nos proporcionéis cuanto antes una **dirección postal** fiable a la que poder enviarla.
- También os invitamos a seguir la actualidad del proyecto en las **redes sociales** de Ibercivis (Twitter, Facebook e Instagram), donde le daremos difusión. También podéis animaros a compartir parte de la experiencia en vuestras redes sociales, para lo cual podéis etiquetarnos junto al proyecto principal RadoNorm.

Por último, podéis **contestar a este correo** electrónico para hacernos llegar la dirección de correo postal, así como vuestro consentimiento para grabar la sesión online del lunes. Ambos se usarán exclusivamente para los fines explicados anteriormente, sin ninguna difusión.

Comienzan tres estimulantes meses de aprendizaje y colaboración con la ciencia... juntos :)
Un cordial saludo.
Ibercivis y LaRUC

Proyecto RADOHOW - 2ª circular

[redacted]

vie, 29 sept 2023, 9:13

Buenos días a todos y todas.

Esperamos que todo esté yendo bien con los detectores, recordad que cualquier problema o duda podéis escribirme.
Nos gustaría haceros llegar la 2ª circular con información relevante sobre varios puntos del proyecto:

- Nos gustaría pediros que rellenarais este **cuestionario inicial** (10 min. máx.), para llevar un control del inicio del proyecto.
- Asimismo, creemos que puede ser útil tener una **breve reunión online de control el jueves 5 de octubre a las 18h**. Llegado el momento, podéis acceder a ella pinchando en este **enlace de Zoom** (Código de acceso: 5Rwgrh). Será más breve que la anterior, y simplemente podremos compartir las experiencias de este mes y resolver alguna duda si las hay. De nuevo podremos grabar la sesión para poder enviársela de manera individual a las personas que no hayan podido asistir.
- Recordamos que vamos a empezar a preparar un **evento por el día europeo del radón** (el 7 de Noviembre), que será presencial en Torrelodones (Madrid) ¡Os mantendremos al tanto de las actividades!
- Si queréis podéis mandarnos algunas **fotos de los detectores**, para poder compartirlas en redes sociales. También os animamos a compartir parte de la experiencia en Twitter, si tenéis, para lo cual podéis etiquetarnos a Ibercivis junto al proyecto principal RadoNorm.

Seguimos juntos y juntas en esto :)
Un cordial saludo.
Ibercivis y LaRUC

Proyecto RADOHOW - Día Europeo del Radón

[redacted]

vie, 27 oct 2023, 14:28

Buenos días a todos y todas,

Se acerca el **Día Europeo del Radón, que se celebra el 7 de noviembre**, y en él diferentes organizaciones europeas planean actividades e iniciativas divulgativas.

Desde el proyecto al que pertenecemos, **RadoNORM**, vamos a organizar una **actividad online**:
- Un webinar online donde se explicarán todas las iniciativas, como RadoHOW, que estamos participando a menor escala (adjunto póster).
  Será online, el mismo día 7 de noviembre, entre las 10:00 y las 17:30h.
  Podéis registraros para participar en este link.
  La sesión será grabada y posteriormente difundida en el perfil del YouTube del proyecto.

También hemos preparado otras actividades, en este caso **presenciales, desde RadoHOW**:
- Una Jornada Técnica sobre el Plan Nacional del Radón, con Beatriz Robles (Consejo de Seguridad Nuclear) y Marian Mendoza (Ministerio de Sanidad) como ponentes (adjunto póster).
  Será en el Salón de Actos del Ayto de Torrelodones (Madrid), el 6 de noviembre de 18:00 a 20:00h.
- Una Jornada Divulgativa sobre nuestro proyecto de RadoHow, en la que explicaremos la metodología a la ciudadanía.
  También en Torrelodones, el mismo día 7 de noviembre a lo largo del día.

¡Os animamos a uniros a una de estas jornadas del Día Europeo del Radón!
Como parte vital de nuestro proyecto de ciencia ciudadana, vuestra presencia es importante.
Además, podréis aprender de los expertos y profundizar más en el conocimiento del radón.

¡Sigamos descubriendo más sobre este elemento y su impacto juntos!

RADOHOW

Un saludo,

Proyecto RADOHOW - 3ª circular

[redacted]

27 nov 2023, 9:59

Buenos días a todos y todas,

Ya estamos llegando al final del periodo de toma de datos del proyecto, así que os escribimos para informaros de varias cosas.

- Las mediciones continuarán **hasta la semana del 11 de diciembre**. Sabemos que los papeles de registro del horario en el que los detectores están abiertos terminan este mes de noviembre, pero nos gustaría pediros que, en la carilla opuesta, marquéis a mano el horario de los días de diciembre que midáis hasta que devolváis los detectores.
- Seguramente, el **procedimiento de recogida** de los detectores sea el mismo que el de entrega. Luis Quindós irá a recogerlos y hablará con aquellos localizados en Cantabria, Salamanca, Madrid y Galicia. Desde Ibercivis gestionaremos los de Zaragoza, por lo que también nos pondremos en contacto con vosotros.
- Cuando se acerquen esas fechas, os pediremos que empaquetéis los detectores y las hojas con los horarios igual que como los recibisteis. Los 4 detectores integrados cerrados y los dos continuos dentro de sus cajas, y todo ello en su caja del proyecto, si es que la conserváis. Os pediremos también que, a su vez, todo ello vaya dentro de una bolsa de plástico de supermercado. Si no conserváis las cajas, con la bolsa es suficiente.

Por otra parte, comentaros que las actividades del día del radón el pasado 7 de noviembre, y aquellas llevadas a cabo por LaRUC en diferentes eventos posteriores, han sido muy beneficiosas para el proyecto y las comunidades. Al webinar de RadoNorm llegaron a asistir más de 100 personas de toda Europa.

¡Gracias por vuestra colaboración!
Seguimos en contacto, si tenéis cualquier problema podéis decirnos.

RADOHOW

Proyecto RADOHOW - 4ª circular

[redacted]

30 ene 2024, 13:20

Buenos días a todos y todas,

¡RadoHOW sigue! Después de este parón para recoger los detectores y hacer un análisis preliminar de los resultados nos gustaría interpretarlos con vosotros/as para co-crear individual y colectivamente los pasos que pueden darse a continuación. Para ello:
- Nos gustaría **reunirnos individualmente** con cada uno de vosotros la semana del 19 al 23 de febrero, en formato online. En estas reuniones interpretaremos los datos juntos. Podéis escribirnos a este correo con vuestra disponibilidad y os mandaremos un enlace.
- También queríamos proponer la **3ª reunión colectiva**, para comentarlos y ampliar el alcance del proyecto. Sería el martes 12 de marzo, de 16:30 a 17:30, pero os lo terminaremos de confirmar más adelante.

¡Gracias por vuestra colaboración!
Seguimos en contacto, y si tenéis cualquier duda podéis escribirnos.

Un cordial saludo,
Ibercivis y LaRUC

RADOHOW


Evento final + Encuesta - Proyecto RadoHOW

[redacted] jue, 7 mar, 15:00

Buenos días a todos y todas.

Solamente recordaros que el próximo lunes será nuestro evento online final:
11 de marzo
15:30h
Google meet
meet.google.com/fss-bsza-tkn

También nos gustaría animaros a que hagáis la encuesta final de RadoNORM:
https://sl-pool.madiamagroup.net/wamdl/survey/index.php?loginSID=d9f5061305debdb-3465443

¡Gracias por vuestra colaboración!

Un cordial saludo,
Ibercivis y LaRUC

ANNEX 5. General poster for dissemination and specific guidelines of RadoHOW.


RadoNorm
Managing risks from radon and NORM
PROYECTO DE CIENCIA CIUDADANA
RADOHOW:
DOSIS DE RADÓN EN EL
HOGAR vs TRABAJO
LaRUC
Laboratorio de Radiactividad Ambiental
ibercivis
gente haciendo ciencia
Forma parte del primer proyecto científico que estudiará
la concentración del gas radiactivo radón
a la que nos exponemos en el hogar y en el trabajo
Con el objetivo de dar a conocer este gas, ayudar a protegernos de él
y concienciar sobre sus efectos para la salud
This project has received funding from the
Euratom research and training programme 2019-2020
under grant agreement Nº 900009

1 EL GAS RADÓN

- Es un gas radiactivo de **origen natural** que procede de la desintegración del radio y del uranio.
- Estos elementos están presentes **en muchas de las rocas que forman el suelo** que pisamos, y su concentración depende de la composición y características de estas rocas.
- Durante su desintegración, el gas radón emana del suelo y **puede disiparse** por la atmósfera **o acumularse** en los hogares y puestos de trabajo.
- Al ser un gas radiactivo, su inhalación durante largos periodos de tiempo puede provocar **cáncer de pulmón** en las personas que los habitan.

SU IMPORTANCIA 2

- Dependiendo de la geología de cada lugar, existen **zonas con más concentración** de gas radón que otras. La exposición también aumenta dependiendo de las infraestructuras, de sus características arquitectónicas o de la profundidad que alcanzan.
- En España, el proyecto se realizará en **5 localizaciones**:
  - **Galicia:** por ser una zona con potencial alto de radón
  - **Cantabria:** por tener unas características geológicas de tipo kárstico
  - **Salamanca:** por ser una zona minera de uranio
  - **Zaragoza:** por ser una zona con potencial bajo de radón
  - **Madrid:** por ser una zona con potencial alto de radón en España, así como superpoblada
- Según la Organización Mundial de la Salud (OMS), el radón provoca entre un 3% y un 14% de los casos de cáncer de pulmón en la población general. **En España ya supone entre 1500 y 1600 muertes cada año**.

3 EL PROYECTO

- Forma parte de la comunidad científica RadoNorm **midiendo las dosis de este gas**, que después serán analizadas por el Laboratorio de Radiactividad Ambiental (LaRUC) de la Universidad de Cantabria.
- Las mediciones durarán los meses de **septiembre, octubre y noviembre**.
- También se participará en las **actividades de comunicación y divulgación** del proyecto.

LEGISLACIÓN 4

- Medir las dosis de radón en los puestos de trabajo es de obligado cumplimiento según:
  - **Directiva 59/2013/Euratom**, sobre normas de seguridad básicas para proteger a la población de los riesgos de exposición a radiaciones ionizantes.
  - **International Basic Safety Standards**.
  - **Instrucción IS-33** (BOE), de 21 de diciembre de 2011, del Consejo de Seguridad Nuclear, sobre criterios radiológicos para la protección frente a la exposición a la radiación natural.
  - **Real Decreto 1029/2022** (BOE), de 20 de diciembre de 2022, sobre el Reglamento de protección de la salud contra los riesgos derivados de la exposición a las radiaciones ionizantes.

5 SOLUCIONES DE MITIGACIÓN

- Dos ejemplos de técnicas principales para **reducir las concentraciones** en los hogares y puestos de trabajo:
  - Eliminando el radón existente, por ejemplo, mediante ventilación.
  - Impidiendo su entrada, con materiales de construcción adecuados.

MÁS INFORMACIÓN EN

PROYECTO RADOHOW: DOSIS DE RADÓN EN EL HOGAR vs TRABAJO

RadoNorm

INFORMACIÓN ESPECÍFICA

- A cada participante se os proporcionarán **4 detectores de medición integrada** de gas radón (tipo CR-39): 2 para el hogar y 2 para el trabajo. Las mediciones de la concentración con estos detectores durarán los **meses de septiembre, octubre y noviembre**.
- También se os proporcionará **1 detector de medición continua** adicional, durante un **periodo de tiempo más corto**.

PLANIFICACIÓN

AGOSTO

A finales:

- Realización de un breve cuestionario inicial.

SEPTIEMBRE

Primera quincena:

- Entrega de los detectores integrados y toma de datos durante 3 meses (en casa y en el trabajo a la vez).
- Primera reunión online breve para explicar los detalles y resolver dudas.

OCTUBRE

Primera quincena:

- Entrega de los detectores continuos y toma de datos durante 2 semanas (1 en casa y 1 en el trabajo). Después se enviarán para analizarlos.
- Segunda reunión online para aprender y compartir experiencias.

NOVIEMBRE

7 de noviembre:

- ¡Evento especial del día europeo del radón!

DICIEMBRE

Primera quincena:

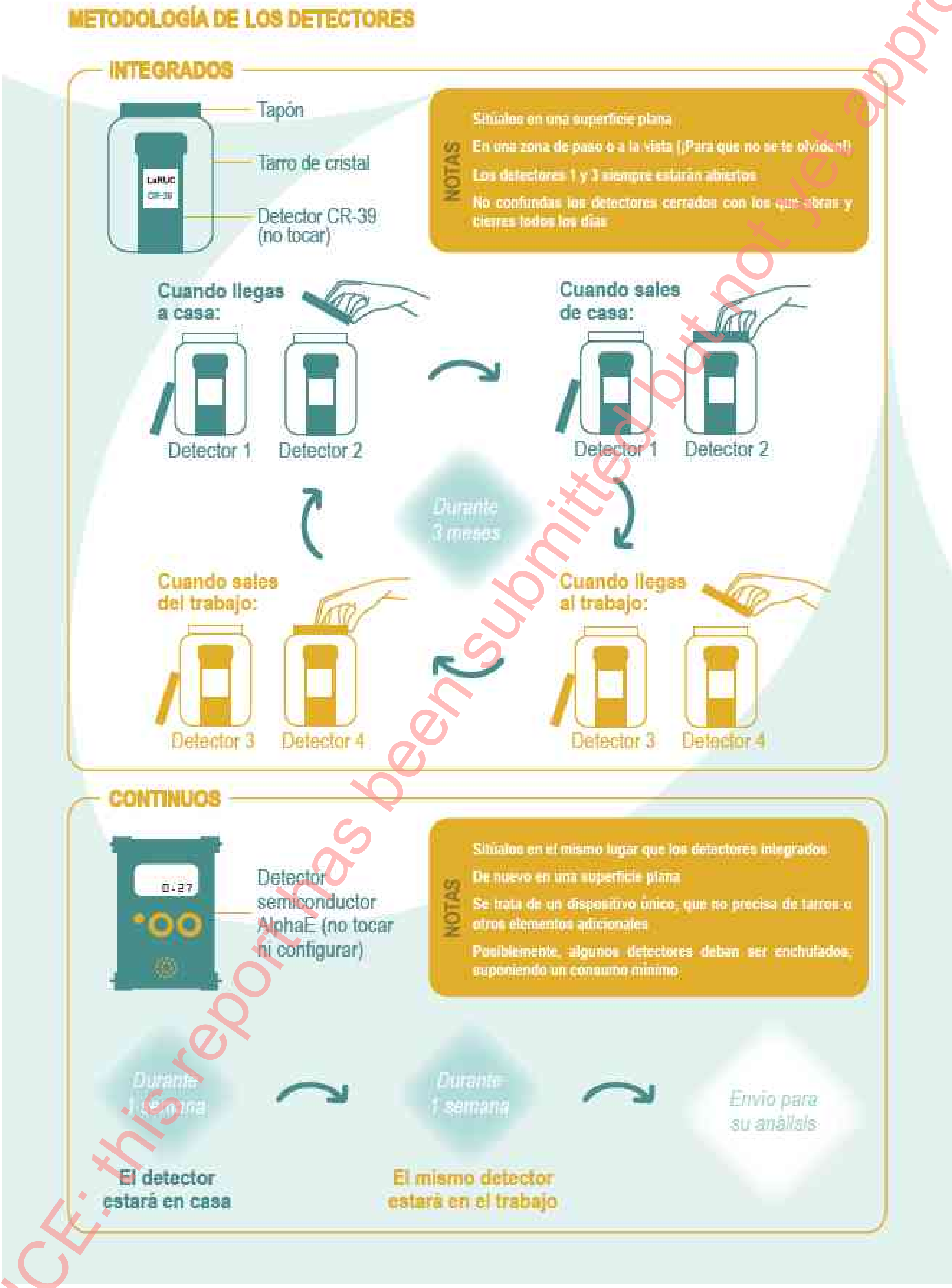
- Envío de los detectores integrados para analizarlos y fin de la toma de datos.
- Realización de un cuestionario final.
- Tercera y última reunión online para sacar conclusiones.

DESPUÉS SIGUE LOS RESULTADOS Y AVANCES DEL PROYECTO EN:

LaRUC Laboratorio de Radiactividad Ambiental

ibercivis gente haciendo ciencia

This project has received funding from the Euratom research and training programme 2019-2020 under grant agreement Nº 900009


METODOLOGÍA DE LOS DETECTORES
INTEGRADOS
Tapón
Tarro de cristal
Detector CR-39
(no tocar)
NOTAS
Sitúalos en una superficie plana
En una zona de paso o a la vista (¡Para que no se te olviden!)
Los detectores 1 y 3 siempre estarán abiertos
No confundas los detectores cerrados con los que abras y cierres todos los días
Cuando llegas a casa:
Detector 1
Detector 2
Cuando sales de casa:
Detector 1
Detector 2
Durante 3 meses
Cuando sales del trabajo:
Detector 3
Detector 4
Cuando llegas al trabajo:
Detector 3
Detector 4
CONTINUOS
Detector semiconductor AlphaE (no tocar ni configurar)
NOTAS
Sitúalos en el mismo lugar que los detectores integrados
De nuevo en una superficie plana
Se trata de un dispositivo único, que no precisa de tarros o otros elementos adicionales
Posiblemente, algunos detectores deban ser enchufados, suponiendo un consumo mínimo
Durante 1 semana
Durante 1 semana
Envío para su análisis
El detector estará en casa
El mismo detector estará en el trabajo

8.8.5 ANNEX 6. Final infographics with the main aspects and conclusions.


RADOHOW
RadoNorm
RadoHOW
y la ciencia ciudadana...
...¡Online!
Reuniones regulares con la comunidad RadoHOW, procedente de 5 provincias diferentes: para co-crear la metodología, entender los protocolos y llevar un seguimiento.
Reuniones individuales con cada participante: para interpretar sus resultados, tratar sus preocupaciones y/o reflexiones al respecto, y co-crear las posibles estrategias de mitigación.
Evento final: wrap-up de la información y resultados obtenidos en todas las localizaciones estudiadas, puesta en común de las estrategias de mitigación y difusión co-creadas, y debate final entre la comunidad.
...¡Y en persona!
Día Europeo del Radón (7 de noviembre): un día para intercambiar experiencias entre la comunidad científica centrada en radiaciones ionizantes, investigadores en el campo de las ciencias sociales y la ciudadanía
Difusión del proyecto y de los riesgos del gas radón para la salud: en la Facultad de Medicina de la Universidad de Cantabria, para grupos de espeleología en Motril ¡y mucho más!
UC LaRUC
ibercivis
gente haciendo ciencia
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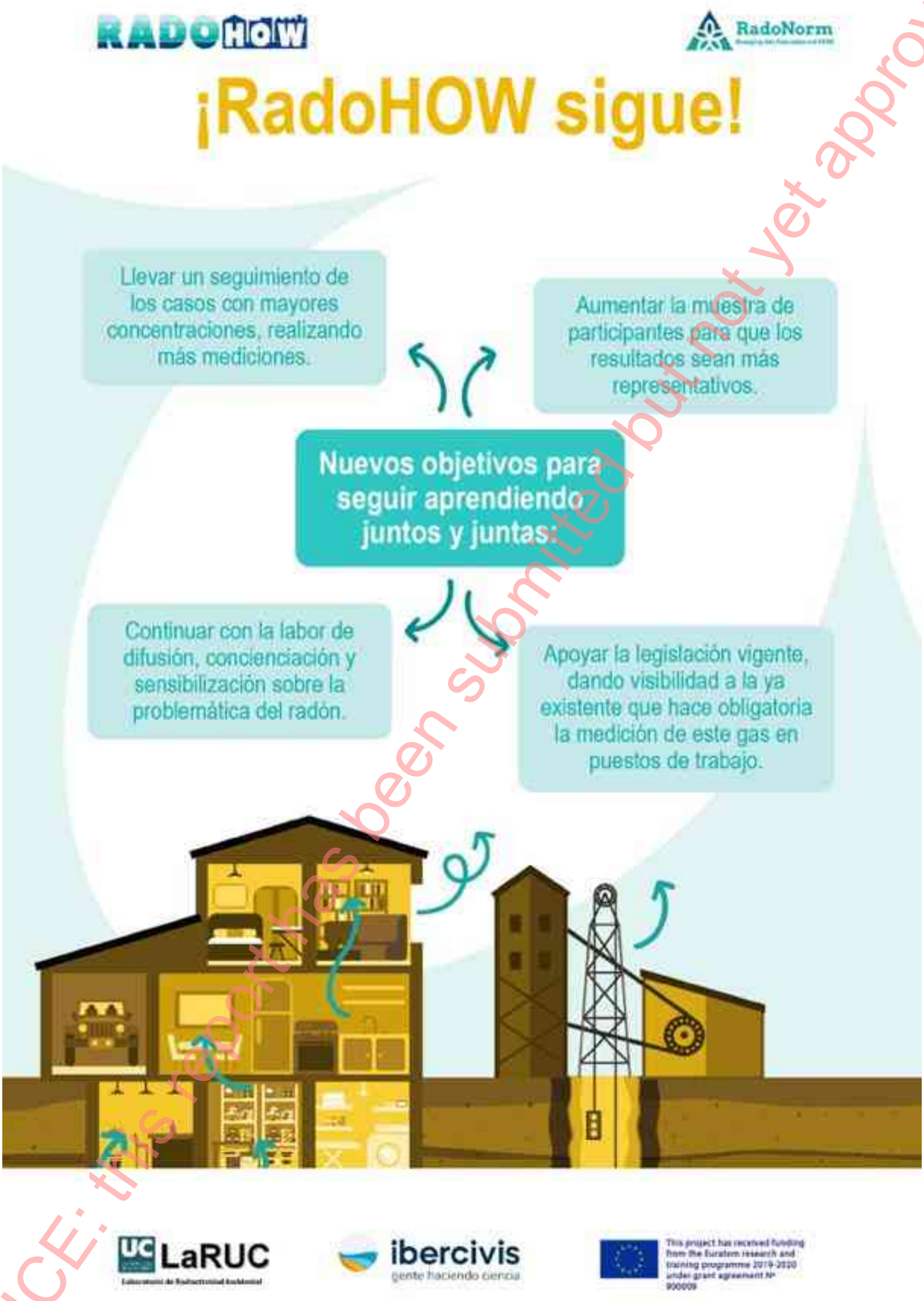
RADOHOW
RadoNorm
RadoHOW y los resultados generales de nuestros participantes en...
Concentración simplificada de gas radón respecto a los 1000 Bq/m³
CANTABRIA
GALICIA
ZARAGOZA
SALAMANCA
MADRID
En hogares
CANTABRIA
GALICIA
ZARAGOZA
SALAMANCA
MADRID
En el trabajo
MUY BAJO
BAJO
ALTO
MUY ALTO
Esto se debe a que
Las características geológicas, arquitectónicas y demográficas, que propician una mayor o menor exhalación y acumulación de gas radón, son diferentes en cada región.
Existen oficios que exponen a sus trabajadores a mayores concentraciones de gas radón, como en el ámbito de la minería o de las centrales nucleares, entre otros.
LaRUC
Laboratorio de Radiactividad Ambiental
ibercivis
gente haciendo ciencia
This project has received funding from the Euratom research and training programme 2019-2020 under grant agreement Nº 900009


RADOHOW
RadoNorm
Estrategias co-creadas por la comunidad RadoHOW
¡Hemos compartido experiencias entre participantes con más de 40 años de experiencia y participantes nuevos en la materia!
Co-creación de estrategias de mitigación personalizadas
Para ventilar y/o modificar los inmuebles
Complementadas con más mediciones profesionales
A nivel de la comunidad y de difusión:
En puestos de trabajo: contactar con las unidades de prevención de riesgos laborales e interiorizar la normativa existente.
Difusión y concienciación sobre los riesgos para la salud de la exposición al radón, y las medidas de protección y de mitigación disponibles.
En hogares: compartir las sensaciones con círculos cercanos, contactar con la comunidad de propietarios y abrir el debate en reuniones de vecinos, siempre comunicándote asertivamente.
LaRUC
ibercivis
gente haciendo ciencia


RADOHOW
RadoNorm
¡RadoHOW sigue!
Llevar un seguimiento de los casos con mayores concentraciones, realizando más mediciones.
Aumentar la muestra de participantes para que los resultados sean más representativos.
Nuevos objetivos para seguir aprendiendo juntos y juntas:
Continuar con la labor de difusión, concienciación y sensibilización sobre la problemática del radón.
Apoyar la legislación vigente, dando visibilidad a la ya existente que hace obligatoria la medición de este gas en puestos de trabajo.
UC LaRUC
ibercivis
gente haciendo ciencia

8.8.6 ANNEX 7. Other materials of RadoHOW.

European Radon Day Leaflet:

Roll-up:


RADOHOW
DOSIS DE RADÓN EN EL HOGAR vs TRABAJO
RadoNorm
This project has received funding from the Euratom research and training programme 2019-2020 under grant agreement Nº 900009
LaRUC
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8.8.7 ANNEX 8. Photographs of the organised activities.

JORNADA CIENCIA CIUDADANA

PROGRAMA:

10:00 Apertura y presentación (10 minutos)
Juan Carlos Lentijo
Presidente CSN

10:10 Casos de éxito de uso de ciencia ciudadana para medidas de la radiactividad ambiental empleando teléfonos móviles.

Jean François Bottollier-Depois
Head of external dosimetry department
Institute for Radiological Protection and Nuclear Safety (IRSN, France)

Francesco D'Errico, PhD
Radiology & Biomedical Imaging
Yale Cancer Center – Yale School of Public Health
New Haven - United States

Café

12:15 Mesa Redonda y coloquio: Protección Radiológica y ciencia ciudadana (intervenciones de 10 minutos por ponente y coloquio)

Ponentes:
Arturo Vargas
Director Instituto de Técnicas Energéticas - Eurados
Universidad Politécnica de Cataluña

Luis Quindós
Catedrático adscrito al Departamento de Facultad de Medicina
Universidad de Cantabria

Alfonso Tarancón
Investigador del Dpto. Física Teórica
Instituto de Biocomputación y Física de Sistemas Complejos - BIFI – Ibercivis
Universidad de Zaragoza

Pura Fernández
Vicepresidenta Adjunta de Cultura Científica y Ciencia Ciudadana
Directora de Editorial CSIC

Agustina Sterling
Subdirección de Protección Radiológica Ambiental – CSN, ICRP

Moderador:
Javier Zarzuela
Director Técnico Protección Radiológica - CSN


CSN
DOSIS DE RADÓN EN EL HOGAR vs TRABAJO

LaRUC
Laboratorio de Radiactividad Ambiental

UNIVERSIDAD DE CANTABRIA
Facultad de Medicina
Avda. Cardenal Herrera Oria, s/n
39011 Santander- Cantabria-ESPAÑA
Tel: +34 942 20 22 07

DÍA EUROPEO DEL RADÓN

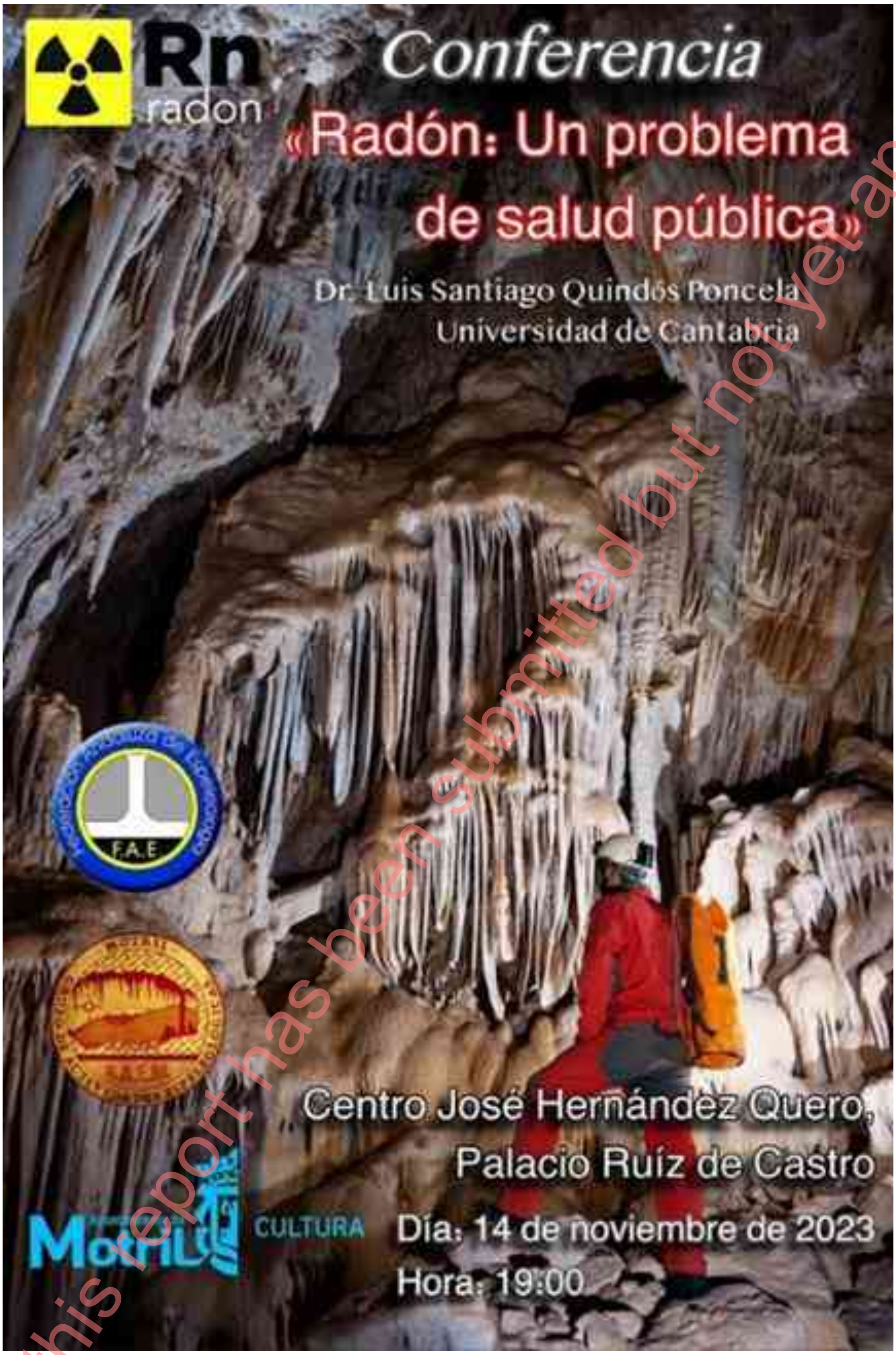
JORNADA TECNICA SOBRE EL PLAN NACIONAL DEL RADON

Salón de Actos del Ayto de Torrelodones
6 de noviembre
18 h a 20 h

PONENTES

Beatriz Robles, Consejo de Seguridad Nuclear
Marian Mendoza, Ministerio de Sanidad


RADOHOW
DOSIS DE RADÓN EN EL HOGAR vs TRABAJO
LaRUC
ibercivis
LaRUC


Rn
radon
Conferencia
«Radón: Un problema de salud pública»
Dr. Luis Santiago Quindós Poncela
Universidad de Cantabria
F.A.E
Centro José Hernández Quero,
Palacio Ruíz de Castro
CULTURA
Día: 14 de noviembre de 2023
Hora: 19:00


PROYECTO DE CIENCIA CIUDADANA:
DOSIS DE RADÓN EN EL HOGAR vs TRABAJO
RadoNorm
RADOHOW: IBERCIVIS & UNIVERSIDAD DE CANTABRIA
MOTRIL 14 DE NOVIEMBRE de 2023
Radón: Un problema de salud publica
Luis Santiago Quindos Poncela
Catedrático de la Universidad de Cantabria
GRUPO RADON

8.8.8 ANNEX 9. Results of CR39 detectors in detail

	ID	Hours	Exposition (kBq.m-3.h)	Concentration (Bq.m-3)
G1 work	EC3279	1814	50	27.6
G1 work	EC3849	487	50	102.7
G1 home	EC3257	1797	50	27.8
G1 home	EC3811	1298	83.1	64.0
G2 work	EC4060	802	163.4	203.8
G2 work	EC3264	200	70.0	350.0
G2 home	EC3363	840	276.1	328.7
G2 home	EC3536	469	184.2	392.7
G3 work	EC3776	1500	83.7	55.8
G3 work	EC3789	365	50	137.0
G3 home	EC3790	1498	337.8	225.5
G3 home	EC3514	1250	273.9	219.1
G4 work	EC4072	1617	100.0	61.8
G4 work	EC3981	367	83.0	226.2
G4 home	EC2834	1611	106.0	65.8
G4 home	EC3963	1187	171.0	144.1

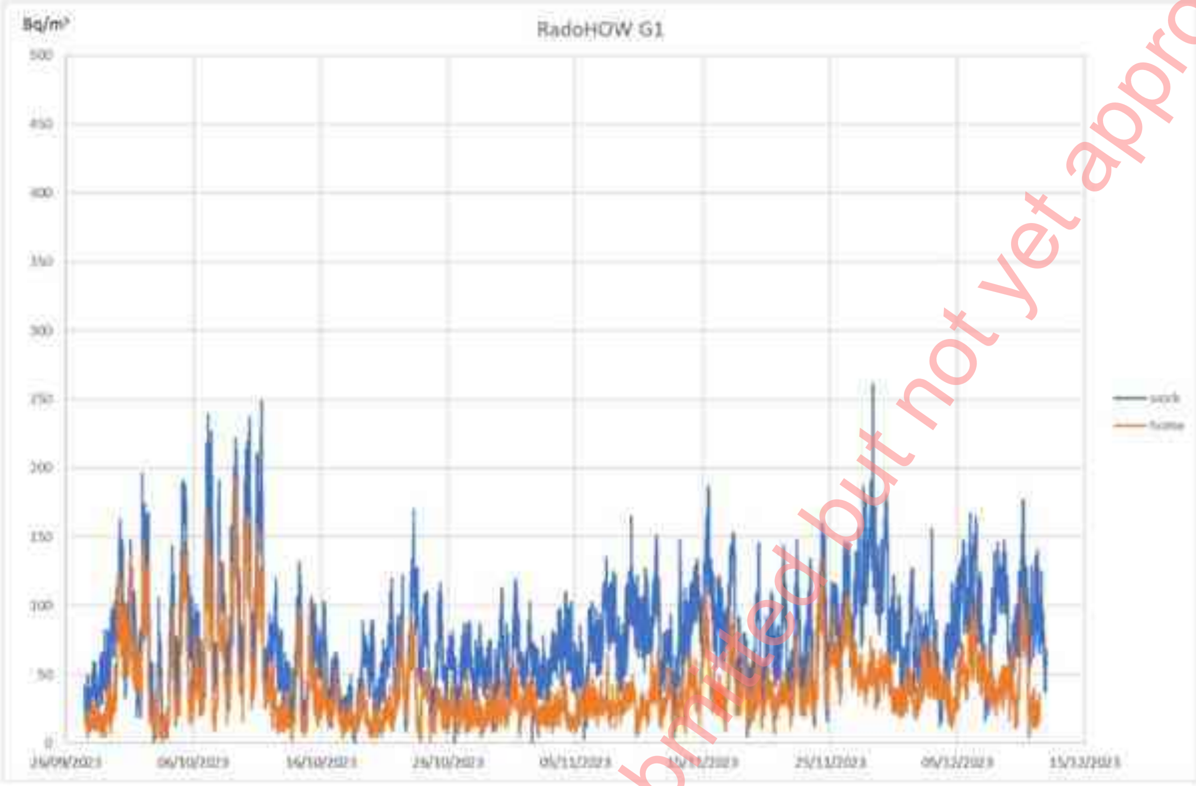
C1 work	EC3115	2033	50	24.6
C1 work	EC3802	486	89.6	184.4
C1 home	EC3805	2040	50	24.5
C1 home	EC3773	602	98.7	164.0
C2 work	EC3679	1610	939.8	583.7
C2 work	EC2808	381	250	656.2
C2 home	EC4288	1626	311.7	191.7
C2 home	EC3834	1182	173.1	146.5
C3 work[1]	EC3841	1528	6434.4	4211.0
C3 work	EC3535	340	5065.3	14897.8
C3 home	EC3334	1519	50	32.9
C3 home	EC3526	803	50	62.3
C4 work	EC3395	1617	150.5	93.1
C4 work	EC2757	367	166.5	453.6
C4 home	EC3711	1611	171.2	106.3
C4 home	EC3331	1187	208.2	175.4
Z1 work	EC3490	1815	50	27.5

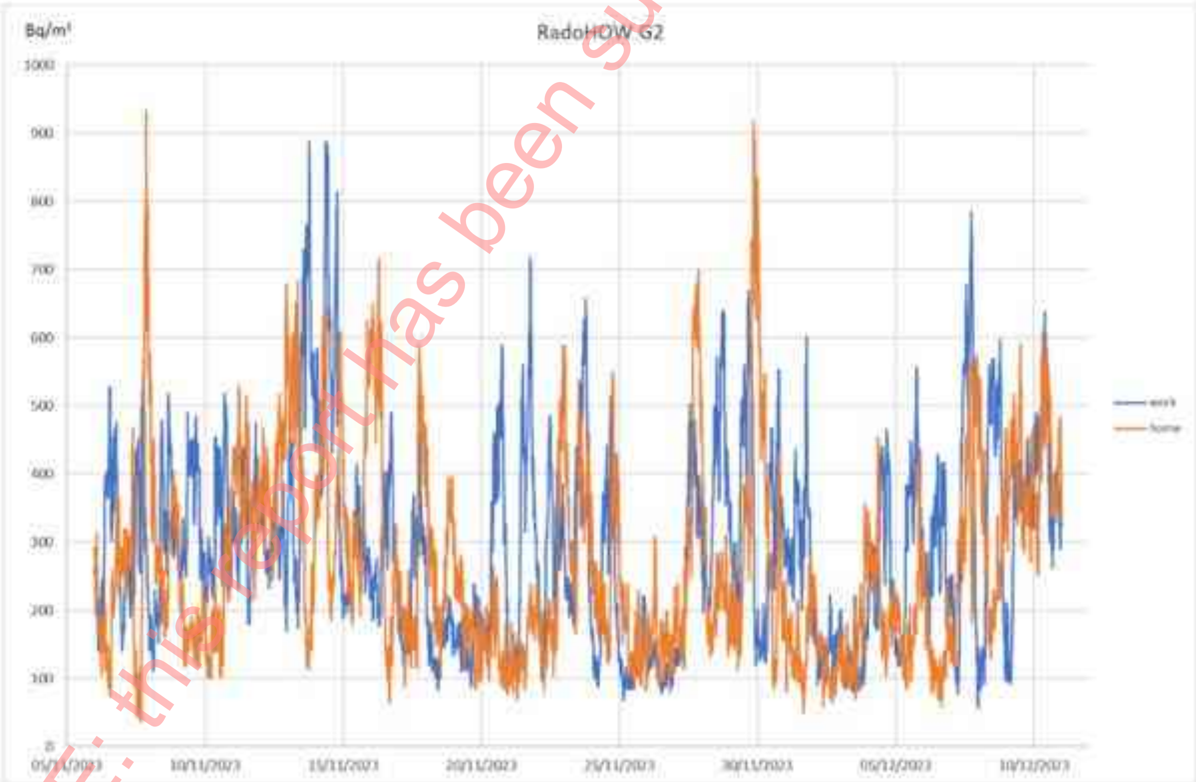
Z1 work	EC3993	429	50	116.6
Z1 home	EC3720	1795	50	27.9
Z1 home	EC2726	1096	50	45.6
Z2 work	EC3291	2096	50	23.9
Z2 work	EC3848	464	50	107.8
Z2 home	EC3808	2119	50	23.6
Z2 home	EC4262	1672	50	29.9
Z3 work	EC3524	1809	67.6	37.4
Z3 work	EC2712	358	50	139.7
Z3 home	EC3494	1837	50	27.2
Z3 home	EC2785	1377	50	36.3
Z4 work	EC3657	1957	50	25.5
Z4 work	EC2766	310	50	161.3
Z4 home	EC3521	1968	80.7	41.0
Z4 home	EC3707	1689	50	29.6

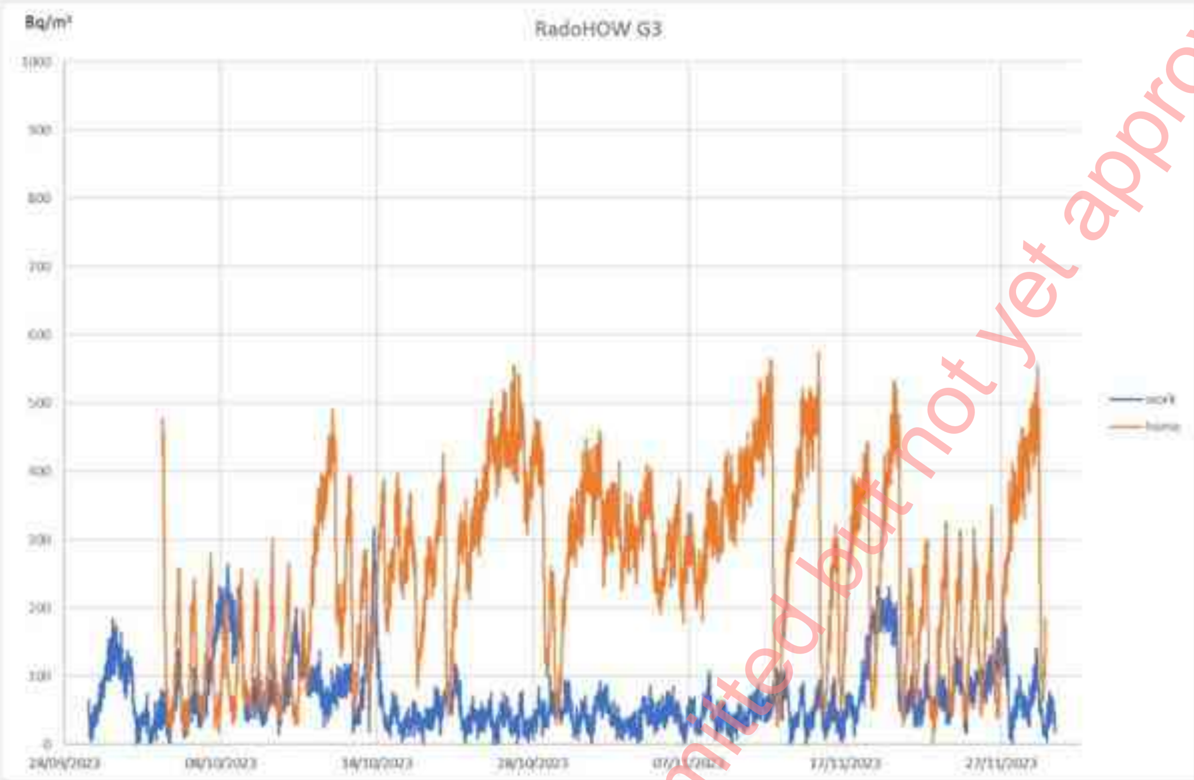
	ID	Hours	Exposition (kBq.m-3.h)	Concentration (Bq.m-3)
M1 work	EC3984	2164	449.2	207.6
M1 work	EC3042	400	139.8	349.6
M1 home	EC3427	2124	50	23.5
M1 home	EC2833	736	50	67.9
M2 work	EC3306	1885	99.5	52.8
M2 work	EC3318	438	50	114.2
M2 home	EC3497	1998	95.7	47.9
M2 home	EC3313	1355	74.5	55.0
M3 work	EC3682	1883	703.8	373.7
M3 work	EC3338	287	334.4	1165.3
M3 home	EC3413	2122	50	23.6
M3 home	EC3801	1311	50	38.1
M4 work	EC4352	1351	194.5	144.0
M4 work	EC4356	480	112.9	235.2

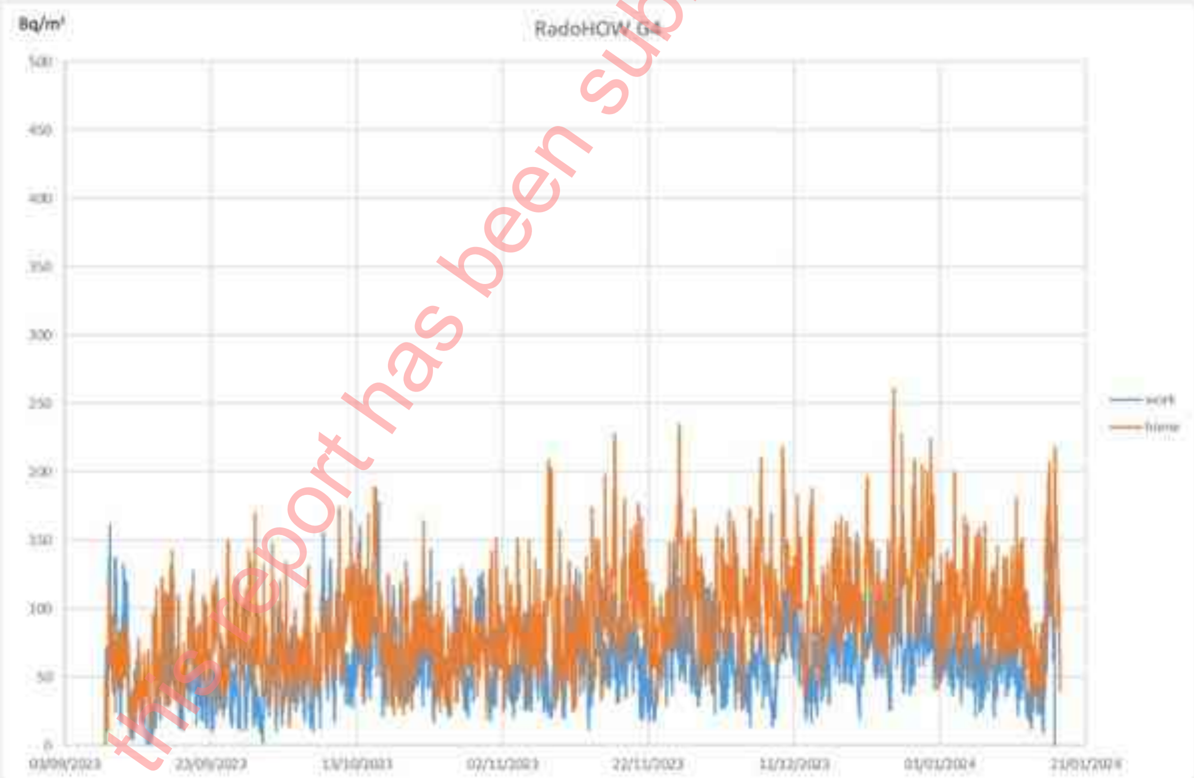
M4 home	EC4355	1503	198.5	132.1
M4 home	EC4373	442	50	113.1
V1 work[2]	EC3809	2165	2508.7	1158.7
V1 work	EC3476	144	1960.5	13614.8
V1 home	EC3387	2211	2679.4	1211.8
V1 home	EC3768	1821	2628.8	1443.6
LRN work[3]	EC3839	2000	17391.2	8695.6
LRN work	EC3759	416	7264.7	17463.1
LRN home	EC3761	1993	2442.8	1225.7
LRN home	EC3803	1700	2471.4	1453.7
CRF work	EC3327	1857	496.9	267.6
CRF work[4]	EC3781	446	124.2	278.4
CRF home	EC3830	2000	96.6	48.3
CRF home	EC3760	1196	94.6	79.1
S1 work[5]	EC3763	2000	5913.2	2956.6
S1 work	EC3340	409	4940.8	12080.1
S1 home	EC3276	1993	1256.0	630.2
S1 home	EC3845	1528	1275.2	834.5

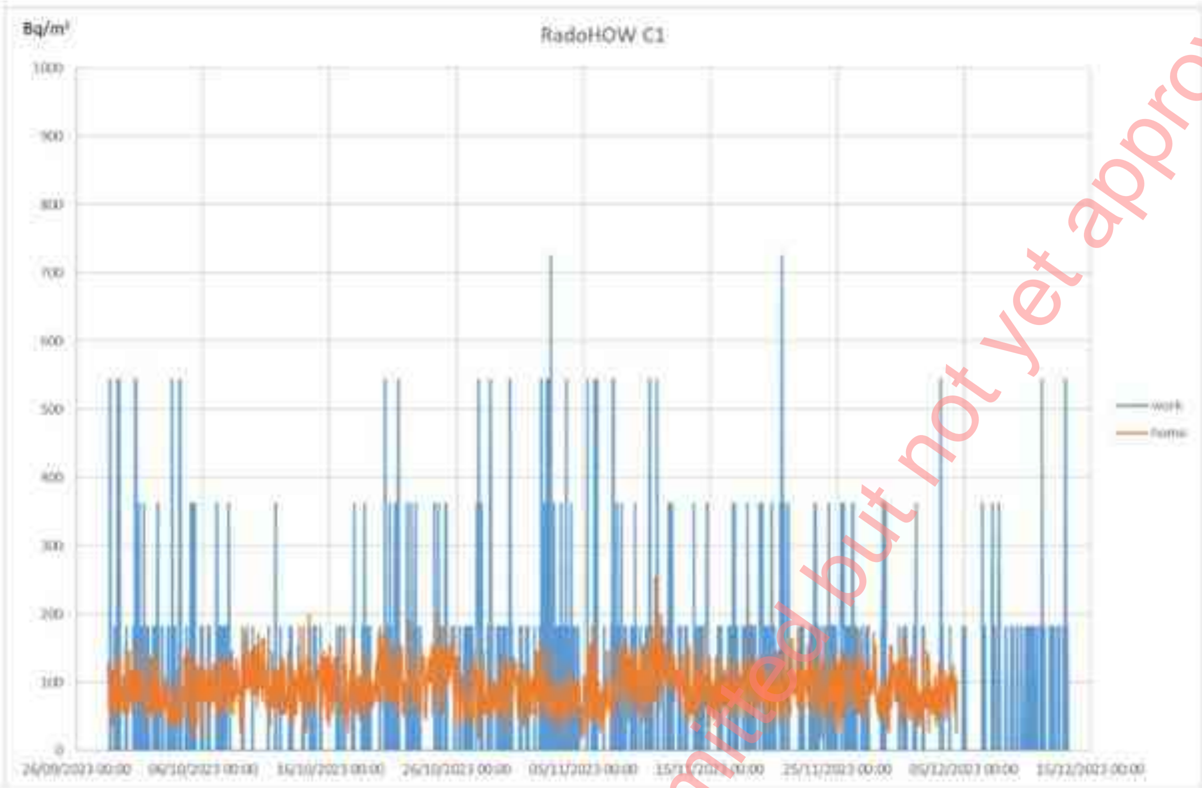
8.8.9 ANNEX 10. Results of continuous measurements

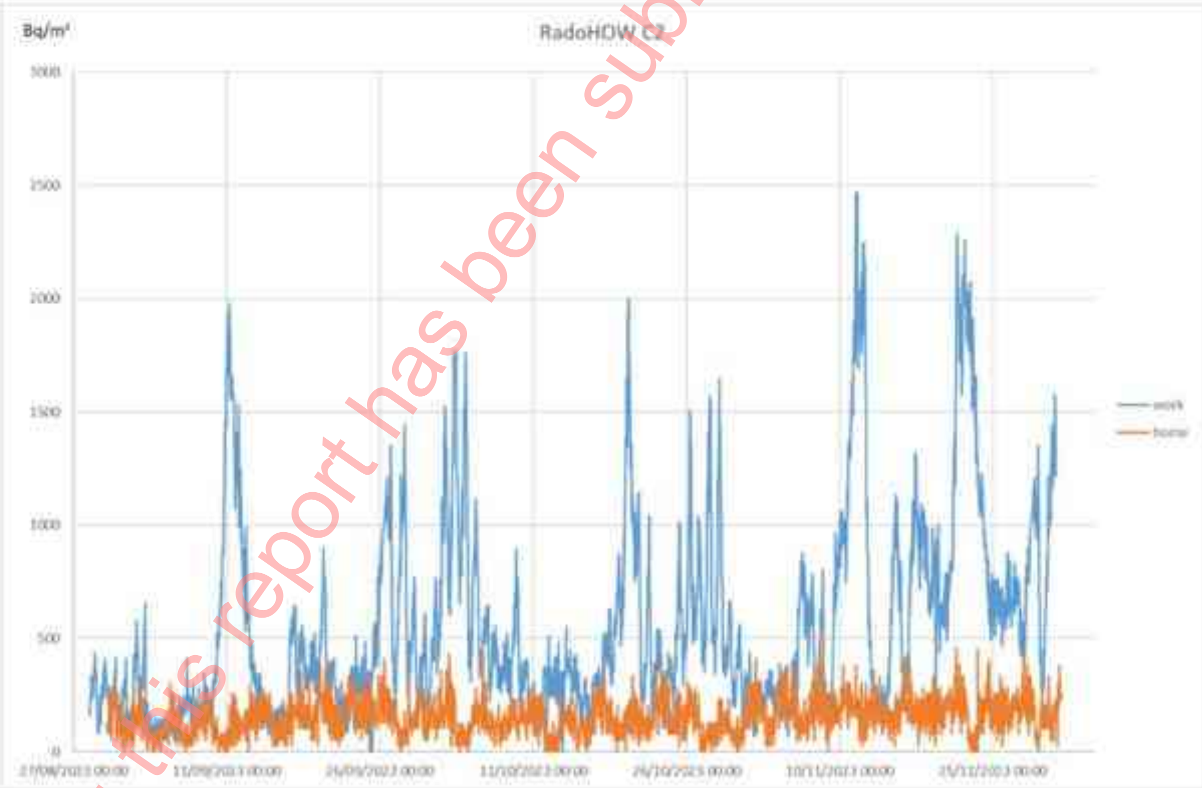


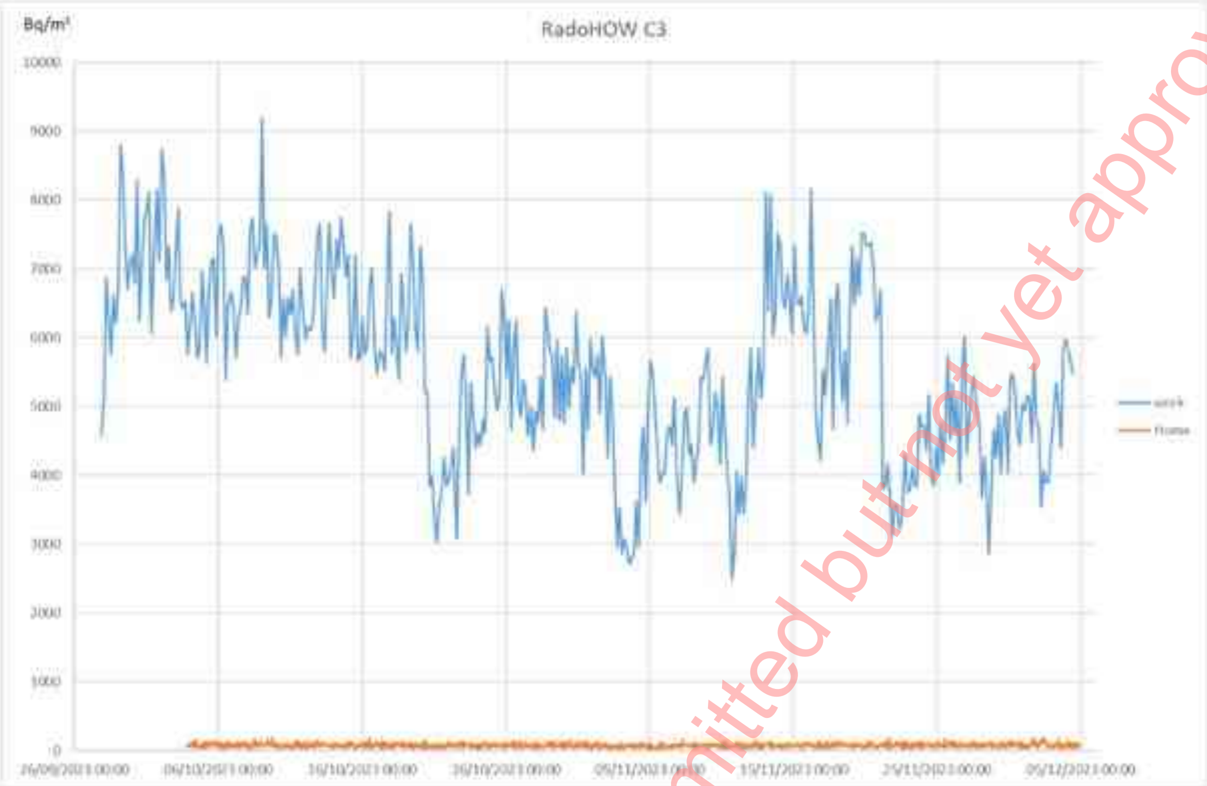


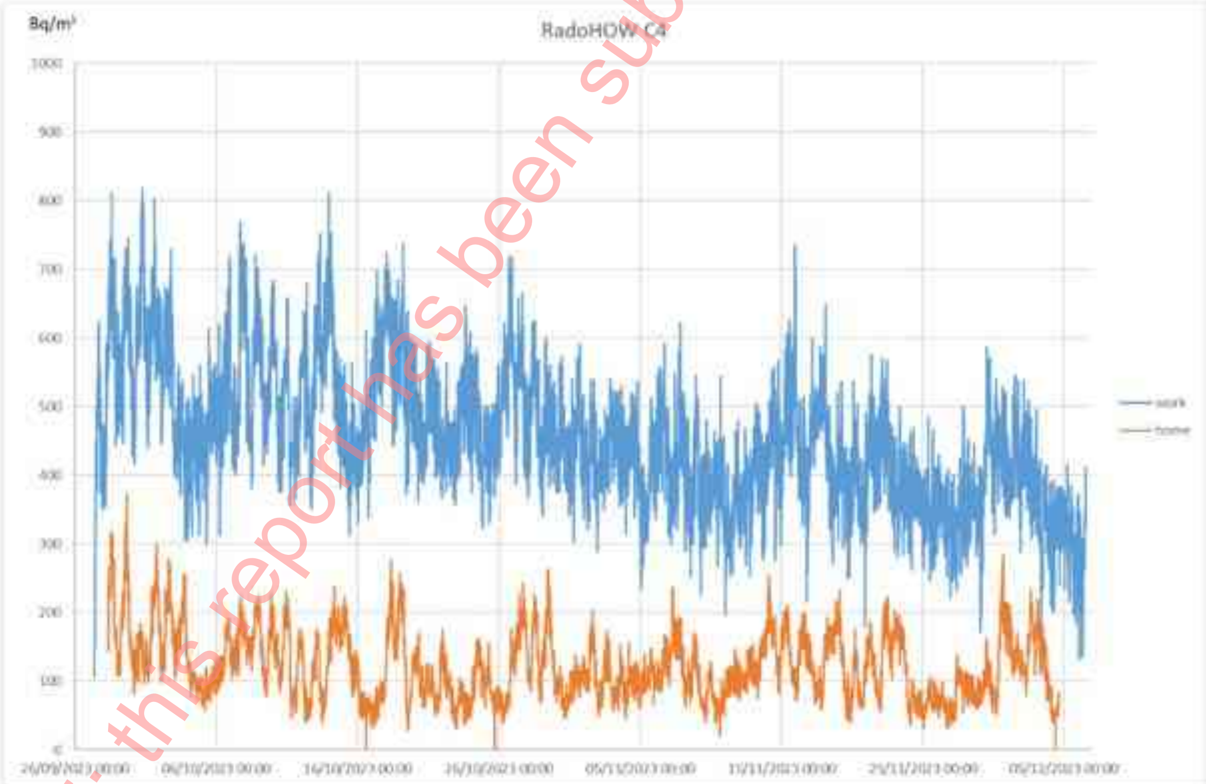

Bq/m³
RadoHOW G3
work
home

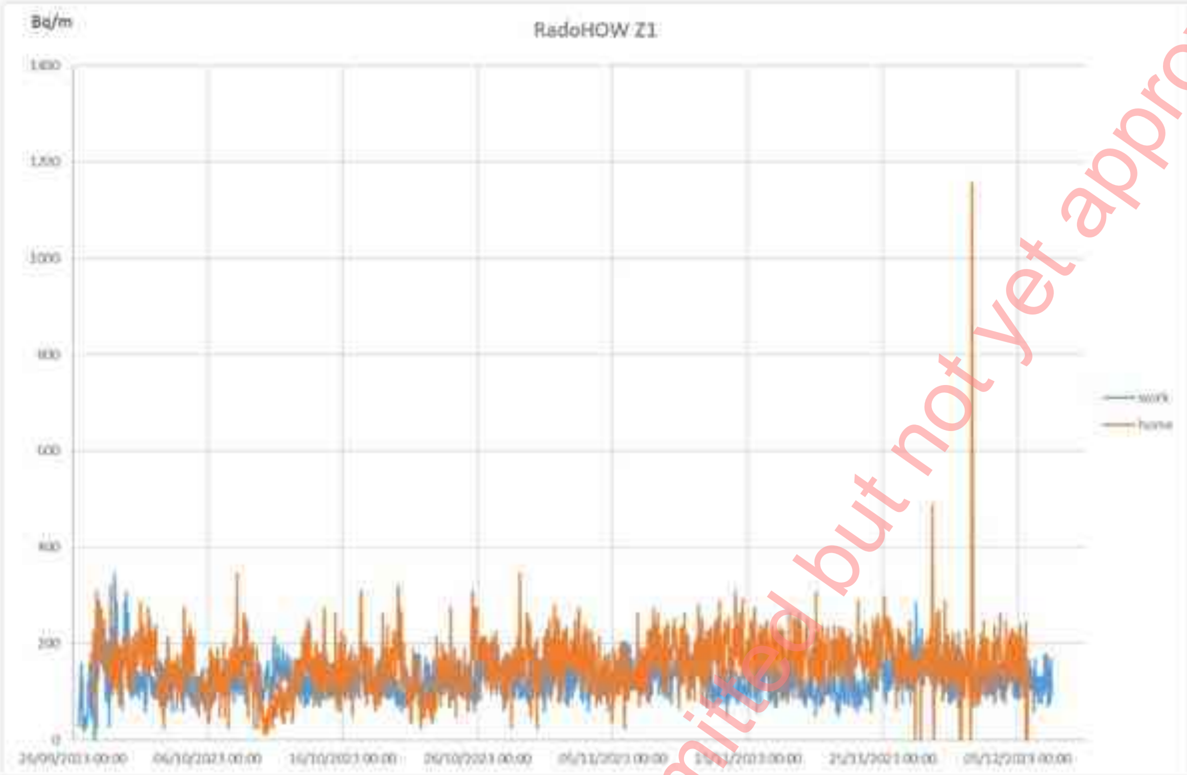

Bq/m³
RadoHOW G4
work
home

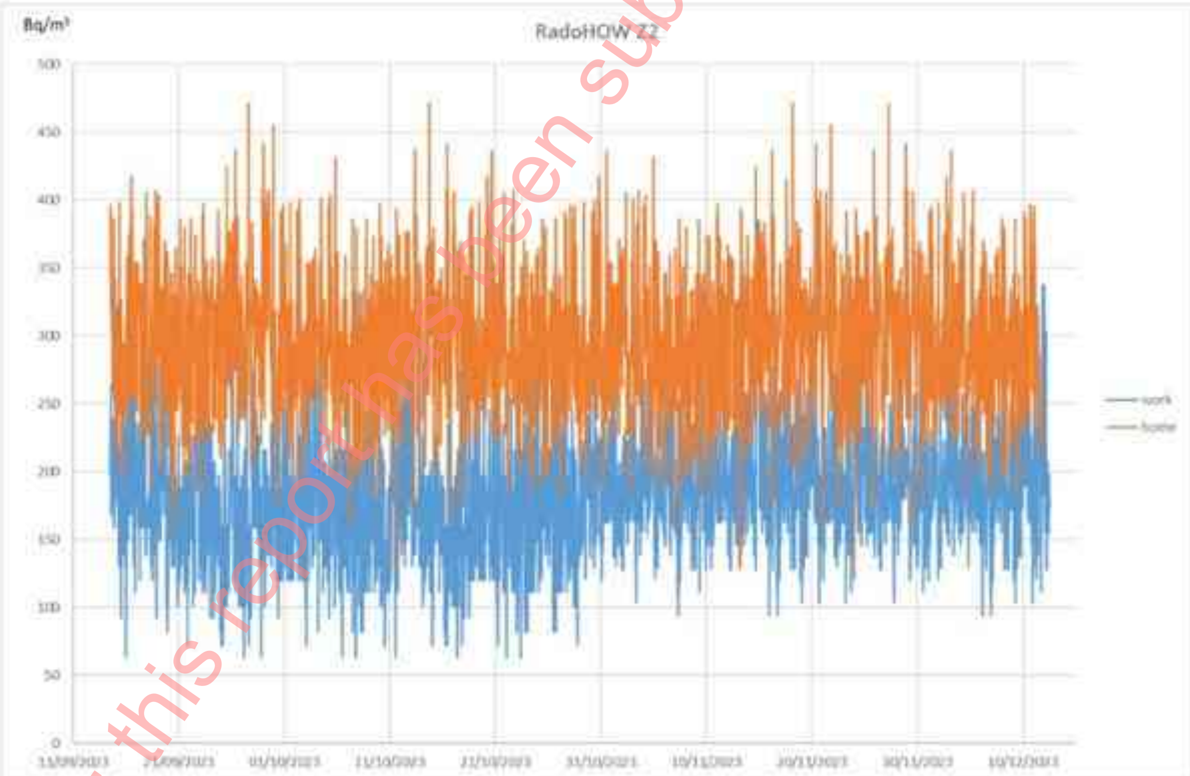

Bq/m³
RadoHOW C1
1000
900
800
700
600
500
400
300
200
100
0
work
home

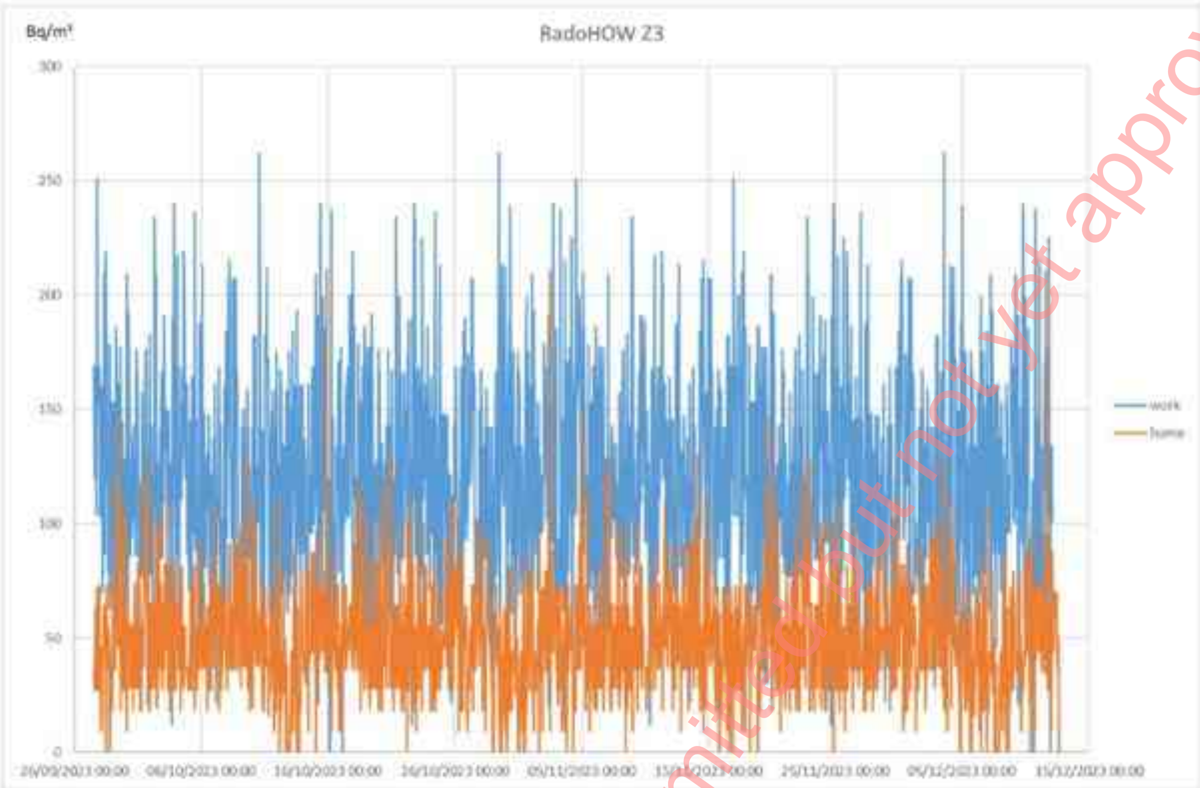

Bq/m³
RadoHOW C2
3000
2500
2000
1500
1000
500
0
work
home

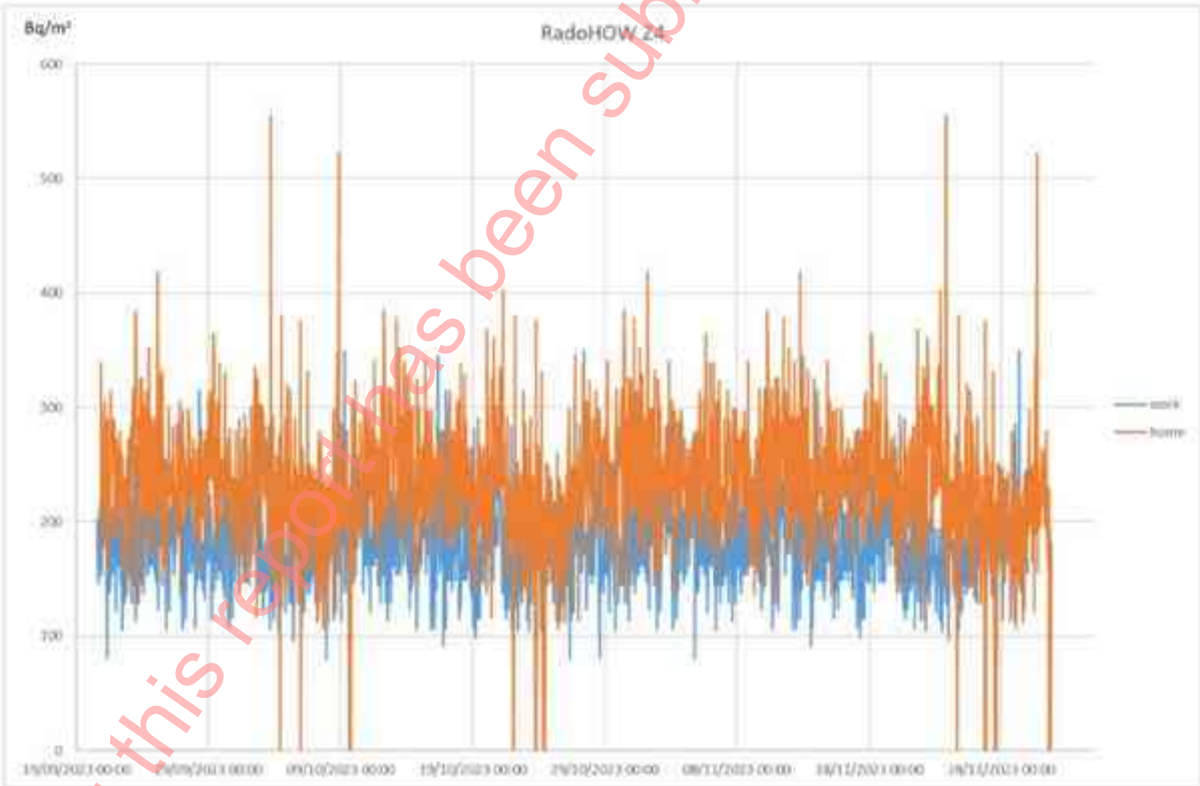

Bq/m³
RadoHOW C3
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
work
home

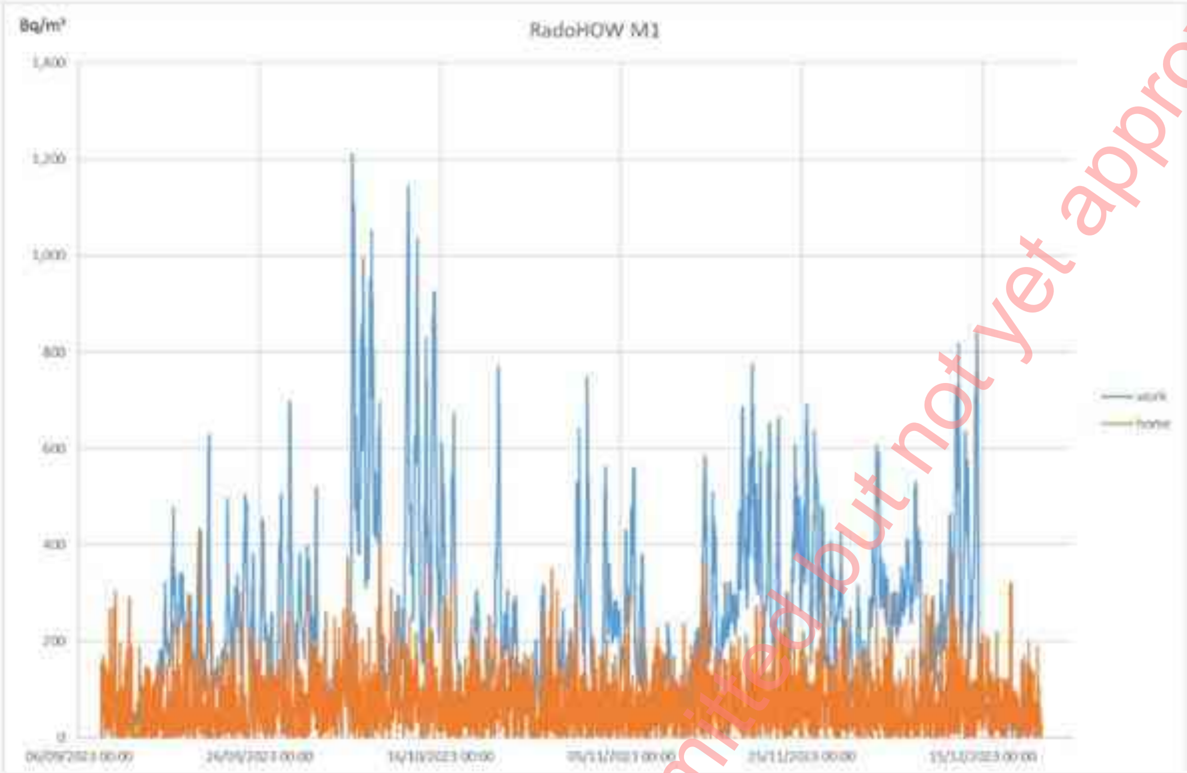

Bq/m³
RadoHOW C4
1000
900
800
700
600
500
400
300
200
100
0
work
home

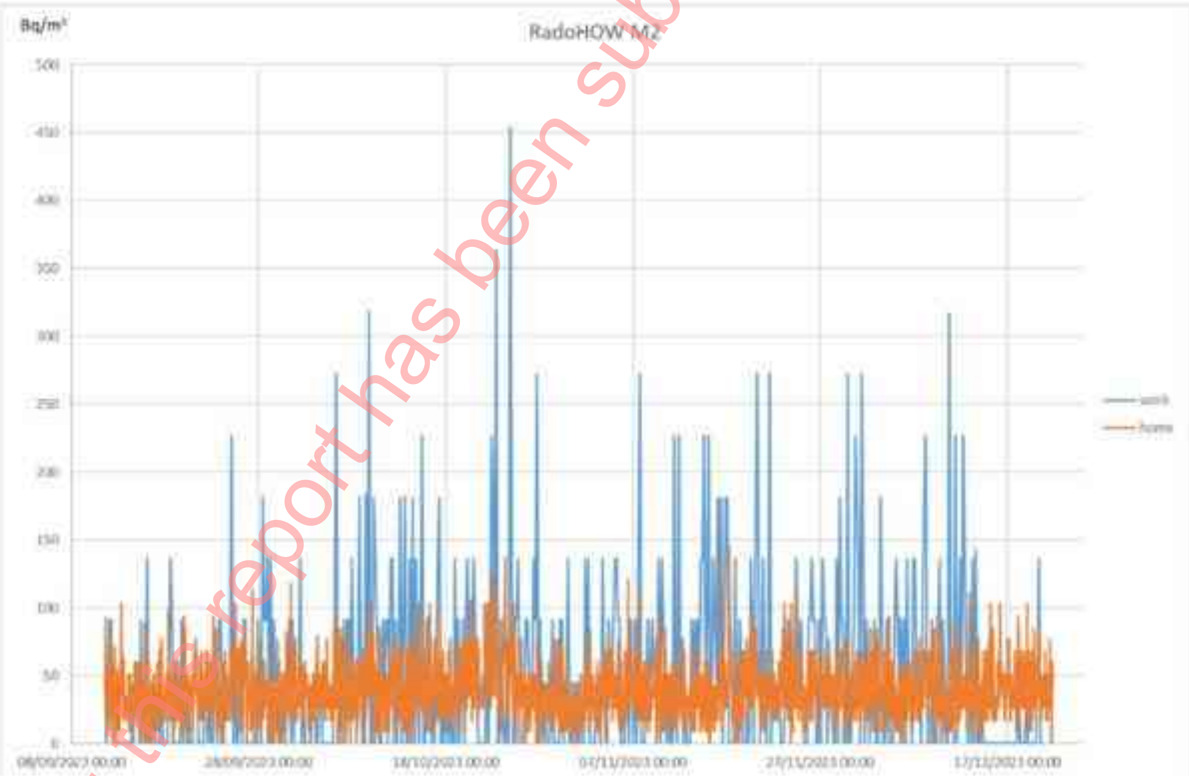

Bq/m
RadoHOW Z1
1400
1200
1000
800
600
400
200
0
work
home

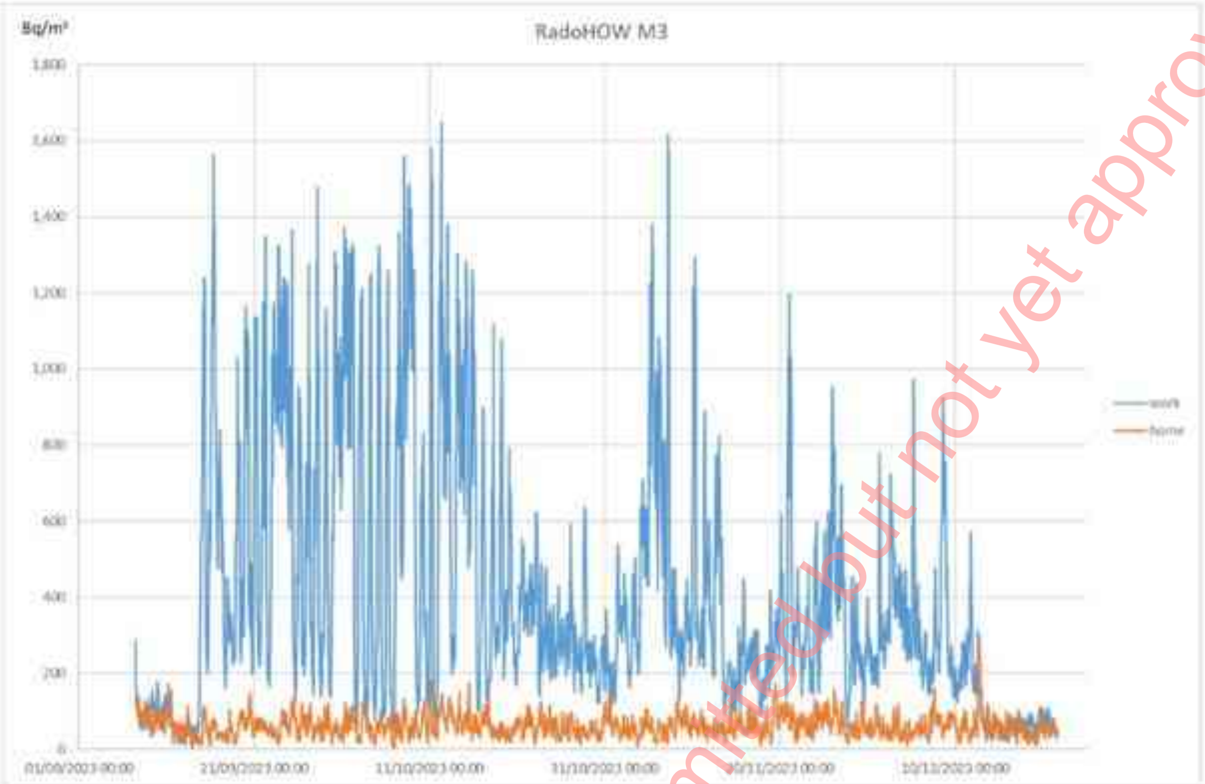

Bq/m³
RadoHOW Z2
500
450
400
350
300
250
200
150
100
50
0
work
home

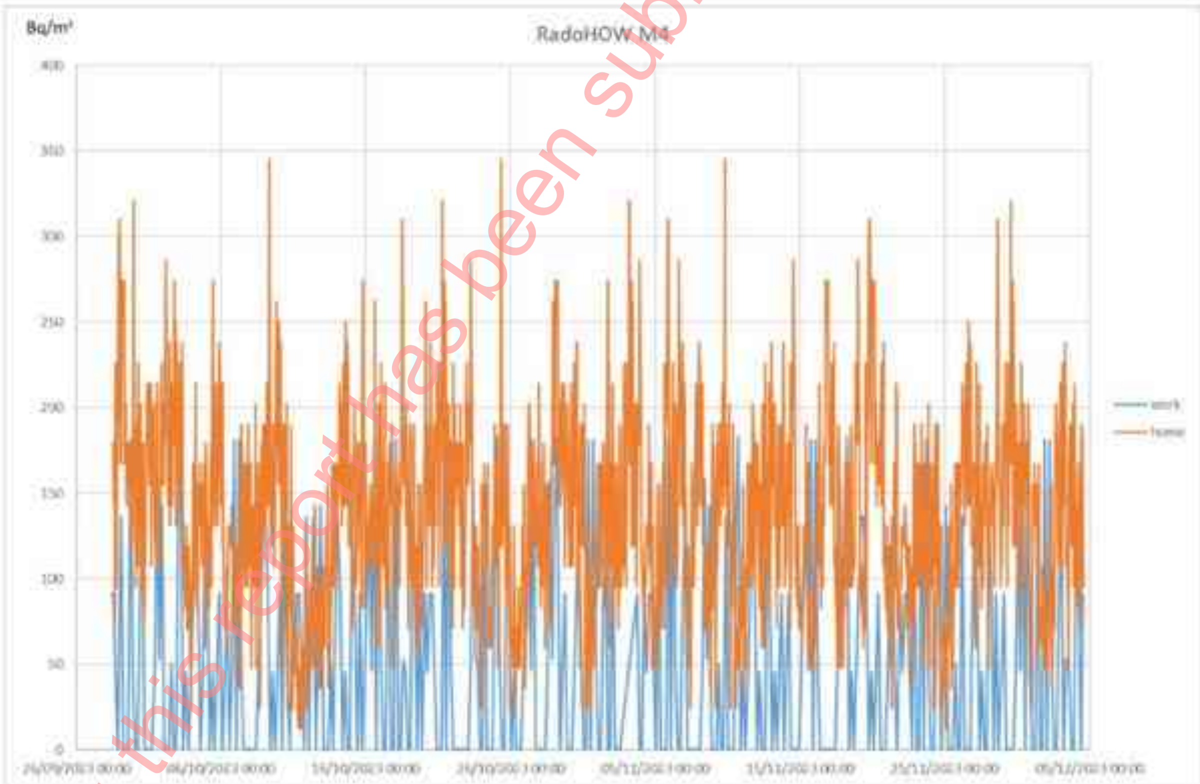

Bq/m³
RadoHOW Z3
300
250
200
150
100
50
0
26/09/2023 00:00
06/10/2023 00:00
16/10/2023 00:00
26/10/2023 00:00
05/11/2023 00:00
15/11/2023 00:00
25/11/2023 00:00
05/12/2023 00:00
15/12/2023 00:00
work
home

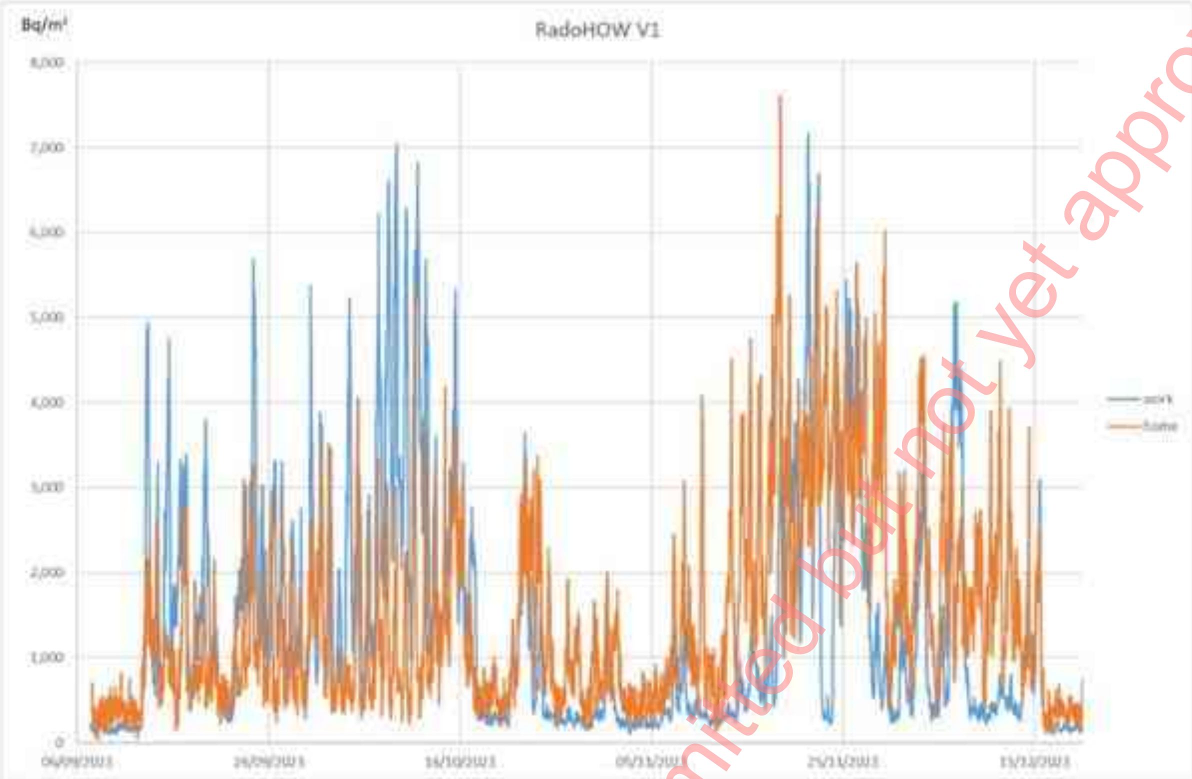

Bq/m³
RadoHOW Z4
600
500
400
300
200
100
0
work
home

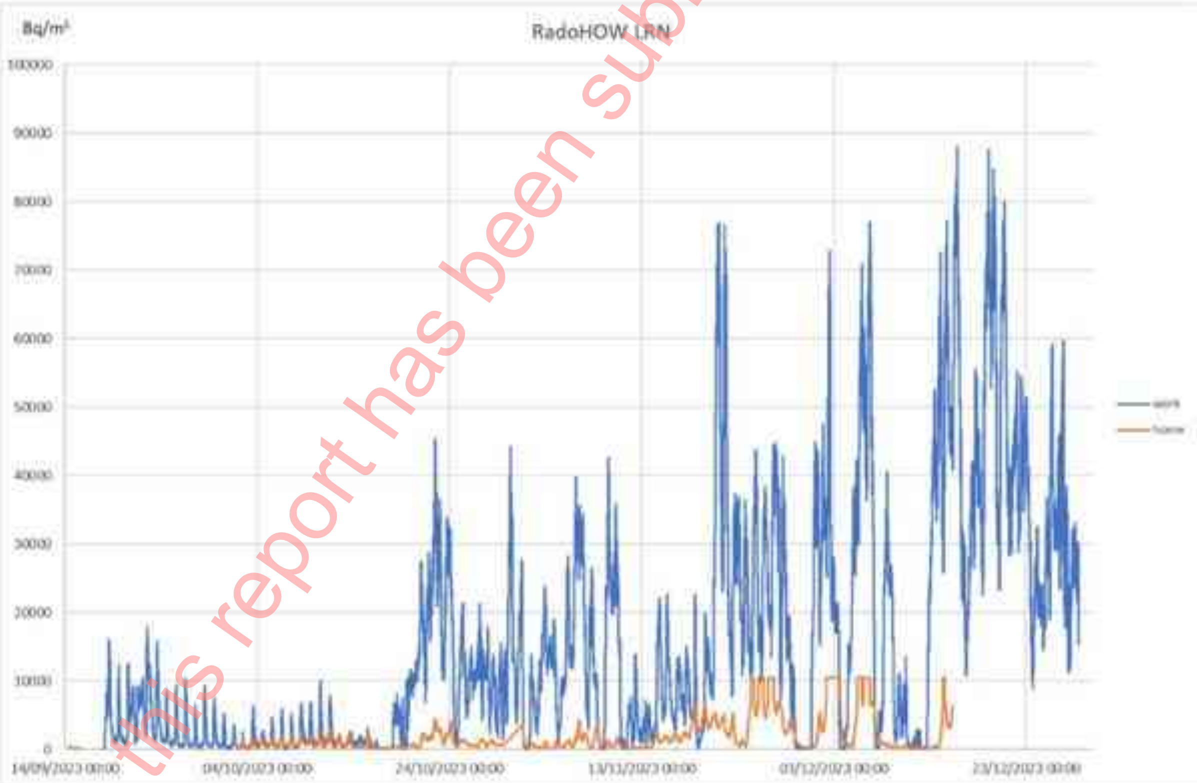

Bq/m³
RadoHOW M1
1,400
1,200
1,000
800
600
400
200
0

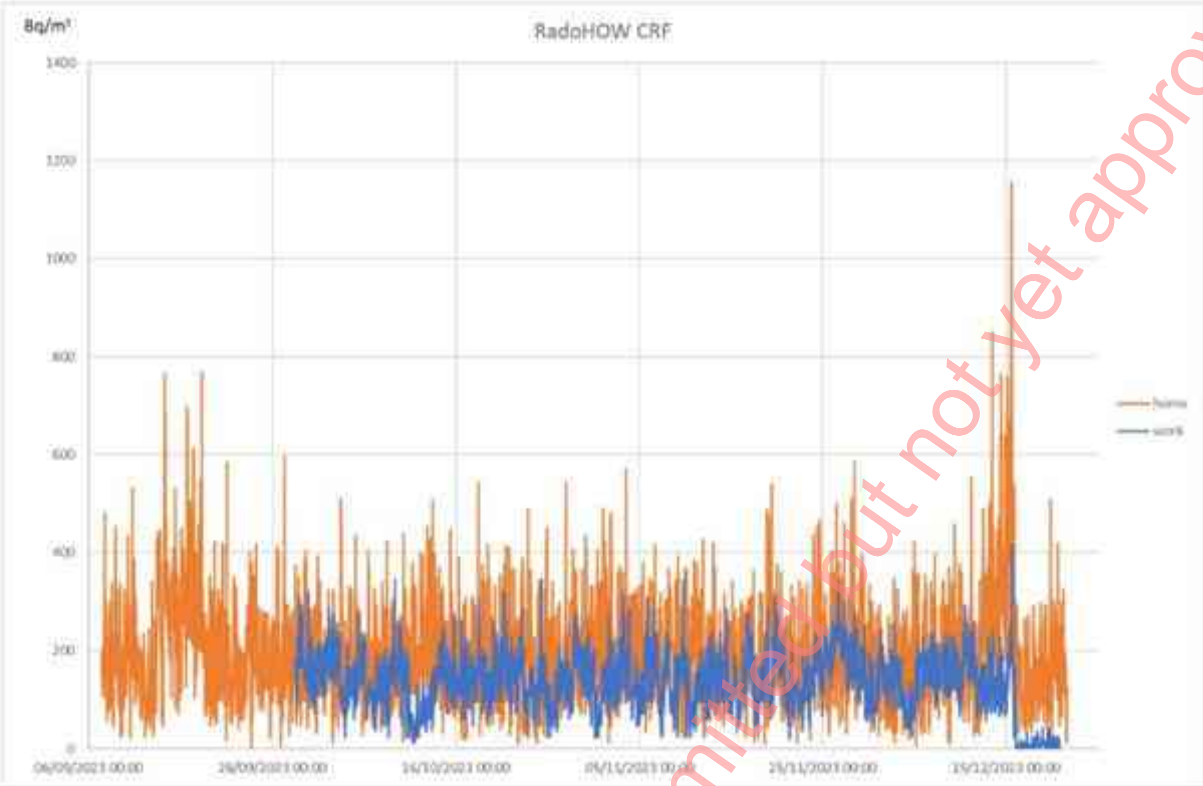

Bq/m³
RadoHOW M2

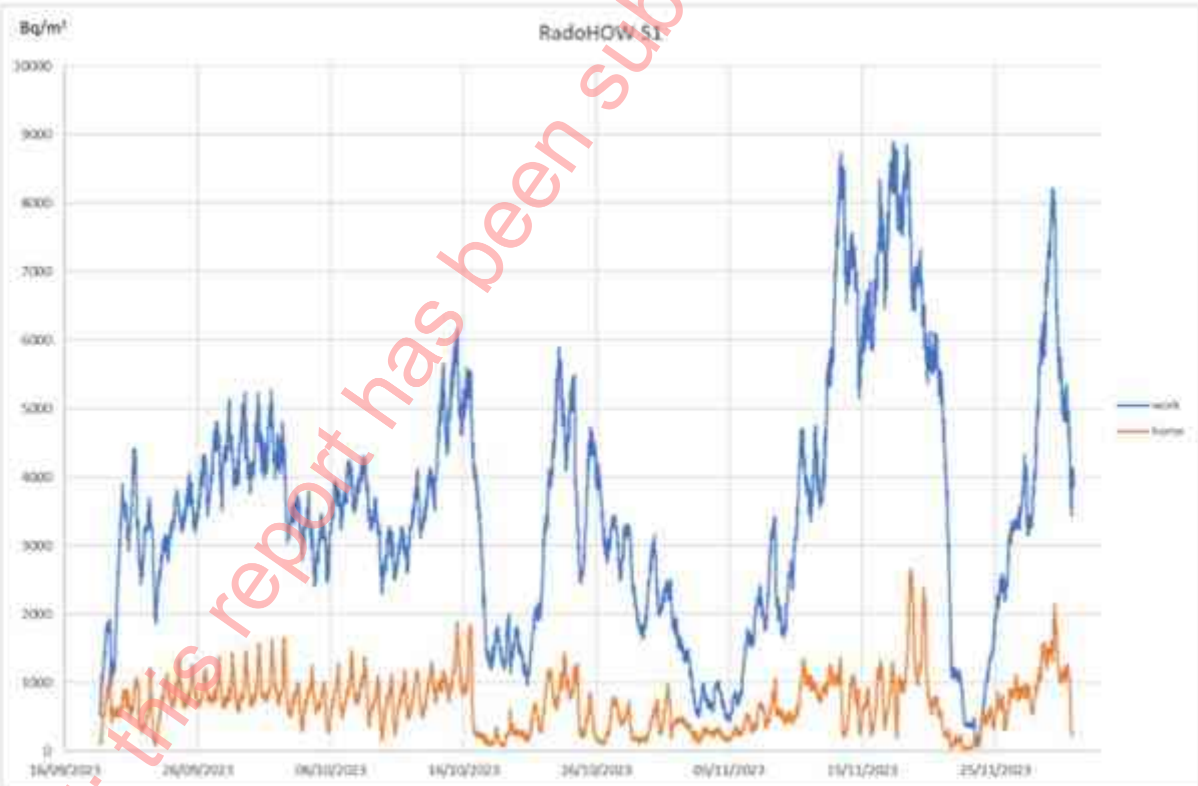

Bq/m³
RadoHOW M3
work
home


Bq/m³
RadoHOW M4
work
home


Bq/m³
RadoHOW V1
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0


Bq/m³
RadoHOW LRN
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
14/09/2023 00:00
04/10/2023 00:00
24/10/2023 00:00
13/11/2023 00:00
03/12/2023 00:00
23/12/2023 00:00


Bq/m³
RadoHOW CRF
1400
1200
1000
800
600
400
200
0
06/09/2023 00:00
26/09/2023 00:00
16/10/2023 00:00
05/11/2023 00:00
25/11/2023 00:00
15/12/2023 00:00
home
work


Bq/m³
RadoHOW S1
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
16/09/2023
26/09/2023
06/10/2023
16/10/2023
26/10/2023
05/11/2023
15/11/2023
25/11/2023
work
home

ANNEX 11. Results of continuous measurements for "special cases"

As mentioned in another section of the Report, the use of trace detectors for the evaluation of the concentration of radon gas and, from it, the dose received by workers when the concentrations are high (above 2000 Bq/m3) present the problem of "decay" which basically consists of the increase of traces in the detectors when the detector is closed and until the next opening continue the presence of radon in the detector increasing the number of tracks in the CR39. This effect means that, as the exposure times are short and this effect artificially elevates the exposure, the derived concentration turns out to be very high and, therefore, the doses to be evaluated as well.

In the Project, we have been able to have continuous measurements; therefore, based on the variations that these present, we have been able to calculate the actual exposure, considering the hours provided by the participants as we can see in the next four figures, and, with this selection, calculate the average concentration.Likewise, the results obtained corresponding to the six significant cases are attached:

C3 work: 14897 Bq/m3 becomes from continuous to 5423 Bq/m3

V1 work: 13615 Bq/m3 becomes from continuous to 1541 Bq/m3

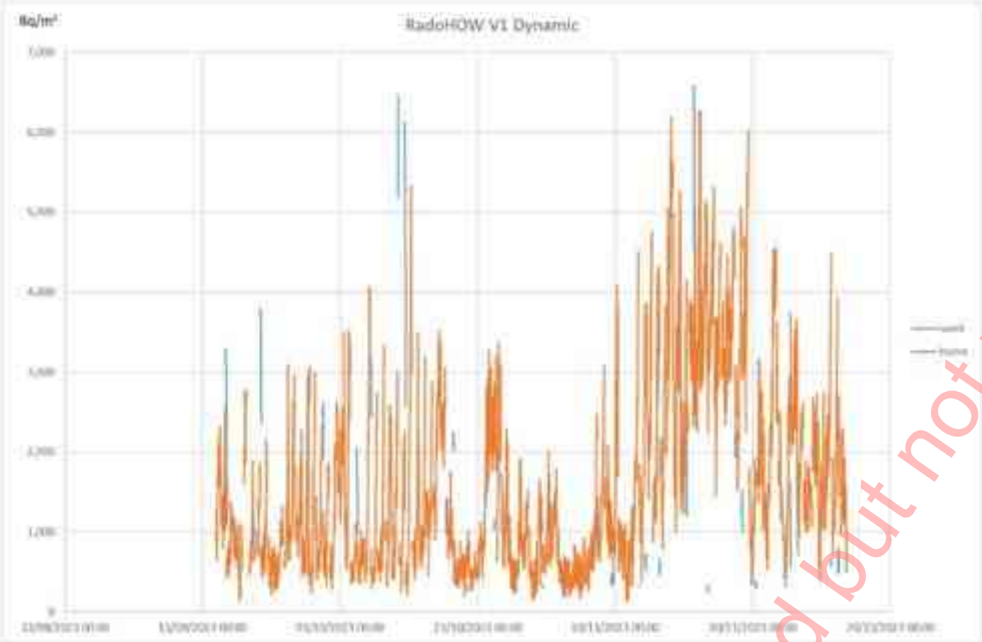
LRN work: 17463 Bq/m3 becomes from continuous to 10828 Bq/m3

LRN home: 1453 Bq/m3 becomes from continuous to 1927 Bq/m3

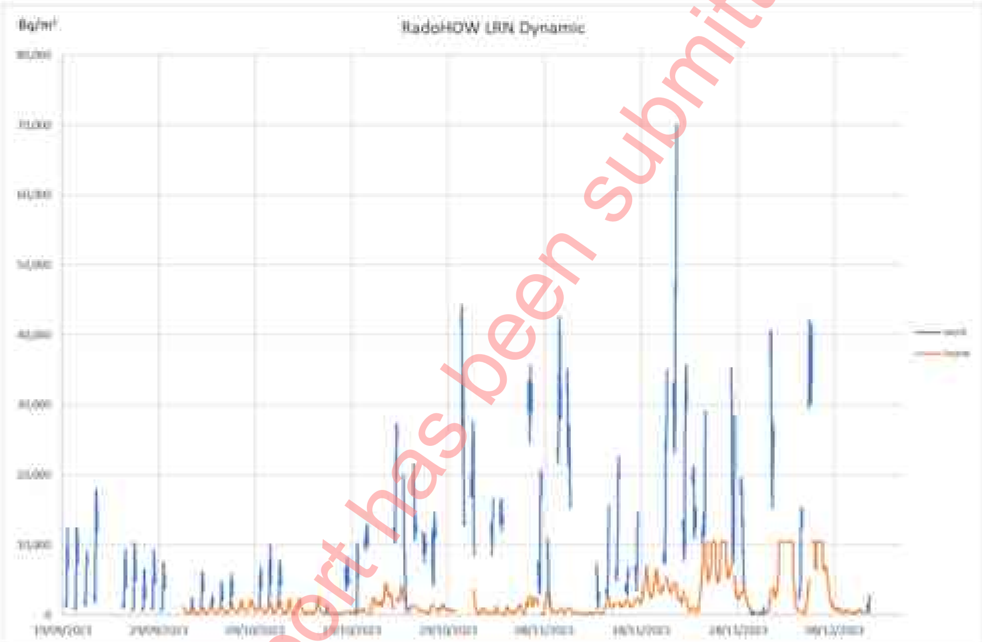
CRF work: 278 Bq/m3 becomes from continuous to 186 Bq/m3

S1 work: 12080 Bq/m3 becomes from continuous to 3700 Bq/m3

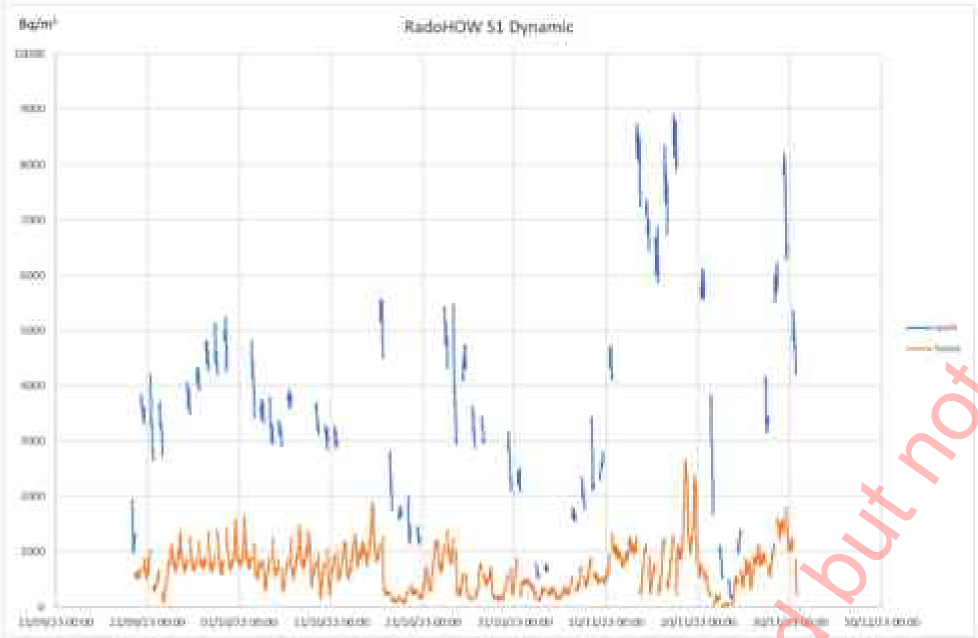
Section 4: C3



Section 4: V1



Section 4: LRN



Section 4: S1

Section 4: CRF