

RadoNorm

Newsletter

N°1-10 (2021-2025)

Collected Edition



RadoNorm
Managing risks from radon and NORM

Establishment of a European research platform on radon and NORM



Bringing societal and scientific risk perspectives into traditionally technical projects



Training a new generation of experts and creating a sustainable model for knowledge transfer



Development of policy-oriented tools and recommendations for implementation across Europe



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RadoNorm Newsletter



Newsletter of the RadoNORM project, funded by Euratom research and training programme 2019-2020 under grant agreement No 900009.

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Editorial



Dr. Nadja Železnik, leader of Work Package 8, EIMV

Dr. Nadja Železnik holds a BSc in Physics and an MSc in Reactor Physics from the Faculty of Mathematics and Physics, as well as a PhD in Psychology from the Faculty of Arts, all awarded by the University of Ljubljana, Slovenia. She is an expert in nuclear technology and radioactive waste management, with extensive experience in emergency preparedness and response, as well as in risk perception, communication, education, and training in environmental and nuclear projects.

She has acted as a civil society expert and knowledge manager in numerous European research initiatives, including EURAD-1 and -2, ECOSSENS, and RadoNorm. Her contributions include the development of national strategies, legislative frameworks, feasibility studies, safety and radiological assessments, and stakeholder engagement plans. She has authored communication strategies, training programmes, and information materials to foster public understanding and informed participation in the nuclear and environmental domains.

It is with great pleasure that we present the collected volume of the RadoNorm Newsletter, comprising ten issues published between June 2021 and August 2025. The magazine compilation serves as both a record and a celebration of the project's dissemination efforts, highlighting the multidisciplinary progress made under the Horizon 2020 Euratom-funded RadoNorm initiative.

The newsletter has consistently aimed to inform and engage a wide audience, including scientists, regulators, policymakers, early-career researchers, and members of the public. Over the course of the project, it has offered regular insights into scientific developments, field activities, societal research, stakeholder engagement, and international events. The format has proved valuable in showcasing the collaborative achievements of the RadoNorm consortium, which spans over 50 partners across Europe.

This volume provides a comprehensive overview of the project's evolving research landscape, covering advances in radon and NORM exposure assessment, biological effects, risk modelling, mitigation strategies, public communication, and social science.

RadoNorm

Newsletter

N°1 - June 2021



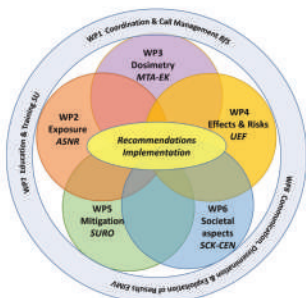
RadoNorm
Managing risks from radon and NORM

RadoNorm Newsletter
1st issue introduces goals, structure, progress, highlights, partners, outlook, engagement

Dr. Jelena Mrdakovic Popic - Researcher in a spotlight
Leads European mapping and risk analysis of NORM

Dr. Árpád Farkas - Researcher in a spotlight
Models health effects of inhaled radioactive particles

Dr. Martin Jiránek - Researcher in the spotlight
Develops radon prevention and mitigation methods



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- 16 Engagement opportunities
- 18 Sources



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Editorial

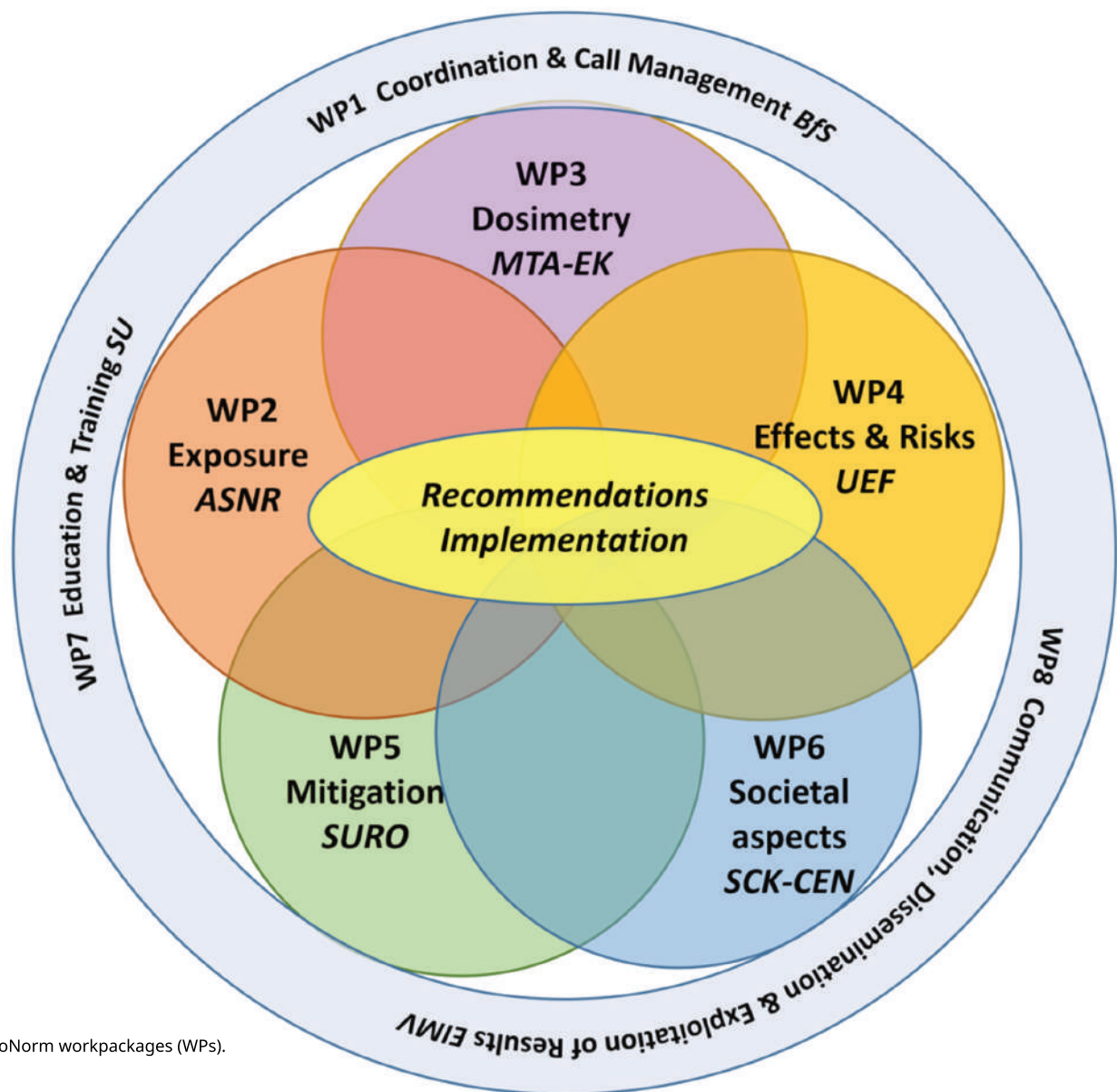


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It is with great enthusiasm that we welcome you to the first issue of the RadoNorm newsletter – an introduction to Europe's most ambitious research initiative dedicated to radon and naturally occurring radioactive materials (NORM). This inaugural edition sets the stage for a project rooted in scientific excellence, societal relevance, and cross-sector collaboration and offers a glimpse into the early progress made across its diverse work packages. Launched amidst continued global uncertainty, the first ten months of RadoNorm have been defined by the dedication of our partners and the seamless coordination of multidisciplinary efforts. From radiation physics and biology to social science, mitigation engineering, and stakeholder engagement, the project is already demonstrating how integrated approaches can generate meaningful advances in radiation protection.

In this issue, we highlight foundational activities across key research domains – including the characterisation of exposures, modelling of dose distributions, biological mechanisms of radon and NORM effects, and the evolving societal landscape of public awareness and behaviour.



RadoNorm workpackages (WPs).

Note from PC and About RadoNorm

RadoNorm's first newsletter shares key project info and outlooks beyond implementation.

With strong partner commitment, the project progressed smoothly in its first 10 months. Aiming to reduce radon and NORM risks, RadoNorm combines science and social insight.

News, results, and engagement options are shared via the website, social media, and this newsletter.

RadoNorm unites science and society to reduce radon and NORM risks.

Note from PC

Dear RadoNorm partners and followers, it is a great pleasure for me to share with you RadoNorm's first newsletter. As a start, we are sharing general information regarding the RadoNorm project in this issue as well as future prospects of the project beyond the implementation phase.

Thanks to the great commitment of our project partners, we have made great strides in implementing the project and running it smoothly for the first ten months.

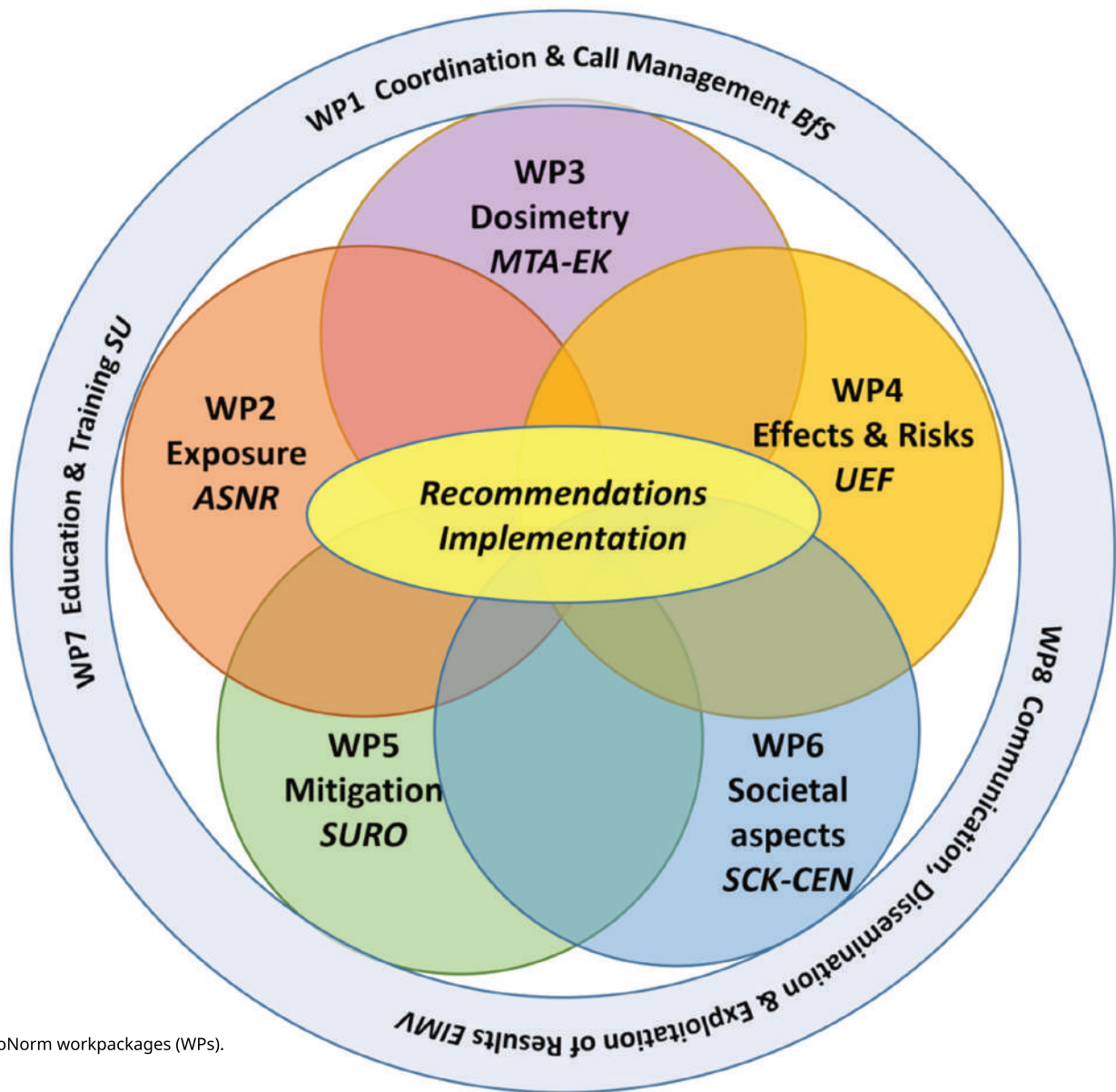
I hope you enjoy reading this and the upcoming newsletters. We invite you to provide your feedback concerning the newsletter and to share your ideas about what you expect from it. Your comments will be most welcome.

About RadoNorm

RadoNorm project with a title "Towards effective radiation protection based on improved scientific evidence and social considerations – focus on Radon and NORM" is the biggest EC co-funded project in the area which aims to provide answers to open questions related to radon and NORM exposure of humans and the environment and to provide sound, feasible and applicable solutions for radiation risk reduction which are widely acceptable for the individuals and the public. The RadoNorm website provides many information about the project, the challenges to be addressed, its development and results, interaction and engagement possibilities. The connected RadoNorm social media with LinkedIn, Twitter and YouTube emphasise the latest news and events to fulfil the foreseen dissemination. Most important updates and results will be regularly published in the RadoNorm Newsletter.



Dr. Ulrike Kulka, RadoNorm coordinator, BFS



RadoNorm workpackages (WPs).

WPs short presentations

RadoNorm's work packages span coordination, exposure assessment, biological and societal impact, risk mitigation, education, and outreach. Highlights include improved radon/NORM modelling, citizen science, training of early researchers, and novel communication tools, all aiming to enhance radiation protection and stakeholder engagement across Europe.

The objective of **WP1** is to ensure the project is conducted on time, according to the budget and directed towards the overall project objectives. This includes technical project coordination, management of financial aspects, especially the project funding and legal aspects.

The aims of WP 1 are to:

- Coordinate the technical activities of the project and link together all project components,
- The overall legal, contractual, financial and administrative management,
- Maintain the communication with the European Commission and manage the internal communication with each partner,
- Monitor deliverables and milestones.

To meet this goal, BfS, as the coordinating partner, has a qualified and experienced team to guarantee the competent management of the project.



Dr. Mandy Brischwilks,
leader of Work Package 1, BfS

WP2 aims at providing a better characterisation of exposures of humans (public and workers) and biota to radon and NORM. Acquisition of scientific knowledge, development of methods and protocols are foreseen in 8 sub-domains:

- Reducing uncertainties in radon measurements,
- Transport of radon in the environment,
- Exposure to radon in buildings,
- Methods of identification of high indoor radon levels,
- Characterisation of NORM sites and associated exposure scenarios,
- Transfer of NORM to plants,
- Mobility of NORM in soils,
- Long-term prediction modelling of NORM transfer in the environment.

To achieve these goals, WP2 relies on a multidisciplinary team of experienced researchers (physicists, modellers, statisticians, geochemists) as well as PhD and post-doctoral students.



Dr. Laureline Fevrier,
leader of Work Package 2, IRSN

Assessment of any dose-effect relationships requires reliable dose estimation. Therefore, one of the main aims of **WP3** is to support WP4 by providing data on doses, dose distributions, and their uncertainties. WP3 also aims to identify specific human subpopulations potentially more sensitive to radon exposure than the general public, and to develop a new dose concept accounting for spatial dose inhomogeneity.

Since the start of the project, WP3 has had two general meetings, several task group meetings, and specific meetings with collaborating partners in WP4. In several tasks, collaboration platforms have been set up for collecting and reviewing references, while early simulation results were also obtained, e.g. for describing doses and dose distributions in diseased airways.



Dr. Balázs Madas,
leader of Work Package 3, EK

WP4 generates new knowledge related to biological effects and responses after exposure to radon and NORM that have implications for risk assessment and radiation protection of humans and the environment. We study the interaction between radon and smoking for lung cancer, risks of radon outside of the lung, risks associated with radon exposure during childhood, risks from radon and NORM in drinking water, mechanisms of radiation action in the disease processes, and quantification of various sources of uncertainties in risk inference. Studies on non-human biota address the combined effects of NORM and other stressors and adverse outcome pathways leading to such effects.

The main goal of **WP5** is to improve and optimise radiation protection of people and the environment against the harmful effects of ionising radiation caused by the presence of natural radionuclides in natural and work environment, utilising innovative mitigation techniques and systems. The aims of WP 5 are to:

- Improve radon mitigation systems efficiency and sustainability,
- Develop NORM residues/waste final treatment strategies based on preventive actions and mitigation methods with respect to existing circumstances corresponding to specific NORM involving industries, technological processes, legacy sites and environmental conditions.

To meet the main objectives, SURO, as the WP 5 leader, facilitates collaboration between 12 partners' organisations from nine European countries, involving research institutes, radiation and nuclear safety authorities, public health institutes and universities. All research activities are being carried out within the five individual Tasks addressing the existing knowledge gaps in mitigation systems design and operation, and remedial strategies development and implementation focused on radon and NORM exposures in dwellings and workplaces, including NORM involving industries and legacy sites.

In **WP6**, we study the societal aspects related to radon and NORM exposures. We focus, among others, on:

- Methodological innovations for understanding and changing people's behaviour with regard to radon and NORM
- The development and testing of an effective and novel communication tool
- The involvement of the public in radon remediation through citizen science initiatives.

Over the past months, WP6 partners have conducted a thorough literature review of 142 social scientific research articles on the subject of radon and/or NORM. Particularly exploring the methodological state-of-the-art and caveats of this literature, the review serves as a catalogue of methodological aspects for research related to radon and NORM exposure situations, and provides valuable input for future research, both in and beyond the RadoNorm project.



Dr. Sisko Salomaa,
leader of Work Package 4, STUK



Dr. Ales Fronka,
leader of Work Package 5, SURO



Dr. Tanja Perko,
leader of Work Package 6, SCK CEN

Initial steps have also been taken with regard to the development and implementation of surveys on radon awareness, perception and behaviour in different European member states. A first survey, conducted in Belgium at the end of 2020, revealed among others how more respondents seem to believe that radon exposure can cause headaches, than there are respondents who indicated radon exposure can cause lung cancer.

Finally, over the past months, we have started setting up a citizen science model focused on involving local communities in radon mitigation initiatives. A first article on the subject has been submitted, and the pilot phase of the citizen science model, which will be launched in autumn, is currently being designed. To be continued!

The aim of **WP7** is to organise the education and training programme of RadoNorm, focusing on PhD students and early career researchers (ECR). To this end, WP7 will monitor and support the progress of PhD and ECR projects and contribute to their professional development by organising targeted courses and exchange visits.

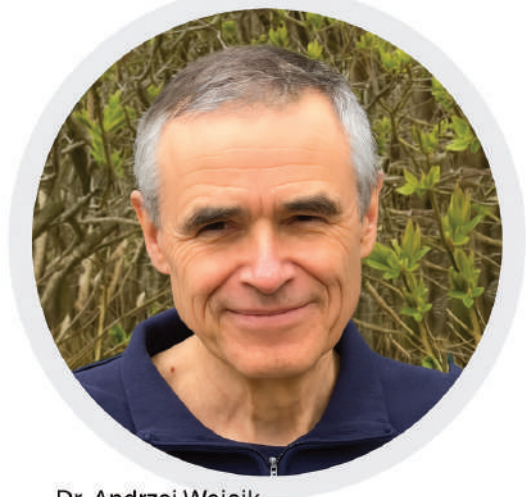
During the first nine months, 11 of 18 PhDs and 1 of 12 ECR were recruited. The remaining positions will be filled at a later stage.

Two PhD and ECR virtual meetings were also organised, where each young researcher presented his/her project and answered questions. Such meetings will be repeated regularly in order to foster collaboration between Europe's future radiation researchers. Two training courses have already been held. Three more will be organised during 2021.

The focus of **WP8** Communication, dissemination activities and exploitation of results is to ensure real intake of project results for the wide variety of stakeholders in a two-way exchange. Therefore, the main contents, tools and channels have been developed: the basis is the internet website with related social media, different materials to be used for dissemination and communication, events and other interaction opportunities, open access to research publication and data by the STOREDB platform, active stakeholder engagement and monitoring of activities. Two very important features are the News and the Events.



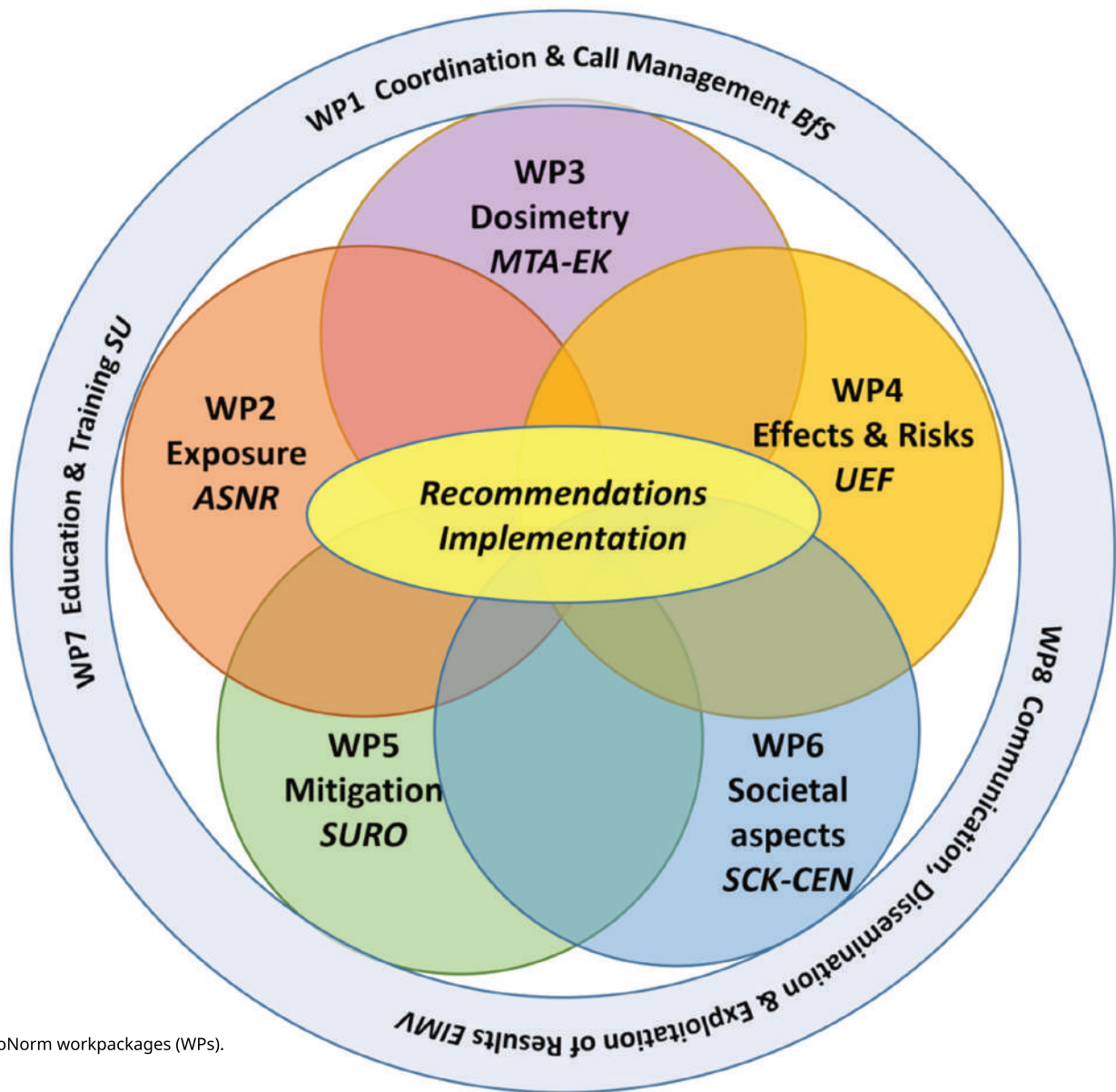
Dr. Tanja Perko,
leader of Work Package 6, SCK CEN



Dr. Andrzej Wojcik,
leader of Work Package 7, SU



Dr. Nadja Železnik,
leader of Work Package 8, EIMV



Events and trainings: past and future

RadoNorm organises and joins events like webinars, workshops and courses to promote research and stakeholder engagement. The Kick-Off took place online in Sept 2020 with 170 participants. Since then, events included a “Liquid NORM” workshop, PhD/ECR Days, and training courses. The first Annual Meeting with stakeholder involvement is set for 6–7 Sept 2021.

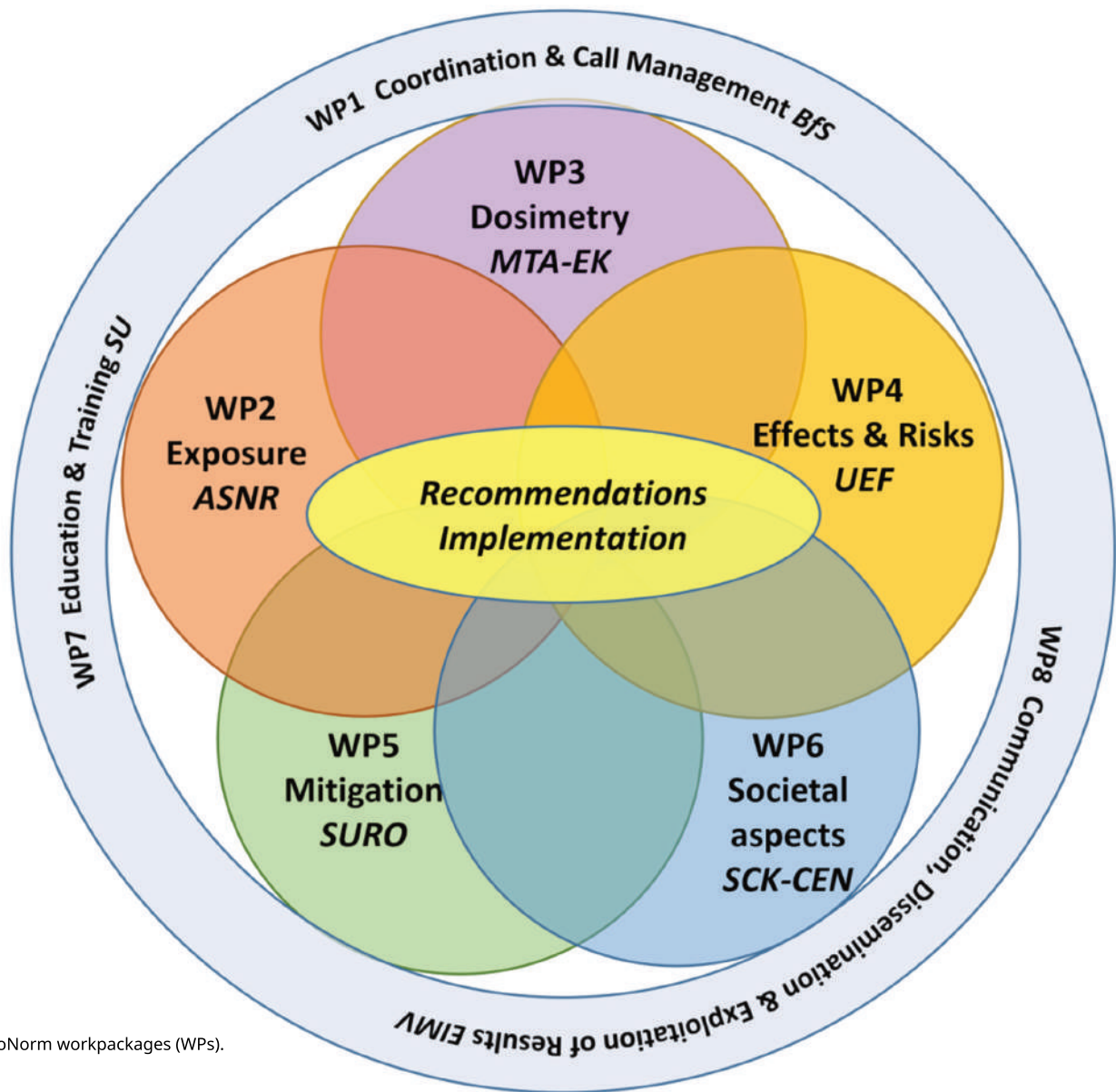
RadoNorm will, over the life of the project, host as well as attend a range of events including webinars, workshops, short courses and more, which aim to promote research and foster the research community and stakeholder engagement.

So the project's Kick-Off meeting was held virtually on 09-10 September 2020 and was the first opportunity for approx. 170 representing the 56 partners coming from 22 EU member states and associated countries, to gather online to introduce the project and lay the foundation for future cooperation.

Since then RadoNorm attended as well as held several events e.g. hosted the online workshop "Liquid NORM – sources, impact assessment and treatment" with industry representatives and relevant authorities dealing with radioactivity in water, attended the CARST 2021 conference organised two RadoNorm – PhD/ECR Days in which students shortly reported about the objectives of their work and the plan for research and held its first E&T courses.

The RadoNorm Annual Meeting is scheduled for 6-7 September 2021, where on 7 September also RadoNorm stakeholders will also be engaged.





RadoNorm workpackages (WPs).

Latest deliverables and publications

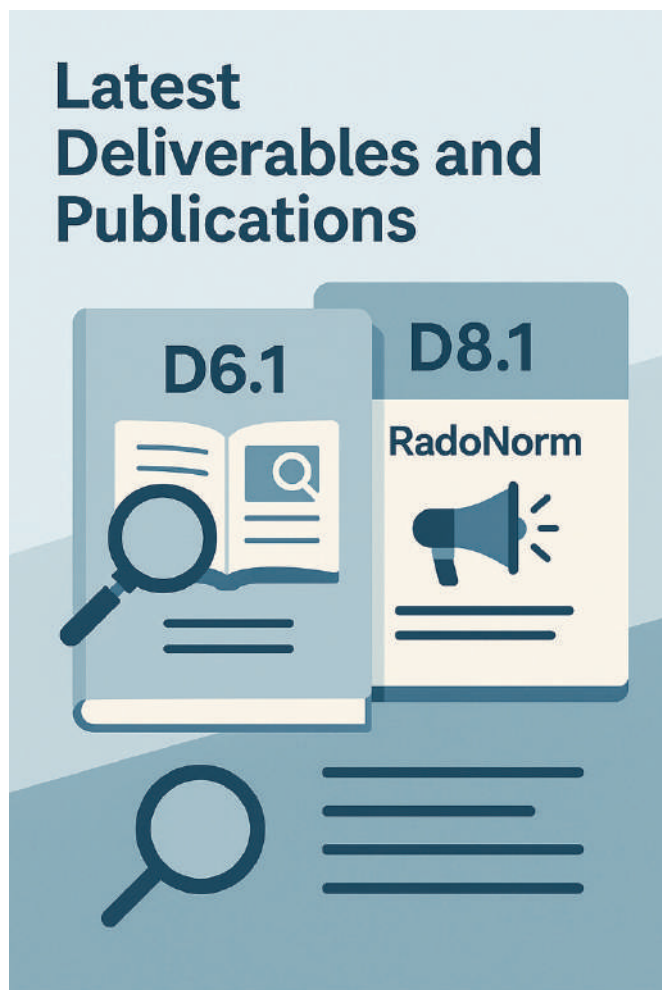
D6.1 reviewed 142 studies to assess methods used in research on societal aspects of radon and NORM, revealing key gaps, especially for NORM. These findings will support the development of future guidelines. D8.1 outlines RadoNorm's plan for communication, dissemination and exploitation to ensure broad impact.

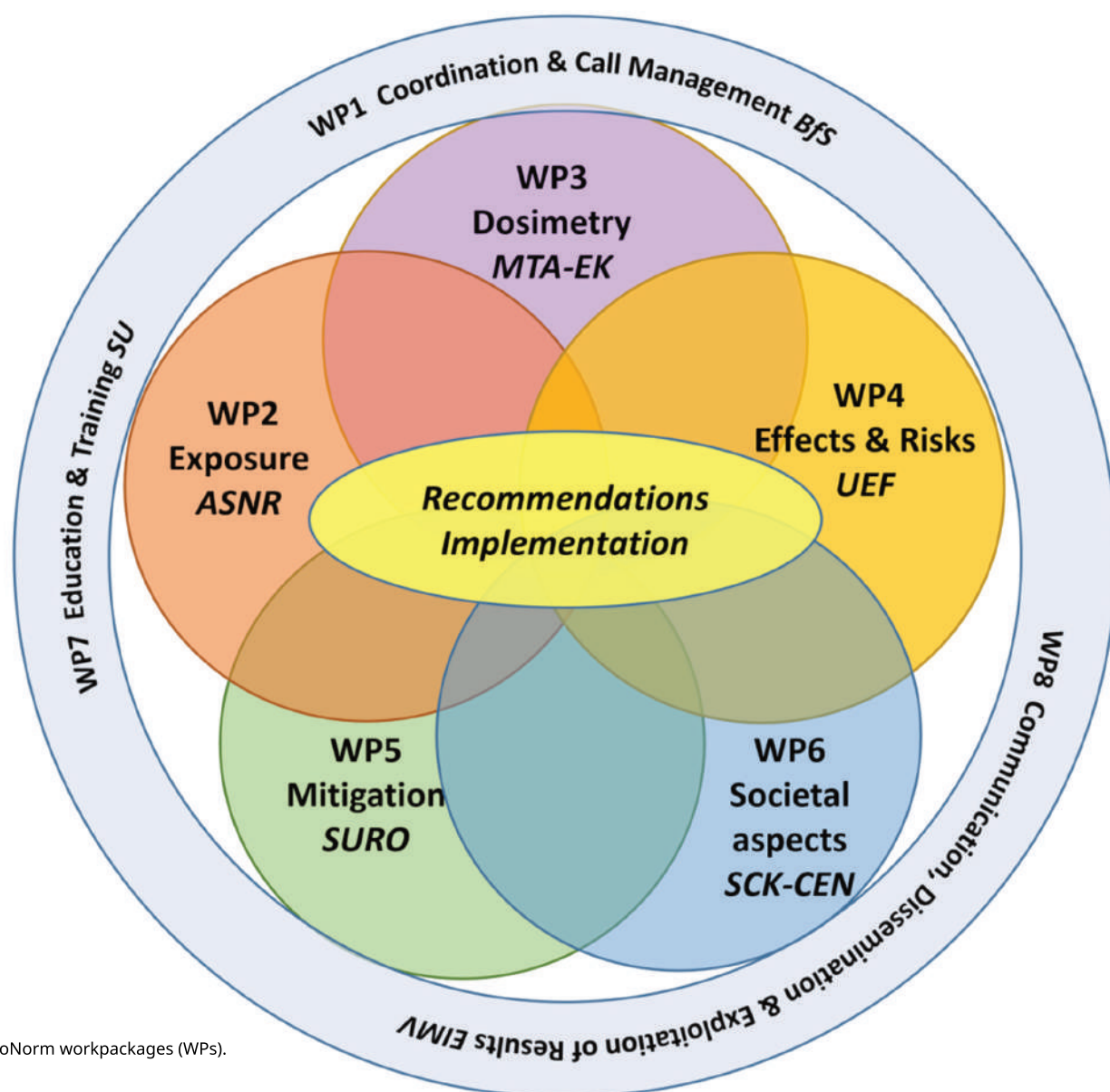
D6.1 – Collection of existing methods, databases, scales, protocols and other tools – state of the art

It is important to improve the methodological qualities of the research that investigates societal aspects of radon and NORM exposure situations. In deliverable 6.1, we performed a systematic review of scientific literature focusing on the methodological approaches that have been used so far. Our analysis of the 142 articles demonstrated some gaps in research on societal aspects, especially for NORM. These results will support the development of methodological guidelines for investigating affected populations and stakeholders with special attention to different socio-political and cultural environments.

D8.1 – Strategy and plan for communication, dissemination and exploitation of results

The deliverable 8.1 is the first version of the communication, dissemination and exploitation plan of the RadoNorm project and provides a basis for both external and internal communication, dissemination activities and approach to the exploitation of results. The overall aim of this document is to identify the most efficient means and set a plan for the implementation of dissemination, exploitation and communication activities. RadoNorm's outreach activities aim at communicating and disseminating the project results during the project lifetime and increasing the impact after the end of the project.





RadoNorm workpackages (WPs).

Researchers in a spotlight

Jelena Mrdakovic Popic (DSA) leads work on mapping and characterising NORM sites in Europe. Árpád Farkas (HUN-REN) models inhaled radionuclide doses in lungs for WP3.

Martin Jiránek (CTU) focuses on radon mitigation techniques, modelling and standardisation, with over 100 publications and several patents.

Jelena Mrdakovic Popic, PhD, is a Senior Advisor at the Norwegian Radiation and Nuclear Safety Authority (DSA). My day-to-day work consists of combining scientific and regulatory aspects of ionising radiation, in particular of naturally occurring radioactive materials (NORM). This is also well reflected in the RadoNorm project, in task 2.5. where I have the lead. The aim of this task is to gather information on existing NORM sites across Europe in order to obtain a general European overview. Furthermore, this task attempts to characterise, in more detail, exposure scenarios, including multiple hazard scenarios. It is expected that the results of this RadoNorm work will contribute to a better NORM understanding and subsequently improved regulatory control and risk communication.



Dr. Jelena Mrdakovic Popic,
DSA, Norway

Árpád Farkas, PhD, is a senior research fellow at the Centre for Energy Research of Budapest. He previously had research positions at the University of Salzburg and the Brno University of Technology. He completed his PhD at ELTE University on the biological effects of inhaled radioactive aerosols. Árpád has more than two decades of experience in modelling airway deposition and the health effects of different types of inhaled particles. His work within WP3 of the RadoNorm project includes numerical modelling of regional and local doses of the inhaled radionuclides in the healthy and diseased human lungs and in the rat airways. The aim of these simulations is to quantify the biological endpoints associated with radon inhalation and to provide input data for the in vitro irradiation experiments in WP4.

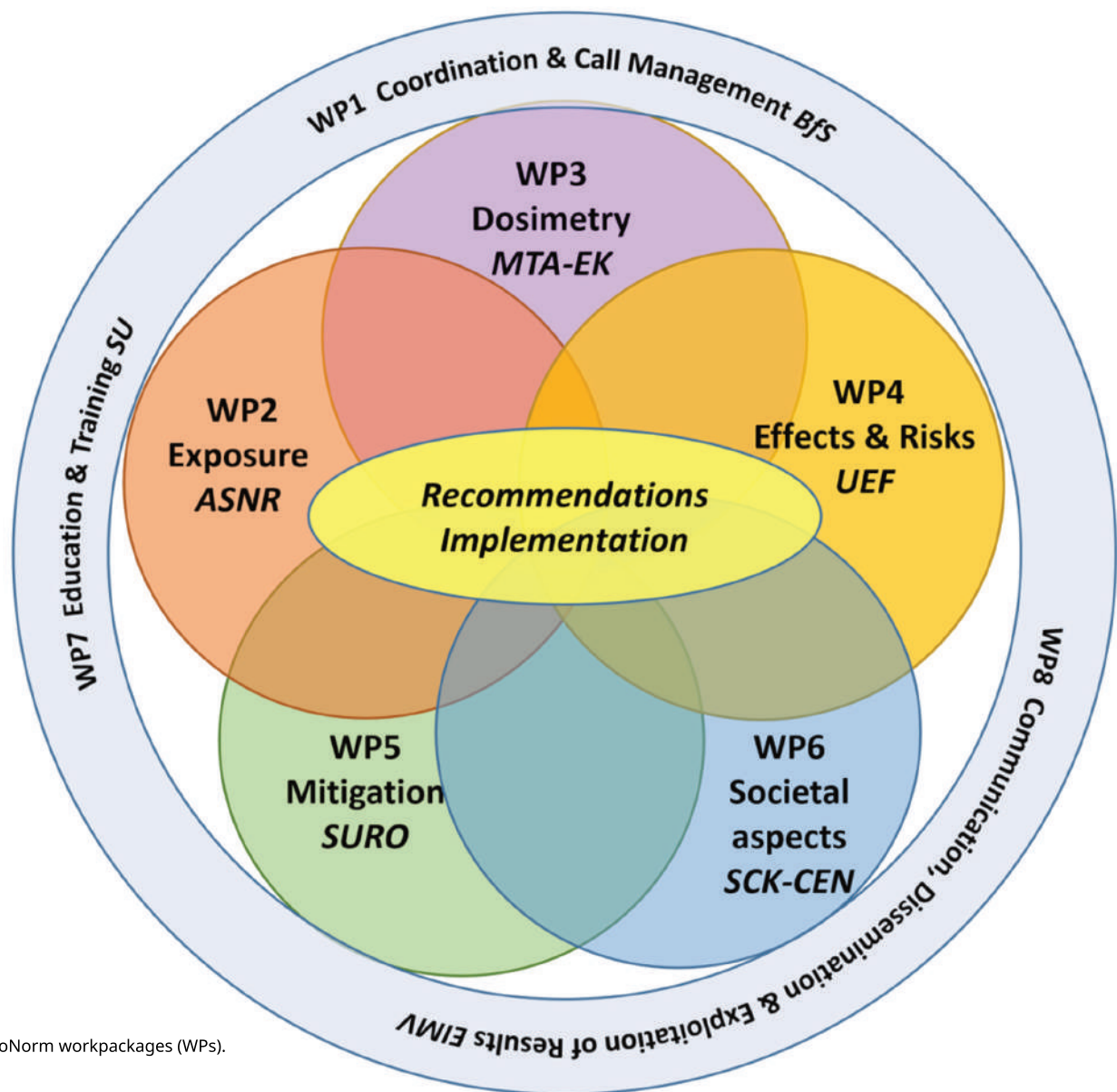


Dr. Árpád Farkas,
HUN-REN, Hungary

Martin Jiránek, PhD, is a professor of Architectural Engineering at the Faculty of Civil Engineering of CTU in Prague. His research is focused on the development of radon reduction techniques and verification of their reliability and effectiveness, numerical modelling of radon transport mechanisms, simulation of radon reduction methods behaviour, optimisation and standardisation of radon preventive and remedial measures and development of methods for determining the radon diffusion coefficient in waterproofing materials. Besides his research and teaching activities, he is also a supervisor of PhD students and is active in national and international research projects. He is the author of the Czech technical standard for designing radon protective and remedial measures and the author or co-author of more than 100 scientific and professional articles and 6 patents.



Dr. Martin Jiránek,
CTU, Czech Republic



RadoNorm workpackages (WPs).

RadoNorm engagement opportunities

RadoNorm set up stakeholder groups to involve relevant actors in testing tools, shaping regulations, and discussing findings. Interested parties can subscribe to updates and join the network. Partners receive regular info on news and events. All contact data is managed per RadoNorm's privacy policy.

RadoNorm actively involves stakeholders in project activities, tool testing, and knowledge exchange through dedicated groups and regular updates.

RadoNorm established different engagement opportunities for the related and interested stakeholders. The stakeholders network groups are established for active involvement of different representatives in the project's activities, such as pilot testing of communication tools, development of new regulatory standards, discussions on scientific findings, or to be just informed about the RadoNorm results. The subscription to more information, like Newsletter issues, is organised, and the group is also invited to become a member of the stakeholders' groups. The RadoNorm partners are regularly informed of all news, events and call opportunities. All developed contact databases are managed according to the RadoNorm Privacy policy.



Dr. Nadja Železnik, leader of Work Package 8, EIMV

Sources



About RadoNorm

- ✿ RadoNorm website, <https://www.radonorm.eu/>
- ✿ LinkedIn, <https://www.linkedin.com/company/radonorm/>
- ✿ Twitter (now X), <https://twitter.com/RadoNorm>
- ✿ YouTube, <https://www.youtube.com/channel/UC6yCORiPX5DXgmu5AaGLn9Q>
- ✿ RadoNorm Newsletter, <https://www.radonorm.eu/newsletter/>

Short news from WPs

- ✿ WP1, <https://www.radonorm.eu/workpackages/wp1/>
- ✿ WP2, <https://www.radonorm.eu/workpackages/wp2/>
- ✿ WP3, <https://www.radonorm.eu/workpackages/wp3/>
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- ✿ WP5, <https://www.radonorm.eu/workpackages/wp5/>
- ✿ WP6, <https://www.radonorm.eu/workpackages/wp6/>
- ✿ WP7, <https://www.radonorm.eu/workpackages/wp7/>
- ✿ WP8, <https://www.radonorm.eu/workpackages/wp8/>
- ✿ STOREDB platform, https://www.storedb.org/store_v3/
- ✿ News, <https://www.radonorm.eu/news/>
- ✿ Events, <https://www.radonorm.eu/event/>

Events and trainings: past and future

- ✿ Kick-Off meeting, <https://www.radonorm.eu/news/radonorm-virtual-kick-off-meeting/>
- ✿ Online workshop “Liquid NORM – sources, impact assessment and treatment”,
<https://www.radonorm.eu/news/workshop-liquid-norm-sources-impact-assessment-and-treatment-2/>
- ✿ CARST 2021 conference, <https://www.radonorm.eu/news/radonorm-at-carst-2021-conference/>
- ✿ RadoNorm – PhD/ECR Days, <https://www.youtube.com/channel/UC6yCORiPX5DXgmu5AaGLn9Q/featured>
- ✿ E&T courses, <https://www.radonorm.eu/calls/call-for-courses/>

Latest deliverables and publications

- ✿ Deliverable 6.1, https://www.radonorm.eu/wp-content/uploads/file_exchange/D6.1_Methodological-state-of-the-art_approved26052021-1.pdf
- ✿ Deliverable 8.1, https://www.radonorm.eu/wp-content/uploads/2020/12/D8.1_Strategy-and-plan-for-communication-dissemination-and-exploitation-of-results_approved30112020.pdf

RadoNorm engagement opportunities

- ✿ Stakeholders network groups, <https://www.radonorm.eu/stakeholders/>
- ✿ Newsletter issues, <https://www.radonorm.eu/newsletter/>
- ✿ RadoNorm Privacy policy, <https://www.radonorm.eu/privacy-policy/>

Key takeaways



- ☢ **RadoNorm's mission is to enhance radiation protection concerning radon and NORM, combining scientific and societal perspectives in the largest EC co-funded project of its kind.**
- ☢ **Work Package updates show strong interdisciplinary collaboration: WP2 on exposure characterisation, WP3 on dose assessment, WP4 on biological effects, WP5 on mitigation, WP6 on societal aspects, WP7 on training, and WP8 on communication.**
- ☢ **WP6 conducted a review of 142 studies on societal aspects of radon and NORM, revealing significant methodological gaps, especially regarding NORM, guiding future guideline development.**
- ☢ **WP8 established a strategic plan for communication, dissemination and exploitation to ensure that RadoNorm results reach a wide audience and generate long-term impact.**
- ☢ **PhD and ECR integration is progressing, with 12 of 30 positions filled in the first 9 months, alongside virtual collaboration events and targeted training courses.**
- ☢ **RadoNorm events include a virtual Kick-Off, the "Liquid NORM" workshop, PhD/ECR Days, and the upcoming Annual Meeting (Sept 2021) involving key stakeholders.**
- ☢ **Stakeholder engagement is actively promoted through working groups, pilot testing, and regular updates across digital platforms, ensuring inclusive project participation.**

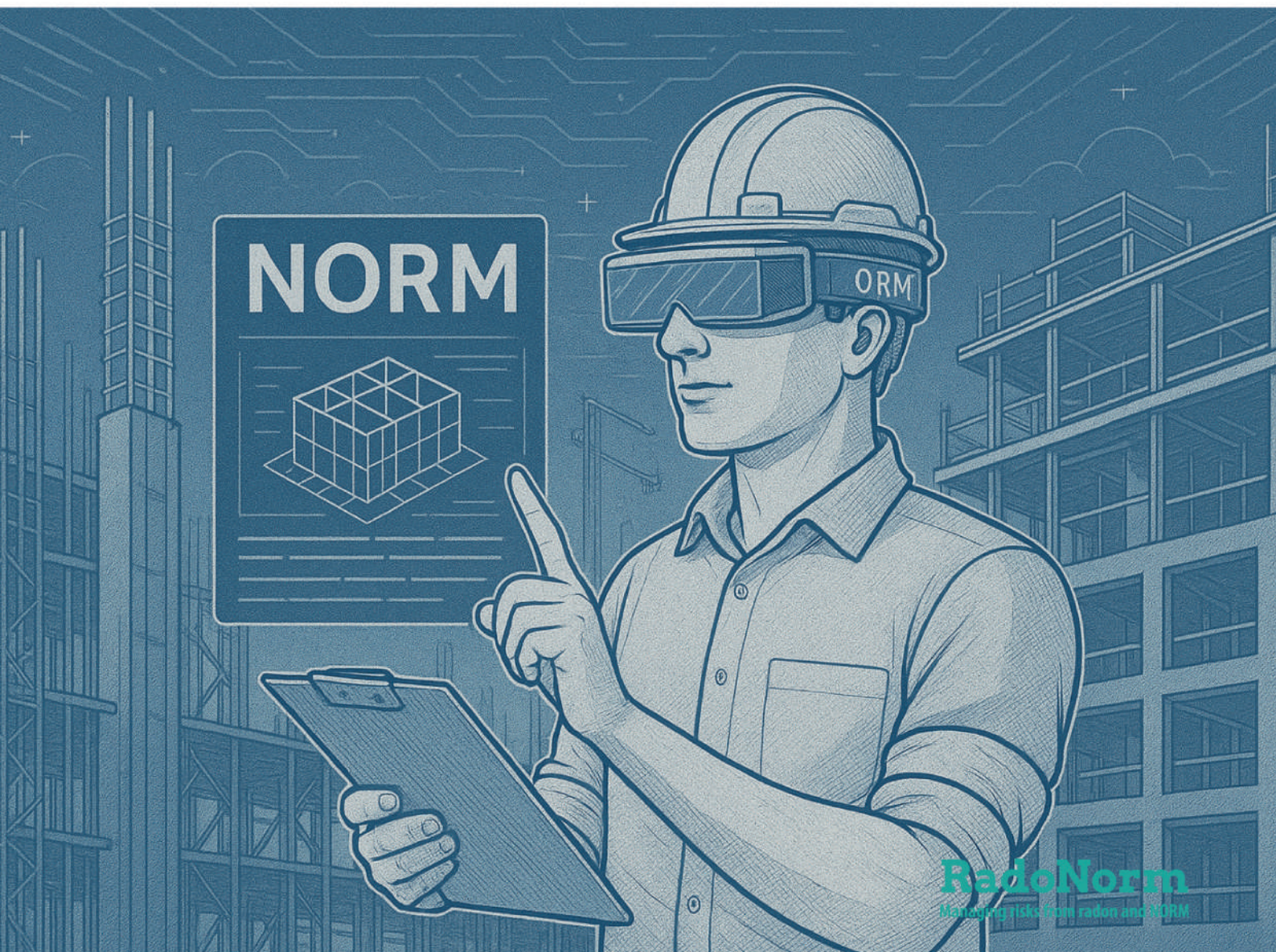


RadoNorm
Managing risks from radon and NORM

RadoNorm

Newsletter

N°2 - December 2021



**Dr. Laura Urso -
Researcher in a spotlight**
Leads modelling of
radionuclide transfer and
exposure pathways



**Dr. Robbe Geysmans -
Researcher in a spotlight**
Explores societal
challenges of radon and
NORM exposure



**Dr. Anssi Auvinen -
Researcher in a spotlight**
Studies childhood cancer
risks from residential radon
exposure



**Dr. Ben Spycher -
Researcher in the
spotlight**
Dependence of childhood
cancer risks on radiation



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RadoNorm Newsletter



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Editorial



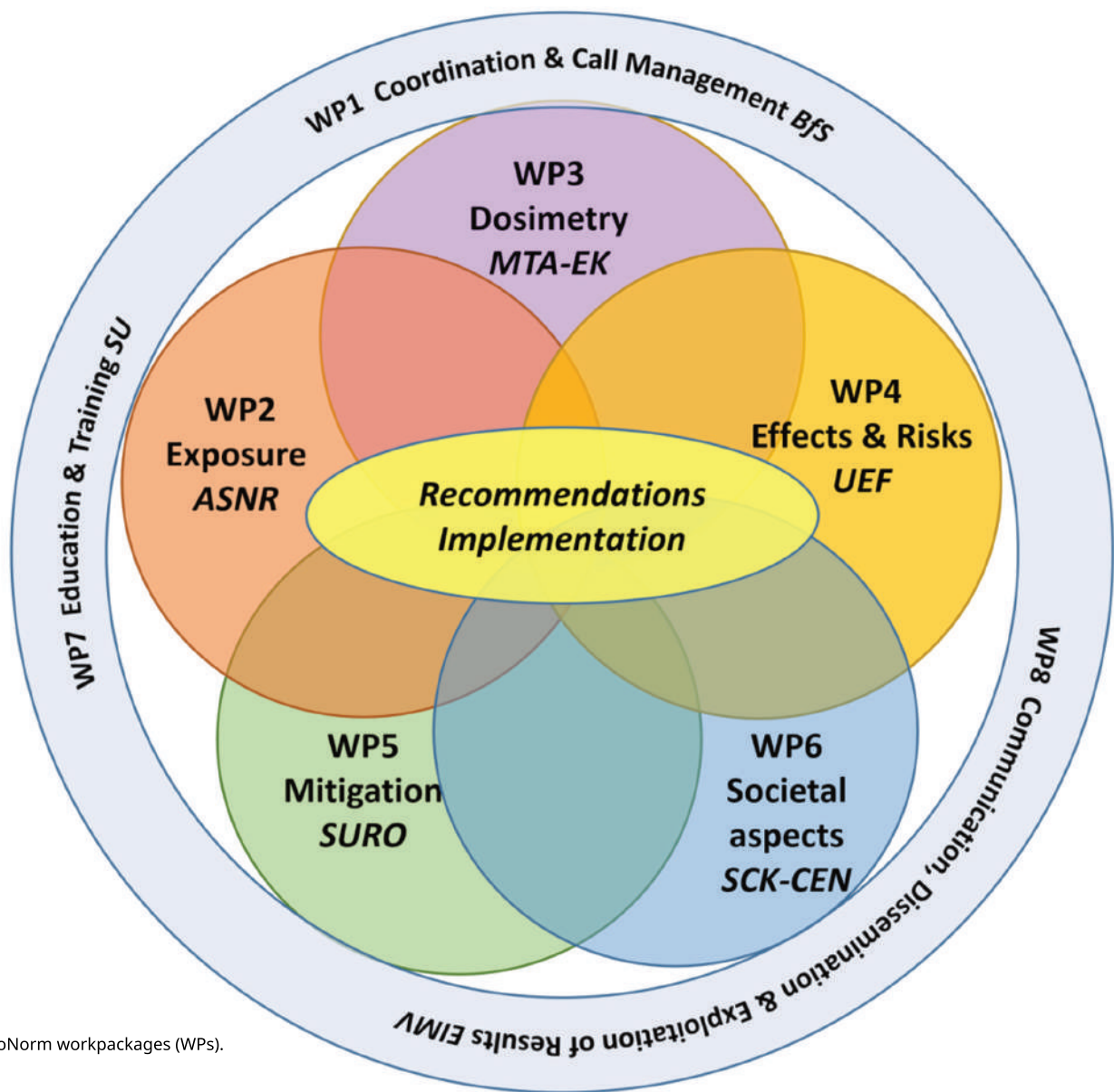
Dr. Nadja Železnik, leader of Work Package 8, EIMV

Dr. Nadja Železnik holds a BSc in Physics and an MSc in Reactor Physics from the Faculty of Mathematics and Physics, as well as a PhD in Psychology from the Faculty of Arts, all awarded by the University of Ljubljana, Slovenia. She is an expert in nuclear technology and radioactive waste management, with extensive experience in emergency preparedness and response, as well as in risk perception, communication, education, and training in environmental and nuclear projects.

She has acted as a civil society expert and knowledge manager in numerous European research initiatives, including EURAD-1 and -2, ECOSENS, and RadoNorm. Her contributions include the development of national strategies, legislative frameworks, feasibility studies, safety and radiological assessments, and stakeholder engagement plans. She has authored communication strategies, training programmes, and information materials to foster public understanding and informed participation in the nuclear and environmental domains.

It is with great pleasure that we reflect on the first full year of RadoNorm's activities, a year marked by vibrant scientific progress, strong stakeholder engagement, and an unwavering commitment to multidisciplinary collaboration. Despite the continuing constraints imposed by the global COVID-19 pandemic, the RadoNorm community rose to the challenge with exceptional flexibility and innovation, laying a robust foundation for impactful research in radiation protection.

This issue looks at the early achievements of the project, illustrating the breadth of work underway across exposure science, dosimetry, biology, social science, and regulatory practice. Methodological advances in the assessment of radon and NORM exposure, indoors, in the workplace, and in the environment, have been accompanied by the development of new models, measurement protocols, and inter-comparison studies. Progress has also been made in characterising spatial and temporal variability, source attribution, and critical exposure pathways.



Reflection after one year

Since its launch, RadoNorm has actively shared results at international events, many held online due to COVID-19. Highlights include major conferences, dedicated workshops, and early career researcher events. The 2021 Annual Meeting showed strong stakeholder interest. Despite challenges, the project achieved impressive progress through committed collaboration.

RadoNorm actively engages in international conferences, fosters stakeholder collaboration, and supports early-career researchers.

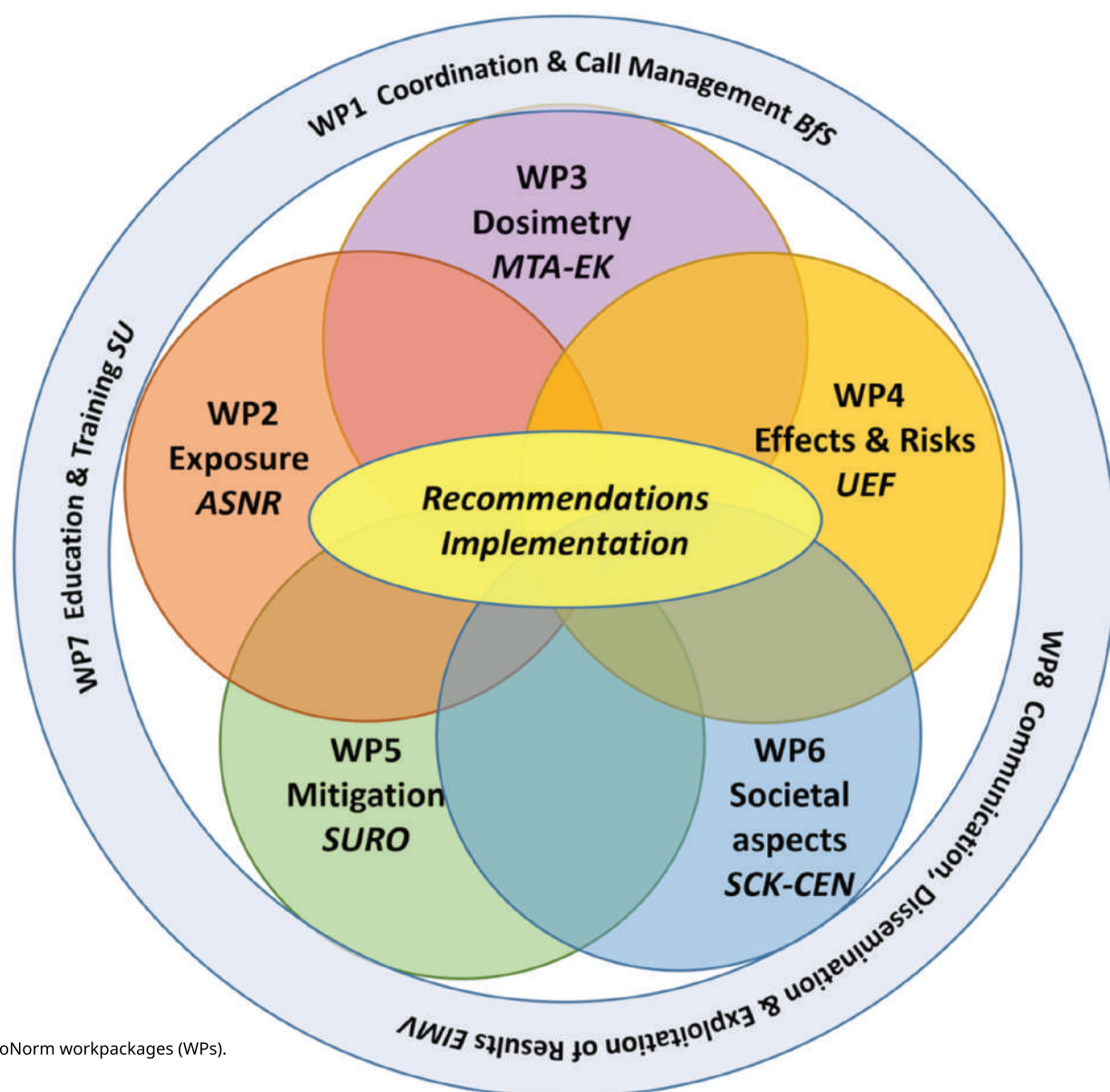
Since the start of RadoNorm, the project and its results have been presented to different audiences. We have been participating in many events on a regular basis. Here are listed just a few of those to which we contributed: Pre-RICOMET 2020, RICOMET 2021, IAEA NORM 2021, HERCA Pre-workshop event 2021, CARST 2021, ConRad 2021, ERPW 2021, IRPA conference and similar. Most of the events were organised online due to COVID-19 restrictions; however, the presentations were recorded, and discussions were enabled online. The information about the contributions is given in the News with a link for further information if available. There were also two events organised for RadoNorm PhD/Early Career Researchers, presenting the research topics and expected results. The online workshop devoted to liquid NORM was organised as part of the project's milestone in WP5. The first annual meeting provided an opportunity to present the first results from the project, but also enabled discussion of the needs and challenges with members and RadoNorm stakeholders.

The high interest in the RadoNorm project also became clear during the first annual project meeting, which took place on 6th and 7th September 2021 as an online event. The first day was dedicated to the RadoNorm General Assembly, while the second day was organised as an open event. The vivid discussions and broad involvement of researchers and stakeholders, also beyond Europe, clearly demonstrated the external impact of RadoNorm and its activities.

Considering all the challenges we had to face and handle since project start, above all, but not exclusively, the corona pandemic, it is amazing what has been achieved since project start. Leaders of work packages and tasks, scientists, early career researchers, students, and, of course, members of the administration have been highly flexible and imaginative in carrying out their work and enabling whatever is possible. This is also an output of RadoNorm, which should not be underestimated.



Dr. Ulrike Kulka, RadoNorm coordinator, BFS



RadoNorm workpackages (WPs).

Short news from WPs

RadoNorm advances radon and NORM exposure research through new protocols, field campaigns, dose modelling, biological effect studies, social science integration, and stakeholder engagement. Achievements include computational lung dose estimates, radon control surveys, and studies on NORM mobility, risk perception, and public communication tools.

In **WP2**, regarding exposure to radon, methodologies and protocols to compile or acquire new data have been established for the (1) characterization of temporal and spatial uncertainty of indoor radon measurement, (2) characterization of radon aerosols in underground workplaces, (3) assessment of radon exposure in workplaces, (4) assessment of building materials as a source of indoor radon exposure, (5) improvement of methods to identify high indoor radon levels, and (6) assessment of radon and thoron outdoor concentrations and exhalation rate.

Regarding exposure to NORM, questionnaires have been developed, and an e-survey in collaboration with WP5 will soon be launched to collect information on NORM exposure sites at the European level. Experimental studies and first field campaigns have been launched to better understand the influence of speciation, plant metabolites, earthworms or microorganisms on the mobility of uranium and radium in soils, their transfer to plants, and to support the development of new modelling approaches to predict their reactivity in soils. Finally critical reviews of exposure pathways considered for dose assessment of public and wildlife at NORM industrial/legacy sites have begun for three selected topics: (1) the management of NORM in the context of conventional waste disposal, (2) the groundwater exposure pathways and the consideration of leaching, (3) the use of sludge from sewer depuration systems of liquids effluents as fertilizer in agriculture.



One of the specific aims of **WP3** is to quantify the in vivo dose distributions in human lungs to provide realistic exposure conditions for in vitro experiments with cell cultures and organotypic tissue models. The first output of this activity was Milestone 40 entitled “Dose distributions in human lungs”. Two computational modelling approaches were combined in order to estimate absorbed doses in different cell nuclei in the case of several exposure conditions, including home and uranium mine environments. Considering the spatially inhomogeneous dose distribution, both average doses in the bronchial airways and maximum doses in the deposition hot spots were estimated. Based on the simulations, recommendations have been made on how to mimic the effects of one Working Level Month exposure. The results will also be included in Deliverable 3.5 entitled “Report on results of computational microdosimetry supporting the preparation and evaluation of experiments”. Until then, further research will be performed within Task 3.5 to estimate other quantities and to characterise other exposure scenarios based on the comments and requests from WP4.



Dr. Laureline Fevrier, leader of Work Package 2, IRSN
Dr. Balázs Madas, leader of Work Package 3, EK



Dr. Sisko Salomaa, leader of Work Package 4, STUK
Dr. Ales Fronka, leader of Work Package 5, SURO



The overall objective of **WP4** is to generate new knowledge related to biological effects and responses after exposure to radon and NORM that have implications for risk assessment and radiation protection of humans and the environment, and to reduce the existing uncertainties in risk assessment. To achieve this goal, we address major knowledge gaps in human health risk assessment of radon and NORM, such as interaction between radon and smoking for lung cancer, risks of radon outside of the lung, risks associated with radon exposure during childhood, risks from radon and NORM in drinking water, mechanisms of radiation action in the disease processes, and quantification of various sources of uncertainties in risk inference. Furthermore, we address the major knowledge gaps for the risk assessment of non-human biota related to the combined effects of NORM and other stressors and determining adverse outcome pathways leading to such effects. The methods used in WP4 include epidemiological studies and simulations based on epidemiological datasets, risk modelling, molecular epidemiology, experimental studies on combined effects carried out in realistic co-exposure conditions (radon and tobacco smoke/nanoparticles for human cell systems; NORM and chemicals and particulates for biota) and determining of adverse outcome pathways linking the mechanisms and effects after co-exposures.

There were three Milestones successfully achieved within **WP5** in 2021:

- Workshop “Liquid NORM – sources, impact assessment and treatment” with industry representatives and relevant authorities dealing with radioactivity in water (by GIG in February),
- Review of building materials and technologies with significant impact on indoor radon levels by applying the questionnaire

about experience with the material with elevated content of natural radionuclides or including residues of NORM industries, search in the literature (by SURO in August),

- Selection of case study sites and collation of key parameters and relevant datasets for subsequent model application (by DSA in November).

Several important master questionnaires have been elaborated focusing on information and data gathering with respect to mitigation strategies, systems and methods (preventive measures, corrective actions) to control radon in workplaces and dwellings, including large-scale buildings:

- RCTS – Radon Control Technologies Survey,
- RAS – Regulatory Approaches Survey.

A separate NORM questionnaire has been prepared in close collaboration with WP2 Exposure to gather actual data and information for further working activities within the project RadoNorm.

We have also prepared a special questionnaire for collecting information about the measurement of radon and radon progenies and other relevant parameters that might be important from the point of view of dose from radon calculation and radon mitigation system efficiency evaluation.

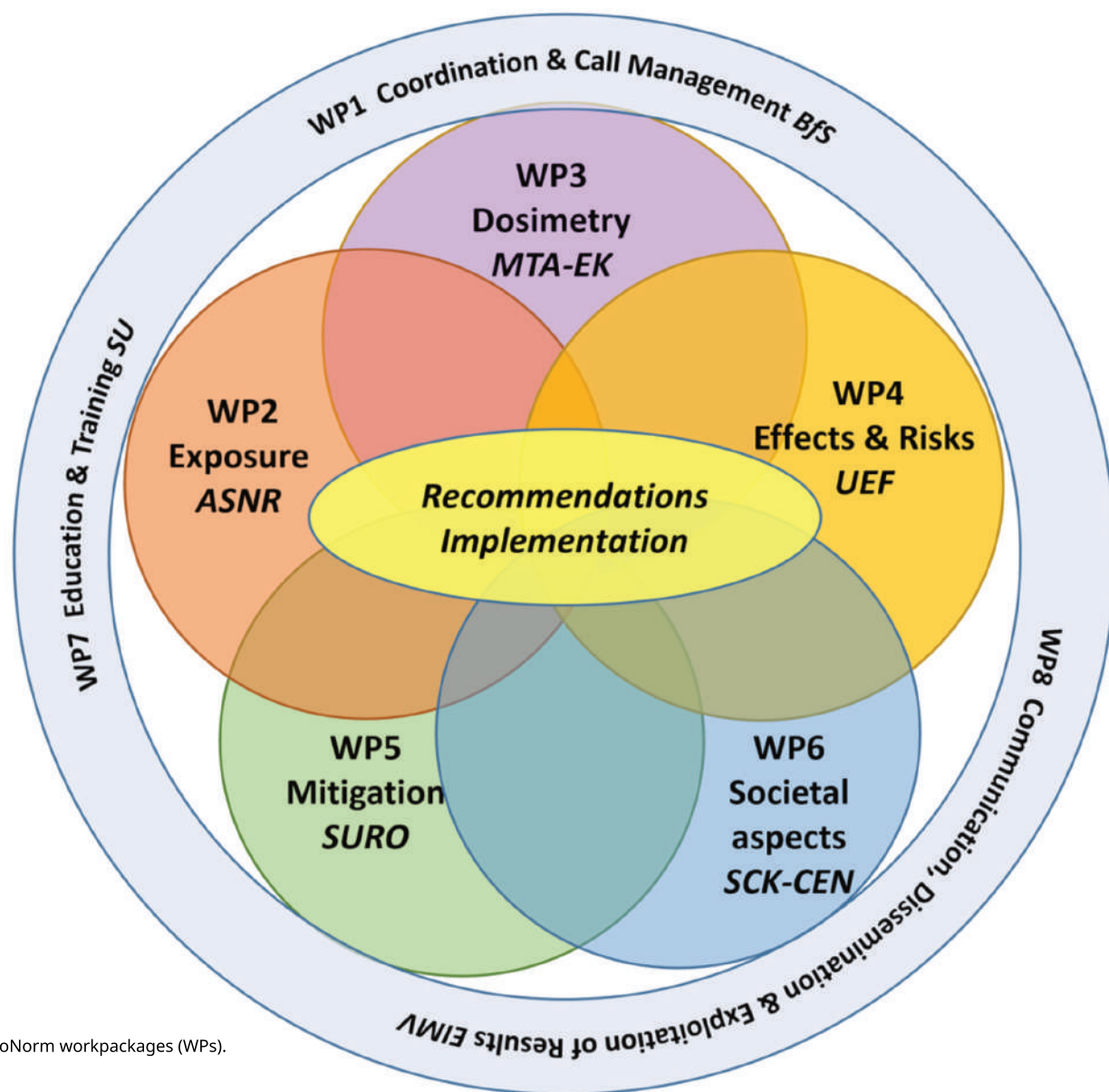
In addition, a set of laboratory experiments, in-situ measurement campaigns in dwellings, underground workplaces and legacy sites have been commenced. Experimental and theoretical works were carried out focusing on testing various methods developed for radon diffusion coefficient determination in radon-proof membranes. Moreover, a selection of active and passive dosimeters was made to prepare a large on-site inter-comparison measurement campaign in selected underground workplaces.

WP6 addresses significant gaps appearing between technical R&D and people's behaviour. In particular, we progress towards the following objectives:

- To develop and test an open source toolbox of qualitative and quantitative methods and scales, including a comprehensive database related to affected populations and stakeholders' risk perception, views, attitudes and behaviour in radon and NORM exposure situations, leading to integration of the radiation protection scientific community at EU level and a better coordination of social science and humanities research efforts;
- To develop and test health communication tools, strategies and methods for behaviour change in radon and NORM exposure situations to address the value-action gap and improve communication campaigns' results.
- To open a citizen science incubator (to set up self-sustainable citizen science initiatives) for radon-prone areas and by this to motivate mitigation actions during and after the project, and enable cooperation of citizens and institutional actors.
- To investigate and address risk perception, communication and governance challenges in specific exposure situations to improve practical measures in view of the effective radiation protection of people and the environment: to sensitize radon issues in the geothermal energy sector; to address apparent controversies between "radon as treatment in radon spas" and radon as threat in "health communication campaigns"; to address societal and marketing challenges related to NORM for building material.
- To provide consolidated and robust science-based policy recommendations related to societal aspects to decision makers, contributing to the existing strategic research agenda for social science and humanities for the radiation protection science community. This will lead to further integration of the radiation protection scientific community at the EU level and better coordination of research efforts.



Dr. Tanja Perko, leader of Work Package 6, SCK CEN



RadoNorm workpackages (WPs).

Events and trainings: past and future

RadoNorm supports 17 PhD students and 3 early career researchers, with plans for expansion. In 2021, it organised 2 ECR events, 5 training courses, and awarded travel grants. An education programme and ECR council were launched to foster collaboration.

Upcoming 2022 activities include new courses, grants, and participation in major conferences like FISA–EURADWASTE.



Dr. Andrzej Wojcik, leader of Work Package 7, SU
Dr. Mandy Birschwilks, Work Package 1, BFS



RadoNorm is currently supporting 17 PhD students and 3 early career researchers, with plans to hire additional people in 2022.

Starting early 2022, an education programme for our RadoNorm PhD students and ECR (hereafter referred to as ECR) will be set up. RadoNorm ECRs shall organise and educate themselves and RadoNorm seniors as well. The ECRs will form a RadoNorm council that will organise regular educational seminars to give, e.g. as a start, an overview of problems and known unknowns in the field tackled by each WP of RadoNorm. The seminars will stimulate discussion and – ideally – promote collaboration amongst the young scientists.

In the year that will shortly come to an end, we organised a) two events for RadoNorm PhD/Early Career Researchers presenting the research topics and expected results, b) organised 5 training courses (see following), and c) provided travel grants.

Currently, the call for the next course series is open. The plan of RadoNorm training courses 2022 will be published on the website end of January 2022.

There is also the last 2021 call for travel grants active. Respective deadlines can be seen [here](#).

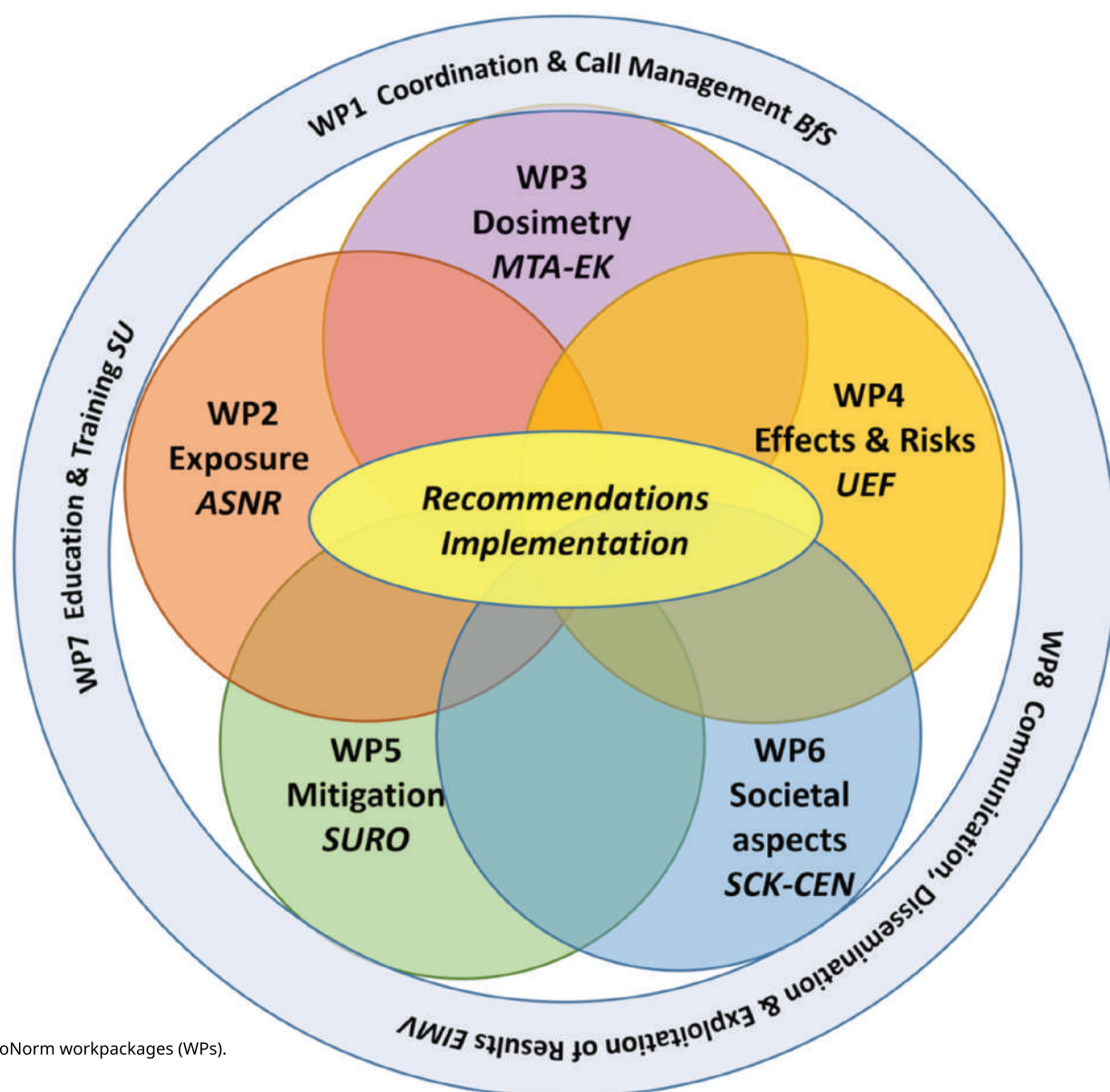
We also want to draw your attention to the Euratom Conferences FISA 2022 – EURADWASTE '22 organised by the French Presidency of the Council of the EU and the European Commission, will take place on Monday, 30 May – Friday, 3 June 2022 in Lyon, France. In addition to joint opening and closing plenary sessions, there will be many

networking opportunities within dedicated parallel and poster sessions, thematic workshops, PhD/MSc and R&D awards, Nuclear Innovation prizes and Young Generation matchmaking opportunities.

The 2021 RadoNorm events are summarised below:

- RadoNorm annual meeting 6-7 September 2021 / RICOMET
- RadoNorm training courses:
 - Naturally occurring radionuclides in work and the natural environment – establishing the problem definition, finding sources and exposure assessment, 12 – 26 April 2021, GIG, online, Poland.
 - The art of public opinion survey analysis: surveying the public on radon and NORM. 26 – 30 April 2021, SCK-CEN and Antwerp University, online, Belgium.
 - Interdisciplinary radiation research on radon – InterRad, 14 – 25 June 2021, BFS, Munich, Germany.
 - NORM impact assessment toolkit: from microorganisms to human cells. 30 August to 10 September, 2021, Aveiro University and Porto University, Portugal.
 - CELET: Cellular and genotoxic effects of high and low LET ionising radiation – introduction to radiation biology. 8 – 19 November 2021, Stockholm University, Sweden.

Events in 2022, like NORM X and the RICOMET conferences, will be promoted via our event calendar page. So, stay tuned for the latest information.



RadoNorm workpackages (WPs).

Latest deliverables and publications

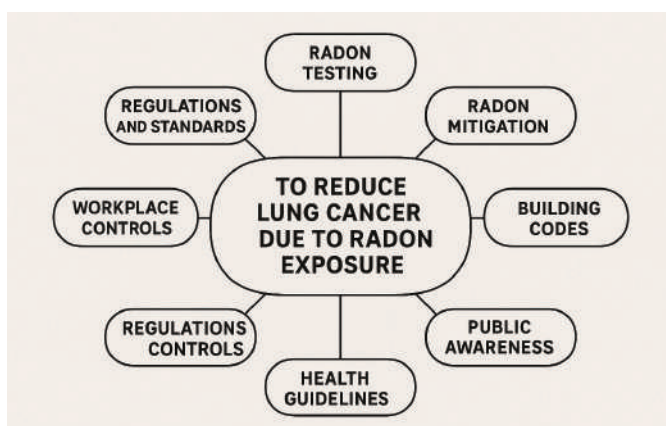
RadoNorm's first scientific paper evaluates citizen science in radon research. It found most projects focus on data collection (crowdsourcing), with few addressing radon mitigation.

RadoNorm aims to launch initiatives where citizens actively reduce radon exposure, supporting lung cancer prevention.

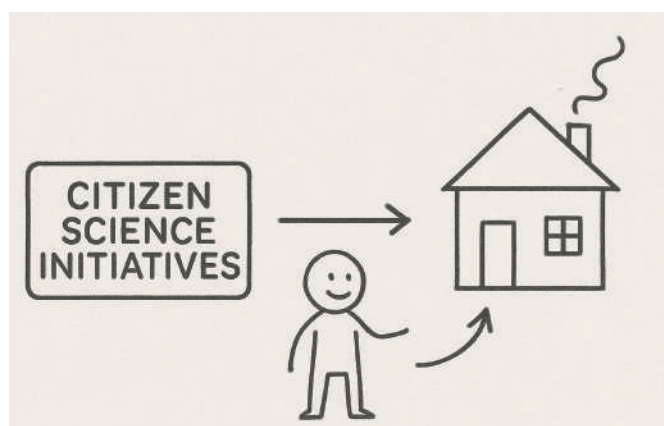


First RadoNorm scientific paper published:

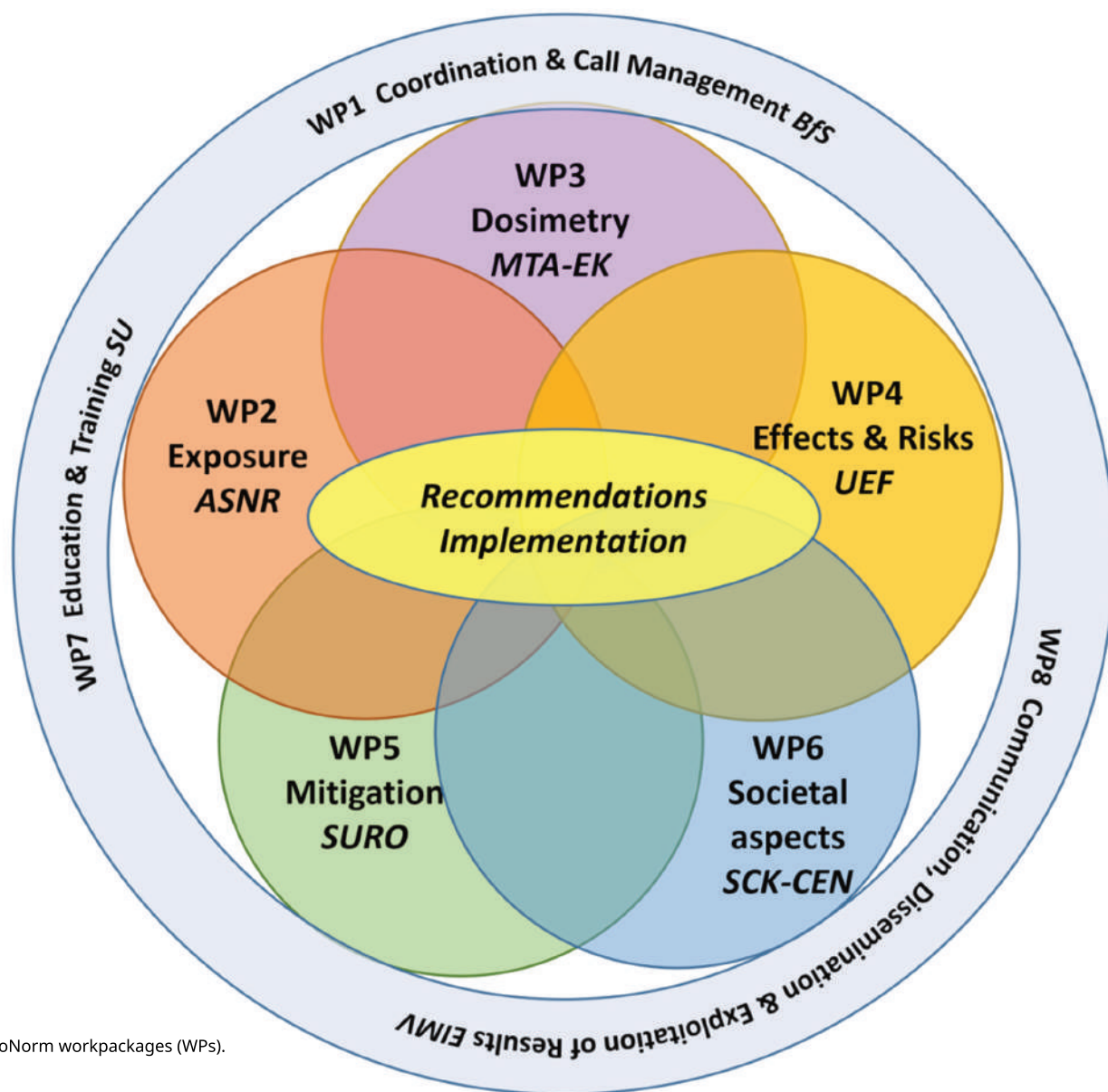
Meritxell Martell, Tanja Perko, Yevgeniya Tomkiv, Stephanie Long, Alison Dowdall, Joke Kenens, (2021), Evaluation of citizen science contributions to radon research, Journal of Environmental Radioactivity, Volume 237, ISSN 0265-931X.



The paper reports on the identified existing civil society initiatives in the field of radon and evaluates the extent to which these civil society initiatives contribute to radon research and/or radiation protection from radon in order to reduce lung cancer due to radon exposure situations. Most of the current citizen science projects apply the simplest form of participation (crowdsourcing), and only one of the eight identified focuses on radon mitigation.



The development of citizen science initiatives which consider not only testing but also radon mitigation may contribute to a decrease in radon-related lung cancer. The aim of RadoNorm is to launch citizen science initiatives where citizens actively reduce the levels of radon exposure in their houses. You can read the full paper on <https://www.sciencedirect.com/science/article/pii/S0265931X21001570>.



RadoNorm workpackages (WPs).

Researchers in a spotlight

Laura Urso (BfS) leads modelling of NORM transfer in soils and groundwater to improve exposure assessments. Robbe Geysmans (SCK CEN) tackles societal challenges of radon/NORM in unusual settings like spas or building firms. Anssi Auvinen (Tampere/STUK) and Ben Spycher (Uni Bern) assess childhood cancer risks from indoor radon via case-control and pooled European studies.



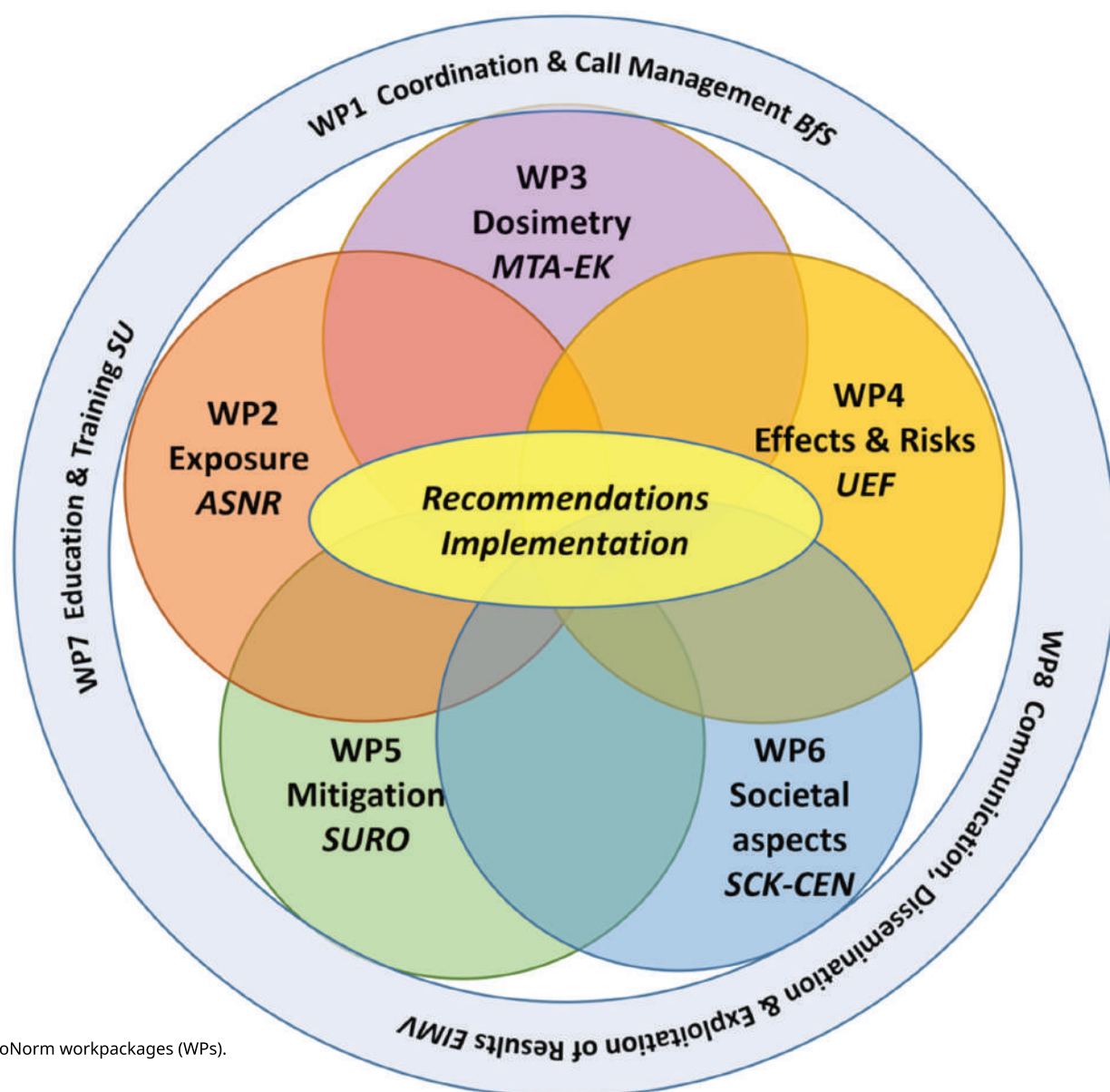
Dr. Laura Urso, BFS, Germany
Dr. Robbe Geysmans, SCK CEN, Belgium
Dr. Anssi Auvinen, STUK, Finland
Dr. Ben Spycher, ISPM, Switzerland

Laura Urso, PhD, is a scientific officer at the German Federal Office for Radiation Protection (BfS) in the Section Radioecology. She is in charge of improving the understanding of physical, chemical and biological mechanisms underlying the transfer of radionuclides in the environment. This is also well-reflected in task 2.8 of the RadoNorm project where she has the lead. The aim of this task is to update radioecological models that deal with the transfer of NOR in situations that may increase the exposure of members of the public, a criterion that often applies to regulatory prescriptions. In particular, this task attempts to make use of knowledge gained during the project on sorption of NOR in soil, to improve the modelling of the groundwater pathway and – if necessary – to reduce the level of conservatism in the exposure assessments in the context of NORM.

Robbe Geysmans, PhD, is a sociologist working at the Belgian Nuclear Research Center SCK CEN, where he conducts research on the socio-technical aspects of ionising radiation. In the RadoNorm project, he assists in the management of WP6 on societal aspects of radon and NORM, and is also the leader of a task on addressing communication and governance challenges in specific exposure situations. This task focuses on rather exotic and unexpected places, such as radon spas, geothermal installations and building companies. However, while seemingly odd at first sight, these places offer important challenges for radon and NORM management, not least from a societal point of view. How, for example, can NORM containing byproducts be brought to the market as sustainable building products? Or how to understand the apparent controversy between radon as a health risk and radon as a spa treatment? These are the sort of questions that Robbe and many other enthusiastic RadoNorm researchers work on.

Anssi Auvinen, PhD, is a professor of epidemiology at Tampere University and a research professor at STUK Radiation and Nuclear Safety Authority in Finland. He has been engaged in research on the health effects of Chernobyl fallout, occupational radiation exposure among airline personnel, nuclear workers and medical staff. In the RadoNorm project, he is leading task 4.3, addressing the risk of childhood leukaemia and brain tumours from residential radon. Few studies have evaluated the risks of childhood malignancies in relation to indoor radon exposure. Within RadoNorm, case-control studies will be conducted in France and Finland, and a pooled analysis of these with previous studies will be performed for integrative risk assessment as a basis for risk assessment and risk management.

Ben Spycher, PhD, is a senior researcher at the Institute of Social and Preventive Medicine of the University of Bern, Switzerland. His research focuses on the environmental risk factors of childhood cancers with an emphasis on ionising radiation. He has led studies on childhood cancer risks and exposure to background radiation in Switzerland and has conducted a national survey on radiation exposure in children involving personal dosimetry. Within RadoNorm, he is leading a pooled analysis of studies from multiple European countries on the risks for childhood leukaemia and brain tumours from exposure to domestic radon and terrestrial gamma radiation.



RadoNorm workpackages (WPs).

RadoNorm engagement opportunities

The RadoNorm website and social media share key updates, results, and events. Stakeholder groups are actively involved in communication pilots, regulation development, and scientific discussions. Newsletter subscription is available, and all contact data are managed according to the RadoNorm Privacy Policy.

The RadoNorm website and social media offer up-to-date project highlights, engagement opportunities, and ways to join stakeholder groups.

The RadoNorm website provides many information about the project, the challenges to be addressed, its development and results, and interaction and engagement possibilities. The linked RadoNorm social media with LinkedIn, Twitter and YouTube emphasise the latest news and events to fulfil the foreseen dissemination. We would be most happy if you would connect with us.

RadoNorm established different engagement opportunities for the related and interested stakeholders. Several stakeholder groups are established for active involvement of different representatives in the project's activities, such as pilot testing of communication tools, development of new regulatory standards, discussions on scientific findings, or to be just informed about the RadoNorm results. You are most welcome to join the RadoNorm stakeholder groups. The subscription to more information, like Newsletter issues, is available. The RadoNorm partners are regularly informed with all news, events and call opportunities. All developed contact databases are managed according to the RadoNorm Privacy policy.



Dr. Nadja Železnik, leader of Work Package 8, EIMV

Sources



Reflection after one year

- 🌐 News, <https://www.radonorm.eu/news/>
- 🌐 RadoNorm PhD/Early Career Researchers, <https://www.youtube.com/channel/UC6yCORiPX5DXgmu5AaGLn9Q>
- 🌐 Liquid NORM, <https://www.radonorm.eu/event/event-material/#245-246-wpfd-liquid-norm-feb-2021>
- 🌐 First annual meeting, <https://www.radonorm.eu/event/event-material/#245-287-wpfd-1st-annual-meeting-2021-1616669128>

Latest publications

- 🌐 RadoNorm PhD/Early Career Researchers, <https://www.youtube.com/channel/UC6yCORiPX5DXgmu5AaGLn9Q>
- 🌐 RadoNorm training courses 2022, <https://www.radonorm.eu/calls/call-for-courses/>
- 🌐 Call for travel grants, <https://www.radonorm.eu/calls/call-for-travel-grant/>

Latest deliverables and publications

- 🌐 Martell et al., <https://www.sciencedirect.com/science/article/pii/S0265931X21001570>

RadoNorm engagement opportunities

- 🌐 RadoNorm website, <https://www.radonorm.eu/>
- 🌐 LinkedIn, <https://www.linkedin.com/company/radonorm/>
- 🌐 Twitter (now X), <https://twitter.com/RadoNorm>
- 🌐 YouTube, <https://www.youtube.com/channel/UC6yCORiPX5DXgmu5AaGLn9Q>
- 🌐 RadoNorm stakeholder, <https://www.radonorm.eu/stakeholders/>
- 🌐 Subscription to more information, <https://www.radonorm.eu/newsletter/>
- 🌐 RadoNorm Privacy policy, <https://www.radonorm.eu/privacy-policy/>

Key takeaways



- ☢ **WP1 facilitated project-wide visibility through participation in international scientific conferences and the successful organisation of the first online Annual Meeting (6–7 September 2021), promoting open dialogue on challenges and future directions despite pandemic constraints.**
- ☢ **WP2 developed robust methodologies for assessing radon and NORM exposure, including aerosol characterisation, indoor radon source identification, and tools to improve spatial and temporal uncertainty analysis.**
- ☢ **WP3 generated new in vivo dose distribution models in human lungs using computational simulations, enabling realistic exposure scenarios and informing future experimental designs.**
- ☢ **WP4 advanced biological and epidemiological research on health risks from radon and NORM, addressing key uncertainties including co-exposures (e.g. smoking), childhood vulnerability, and risks beyond the lungs.**
- ☢ **WP5 launched measurement campaigns and stakeholder workshops, reviewed radon-prone construction materials, and developed master questionnaires for mitigation strategies in buildings and workplaces.**
- ☢ **WP5 completed in-situ radon measurement campaigns in historical mines, developed a dynamic risk modelling tool for underground workplaces, and collaborated with WP2 on analysing NORM-related survey data.**
- ☢ **RadoNorm supported 17 PhD students and 3 early career researchers, offering five multidisciplinary training courses and fostering collaboration across scientific and societal disciplines.**
- ☢ **The first RadoNorm scientific article was published in the Journal of Environmental Radioactivity, evaluating the contribution of citizen science initiatives to radon protection and research.**



RadoNorm
Managing risks from radon and NORM

RadoNorm

Newsletter

N°3 - July 2022



Spring of River Krupa, Slovenia
(photo N. Zeleznik)

RadoNorm
Managing risks from radon and NORM

RadoNorm to Dr. Sisko Salomaa

A big thank you for your hard work and very nice collaboration!



Dr. Susanne Sachs - Researcher in a spotlight

Studies radionuclide-plant interactions and models NORM mobility



Dr. Thuro Arnold - Researcher in a spotlight

Studies radionuclide behaviour in environments



Dr. Tuukka Turtiainen - Researcher in a spotlight

Develops radon exposure methods and sampling protocols



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RadoNorm Newsletter



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Editorial



Dr. Nadja Železnik, leader of Work Package 8, EIMV

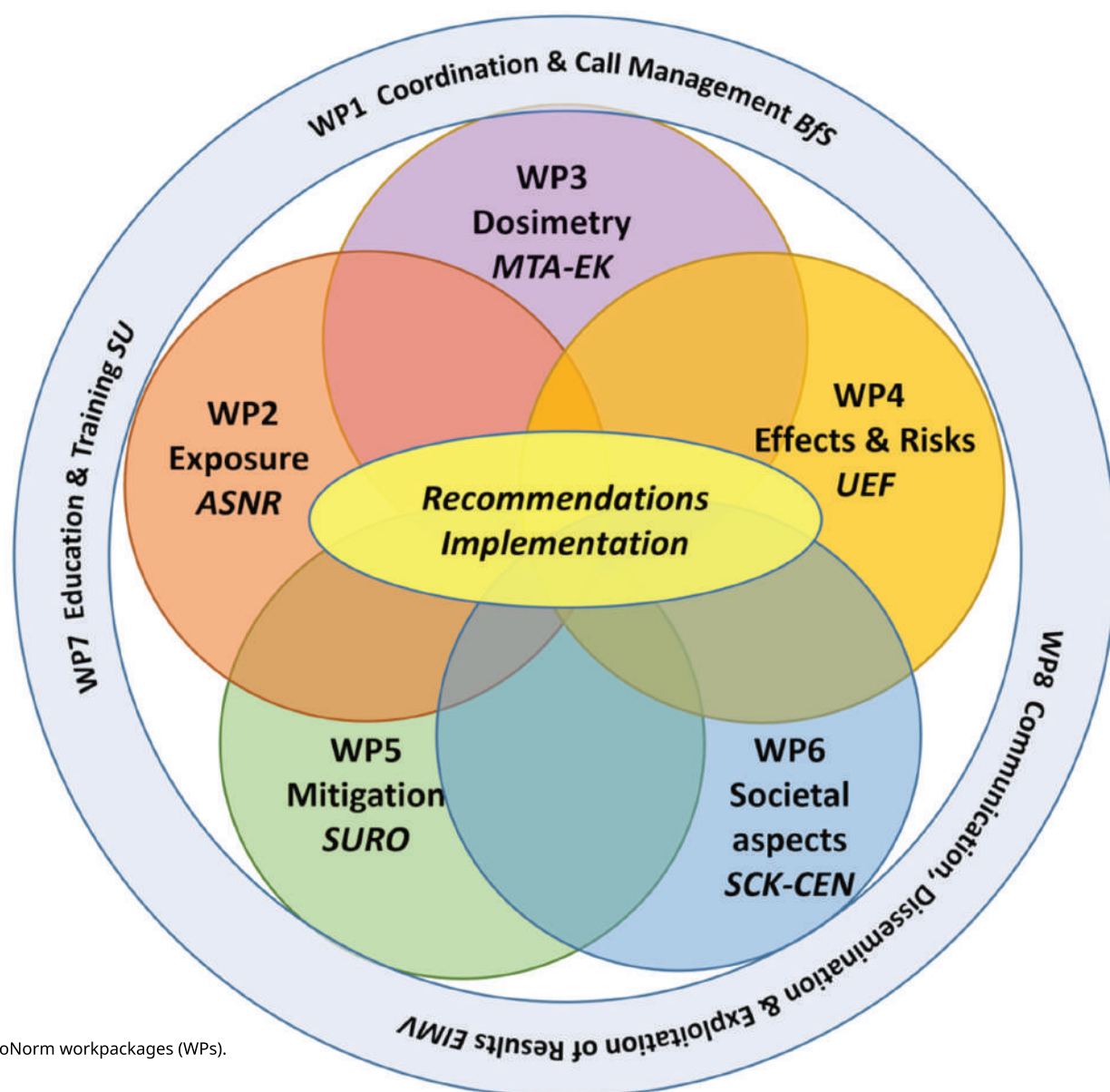
Dr. Nadja Železnik holds a BSc in Physics and an MSc in Reactor Physics from the Faculty of Mathematics and Physics, as well as a PhD in Psychology from the Faculty of Arts, all awarded by the University of Ljubljana, Slovenia. She is an expert in nuclear technology and radioactive waste management, with extensive experience in emergency preparedness and response, as well as in risk perception, communication, education, and training in environmental and nuclear projects.

She has acted as a civil society expert and knowledge manager in numerous European research initiatives, including EURAD-1 and -2, ECOSENS, and RadoNorm. Her contributions include the development of national strategies, legislative frameworks, feasibility studies, safety and radiological assessments, and stakeholder engagement plans. She has authored communication strategies, training programmes, and information materials to foster public understanding and informed participation in the nuclear and environmental domains.

It is with great pleasure that we present the third issue of the RadoNorm Newsletter, marking the close of the project's second year. In spite of persistent challenges related to the pandemic, the RadoNorm consortium has demonstrated resilience and scientific excellence, laying a strong foundation for impactful radiation protection research.

This issue highlights a range of significant achievements across the work packages: from refined models of radon exposure in buildings and workplaces, to molecular investigations of radon-induced health effects and ecotoxicological responses to NORM. Field campaigns across Europe, including in Norway, Poland, and France, have enriched our empirical understanding, while new modelling tools and measurement protocols have advanced the state of the art in risk assessment and regulatory practice.

Social science contributions have gained momentum through qualitative and quantitative studies exploring public perception, stakeholder engagement, communication strategies, and behavioural interventions.



RadoNorm workpackages (WPs).

Steps in second year – main RadoNorm achievements and challenges

Despite pandemic challenges, RadoNorm achieved major progress: five publications, public workshops, and strong presence at international conferences. Collaboration thrived across work packages, showcasing the project's vitality. Enthusiasm remains high ahead of the 2nd Annual Meeting in Munich.

RadoNorm published key studies, led trainings, won awards, and strengthened collaboration across Europe.

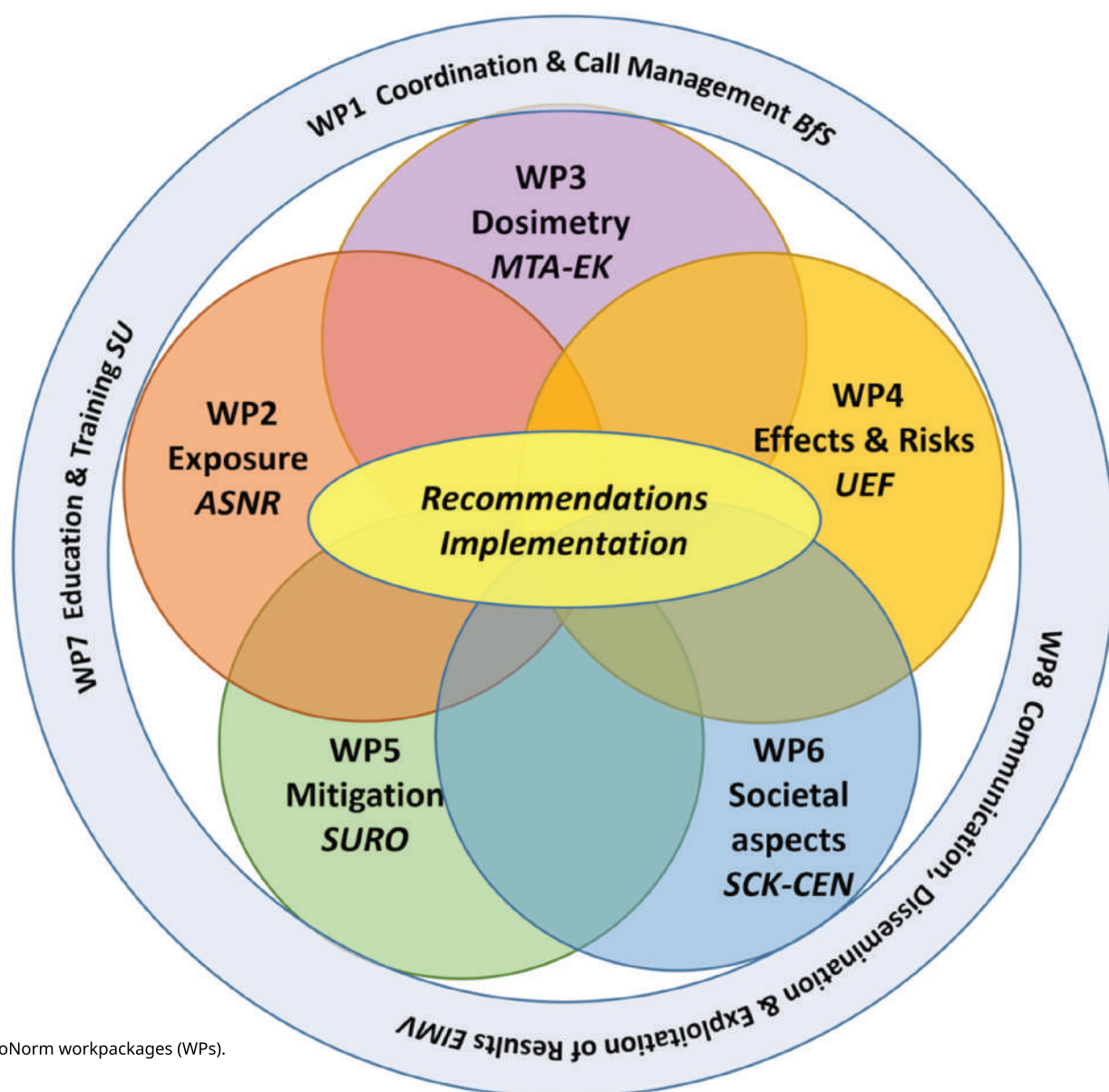
RadoNorm's groundwork has been laid, which has enabled vibrant and intense involvement from each work package. This especially became apparent when the first periodic project report was submitted to the European Commission, reporting on progress made during the first 18 months. It was impressive to see how much has been accomplished despite the hard-hitting restrictions in travel, lab access and even scientific exchange over the last winter season.

In 2022, the project so far has seen the release of five scientific publications, the organisation of various E&T courses and workshops involving the public, as well as contributions to international conferences in radiation research. In such meetings as NORM X, RICOMET2022, IRPA2022 and FISA2022, to name a few of them, the concept of the project was introduced, and its key findings were shared. Several delegates from RadoNorm were also awarded prizes at these conferences, demonstrating the diverse talents in the project and the vitality of the work that is being carried out. The output has been substantial and is the result of eager collaboration not only within work packages but between them as well.

There is no doubt that motivation and enthusiasm remain high among the leaders, scientists and students, participating in the project. As the pandemic restrictions further ease or even finish over summer, we look forward to our 2nd Annual Meeting in October in Munich, Germany, preceding the European Radiation Protection Week in Portugal.



Dr. Ulrike Kulka, RadoNorm coordinator, BFS



RadoNorm workpackages (WPs).

Short news from WPs

WP2–WP6 advanced radon/NORM risk understanding through reports, fieldwork, modelling, social science studies, citizen science, and training. Key topics included workplace exposure, risk communication, lung cancer mechanisms, and environmental transfer, supported by cross-European collaboration and expert engagement.

WP2 launched radon fieldwork and forest modelling, advanced NORM exposure tools, plant transfer studies, and risk assessment simulations.

Regarding activities devoted to improving radon exposure, the latest outcomes from WP2 include:

- The release of three milestone reports (MS3 – Agreed review basis and collection of relevant survey data from various countries, MS4 – Survey design for studying seasonal and spatial variation and MS5 – Identification of measurements sites) that fix the planning and organisation activity to quantify the spatial and temporal variabilities affecting the annual/long-term radon concentration evaluation in buildings.
- The release of two milestone reports that review the situations concerning radon risk monitoring in EU Member States – and also, to some extent, in other countries – and propose a first identification of gaps related to the characterisation of radon exposure of workers at selected workplaces (MS9 – Data base for collection of relevant information and MS10 – Collection of characteristic data of radon-progeny activity concentration and aerosol characteristics at selected workplaces – Gap analysis)
- The release of a milestone report that presents a field test that will be implemented during the timeframe of RadoNorm to estimate radon – radon progeny equilibrium factor, aerosols properties and attached /

unattached fraction ratio at a real underground workplace (MS11 – Decision on potential field surveys and objects). The historic mine of lead, silver and zinc ores with its underground water galleries in Tarnowskie Góry, Poland, is the selected site.

- The release of a milestone report (MS19 – Synthesis of European surveys of radon in workplaces and identification of the different workplaces typologies according to criteria that have an impact on the radon concentration behaviour in workplaces) that reviews the different measurement protocols used to manage radon risk in the workplaces of different countries. The report shows important lacking information regarding radon decay products, which are almost never considered in these protocols, and highlights the major needs of measurement protocols for some specific workplaces or situations.
- The realisation of a first field campaign to improve our understanding of Rn and progeny distribution in a forest ecosystem in Norway at the Fen site. Radon and thoron progeny, Pb-210 and Pb-212, as well as Ra-226 and Ra-228 have been analysed on soil, litter, and tree leaf samples at different locations (to study spatial variability).
- The development of a model that couples the SCK CEN models ECOFOR (deposition model in forests) and ECORADON (atmospheric radon exhalation to assess outdoor Rn and progeny concentrations in forest ecosystems).

Regarding activities devoted to improving NORM exposure, the latest outcomes from WP2 include:

- The development of tools and methodology necessary for a systematic information collection about NORM exposure sites. These documents present the main objectives, scope and detailed explanation of the planned work. The collection of information can be done either from scratch using a four tiers system for information collection or using existing European and / or national platforms for industrial activities (including NORM). Each country will decide which data they will provide and how they will get these. The four tiers system of identification allows to collect information based on the (1) inventory of natural resources / raw materials of economic importance, (2) inventory of ongoing mining industry (including other underground workplaces), (3) inventory of mineral processing industry, and / or (4) inventory of products / commodities, its use / application and disposal.



Dr. Laureline Fevrier, leader of Work Package 2, IRSN

- The realisation of a series of experimentation devoted to better understand the transfer of naturally occurring radionuclide to plants or their mobility in soils. These experiments include studies on
 - The influence of plant metabolites and the U speciation on the U transfer and translocation in the model plant *Brassica napus*,
 - The influence of earthworms and microorganisms on ^{226}Ra transfer to ray-grass.
 - The effect of microorganisms on U speciation and mobility in U mine waters.
 - The effect of soil ageing and U contamination form on the mobility of U in soils,
 - The sorption and desorption of Ra and U in scenarios representative of short- and long-term
- The realisation of field campaigns to understand the transfer to plants and the mobility in soils of U, Ra and Th in situ. Two sites are studied: one in Norway and one in France.
- A first exercise on how to carry out dose assessment at conventional waste landfill sites and determination of the disposable mass of NORM residues. This exercise is being developed based on numerical simulations of dose assessments with the RESRAD model to assess the risk from NORM.

Improving radon exposure



Three milestone reports for radon concentration evaluation in buildings



Two reports reviewing radon risk monitoring in workplaces



Field test for radon and radon progeny in historic mine



Report on European surveys and workplace measurement protocols



Field campaign on radon and progeny in forest ecosystem

Improving NORM exposure



Tools for systematic collection about NORM exposure sites



Experiments on mobilization of naturally occurring radionuclides



Field campaigns on radionuclide transfer to plants and soils



Dose-assessment exercise at landfill sites

WP3 held its first in-person meeting in Budapest, boosting collaboration, sharing results, and welcoming new RadoNorm researchers.

The Dosimetry Work Package held its first face-to-face meeting in Budapest on 30th May. Since several WP3 participants attended the 6th European IRPA Congress in Budapest, it was reasonable to dedicate one day to the RadoNorm project. Those who did not participate in person could join virtually.

During the meeting, all task leaders provided a general overview of the task activities, while other participants provided more detailed presentations about their recent results and future plans. Meeting in person significantly helped the discussions, because of the simple fact that there were multiple channels to talk to each other at the same time as opposed to a virtual meeting with its single channel.

It was great to see familiar faces as well as people newly recruited for the RadoNorm project, including young investigators. We also took the opportunity to visit the Castle Hill of Budapest in the evening and to have dinner together. We are looking forward to our next face-to-face meeting in Munich in October as part of the 2nd Annual Meeting.



Dr. Balázs Madas, leader of Work Package 3, EK



Dr. Sisko Salomaa, WP4, STUK

Dr. Sisko Salomaa will retire in September 2022.

**A BIG THANK YOU FOR YOUR HARD WORK AND VERY NICE
COLLABORATION!**

Dr. Päivi Roivainen took over WP4, advancing research on radon/NORM health effects, co-exposures, risk assessment in humans and the environment.

Dr. Päivi Roivainen will start as a new WP4 leader in September 2022. She has a PhD degree in environmental science and works as a senior researcher at University of Eastern Finland (UEF). She has been involved in several national and international projects at UEF and Radiation and Nuclear Safety Authority (STUK) since 2006. In RadoNorm she also participates in WP2.

The overall objective of WP4 is to generate new knowledge related to biological effects and responses after exposure to radon and NORM that have implications for risk assessment and radiation protection of humans and the environment and to reduce the existing uncertainties in risk assessment. To achieve this goal, WP4 is structured into nine Tasks (4.1-4.9). We address major knowledge gaps in human health risk assessment of radon and NORM, such as interaction between radon and smoking for lung cancer, risks of radon outside of the lung, risks associated with radon exposure during childhood, risks from radon and NORM in drinking water, mechanisms of radiation action in the disease processes, and quantification of various sources of uncertainties in risk inference. Furthermore, we address the major knowledge gaps for the risk assessment of non-human biota related to the combined effects of NORM and other stressors and determining adverse outcome pathways leading to such effects. The methods used in WP4 include epidemiological studies and simulations based on epidemiological datasets, risk modelling, molecular epidemiology, experimental studies on combined effects carried out in realistic co-

exposure conditions (radon and tobacco smoke/nanoparticles for human cell systems; NORM and chemicals and particulates for biota) and determining of adverse outcome pathways linking the mechanisms and effects after co-exposures.

During the first 18 months of the RadoNorm project, work has started in all tasks. Preparatory actions for epidemiological studies have included important steps such as data transfer agreements and ethical permissions. Smoking risk models with a temporal exposure window have been developed to include intensity and duration of smoking and time since quitting smoking, and geometric mixed models for interaction between cumulated radon exposure and smoking have been developed. To study radon-related risks other than lung cancer among adults, detailed specifications of analysis plans regarding outcomes, risk models and subgroups have been carried out. Aiming at pooled analyses of national studies on the association of radon and childhood cancers, leukaemia and brain cancer, studies on national cohorts have been continued. Radon detectors that are sensitive to thoron (^{220}Rn) can overestimate radon (^{222}Rn) exposure. This leads to an underestimation of lung cancer risk per radon exposure. To study this, the detectors used in previous epidemiological studies are tested for their sensitivity to thoron. Mechanisms of radiation action in lung cancer are studied among never smokers exposed to radon. In addition to molecular characterisation of non-small-cell-lung-cancer among 1000 patients, the genetic alterations found with the molecular phenotype in animals (rats) and humans exposed at work (miners) are studied. Various sources of uncertainties in radon-induced lung cancer risk inference are studied. To develop and fit Bayesian hierarchical models based on survival disease models and shared error structures may provide improved considerations of exposure and dosimetric uncertainties. Biologically-based models on lung carcinogenesis are developed that integrate molecular data, calculate lifetime risk and contribute to the AOP development. There are few studies focusing on the risk from ingestion of naturally occurring radionuclides such as radon, uranium and radium, and better exposure characterisation from different drinking water sources is needed. Experimental studies on effects and mechanisms of action of combined exposures to radon or NORM and other stressors relevant of true exposure situations of humans and biota have been started by reviewing and setting up co-exposure systems (cells, rodents, aquatic organisms). Based on the experimental data, predictive models will be established for the combined effects of multiple stressors for lung cancer caused by radon/tobacco and ecotoxicologically relevant endpoints.



Dr. Päivi Roivainen, leader of Work Package 4, UEF



Dr. Ales Fronka, leader of Work Package 5, SURO

Special theoretical and experimental works were carried out focused on determining the scientific correctness of two measurement methods for radon diffusion coefficient determination in waterproof membranes – the one-side method according to ISO/TS 11665-12 versus the two-side method according to ISO/TS 11665-13. For the evaluation of the measurements, a numerical model was developed and validated in accordance with ISO/TS 1165-12:2018. Within the established boundary conditions, both methods were found to be in agreement, but the limited applicability of the single-sided method in the measurement of composite materials was also demonstrated.

A comprehensive questionnaire aiming to collect information about approaches currently used in European countries related to the measurement of radon progenies, attached and unattached fraction, aerosol concentration and other parameters describing workplace conditions was developed. The questionnaire was distributed among the partners of subtask 5.4.2; collected responses were summarised.

Underground workplace located in a publicly accessible historical tin mine was selected by SURO for detailed in-situ measurement campaigns; the measured quantities are radon concentration via continuous radon monitors and integrating detection systems, short term periodical campaigns to assess radon decay products concentration and unattached fraction. The workplace is typical with

rapid changes in radon concentration, ranging from hundreds of Bq/m³ up to tens of kBq/m³.

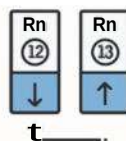
During the monitored period, a document “Comparison of personal dose assessment of workers from radon and radon progeny based on personal dosimeters application and workplace continuous and integral monitoring” has been elaborated. The first part of the document describes the basics of measurement and detection principles of various types of personal dosimeters to determine the effective dose from inhalation of radon or radon decay products. The second part of the document will contain the results of comparison measurements of all available personal dosimeters, a description of implemented test procedures, and evaluation methods.

A mathematical dynamic model was elaborated upon for radon isotopes and their decay products, the temporal and spatial dispersion of radon isotopes and their decay products in an object with forced ventilation. Based on Ventgraph, a software used for ventilation system simulation in underground mines, an additional software module was developed for predicting radon risk (including both radon isotopes, i.e. Rn-222 and Rn-220, and their progeny) in underground workplaces. The software is under testing and verification in Old Silver Mine in Tarnowskie Góry, Poland. The use of this software has been offered to other RadoNorm partners.

Data and information gathered through an e-NORM survey (Survey on naturally occurring radioactive materials) are currently being analysed as a joint WP2 and WP5 project effort focused on NORM research activities.

One of the important achievements was the successful organisation of a workshop with the European NORM Association (ENA). A decision was taken together with ENA vice president Mr. Christian Kunze and the NORM X organising committee to include RadoNorm research presentations in several ENA sessions and to organise a panel discussion dedicated to RadoNorm. The panel discussion was moderated by the ENA vice president, Christian Kunze and RadoNorm representative, Cristina Nuccetelli. The workshop aims were achieved, i.e. collections of critical and constructive remarks concerning NORM e-survey structure, broadened target group of potential responders and identification of new sources of data and further collaboration. All Symposium presentations are available for download at the ORPNET webpage of the IAEA with the link: <https://nucleus.iaea.org/sites/orpnet/resources/SitePages/NORMX.aspx>

An application of radioecological models for NORM waste treatment based on mixing and blending of solid NORM in coal subsurface mining was assumed. The legacy site considered is the former mining site S0ve, a decommissioned facility for niobium (Nb) reduction in the Norwegian county of Telemark, south-eastern Norway. Review of the preliminary data available was done. Depending on data collected in WP 5.1, other options are under consideration, such as a former coal mining area in the Czech Republic and other NORM sites in Finland.



The scientific correctness of two methods for radon diffusion coefficient determination in waterproof membranes was evaluated.



A questionnaire was developed to gather information on measurement approaches currently used in European countries.



An underground tin mine was chosen for in-situ radon measurement campaigns.



A document outlining the comparison of personal dose assessment methods was elaborated.



A workshop with European NORM Association was organized.



An application of radioecological models for NORM waste treatment in coal subsurface mining was assumed.



An application of radioecological models for NORM waste treatment in coal subsurface mining was assumed.

WP6 applied diverse research methods to explore radon risk perception, communication, industry attitudes, and citizen engagement.

Multiple qualitative, quantitative and mixed method studies were developed and applied in WP6 in the last period: systematic literature reviews, semi-structured interviews (Belgium, Slovenia, Czech Republic), public opinion surveys (Belgium, Czech Republic), design thinking workshops (Slovenia, Belgium), focus groups discussions (Ireland), framing analysis (9 EU member states), media content analysis (Belgium), lab experiments (Ireland, Belgium), and engagement methods for citizen science projects (France, Ireland, Hungary, Norway).

Through interviewing representatives of the concrete industry, numerous factors were identified that impact industry's perception and potential acceptance of using NORM containing by-products in construction materials. Interestingly, each of these factors was linked by the interviewed representatives to the expectation that government –rather than industry- should take action (Love N. et al. 2022).

Public opinion surveys showed that there is room for methodological improvements in surveys, for instance, control for bias or considerations for multi or unidimensionality of measurements (Muric M., 2022; Perko

et al. 2022).

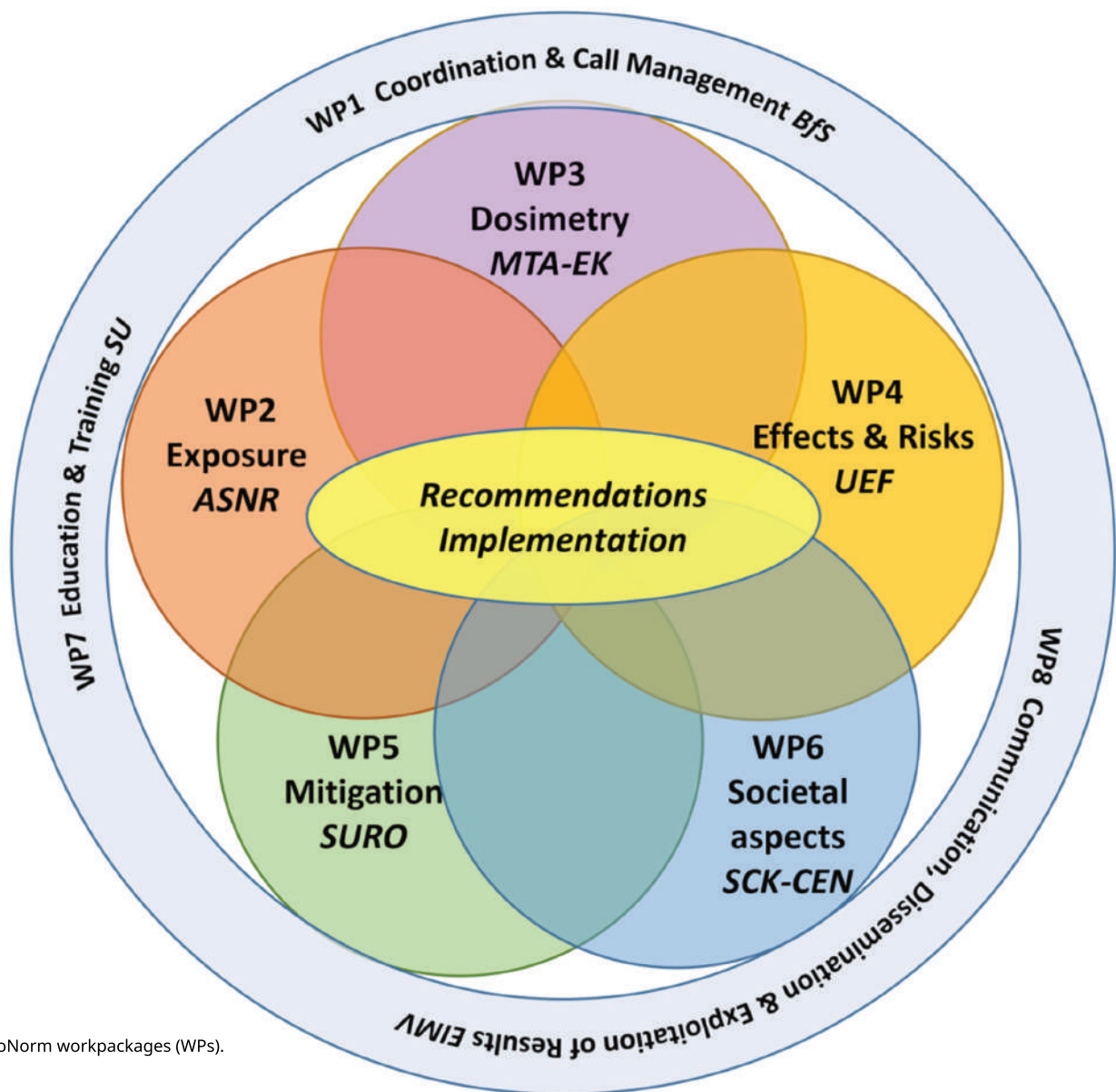
Design thinking workshops confirmed that various interventions are needed to address the gap between radon awareness and protective behaviour, including policy and information interventions, as well as economic policy instruments. Regarding communication, the results show that all types should be adopted: stakeholder communication, mass communication, traditional media, social media, and interpersonal communication (Apers et al. 2022). Focus groups highlighted, among others, that those not remediating for radon believe less that there is a threat due to radon and that they have lower trust in the radon-related information shared by authorities and contractors than remediators. Remediators perceive radon as a high risk that may have negative health consequences; in contrast, non-remediators think that lung cancer is a complex issue, which cannot be explained solely by radon. Having children in a dwelling was a motivator for remediation, while not having children in the dwelling provided an “excuse” not to remediate (Hevey et al. 2022).

Being aware of the existence and contents of radon frames which potentially challenge or contradict public health interventions, e.g. in the context of “radon spas”, helps responsible authorities to design more effective campaigns and interventions (Geysmans et al. 2022). Furthermore, four pilot citizen science initiatives have been prepared, and at the ERPW, a call for citizen science initiatives on radon launched across Europe will be presented. (Martell et al. 2022; Schieber et al, 2022).

In addition, the RICOMET 2022 conference <https://nucleus.iaea.org/sites/orpnet/resources/SitePages/NORMX.aspx> dedicated specific RadoNorm sessions through two days of the conference.



Dr. Tanja Perko, leader of Work Package 6, SCK CEN



RadoNorm workpackages (WPs).

Events and trainings: past and future

Spring and summer enabled lively scientific exchange, with PhD students presenting at major conferences and joining summer schools. WP6's Sofie Apers earned a best method award at RICOMET. New PhD/ECR positions were opened, and GIG ran a successful international training course. Travel grant interest also reached a record high.

Events and trainings: past and future



Dr. Andrzej Wojcik, leader of Work Package 7, SU
Dr. Warren John, leader of Work Package 1, BfS

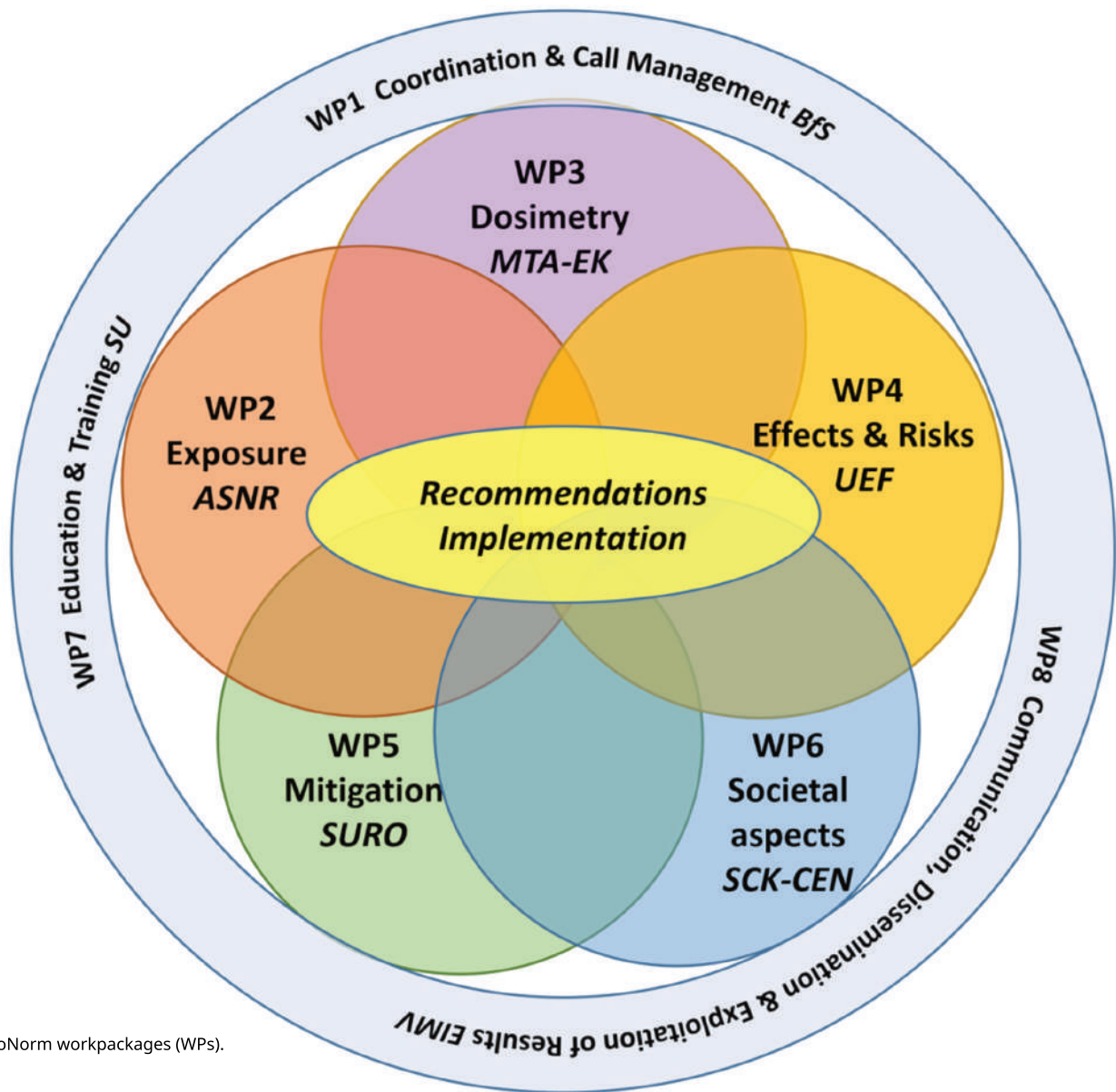


The onset of spring and summer brought many opportunities for travel, exchange and interaction among the scientific community. Institutes and governments have been easing travel restrictions, making it easier for our young scientists to participate in research conferences and summer schools. A number of enthusiastic PhD students held talks and presented their posters in conferences such as NORM X, RICOMET 2022, CARST 2022 and IRPA 2022, as well as spent time in summer schools and exchange programs in Europe. Sofie Apers proudly represented WP6 at RICOMET 2022 and was awarded a prize for the best method.

At least eight PhD and ECR positions were also opened in the framework of RadoNorm to contribute to various work packages in the project. Several of these positions have already been filled, with ongoing recruitment for the remaining open positions.

Furthermore, the Silesian Centre for Environmental Radioactivity (GIG, Poland) successfully conducted its course titled “Naturally occurring radionuclides – when and why their presence is considered in terms of radiation protection?” for the second time, with 17 participants from 12 countries. The course spanned a length of two weeks and was well-received by the participants.

The last call for travel grant applications brought the highest number of applications since the start of the project. We are therefore hopeful that we can look forward to much livelier summer and fall seasons.



RadoNorm workpackages (WPs).

Latest deliverables and publications

Four new RadoNorm papers address societal NORM challenges, impact of building codes on indoor radon, improvements to national radon policies, and conflicting health frames on European radon spa websites, highlighting the need for better risk communication and evidence-based interventions.

Four new papers have been published as part of the RadoNorm achievements:

Turcanu C, Perko T, Muric M, Popic JM, Geysmans R, Železnik N. **Societal aspects of NORM: An overlooked research field.** J Environ Radioact. 2022 Apr; 244-245:106827. doi: 10.1016/j.jenvrad.2022.106827. Epub 2022 Feb 1. PMID: 35114639.

While technical aspects of exposures to the naturally occurring radioactive material (NORM) are well explored, social science research on NORM is scarce, poorly indexed and dispersed across peer-reviewed literature, as well as various academic disciplines. Through an exploratory review of grey literature and a systematic review of scientific peer-reviewed articles published until December 2020, this paper addresses the following questions: (a) What are the societal challenges related to NORM? (b) What type of scientific research is being conducted on the societal aspects of NORM, and (c) To what extent do the findings answer the identified challenges? Unfortunately, the results of this study demonstrate a research gap related to the social, economic and cultural aspects of NORM management. Although the few existing studies offer some insights, for instance in relation to risk perception and risk communication, most of the societal challenges identified have not been addressed yet. This demonstrates the strong need for evidence-based social science studies in order to improve the management of NORM.

Haanes H., Kolstad T., Finne I. E., & Olsen B. (2022). **The effect of new building regulations on indoor radon in radonprone municipalities.** Journal of the European Radon Association, 3. <https://doi.org/10.35815/radon.v3.7886>

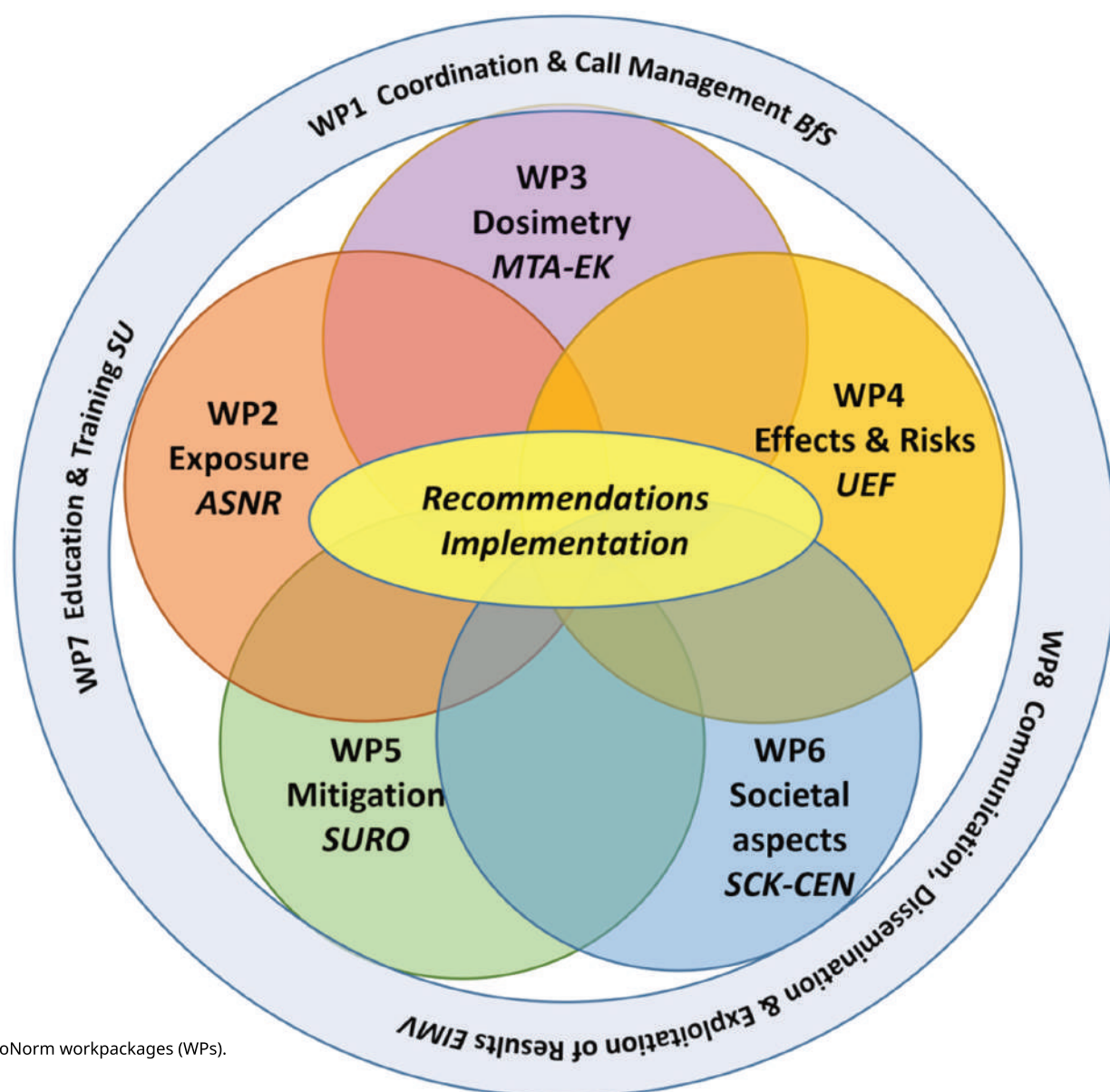
Radon is an important contributor to public radiation dose, and it is important to monitor levels in homes and introduce measures to reduce radon concentration levels, both overall and where levels are especially high. In Norway, new building regulations were introduced in 2010, which required balanced ventilation and preventive measures to reduce indoor radon levels, including a radon barrier toward the ground and pressure-reducing features beneath the building that prevent soil gas from entering (radon sump). Investigations of randomly selected homes all across Norway have shown that houses built under these new regulations have significantly lower radon levels. However, a few municipalities in Norway are especially radon-prone and have houses with particularly high levels. It is crucial to verify the effect of the new regulations in these municipalities, which we have done in this study. Here, we show that both preventive radon measures and balanced ventilation and the building regulations of 2010 have significant effects on reducing the radon levels in the houses of the public. Noticeably for management, houses with a well-ventilated crawl space, which have been exempt from the required preventive measures, still, in some cases, have levels above the action and maximum recommended levels.

Mc Laughlin JP, Gutierrez-Villanueva JL, Perko T. **Suggestions for Improvements in National Radon Control Strategies of Member States Which Were Developed as a Requirement of EU Directive 2013/59 EURATOM.** Int J Environ Res Public Health. 2022 Mar 23;19(7):3805. doi: 10.3390/ijerph19073805. PMID: 35409491; PMCID: PMC8997596.

Exposure to the indoor air pollutant radon is considered to be a significant health risk globally, as has been demonstrated by many studies over time. A recent WHO statement on radon estimates that, worldwide, approximately 80,000 people may die every year due to lung cancer associated with radon exposure. The recent years have also seen huge improvements in radon policies in European countries, as a consequence of the issuing, in 2013, of the Council Directive 2013/59/Euratom. Although the protection of workers from radon exposure is well established, the protection of the general public needs more improvements. The main objective of this paper is, first, to acknowledge and recognise the improvements in radon protection policies, but also to show that there are many areas where improvements are desirable and possible. The final goal is to suggest better ways to protect the general population from exposure to radon gas. The suggestions are based on the experiences of the co-authors, who come from different disciplines related to radon management. The following fields or areas where improvements are possible are identified: risk communication, building codes, radon policies, including funding, research and protection of children. We describe the work that has been conducted and the possible improvements and solutions in these fields.

Geysmans R, Perko T, Keser M, Pözl-Viol C, Fojtíková I and Mihók P (2022) **Cure or Carcinogen? A Framing Analysis of European Radon Spa Websites.** Int J Public Health 67:1604559. doi: 10.3389/ijph.2022.1604559

Radon, a radioactive gas, is among the leading causes of lung cancer worldwide. While public health authorities emphasise radon's health risks, there are spas across Europe which claim health benefits of radon. This study investigates how websites of European radon spas frame radon gas, in order to understand the potential controversy between "radon as carcinogen" and "radon as cure," and its potential impact on public health interventions. A two-phased frame analysis of websites of radon spas (n = 26) situated in the European Union. Five frames are identified, which present radon as a 1) source of health, 2) natural gas, 3) (non) risk, 4) luxury and 5) fountain of youth. These five partly overlapping frames are at times in clear contrast with the ways in which radon is presented in a public health context. Being aware of the existence and contents of radon frames, which potentially challenge or contradict public health interventions, helps responsible authorities in designing more effective campaigns and interventions.



RadoNorm workpackages (WPs).

Researchers in a spotlight

Susanne Sachs and Thuro Arnold (HZDR) co-lead RadoNorm task 2.7, focusing on geochemical and biological processes controlling NORM mobility in soils. Arnold specialises in radionuclide biotransformation. Tuukka Turtiainen (STUK) contributes to tasks on indoor radon variation and thoron-related measurement uncertainties.

Researchers in a spotlight



Dr. Susanne Sachs, HZDR, Germany
Dr. Tuukka Turtiainen, STUK, Finland



Susanne Sachs, PhD, is a senior scientist in the Department of Biogeochemistry of the Institute of Resource Ecology at the Helmholtz-Zentrum Dresden-Rossendorf. Her current research interest is the investigation of the interaction of radionuclides with plants on the molecular and cellular level to obtain a more profound process understanding for the improvement of radioecological models. In the RadoNorm project, Susanne Sachs, together with Thuro Arnold, leads task 2.7 that aims to identify geochemical and biological processes controlling NORM mobility in soils. The main objectives involve the effects of NOR speciation, including changes induced by microbial processes, as well as the identification of soil properties that govern the mobility of NOR in soils, the dynamics of sorption and desorption reactions and the development of models to predict K_d values from site-specific information and laboratory experiments. In addition, she is involved in task 2.6 by studying the influence of the uranium speciation on its transfer to plants. Together with Thuro Arnold, Susanne Sachs also leads the topical roadmap working group NORM in the European Radioecology ALLIANCE.

Tuukka Turtiainen, PhD, is a radiochemist and environmental scientist specialising in indoor environments. He works as a senior inspector at STUK – Radiation and Nuclear Safety Authority (Finland), where he is responsible for the radon standard laboratory and the regulatory control of radioactivity in construction products. He has been involved with research on radon exposure since the 1990s and has a special interest in the development of exposure assessment methods and sampling. In the RadoNorm project, he is involved in work packages 2.1 and 2.3, dealing with the temporal and spatial variation of radon in buildings to develop improved sampling protocols and in task 4.4 related to the uncertainties of radon measurements due to thoron.

Dr. Thuro Arnold is advancing models of radionuclide behaviour and NORM exposure through geochemical and biological research.

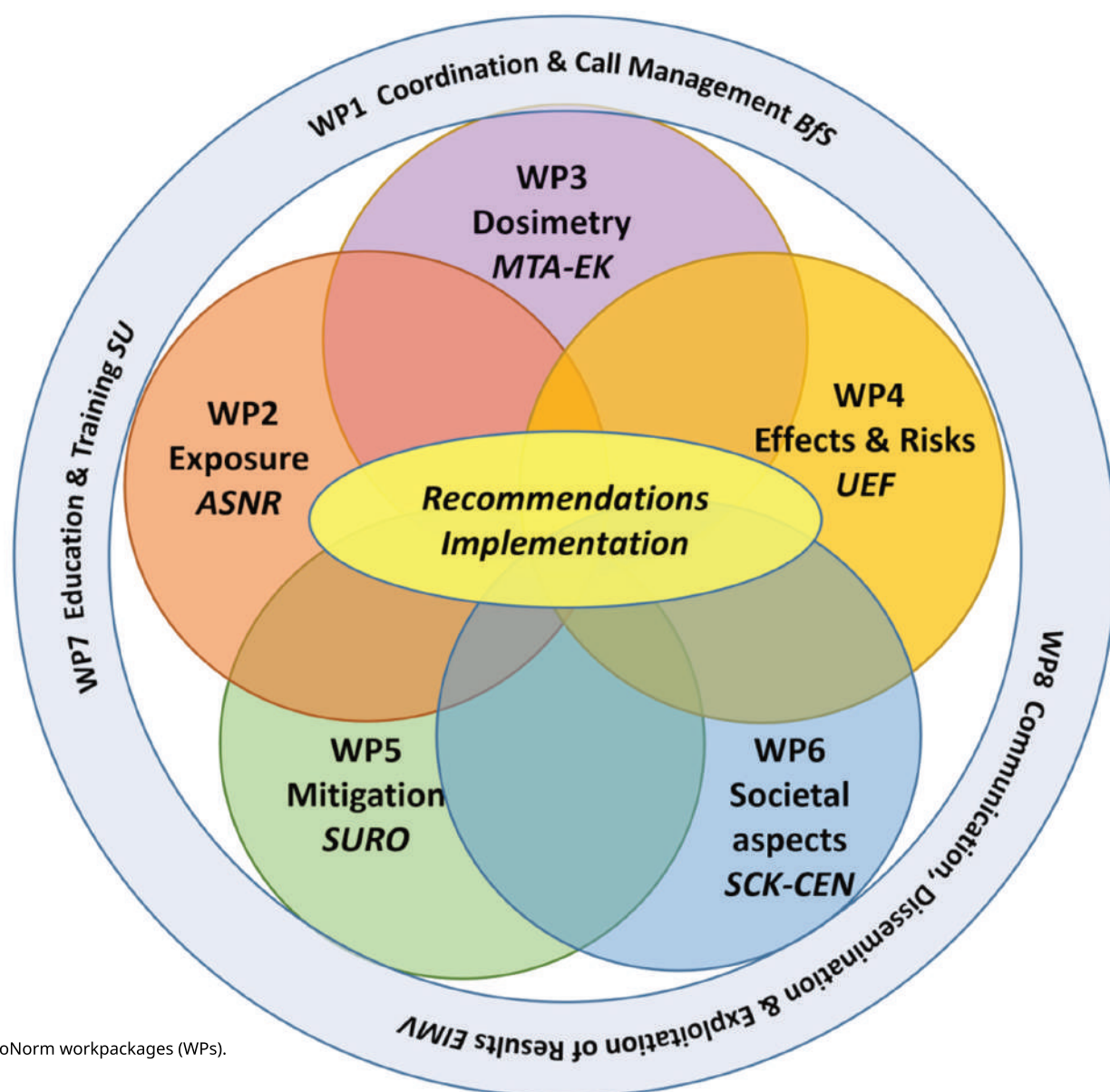
Thuro Arnold, PhD, is a geochemist and was involved in various EU projects. He is the scientific project coordinator of the Institute of Resource Ecology at the Helmholtz-Zentrum Dresden-Rossendorf and is responsible for international and national projects. Currently, he is involved in the EU projects EURAD and RadoNorm, where, together with Susanne Sachs, Thuro Arnold is co-leader of task 2.7.

His field of research is the biotransformation and bioaccumulation of heavy metals and radionuclides in microorganisms and biofilms. He also has a strong background in sorption studies and is involved in the development of models to account for radionuclide movements through rock and soil horizons under varying geochemical and climatic conditions.

HZDR is a member of the European Radioecology ALLIANCE, and together with Susanne Sachs, he is leading the working group NORM of the European Radioecology Alliance. WG NORM is gathering knowledge, which is needed for a more reliable description and prediction of the behaviour of natural radionuclides in environmental compartments, including dynamic processes. This new knowledge is necessary to assess NORM resulting exposures of both humans and non-human populations with substantially reduced uncertainty.



Dr. Thuro Arnold, HZDR, Germany



RadoNorm workpackages (WPs).

RadoNorm engagement opportunities

The RadoNorm website and social media share project updates, results, and engagement options. Stakeholders can join groups, subscribe to the newsletter, and attend events. The 2022 Annual Meeting (5–7 Oct, Munich) will cover radon/NORM measurements, health risks, and mitigation, with stakeholder participation and open discussions.

RadoNorm offers project information, stakeholder engagement, and updates via social media and newsletters.

The RadoNorm website provides much information about the project, the work programme and challenges to be addressed, its development and results, and interaction and engagement possibilities. The linked RadoNorm social media with LinkedIn, Twitter and YouTube emphasise the latest news and events to fulfil the foreseen dissemination of the RadoNorm project. We would be most happy if you would connect with us.

RadoNorm established different engagement opportunities for the related and interested stakeholders. Several stakeholder groups are established for active involvement of different representatives in the project's activities, such as pilot testing of communication tools, development of new regulatory standards, discussions on scientific findings, or to be just informed about the RadoNorm results. You are most welcome to join the RadoNorm stakeholder groups. It is easy to submit your application.

The subscription to more information, like Newsletter issues, is also available. The RadoNorm partners, stakeholders and other groups are regularly informed about publications, news, events, and call opportunities. All developed contact databases are managed according to the RadoNorm Privacy policy.

The Second RadoNorm Annual meeting will be held from the 5th to the 7th of October 2022 in Munich, Germany, at the BfS premises. The meeting will be a hybrid to allow stakeholders to attend; however the registration is required. The proposed topics will address the following:

- Measurements – focused on measuring radon/NORM presence and exposure, actions and communication on testing, regulatory frameworks ...
- Risk and health impacts – focused on effects of exposure, risk perception, epidemiology, managing uncertainties, awareness, dose assessments...
- Remediation/mitigation – focused on limiting exposure, mitigation technologies, governance strategies, remediation behaviours, ...

In all topics, the work done by the RadoNorm project and also future plans will be presented in a holistic and multidisciplinary way, followed by discussion. A separate panel discussion will also include RadoNorm stakeholders.



Dr. Nadja Železnik, leader of Work Package 8, EIMV

Sources



Short news from WPs

- ✚ RICOMET 2022 conference, <https://nucleus.iaea.org/sites/orpnet/resources/SitePages/NORMX.aspx>

Latest publications

- ✚ Turcanu et al., doi: 10.1016/j.jenvrad.2022.106827
- ✚ Haanes et al., <https://doi.org/10.35815/radon.v3.7886>
- ✚ Mc Laughlin JP, doi: 10.3390/ijerph19073805
- ✚ Geysmans et al., doi: 10.3389/ijph.2022.1604559

RadoNorm engagement opportunities

- ✚ RadoNorm website, <https://www.radonorm.eu/>
- ✚ LinkedIn, <https://www.linkedin.com/company/radonorm/>
- ✚ Twitter (now X), <https://twitter.com/RadoNorm>
- ✚ YouTube, <https://www.youtube.com/channel/UC6yCORiPX5DXgmu5AaGLn9Q>
- ✚ RadoNorm stakeholder, <https://www.radonorm.eu/stakeholders/>
- ✚ Subscription to more information, <https://www.radonorm.eu/newsletter/>
- ✚ RadoNorm Privacy policy, <https://www.radonorm.eu/privacy-policy/>

Key takeaways



- ☢ **Strong inter-WP collaboration was established, despite lingering pandemic restrictions, enabling significant scientific progress and successful submission of the first 18-month report to the European Commission.**
- ☢ **WP2 advanced radon and NORM exposure assessments by conducting field campaigns in forest ecosystems, analysing radon-prone workplaces, and developing a multi-tiered methodology for NORM site data collection.**
- ☢ **WP3 held its first in-person meeting in Budapest, facilitating in-depth discussions on internal dosimetry progress and future planning, with a focus on individual dose variation and early-career researcher engagement.**
- ☢ **WP3 held its first in-person meeting in Budapest, improving coordination across dosimetry tasks.**
- ☢ **WP4 launched extensive studies on health risks from radon and NORM, including risk models for smokers, children, and drinking water, alongside the development of biologically based models and adverse outcome pathways.**
- ☢ **WP5 completed in-situ radon measurement campaigns in historical mines, developed a dynamic risk modelling tool for underground workplaces, and collaborated with WP2 on analysing NORM-related survey data.**
- ☢ **WP6 conducted diverse empirical research, such as interviews, design thinking workshops, public opinion surveys, and citizen science engagement strategies to address behavioural gaps in radon protection.**
- ☢ **Radon risk communication was analysed through media and framing studies, revealing tensions between public health messaging and radon spa promotions, with recommendations for more effective interventions.**
- ☢ **RadoNorm strengthened capacity and visibility through new PhD/postdoc positions, international training courses, award-winning conference presentations, and preparations for the hybrid Annual Meeting in Munich.**



RadoNorm
Managing risks from radon and NORM

RadoNorm

Newsletter

N°4 - December 2022

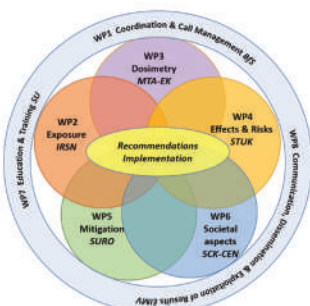


RadoNorm in third year
RadoNorm strengthened collaboration, advanced research, and adapted resiliently post-COVID

Dr. David Broggio - Researcher in a spotlight
Leads dose research, focusing on smoking and uncertainty effects

Dr. Heidi Vandebosch - Researcher in a spotlight
Studies media use, health interventions, radon risk communication strategies

Dr. Olivier Armant - Researcher in a spotlight
Researches radiation ecotoxicology, develops radon outcome pathways



Content

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- 4 Steps in third year – main RadoNorm achievements and challenges
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RadoNorm Newsletter



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Editorial



Dr. Nadja Železnik, leader of Work Package 8, EIMV

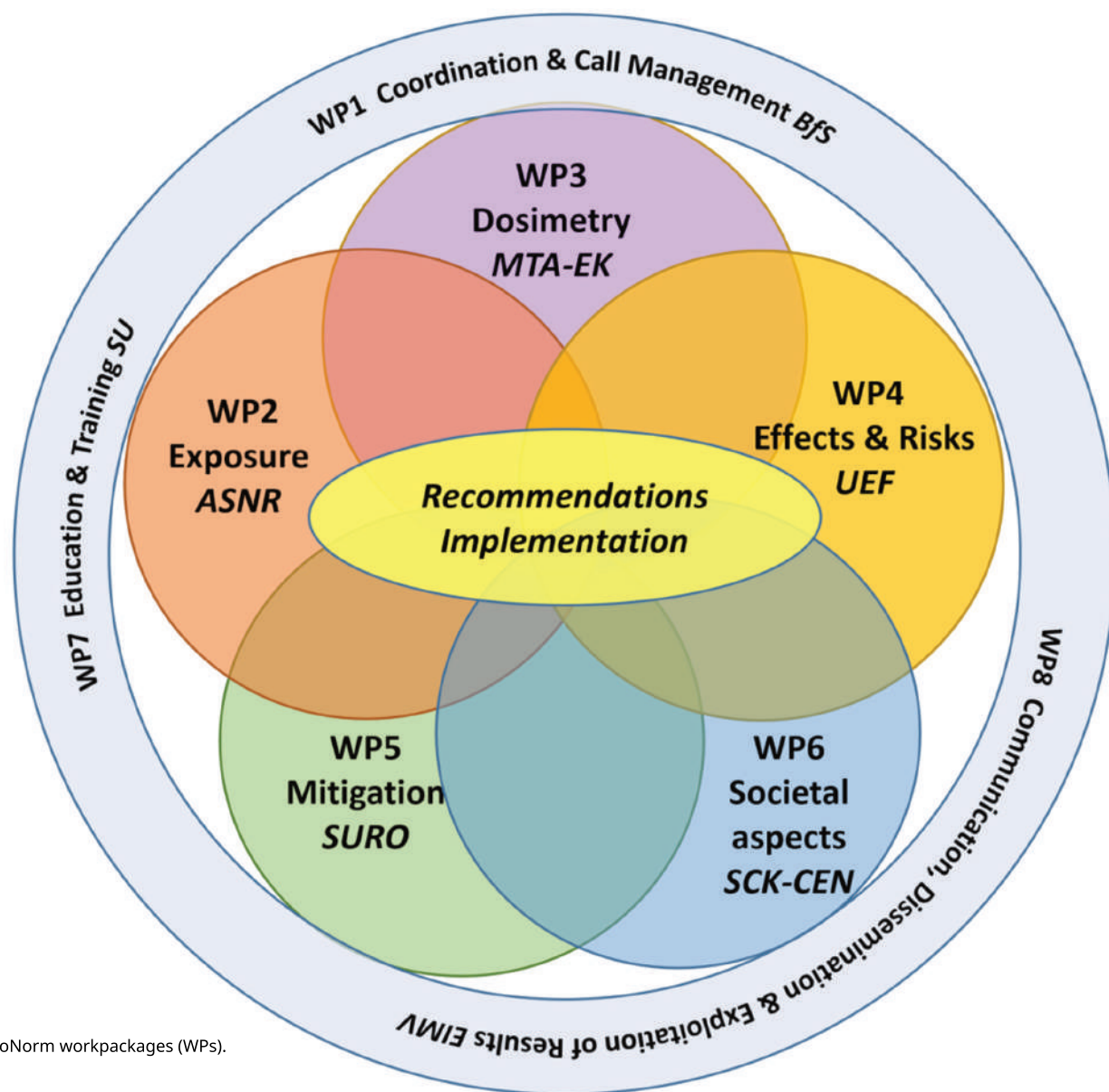
Dr. Nadja Železnik holds a BSc in Physics and an MSc in Reactor Physics from the Faculty of Mathematics and Physics, as well as a PhD in Psychology from the Faculty of Arts, all awarded by the University of Ljubljana, Slovenia. She is an expert in nuclear technology and radioactive waste management, with extensive experience in emergency preparedness and response, as well as in risk perception, communication, education, and training in environmental and nuclear projects.

She has acted as a civil society expert and knowledge manager in numerous European research initiatives, including EURAD-1 and -2, ECOSSENS, and RadoNorm. Her contributions include the development of national strategies, legislative frameworks, feasibility studies, safety and radiological assessments, and stakeholder engagement plans. She has authored communication strategies, training programmes, and information materials to foster public understanding and informed participation in the nuclear and environmental domains.

It is with great enthusiasm that we share this issue of the RadoNorm Newsletter, celebrating the project's steady progress as it enters its third year. With renewed momentum following the easing of pandemic restrictions, RadoNorm has embraced opportunities for collaboration, both virtual and in person, through major scientific events, vibrant annual meetings, and impactful stakeholder engagement.

This issue reflects the deepening scientific and societal contributions across work packages. From pioneering dose modelling and molecular characterisation of radon-induced lung cancer, to citizen science pilots, mitigation technologies, and public behaviour surveys, RadoNorm is strengthening its position as a vital hub for research, policy, and education in radiation protection.

We warmly thank our community of researchers, partners, early career scientists, and stakeholders for their continued dedication and cooperation.



RadoNorm workpackages (WPs).

Steps in third year – main RadoNorm achievements and challenges

In 2022, RadoNorm strengthened collaboration through hybrid meetings, notably its annual meeting in Munich, and active presence at major radiation protection events. Despite challenges, including leadership changes and the war in Ukraine, the project made strong progress. With growing relevance of radiation protection, RadoNorm looks ahead to 2023 with optimism.

RadoNorm advanced research, strengthened collaboration, and adapted to global challenges.

As RadoNorm has just stepped into its third year, it is worthwhile reflecting on key events of 2022. With the COVID-19 restrictions easing out over this year, we have been able to engage more with one another through various meetings. RadoNorm has been well-represented in many European and international radiation protection events, including more notable conferences such as the European Radiation Protection Week (ERPW) 2022 and ICRP2021+1 (organised by the International Commission on Radiological Protection).

Moreover, the coordination team was excited to host this year's annual meeting in October in Munich, Germany. The hybrid event allowed participants to come together to discuss the project's progress and key findings, and many used the opportunity to finally meet colleagues in person and engage in lively discussions. The International Atomic Energy Agency (IAEA) and the International Agency for Research on Cancer, which are part of our advisory board, also remarked that RadoNorm has made solid progress over the last two years and provided guidance for the project's future.

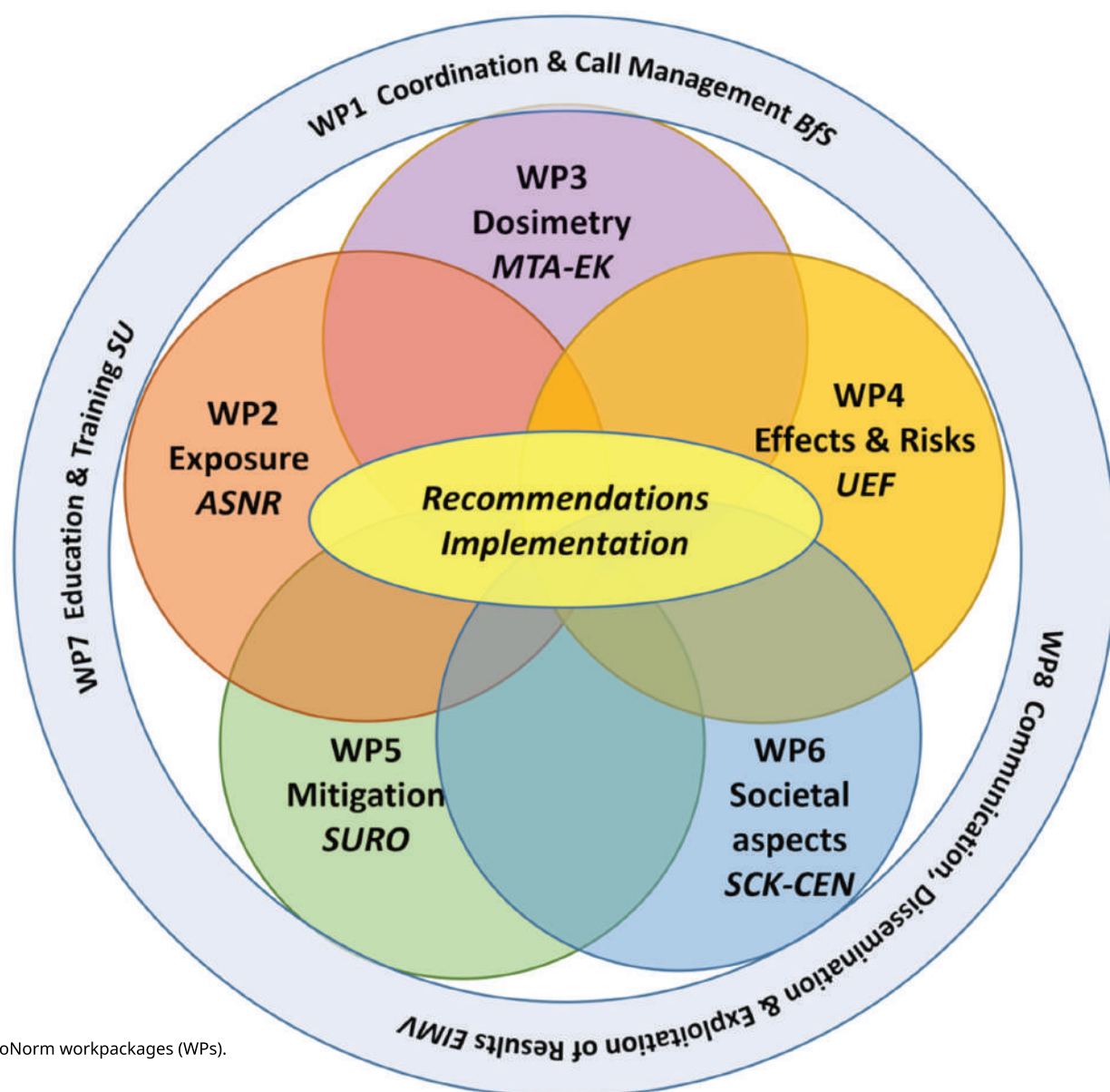
Work package (WP) 4 had to sadly bid farewell to its leader and a very prominent member in the radiation protection community, Sisko Salomaa (STUK). We are very grateful to Sisko for all her hard work in the field and her efforts in WP4, and we wish her all the best for her retirement. At the same time, we are delighted to have Päivi Roivainen (UEF) taking over leadership of WP4, who has already had a dynamic start in her new role.

The many gatherings of this year have repeatedly stressed the importance of radiation protection. With the threat of nuclear attack still looming, radiation protection research has never been more needed. Projects such as RadoNorm therefore help reassure the public that these topics are being addressed and that the European Commission (EC) is taking a proactive stance. In spite of their hardships caused by the war, we are relieved and thankful that our Ukrainian partners are safe and are still very much committed to the project's output.

We have weathered the challenges and crises of this year resiliently and can look forward optimistically to a promising 2023. RadoNorm wishes you season's greetings and a good start to the new year.



Dr. Ulrike Kulka, RadoNorm coordinator, BFS



RadoNorm workpackages (WPs).

Short news from WPs

RadoNorm advanced radon and NORM research in modelling, dosimetry, health effects, mitigation, and public perception. Key achievements include WP milestones, new studies, citizen science initiatives, and Europe's largest radon survey, with strong collaboration and scientific output across all WPs.

WP2 presented key results at major conferences, achieved three milestones, and published NORM site identification tools now of interest to the IAEA.

Results from WP2 have been successfully presented at the ERPW 2022, during our 2nd annual meeting in Munich, and at the International Conference on Radioecology & Environmental Radioactivity (ICRER) 2022 conference, where Joan Serra Ventura from task 2.7 won the 3rd best poster ALLIANCE award.

WP2 also produced three new milestones: one related to task 2.2 on Rn modelling in forest ecosystem (MS15 – “Coupling of the Radon in vegetation model and the ECOFOR SVAT model in the ModelMaker platform”), one related to task 2.3 on the measurement of Rn exposure from building materials (MS18 – “Selection of building materials and description of models and measurement protocols”) and one related to the methodology and tools to identify and characterise the NORM exposure sites (MS22 – “Compiled list (map) of NORM exposure sites of relevance at the European level. Suggestions on available industrial/legacy (with proper data sets) sites to be further used for investigations in the current and evaluation in respecting sub-tasks and other tasks”).

While milestone reports are for private use only and published on the internal RadoNorm website for its participants, WP2 has made publicly available the methodology and tools presented in MS22. These can be used by various institutions in different countries for the identification and characterisation of a variety of NORM sites. Interest in its free access has been shown most recently by the IAEA, which would like to facilitate making NORM inventory in the various IAEA member states. The tools can be found [here](#).



Dr. Laureline Fevrier, leader of Work Package 2, IRSN

Short news from WPs

WP3 results have been shown in different places and via different channels. At the ERPW 2022 in Portugal, the effects of smoking and the effects of different lung diseases on radon dosimetry have been presented. Both talks showed that the same radon exposure may result in different absorbed doses and so in different risks, highlighting an aspect of individual sensitivity rarely discussed. During the ICRP2021+1, models for dose to the embryo and foetus due to radon intakes by the mother were presented as examples of dosimetric peculiarities of people with high public concern. In addition, there is a new publication in Radiation and Environmental Biophysics entitled "Effects of spatial variation in dose delivery: what can we learn from radon-related lung cancer studies?". This review paper summarises the findings of the MELODI Workshop 2020 session on radon, providing an overview of the state of the art in epidemiology, clinical observations, cell biology, dosimetry, and modelling related to radon exposure and its association with lung cancer.

The work is progressing in all nine tasks of WP4. Models for the interaction between cumulated radon exposure and smoking have been developed. Detailed plans to study radon-related risks other than lung cancer among adults have been created. Exchange of information between WP4 and WP3 is essential to calculate doses to individual miners and millers, and preparations for this exchange are ongoing. National studies on the association of radon and childhood cancers are progressing. The final aim is the pooled analysis, for which a safe platform for pooling data has been evaluated, and the availability of background gamma data from a common source has been assessed. The work related to uncertainties in radon risk assessment due to thoron has included a questionnaire, which has been sent to collect information to assess the sensitivity of detectors to thoron. Mechanisms of radiation action in lung cancer are studied among never smokers exposed to radon. In addition to molecular characterisation of non-small-cell-lung-cancer among patients, the genetic alterations found with the molecular phenotype in animals (rats) and humans exposed at work (miners) are studied. Bayesian fitting of several hierarchical models to account for exposure measurement error is carried out, and the corrected risk of death by lung cancer is estimated. To study the risks from radon and NORM in drinking water, a pilot study has been initiated in Norway by collecting water samples. Concerning experimental studies related to combined exposures to radon and NORM and other stressors, the results are ready for the impact of nicotine on alpha-radiation induced DNA damage in BEAS2B cells and co-exposure systems for other experiments with cells and aquatic organisms prepared. Existing data which can be used for the development of Adverse Outcome Pathways have been searched.

One milestone has been delivered: MS42: Exploration of existing data, including information databases (e.g. STORE) for other stressors (tobacco) and endpoint using the AOP-helpFinder Tool.



Dr. Balázs Madas, leader of Work Package 3, EK
Dr. Päivi Roivainen, leader of Work Package 4, UEF

Recently, there have been two important milestones successfully accomplished within the WP 5 Mitigation. Milestone 73 (Workshop with HERCA, IAEA, EC on "Radiation risk mitigation measures applied in NORM involving industries and remediation of legacy sites") is a report that contains information and minutes from workshops that have been accomplished, as well as agendas and schedules for the upcoming events, documenting and mapping the project's progress.

Milestone 69 (Reports on case studies published on the project website) covers activities on data collation concerning existing strategies and technologies applied for the treatment of NORM residues and remediation options at NORM legacy sites. The main objective of these activities is to provide coherent information about existing approaches, identify possible gaps and prepare data for the development of new options. The case studies gathered are intended to be the main input data for the deliverable D5.11 (Report on available solutions and technologies applicable for legacy site remediation, NORM involving industries and treatment of radioactivity in water preparation).

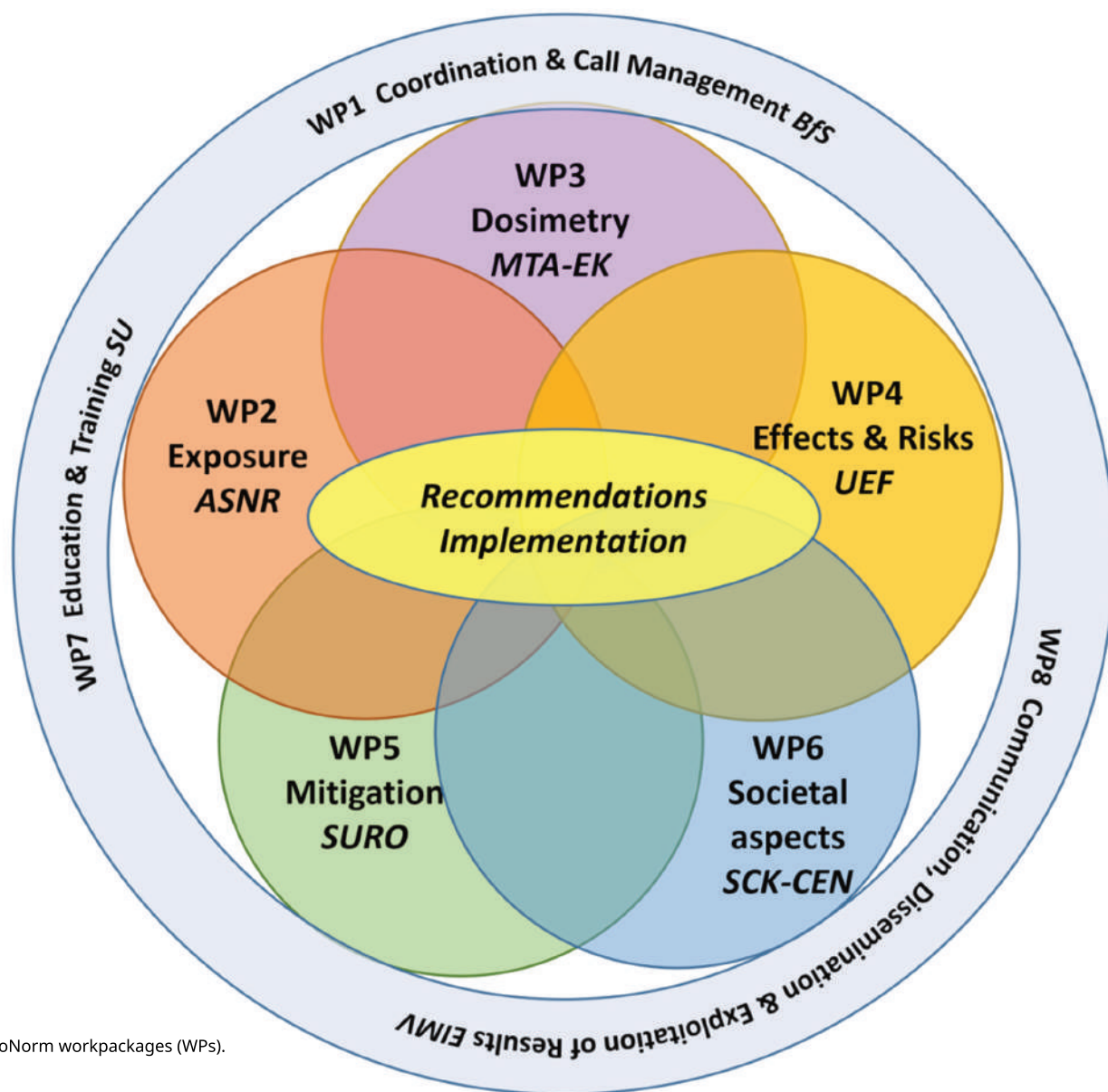
WP6 has managed to publish two deliverables this year and two scientific papers in the last six months, demonstrating the lively engagement within the WP and that the work is progressing well. One particular deliverable, D6.9 (Citizen science model for radon prone areas), has been submitted to the EC for approval and is the first step in the efforts to start citizen science projects across EU member states. The call for citizen science projects has been opened, which will fund several initiatives related to radon testing or radon mitigation in radon-prone areas. The first info webinar was conducted on European Radon Day (7th November) to introduce the concept and answer questions. A second webinar will be organised on 17th February; more information to follow soon. More information about the call can be found [here](#).

Surveys are also underway in Slovenia, Spain, Romania and Ireland and in an additional 11 EUMS and Norway to investigate people's behaviour, attitudes and beliefs related to radon and NORM. This is the biggest ever public opinion survey to take place pertaining to radon and NORM.

WP6 is going to hold its general meeting in February 2023 to discuss progress within the tasks and orient itself for the future.



Dr. Ales Fronka, leader of Work Package 5, SURO
Dr. Tanja Perko, leader of Work Package 6, SCK CEN



RadoNorm workpackages (WPs).

Events and trainings: past and future

RadoNorm ECRs actively participated in conferences, summer schools, and training courses, formed an ECR council, and strengthened collaboration across WPs through new training and networking opportunities.



Dr. Andrzej Wojcik, leader of Work Package 7, SU
Dr. Warren John, leader of Work Package 1, BfS



Our Early Career Researchers (ECRs), consisting of both PhD students and postdocs, participated in a number of events this past summer and autumn. At the ERPW 2022, RadoNorm was well-represented through at least 15 oral and poster presentations. As mentioned above, RadoNorm presented its results at the ICRP2021+1 conference in Vancouver, Canada, where the focus was on the future of radiation protection; a fitting opportunity to involve more young scientists. Summer schools and training courses were also part of the education agenda. Here, several ECRs of WP6, for instance, could participate in external courses for statistics, and other RadoNorm members could take part in internally organised courses such as CELET at Stockholm University or the “NORM impact assessment toolkit: from microorganisms to human cells” course organised by the universities of Porto and Aveiro.

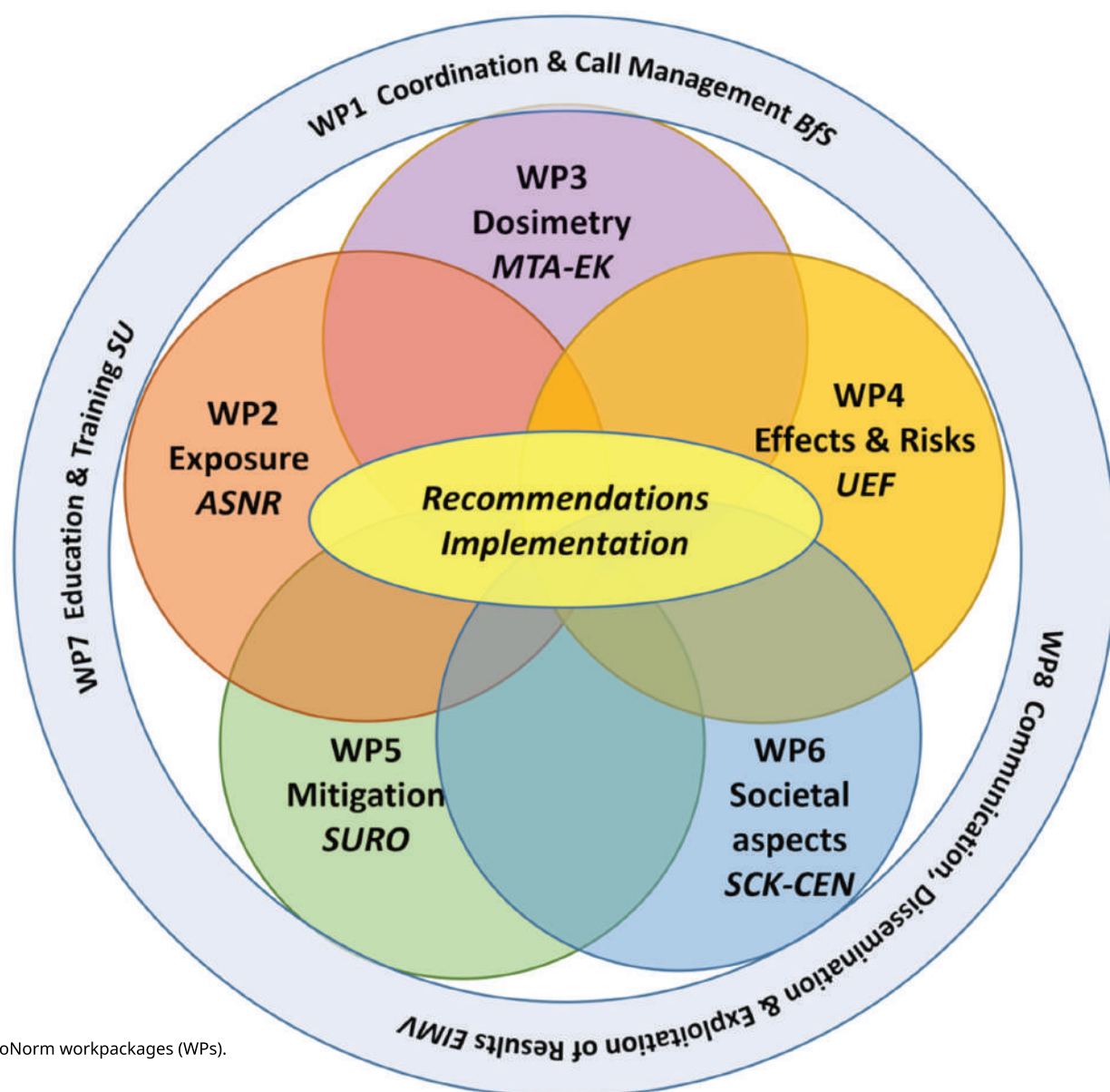
Three new ECRs were welcomed into the project since June. Moreover, the RadoNorm ECR council was founded at the 2nd Annual Meeting in Munich. Here, ECRs volunteered to represent each work package, and it was decided that the council would meet regularly to foster communication between ECRs and to present their research and discuss questions related to radon and NORM. It would help to create a safe space to voice difficulties encountered in research and an environment to get to know members within the project. We are glad that more opportunities were available for interaction

during the year, which has thankfully brought RadoNorm members closer together and fostered some interesting collaborations.

In the last half year, RadoNorm partners organised three training courses:

- From 19th to 30th September 2022, online training on “NORM impact assessment toolkit: from microorganisms to human cells”, by Aveiro University / Porto University (Portugal);
- From 17th to 28th October 2022, training on “Application of Liquid Scintillation Spectrometry (LSC) for NORM measurements”, by GIG (Poland);
- From 14th to 25th November 2022, training on “Cellular effects of high and low LET ionising radiation – Introduction to radiation biology”, by SU (Sweden).

Trainings were very successful and provided, besides educational content, also opportunities for networking and collaboration. More information is available on the website. The RadoNorm calls for training courses during 2023 are now open. Results about the training courses will be announced by the end of January 2023.



RadoNorm workpackages (WPs).

Latest deliverables and publications

New deliverables highlight advancements in social science methods (D6.1), behaviour change communication (D6.5), and PhD recruitment (D7.1). Five papers cover dose modelling, social methodology, radon mitigation, indoor exposure, and risk communication, marking strong interdisciplinary progress.

The following deliverables are now available on the RadoNorm website:

Yevgeniya Tomkiv et al. (2021): **Collection of existing methods, databases, scales, protocols and other tools – state of the art.** D6.1

One of the objectives of the RadoNorm project is to improve methodological qualities of the research related to investigations of societal aspects of radon and NORM exposure situations. This document, the methodological state-of-the-art, provides an overview of the methods that have been applied so far for investigating societal aspects of radon and NORM exposure situations as reported in scientific articles. This is the first attempt to perform a systematic review of the methodological approaches that have been used in social and human studies that aimed at understanding the socio-psychological situation of affected populations and stakeholders. This deliverable can serve as a catalogue of methodological aspects in quantitative, qualitative and mixed-method research related to radon and NORM exposure situations. Moreover, the results of this review will support the development of methodological guidelines for investigating affected populations and stakeholders with special attention to different socio-political and cultural environments in the other tasks of the RadoNorm project. It will also contribute to the development of the new and state-of-the-art methods and approaches to better address technical, health and societal aspects of radon and NORM exposure situations.

Apers S., Vandebosch H., de Grouchy K. K., Perko T. and Hevey, D. (2022): **Empirical study to identify change agents and communication effect in different approaches to behaviour change.** 5.

One of the objectives of the RadoNorm project is to develop health communication tools and methods for behaviour change, focusing on individuals as well as specific groups. The deliverable D6.5 reports the research on determinants of people's behaviour by following the Intervention Mapping Protocol. The deliverable provides evidence, collected by qualitative and quantitative methods, on the most important determinants of (un)healthy behaviours such as: (not) doing a home radon test and (not) applying mitigation actions. For each of these behaviours, there is a wide range of potential behavioural determinants for residents as well as specific target groups such as building professionals (e.g. contractors for remediation actions).

Wojcik A, Birschwilks, M. (2021): **Recruitment of PhD students and Postdocs for specified projects in RadoNorm.** D7.1.

RadoNorm is integrating E&T activities into the scientific and technical development work of the project by initiating a PhD and Postdoctoral grant programme, which will be open to talented students and early career scientists from all European countries. It will be embedded in a joint postgraduate programme organised by RadoNorm and will be organised in a way that the PhD

and early career researchers (ECR) projects will be hosted in RadoNorm partner institutions. The E&T programme of RadoNorm will be based on an open call for PhD students and ECRs and joint supervision in the due course of their projects. It will include financial support for courses, which will be organised in an open-call manner. In this way, future researchers will receive the best possible education in the field of radiation protection research and pave the road for maintaining and expanding relevant competence in Europe.

Five new papers have been published as part of the RadoNorm achievements:

Szabolcs Polgár, Paul N. Schofield, Balázs G. Madas. (2022). **Datasets of in vitro clonogenic assays showing low-dose hyper-radiosensitivity and induced radioresistance.** Scientific Data | (2022) 9:555 | <https://doi.org/10.1038/s41597-022-01653-3>.

Low-dose hyper-radiosensitivity and induced radioresistance are primarily observed in surviving fractions of cell populations exposed to ionising radiation, plotted as a function of absorbed dose. Several biophysical models have been developed to quantitatively describe these phenomena. However, there is a lack of raw, openly available experimental data to support the development and validation of quantitative models. The aim of this study was to set up a database of experimental data from the public literature. Using Google Scholar search, 46 publications with 101 datasets on the dose-dependence of surviving fractions, with clear evidence of low-dose hyper-radiosensitivity, were identified. Surviving fractions, their uncertainties, and the corresponding absorbed doses were digitised from graphs of the publications. The characteristics of the cell line and the irradiation were also recorded, along with the parameters of the linear-quadratic model and/or the induced repair model if they were provided. The database is available in STOREDB and can be used for meta-analysis, for comparison with new experiments, and for development and validation of biophysical models.

Melisa Muric, Peter Thijssen, Catrinel Turcanu, Tanja Perko & Yevgeniya Tomkiv (2022): **Foxes caught in the same snare: a methodological review of social radon studies,** Journal of Risk Research, DOI: 10.1080/13669877.2022.2127850

Mitigating risk from exposures to indoor radon is a critical public health problem confronting many countries worldwide. In order to ensure effective radon risk management based on social scientific evidence, it is essential to reduce scientific uncertainty about the state of social methodology. This paper presents a review of methodological (best) practices and sensitivity to bias in research on public attitudes and behaviours with regard to radon risks. Using content analysis, we examined characteristics of research design, construct measurement, and data analysis.

Having identified certain challenges based on established and new typologies used to assess methodological quality, our research suggests that there is a need for attention to (limitations of) cross-sectional design, representative and appropriate sampling, and a pluralist approach to methods and analysis. Furthermore, we advocate for more comparative research, rigorous measurement and construct validation. Lastly, we argue that research should focus on behavioural outcomes to ensure effective radon risk management. We conclude that for any field to thrive, it is crucial that there is methodological reflexivity among researchers. Our recommendations serve as a useful guide for researchers and practitioners seeking to understand and enhance the rigour of social methodology in their field.

Kulka et al., **RadoNorm – towards effective radiation protection based on improved scientific evidence and social considerations – focus on RADON and NORM**. Published by EDP Sciences, EPJ Nuclear Sci. Technol. 8, 38 (2022), <https://doi.org/10.1051/epjn/2022031>

RadoNorm aims to manage risks from exposures to radon and naturally occurring radioactive material (NORM) to promote effective radiation protection based on improved scientific evidence and social considerations. It supports the European Member States and the EU Commission (EC) in implementing the Basic Safety Standards for protection against ionising radiation hazards at the legislative, executive, and operational levels (Directive 2013/59/EURATOM). The project is grounded on (1) implementation of multidisciplinary and innovative research and technologies, (2) integration of education and training, and (3) dissemination of project results targeting a broad stakeholder community, including the public, regulators, and policymakers. The objectives are achieved through scientific research-related topics (exposure, dosimetry, biology, epidemiology, societal aspects), cross-cutting topics (education and training, dissemination, ethics) and project management. The project will yield guidelines at the legal, executive and operational levels. It will enable consolidated and harmonised decision-making in the field of radiation protection, considering societal aspects and sustainable knowledge transfer. The project contributes to EC activities to strengthen radiation protection in a consistent and joint manner, as has already been done through the establishment of radiation protection platforms, the promotion of projects (e.g., DoReMi, OPERRA) and the partnership CONCERT-EJP. The outcomes may also impact future recommendations.

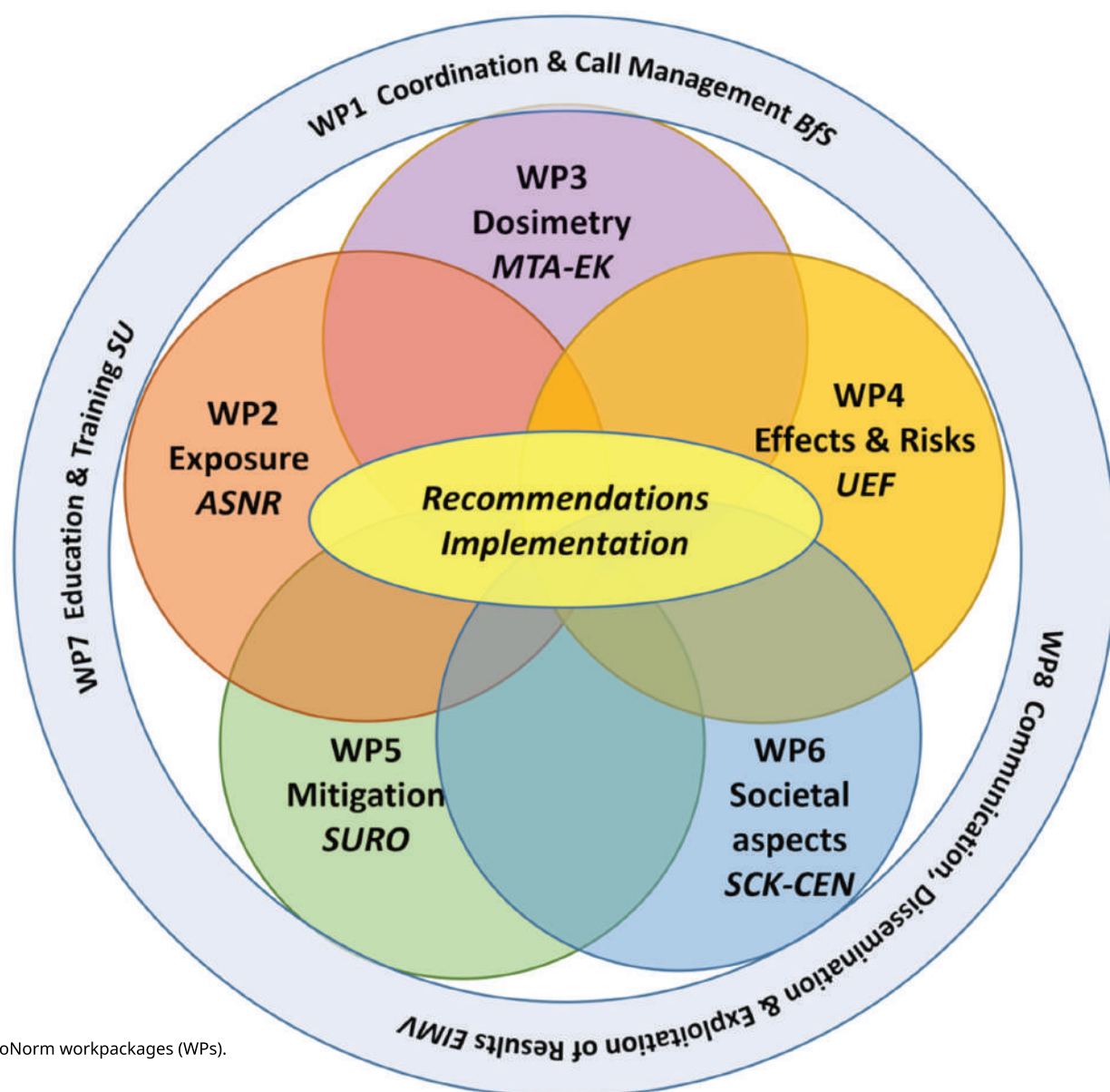
Skubacz, K.; Michalik, B. **Modelling: Activity Concentration of Radon, Thoron, and Their Decay Products in Closed Systems**. Int. J. Environ. Res. Public Health 2022, 19, 16739. <https://doi.org/10.3390/ijerph192416739>

The article presents a model for simulating changes in the activity concentration of radon and thoron, as well as their progeny in closed or poorly ventilated systems. A system can be considered closed when a stream of radon and

thoron flows into a space, but nothing comes out. It was also assumed that there may be devices or installations with a filtering system that would reduce the concentration of radon and thoron decay products. These assumptions may, therefore, correspond to a situation in which, in an isolated chamber, the calibration of radon hazard-monitoring devices is carried out, and nuclides are supplied from an emanation or flow through sources or well-isolated spaces in an environment where the source of nuclides is, for example, radon and thoron exhalation. The differential equations were formulated on the basis of the assumption that the activity concentration of radionuclides of concern in the space is uniform. The equations do not consider possible losses due to diffusion or the inertial or gravitational deposition of aerosols. If these phenomena have a limited impact on changes in the activity concentration of nuclides, the solutions provided may be used to simulate the activity concentration of radon and thoron and their decay products in any confined space, assuming different boundary conditions.

Grygier, A.; Skubacz, K.; Wysocka, M.; Bonczyk, M.; Piech, A.; Janik, M. **Radon Exposure in the Underground Tourist Route – History Silver Mine in Tarnowskie Góry, Poland**. J. Environ. Res. Public Health 2022, 19, 15778. <https://doi.org/10.3390/ijerph192315778>

An assessment of the exposure of workers and tourists to radon in the underground tourist route of the Historic Silver Mine in Tarnowskie Góry was carried out. The study was conducted over a one-year period to capture seasonal variations in radon concentrations. CR-39 track detectors were used to measure radon concentrations, which were exposed in the mine during the following periods: 9 February 2021–19 May 2021, 19 May 2021–26 August 2021, 26 August 2021–25 November 2021 and 25 November 2021–3 March 2022. The annual average radon concentration along the tourist route was 1021 Bq m⁻³. The highest measured concentration was 2280 Bq m⁻³, and the lowest concentration was 80 Bq m⁻³. Based on the measured concentrations, effective doses were calculated, assuming that employees spend 1350 h a year in underground areas and that the time of visiting the mine by tourists is ca. 1 h. The average annual effective dose a worker would receive is approximately 2.5 mSv, and a tourist below 2 µSv. The dose limit expressed as the annual effective dose is 1 mSv for members of the general public and 20 mSv for occupational exposure.



RadoNorm workpackages (WPs).

Researchers in a spotlight

David Broggio studies how smoking affects absorbed doses and dose uncertainties. Heidi Vandebosch leads the development of radon health communication tools. Olivier Armant investigates molecular effects of low-dose radiation and leads the development of Adverse Outcome Pathways for radon and NORM using machine learning.

Researchers in a spotlight

David Broggio, Ph.D., is the head of the Internal Dose Assessment Laboratory at the Institute for Radiation Protection and Nuclear Safety (IRSN, France). His research interest covers several aspects of internal dosimetry: in vivo measurements, bioassay interpretation, and patient dose assessment in nuclear medicine. In the RadoNorm project, he leads task 3.1 about the modification of absorbed doses induced by chronic smoking, and he is also involved in task 3.4 about the assessment of uncertainties on doses. Both tasks are particularly exciting since they challenge the concept of a unique dose attributed to all individuals, whatever their particularity. In task 3.1, D. Broggio benefits from the great support of Edilaine Honorio da Silva, a post-doc at IRSN, and from the experience of co-workers of the Radiation Protection Institute in Kyiv and of the Centre for Energy Research in Budapest.



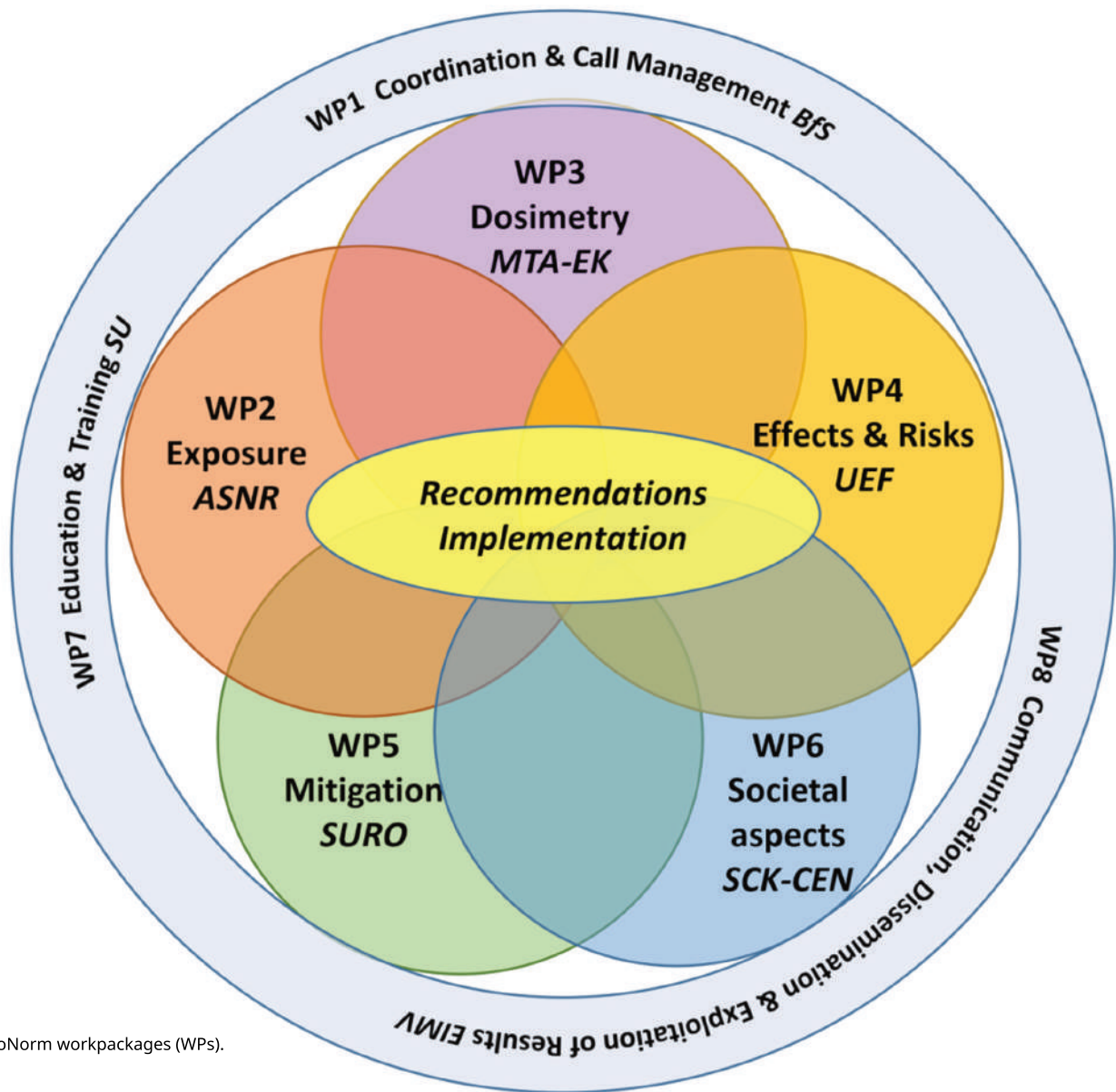
Heidi Vandebosch, Ph.D., is a professor at the Department of Communication Studies at the University of Antwerp, Belgium. Her research focuses on 1) (young) people's uses of media and new technologies (and related risks such as cyberbullying, online sexual harassment, etc.) and 2) the development of evidence-based health interventions (on topics such as physical activity, food intake, chemsex, mental health, etc.). Within the RadoNorm project, she collaborates with Sofie Apers (University of Antwerp), Tanja Perko (SCK CEN), David Hevey (Trinity College Dublin), and Gary Bradley (Trinity College Dublin) on the topic of radon health communication. Using the well-known Intervention Mapping Protocol, this team starts from a problem analysis phase, to then specify the behavioural and change objectives for specific target groups (e.g. residents and homeowners, but also general practitioners, policymakers and radon mitigation professionals), and afterwards select the right behavioural change methods. The latter are then translated into concrete communication materials, which will be tested in lab and field studies.



Olivier Armant, Ph.D., is the head of the Laboratory of Ecotoxicology at the French Institute of Radioprotection and Nuclear Safety (IRSN, LECO, France). His studies focus on the molecular mechanisms deregulated upon exposure to low doses of radiation during embryonic development and post-accidental effects on wildlife in Chernobyl and Fukushima. He is a member of the High-Level Group on Low-Dose Research (HLG-LDR) Joint Topical Group Rad-Chem. Within the RadoNorm project, he leads task 4.9 on the development of Adverse Outcome Pathways of radon and NORM, using machine learning algorithms and in close collaboration with the laboratory of Karine Audouze (University of Paris).



Dr. David Broggio, IRSN, France / Dr. Heidi Vandebosch, University Antwerp, Belgium / Dr. Olivier Armant, IRSN, LECO, France



RadoNorm engagement opportunities

The RadoNorm website and social media share news, results, and engagement opportunities. Stakeholders can join groups, pilot tools, and subscribe to the newsletter. The 2nd Annual Meeting in Munich brought together partners and stakeholders to discuss key topics. Follow us on LinkedIn, Twitter, and YouTube for updates.

RadoNorm offers project information, stakeholder engagement, and updates via social media and newsletters.

The RadoNorm website provides much information about the project, the work programme and challenges to be addressed, its development and results, interaction and engagement possibilities. The RadoNorm social media platforms on LinkedIn, Twitter and YouTube highlight the latest news and events to fulfil the foreseen dissemination of the RadoNorm project. We would be very glad if you would connect with us.

RadoNorm established different engagement opportunities for related and interested stakeholders. Several stakeholder groups are established for active involvement of different representatives in the project's activities, such as pilot testing of communication tools, development of new regulatory standards, discussions on scientific findings, or to be just informed about the RadoNorm results. You are most welcome to join the RadoNorm stakeholder groups. It is easy to submit your application.

The subscription to more information, like Newsletter issues, is also available. The RadoNorm partners, stakeholders and other groups are regularly informed about publications, news, events and calls. All developed contact databases are managed according to the RadoNorm Privacy policy.

For the first time, the RadoNorm consortium and other relevant parties met face-to-face at the Second RadoNorm Annual meeting held from the 5th to 7th of October 2022 in Munich, Germany. Three big RadoNorm topics on measurements, risk and health effects, and remediation / mitigation were presented and discussed. The special session was also devoted to the views of RadoNorm stakeholders, which were very much appreciated by all participants. The next RadoNorm annual meeting is tentatively planned to be organised again in autumn 2023. More information about the meeting will be announced soon. You are invited to follow our News and updates on LinkedIn, Twitter and YouTube.



Dr. Nadja Železnik, leader of Work Package 8, EIMV

Sources



Short news from WPs

- ✚ “Effects of spatial variation in dose delivery: what can we learn from radon-related lung cancer studies?”, <https://link.springer.com/article/10.1007/s00411-022-00998-y>
- ✚ MELODI Workshop 2020, <https://link.springer.com/article/10.1007/s00411-022-01002-3>
- ✚ Second webinar, <https://www.radonorm.eu/activities/radonorm-citizen-science/>

Events and trainings: past and future

- ✚ Training courses, <https://www.radonorm.eu/calls/call-for-courses/>
- ✚ Website, <https://www.radonorm.eu/calls/call-for-courses/>

Latest publications

- ✚ RadoNorm website, <https://www.radonorm.eu/publications/deliverables/>
- ✚ New papers, <https://www.radonorm.eu/publications/scientific-papers/>
- ✚ Polgár et al., <https://doi.org/10.1038/s41597-022-01653-3>
- ✚ Muric et al., DOI: 10.1080/13669877.2022.2127850
- ✚ Kulka et al., <https://doi.org/10.1051/epjn/2022031>
- ✚ Skubacz et al., <https://doi.org/10.3390/ijerph192416739>
- ✚ Grygier, <https://doi.org/10.3390/ijerph192315778>

RadoNorm engagement opportunities

- ✚ RadoNorm website, <https://www.radonorm.eu/>
- ✚ LinkedIn, <https://www.linkedin.com/company/radonorm/>
- ✚ Twitter (now X), <https://twitter.com/RadoNorm>
- ✚ YouTube, <https://www.youtube.com/channel/UC6yCORiPX5DXgmu5AaGLn9Q>
- ✚ RadoNorm stakeholder, <https://www.radonorm.eu/stakeholders/>
- ✚ Subscription to more information, <https://www.radonorm.eu/newsletter/>
- ✚ RadoNorm Privacy policy, <https://www.radonorm.eu/privacy-policy/>
- ✚ Second RadoNorm Annual meeting, <https://www.radonorm.eu/event/event-material/#245-380-wpfd-2nd-annual-meeting>
- ✚ News, <https://www.radonorm.eu/news/>

Key takeaways



- ☢ **RadoNorm entered its third year with strengthened collaboration and visibility at major events like ERPW 2022 and ICRP2021+1, including a successful annual meeting in Munich.**
- ☢ **Stakeholder engagement increased, supported by guidance from IAEA and IARC, recognising the project's solid progress.**
- ☢ **WP2 delivered major milestones on radon modelling in forests, exposure from building materials, and NORM site mapping, tools now of interest to the IAEA.**
- ☢ **WP3 highlighted individual variability in radon dose and risk, publishing new findings on lung disease, embryonic exposure, and DNA damage.**
- ☢ **WP4 advanced studies on radon-related risks, including lung cancer in never-smokers and radon in drinking water, while integrating uncertainty and molecular analysis.**
- ☢ **WP5 held high-level workshops and shared case studies on NORM mitigation strategies and legacy site remediation.**
- ☢ **WP6 launched citizen science calls and public surveys in multiple countries, marking the largest European opinion study on radon and NORM.**
- ☢ **Training and ECR support flourished, with multiple courses, new researchers joining, and the creation of an active ECR council.**
- ☢ **New deliverables and publications on methodology, communication, education, and dosimetry are shaping best practices in radon and NORM research.**
- ☢ **RadoNorm fosters active communication via its website, stakeholder groups, and social media, strengthening ties across disciplines and communities.**



RadoNorm
Managing risks from radon and NORM

RadoNorm

Newsletter

N°5 - July 2023



RadoNorm
Managing risks from radon and NORM

**Dr. Boguslaw Michalik -
Researcher in a spotlight**
Developing monitoring
systems for NORM, mining-
related radiation exposure.



**Dr. Laura Mezquita MD -
Researcher in a spotlight**
Studying radon-related lung
cancer and molecular
oncology in Europe.



**Dr. Edilaine Honorio da
Silva - Researcher in a
spotlight**
Assessing radon dose
impact.



**Dr. Kateřina Navrátilová
Rovenská - Researcher in
a spotlight**
Researching radon control
and worker protection.



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RadoNorm Newsletter



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Editorial



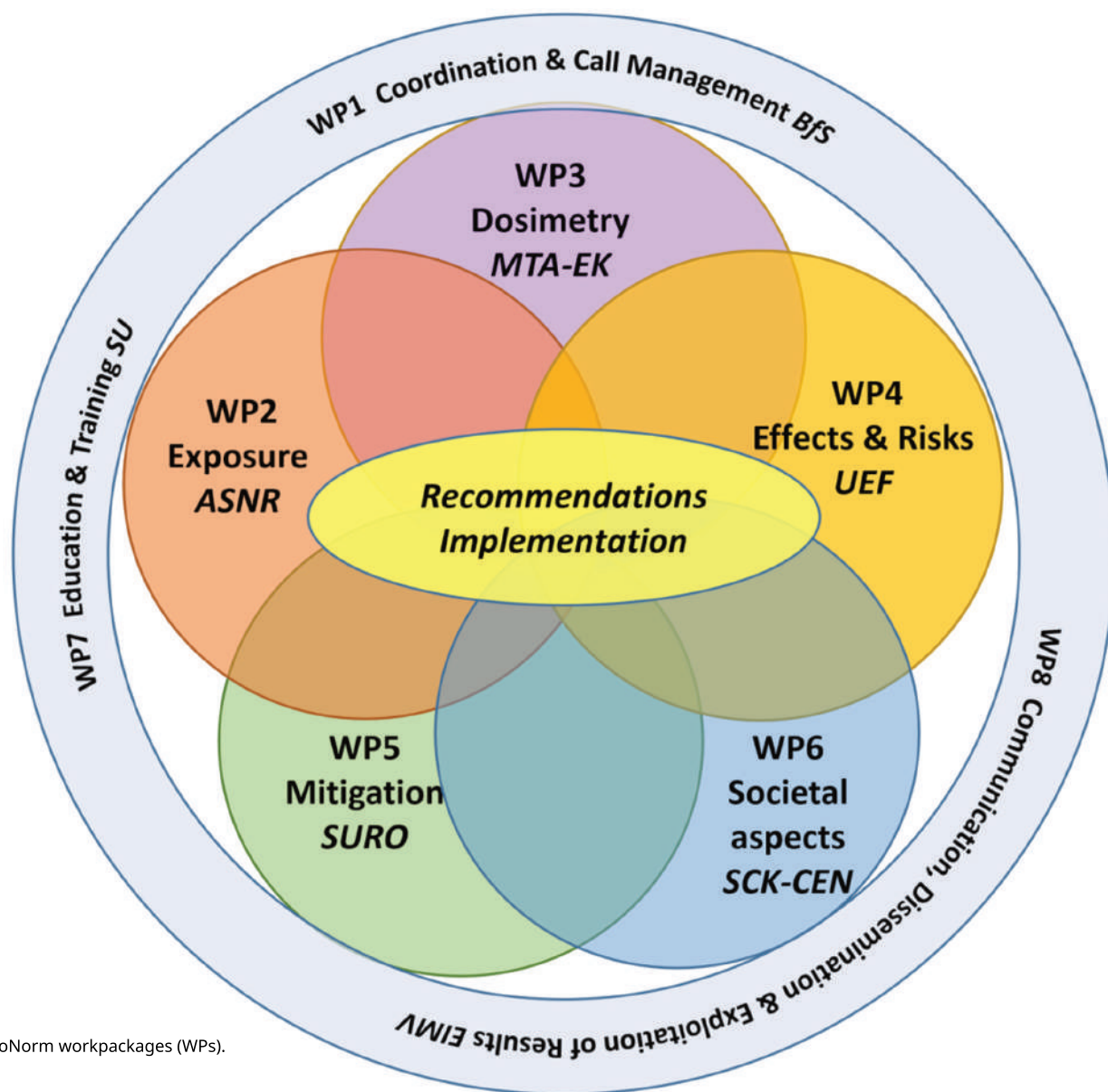
Dr. Nadja Železnik holds a BSc in Physics and an MSc in Reactor Physics from the Faculty of Mathematics and Physics, as well as a PhD in Psychology from the Faculty of Arts, all awarded by the University of Ljubljana, Slovenia. She is an expert in nuclear technology and radioactive waste management, with extensive experience in emergency preparedness and response, as well as in risk perception, communication, education, and training in environmental and nuclear projects.

She has acted as a civil society expert and knowledge manager in numerous European research initiatives, including EURAD-1 and -2, ECOSSENS, and RadoNorm. Her contributions include the development of national strategies, legislative frameworks, feasibility studies, safety and radiological assessments, and stakeholder engagement plans. She has authored communication strategies, training programmes, and information materials to foster public understanding and informed participation in the nuclear and environmental domains.

It is with great pleasure that we present the fifth issue of the RadoNorm Newsletter, marking a significant milestone: the successful passage of our halfway point. With renewed energy and expanding collaboration, the project is now entering its most dynamic phase. The past months have demonstrated RadoNorm's scientific maturity and societal relevance, as well as its unique capacity to connect researchers, practitioners, and communities across Europe in tackling radon and NORM challenges from multiple dimensions.

This issue captures the breadth of our ongoing activities, from impactful publications on radon exposure, dose modelling and mitigation strategies, to field-defining research on societal behaviour and communication. The momentum generated by recent studies on smoking and radon-induced lung cancer, on occupational exposure in mines, on sustainability assessments of mitigation technologies highlights the project's interdisciplinary strength and scientific reach.

We thank all RadoNorm partners, collaborators and stakeholders for their ongoing contributions and engagement.



RadoNorm workpackages (WPs).

After RadoNorm's half-time

RadoNorm has passed its halfway point, with impactful partner publications and growing momentum. New citizen science projects in six countries will raise radon awareness and action. The recent uranium workers' workshop underscored the project's role in advancing dosimetry and collaboration. We look forward to the Annual Meeting in Katowice this September.

RadoNorm advances radon research, launches citizen science projects, fosters expert collaboration, and prepares for its Annual Meeting in Katowice.

RadoNorm has passed its halfway point and has been increasingly gaining momentum. Recent publications from our partners have had profound impacts on radiological protection. These have shed light on topics such as smoking and radon-induced lung cancer, occupational exposure measurements in underground workplaces, sustainability of radon mitigation technologies and evaluation of various communication tools, among others.

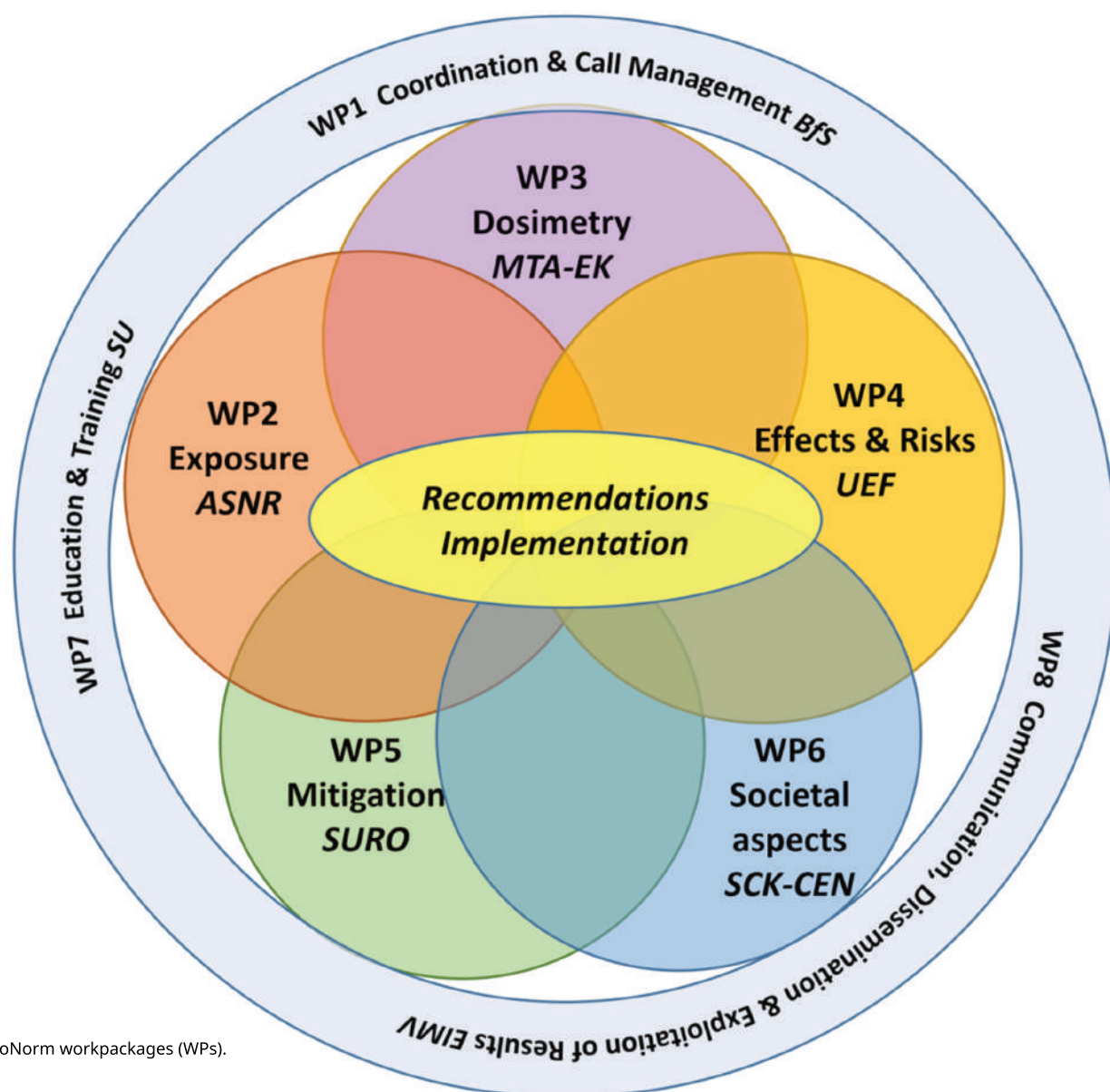
We are also excited to start six citizen science projects, which aim to increase awareness of radon as well as encourage and guide citizens to test and remediate on their own. We congratulate applicants of these six projects in Poland, Spain, Slovakia, Portugal, Italy and Slovenia on their success, and we look forward to interesting partnerships arising from these collaborations.

The recent International Workshop on Studies of Uranium Miners and Uranium Processing Workers showcased the influence of RadoNorm in epidemiological studies with uranium miners and workers and highlighted that dosimetry is not to be disregarded. We are pleased that RadoNorm serves as a platform for encouraging interaction between dosimetrists, biologists and epidemiologists to advance occupational radiation protection.

We look forward to our next Annual Meeting in Katowice, Poland, this September, with our gracious hosts from Główny Instytut Górnictwa, which is celebrating 50 years of its laboratory establishment. Lively scientific discussion, stimulating stakeholder engagement, and warm camaraderie are definitely to be part of this meeting.



Dr. Ulrike Kulka, RadoNorm coordinator, BFS



RadoNorm workpackages (WPs).

Short news from WPs

WP2 published 5 papers and 4 milestone reports on NORM exposure, radon measurement, and microbiological processes affecting radionuclide transfer. Highlights include tools for exposure assessment, studies on uranium in ecosystems, and calibration of thoron monitors. A workshop on radon monitor comparison will be held at ERPW in Dublin this October.

WP2 advanced NORM exposure assessment, radon measurement accuracy, and understanding of radionuclide transfer.

Since the last newsletter, WP2 has produced 5 new papers (see the list of papers below) and 4 milestone reports. Work of task 2.5 on “the Characterisation of exposure at NORM sites” has been published in two papers. The first one by Michalik et al. (2023) presents a methodology for systematic identification of NORM exposure situations, which allows detailed investigation and complete identification of situations where NORM may present a radiation protection concern. The second one by Mrdakovic Popic et al. (2023) presents tools that have been designed to identify and characterise the main concerns of NORM exposure in given situations to develop better risk assessment for workers and the public in such scenarios.

Partners of task 2.6, which deals with “microbiological processes that may impact soil-to-plant transfer of natural radionuclides”, produced two milestone reports:

“MS25 – Radionuclide and trace element distribution in soil-plant-earthworm system”. This report presents results of microcosm experiments performed by SCK-CEN on historically contaminated Belgian soils (mixture of naturally occurring radionuclides, such as ^{226}Ra , artificial

radionuclides, such as ^{137}Cs , ^{60}Co and metal(loid)s, such as As, Cd, Pb, Zn) to (1) evaluate the impact of earthworms on the mobility of radionuclides and metal(loid)s in soil and their transfer to vegetation and (2) study the pathways through which earthworms influence this mobility and transfer by focusing on soil pH and decomposition of organic matter and possible changes to the microbial activity.

“MS26 – Uranium localisation and speciation in soil, plants, bacteria from 2 sites”. This report is a mid-term report that focuses on work performed by CEA, UGR, IRSN and HZDR to understand the distribution of uranium in the soil-plant system of a wetland located downstream of a former uranium mine (Rophin, Puy de Dôme, France) and the role of rhizospheric microorganisms in this distribution. Uranium speciation and environmental bioavailability were determined both in the lab and in situ, where the soil-to-plant transfer factors were determined for two plant species, *Caltha palustris* and *Scirpus sylvaticus*. The microbial diversity was analysed in bulk and rhizospheric soil in order to identify species potentially able to modify uranium speciation.

Milestone report MS28 on the “Review of radioecological models for evaluating exposure at NORM industrial and legacy sites” was produced by partners of task 2.8. Four different topics related to NORM were addressed herein. Two topics dealt with the application of radioecological models for estimating the annual dose from NORM to members of the public when NORM residues are disposed of in a conventional landfill (topic 1) or when NORM sludges from groundwater filtration facilities are reused as fertilisers in agriculture (topic 3). Topic 3 focused on the application of process-based models for understanding water flow processes as well as solute transport at a former uranium mining site (Rophin site, France). The last topic was dedicated to analysing the current status of dose assessment for non-human biota in the context of NORM.

Some main results have been achieved in Task 2.1, in connection with reducing uncertainties in radon measurements. Three papers related to the characterisation of exposure to radon in underground mines have been published by members of the GIG. The first one by Grygier et al. (2022) describes an assessment of the exposure of workers and tourists to radon in the underground tourist route of the Historic Silver Mine in Tarnowskie Góry.



Dr. Laureline Fevrier, leader of Work Package 2, IRSN

The second one by Skubacz and Michalik (2022) presents a model for simulating changes in the activity concentration of radon and thoron, as well as their progeny in closed or poorly ventilated systems. The third one by Skubacz et al. (2023) compares the results of exposure assessments for workers at underground workplaces based on actual conditions prevalent at mining facilities, including the nature of the work performed and direct measurement of agents that affect exposure, such as aerosol size distribution, unattached fraction and PAEC.

Milestone report MS7 – Compilation of metrological capabilities and experiences for thoron and thoron progeny calibration has been released by BfS. The establishment of a thoron / thoron progeny reference calibration chamber following the IEC 61577-4:2009 specification in a laboratory accredited to ISO / IEC 17025 is a prerequisite for the verification and calibration of instruments for the determination of thoron exposure. The IEC 61577-4:2009 already lays down the requirements for the equipment for the production of reference atmospheres containing radon isotopes and their decay products (DP), so-called System for Test Atmospheres with Radon (STAR). Such a STAR is needed for testing, in a reference atmosphere, the instruments measuring radon and Rn DP. Requirements for the production of a thoron / thoron DP STAR differ significantly for the ones of “radon STAR” but some similarities had to be taken into account. The report includes a brief compilation of existing metrological capabilities and experiences for thoron and thoron progeny calibration within the RadoNorm project setting and beyond. It is planned to keep a poll open for the collection of further information on e.g. traceability and consideration of newly commissioned installations or released instrumentation. Thus, this milestone report reflects a snapshot.

Finally, WP2 will host a workshop at the next European Radiation Protection Week in Dublin, Ireland, this year (13th October) to discuss intercomparison between commercially available budget electronic radon monitors. The session will showcase the methodology and results of the performance tests. The workshop is targeted towards manufacturers, users, radiation protection experts, accredited measurement institutions and other stakeholders. We hope to foster a lively exchange between manufacturers and users of electronic radon instrumentation.



Characterization of exposure at NORM sites

- Methodology for systematic identification of NORM exposure situations
- Tools to identify and characterize concerns of NORM exposure



Microbiological processes impact soil-to-plant transfer of natural radionuclides

MS25 Uranium localisation and speciation in soil, plants, bacteria from 2 sites

MS26 Uranium localisation and speciation in soil, plants, bacteria from 2 sites



Reducing uncertainties in radon measurements

MS7 Compilation of metrological capabilities and experiences for thoron and thoron progeny calibration



Metrological capabilities for thoron calibration

Establishment of reference chambers to reference chambers



Upcoming workshop on budget radon monitors

October 13 - conducted on workshop on budget radon monitors

WP3 strengthened cross-task collaboration, explored impacts on radiological protection, and published new findings on smoking and radon dosimetry.

WP3 held its 5th general meeting in a hybrid format at BfS and online on 22nd May. While the activities in almost all tasks were reviewed, particular emphasis was given to the collaborations and synergies between different tasks, either within WP3 or together with WP4. The latter was underlined by participation from the coordination team as well as from Task 4.2. A discussion was also started on how the results in WP3 may impact radiological protection and help epidemiological studies. In order to increase cost effectiveness and reduce the environmental impact of our activities, the general meeting was held as a satellite event of the International Workshop on Studies of Uranium Miners and Uranium Processing Workers. It provided a great forum to exchange ideas with participants of WP4, while results and open questions of WP3 were also presented there. We are grateful to our hosts at BfS for the organisation of both the Workshop and the WP3 meeting. Next time, we will meet during the 3rd Annual Meeting of RadoNorm, where we will focus even more on the integration of activities.

Just before the meeting, a new publication appeared in the Journal of Radiological Protection on the effects of smoking on radon dosimetry. More information about the work as well as its first author, who is an Early Career Researcher, can be found in the Researchers in a Spotlight section below.



Dr. Balázs Madas, leader of Work Package 3, EK

WP4 contributed to the uranium workers workshop, progressed steadily across tasks, and welcomed new ECRs.

Several WP4 tasks contributed to the International Workshop on studies of Uranium Miners and Uranium Processing Workers in Munich on May 23-25. The meeting was organised by BfS and gathered participants from all over the world. Presentations related to RadoNorm were given, and the meeting offered a possibility to exchange ideas and develop plans for the future.

James Marsh, the leader of Task 4.4., retired during spring 2023. WP4 thanks James for his effort in RadoNorm. Fieke Dekkers from RIVM will take over the task leadership. Several ECR positions were open in WP4 during spring, and new researchers are expected to start their work soon.

While small changes and adaptations have had to be made to research plans in some tasks, work in general is progressing without major changes or delays. There are several scientific publications under peer review or close to submission. The forthcoming Annual Meeting will offer a possibility to share results and hopefully foster a lively discussion.



Dr. Päivi Roivainen, leader of Work Package 4, UEF

Developed a new device for measuring radon diffusion and tested mitigation systems in homes using innovative tracer gas and radon measurements.

There have been several important research activities carried out and substantial progress achieved within the WP5 Mitigation since the last issue of RadoNorm Newsletter. I would like to particularly emphasise the following events and achievements.

There was a huge amount of work done in Task 5.2 in collaboration with researchers from Task 5.4 in order to carry out an international comparison measurement in the mixed field radon / thoron atmosphere carried out in the SURO radon calibration and testing facility in the period from 20th March to 24th April 2023. The following 10 institutions participated in the comparison campaign, including SURO as the organiser: AGES (Austria), STUK (Finland), IRSN (France), BfS (Germany), DSA (Norway), GIG (Poland), Hirosaki University (Japan), ZVD company (Slovenia), ISS (Italy).

They submitted an extensive set of active and passive detection systems:

10 active continuous radon-thoron gas monitors allowing continuous radon and thoron activity concentration

measurement and a one passive integral Solid State Nuclear Track Detector (SSNTD) system RADUET for the mean radon-thoron activity concentration assessment;

7 active continuous monitors for the equivalent equilibrium radon and thoron concentration measurement and the unattached fraction of radon and thoron progeny assessment and two integral systems (one active based on TLD detection principle and one passive based on SSNTD).

All participants have been asked to report the instruments' traceability to the relevant national standard and the overall uncertainty budget for their results, including information on the latest calibration. The reference values are going to be calculated on the basis of the reported overall measurement uncertainties and the information from the calibration certificates. The inter comparison results and general outcomes will be presented and discussed in detail during the 3rd Annual Meeting in Katowice.

CTU in collaboration with SURO successfully developed and tested a new prototype of an advanced measurement device for determining the radon diffusion coefficient in building materials, a new design enhancing testing capabilities. Technical documentation of the measuring device is currently being elaborated in order to apply for a utility model registration at the Industrial Property Office of the Czech Republic.

Special indoor radon and tracer gas measurement campaign has been conducted in the heating season, utilising a newly developed PFT integral system for the mean air-exchange rate assessment and a standard SSNTD exposure in order to verify the efficiency of the active mitigation systems (forced ventilation with a heat recovery units) installed in 16 residential apartments.



Dr. Ales Fronka, leader of Work Package 5, SURO

WP6 launched six citizen science radon projects across Europe, advanced the European Radon Behaviour Atlas.

RadoNorm became an incubator for citizen science projects in the field of radon

Through the open call, RadoNorm supports citizen science initiatives related to radon testing or radon mitigation in radon priority areas. RadoNorm sought to partner with: new citizen science projects on radon looking for support, financial and otherwise, to grow and become sustainable; communities interested in co-designing research into radon; organisations in the public and private sectors exploring the use of citizen science in their work related to radon measurements and / or radon remediation. Nineteen project proposals were submitted and evaluated by independent reviewers based on four criteria: overall concept, implementation, impact, and team expertise.

Eventually, six projects were selected for funding, including AHSRadon Hunt in Poland, RadAR in Portugal, OCRA in Italy, RadonGPS in Slovakia, RADOHOW in Spain, and RadoNorm-SLO in Slovenia. These projects will focus on indoor radon measurements, with one project also exploring radon concentrations in tap water and water sold for drinking in spa resorts. Measurements will be 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 will not only address mitigation techniques but also assess their efficacy in reducing radiation exposure. These citizen science projects in the field of radon aim 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 will not only contribute to the advancement of scientific research but also will generate a host of additional impacts that reach beyond traditional scientific boundaries. These impacts span a diverse range of areas, including education, society, policy, and more.

RadoNorm European behaviour Atlas

The largest European study examining societal attitudes and behaviours towards radon in 15 European Member States is ongoing. The data are already collected with the support of national authorities in most of the following countries: Austria, Belgium, Bulgaria, the Czech Republic, Finland, Germany, Greece, Ireland, Norway, Portugal, Romania, Spain, Slovenia and Sweden. These data offer important insights into the public's understanding, attitudes, and behaviour regarding radon. Furthermore, they will contribute to the RadoNorm European Radon Behaviour Atlas, which aims to comprehensively map all relevant factors that influence the successful implementation of national radon action plans across Europe. As radiation protection and radon action plans involve both technical and socio-technical components, this Atlas is an essential tool for effective policy development and implementation. The study is conducted in a comprehensive and holistic manner, through an inter-organisational cooperation involving a multidisciplinary team, with support from both the Radiation Protection Authorities and the H2020 research and innovation RadoNorm project. The team consists of experts from diverse fields, including risk perception and risk communication scientists, methodologists, public opinion experts, social psychologists, sociologists, political scientists, radon mitigation experts, policymakers, and physicists. The inclusion of experts from various disciplines enabled a comprehensive and nuanced understanding of the societal attitudes and behaviours towards radon and provided information on the development of effective policies and strategies to address radon risks.



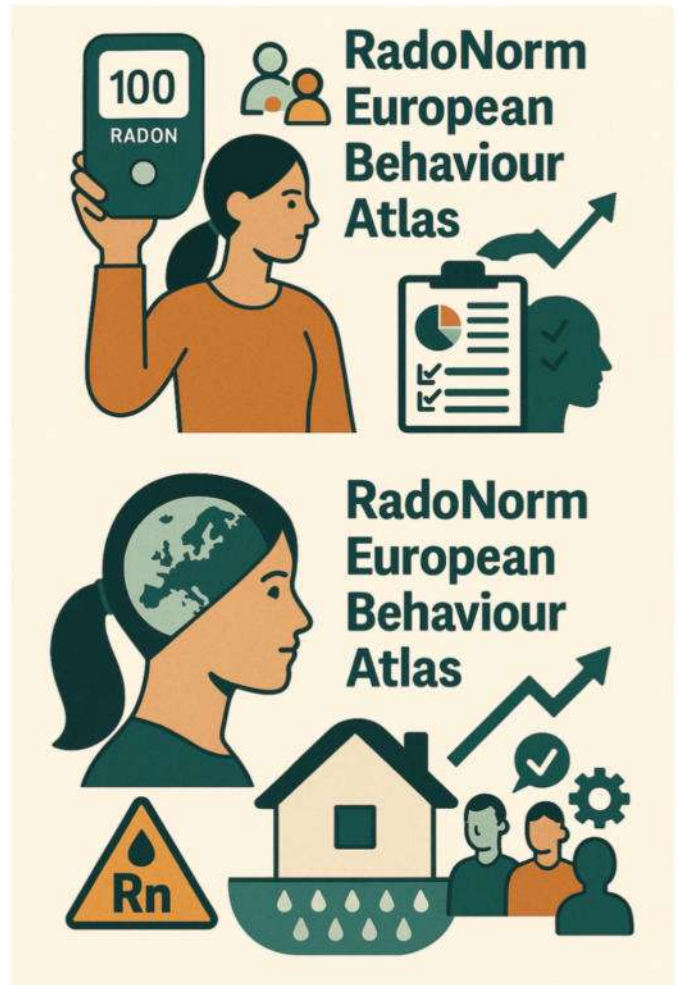
To ensure high ethical standards for this sensitive topic, which impacts people's health, quality of life, and potentially decreases the economic value of their properties, the study was overseen by an independent RadoNorm ethical committee. This committee ensured that the study was conducted ethically and took into account the potential consequences of the study's findings, including the possibility of stigma for affected individuals.

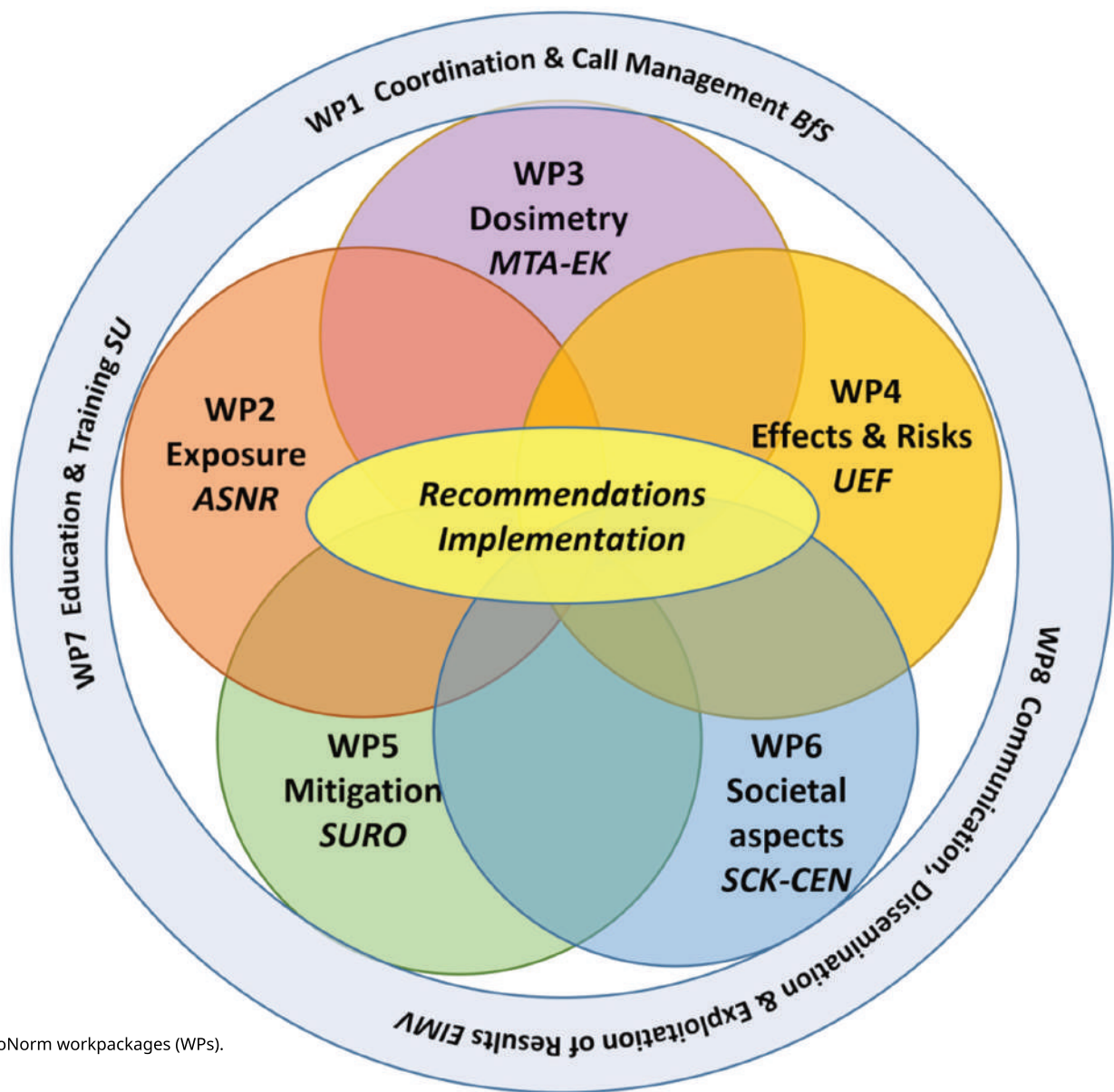
Comprehensive Study Reveals Societal Barriers and Facilitators for Radon Mitigation

A groundbreaking research project has successfully identified the barriers and facilitators associated with mitigating dwellings that exceed safe radon concentration levels. The study encompassed four countries (Belgium, Ireland, Slovenia, and the UK), each facing high radon risks, low mitigation rates, and diverse approaches to radon risk management from 2022 to 2023. Employing a robust multi-method approach, the research team collected data from multiple sources. Online surveys, content analysis of legal documents, group interviews, and workshops were used to gather insights from responsible authorities for radon management. Semi-structured interviews were conducted with radon mitigation contractors in Ireland and the United Kingdom. Additionally, focus groups were held with residents residing in high-radon homes in Belgium, Ireland, and Slovenia.

Authorities highlighted various facilitators, including legal requirements for mitigation in private dwellings, effective radon risk communication through awareness campaigns, low mitigation costs supported by financial assistance, the correlation with indoor air quality and energy-saving programs, and the availability and accreditation of qualified radon mitigation contractors. Contractors echoed the significance of business viability, emphasising the importance of awareness campaigns, low mitigation costs, and being registered as professional mitigators. Residents identified several facilitators, including the perception of radon as a health threat, affordable mitigation costs, trust in the quality of mitigation work, clear information about the mitigation process, and legal requirements for radon mitigation. The study also illuminated barriers at individual, inter-individual, organisational, and authority levels. Participants highlighted the fragmented nature of the mitigation process, emphasising the need for an integrated approach involving all stakeholders to enhance radon mitigation efforts effectively.

These research findings provide invaluable insights for policymakers, authorities, and industry professionals, enabling the development of targeted strategies and initiatives to overcome barriers and optimise radon mitigation. By fostering collaboration among all stakeholders, society can effectively safeguard dwellings against radon and promote healthier living environments.





RadoNorm workpackages (WPs).

Events and trainings: past and future

RadoNorm's ECR programme is thriving: fostering skills, collaboration, and enthusiasm in radiological protection. The ECR council leads monthly meetings, organises training events, and supports mobility with 18 travel grants awarded. Several successful courses have been held, with more upcoming to further enrich early career training.

RadoNorm's ECR programme is thriving, fostering skills, collaboration, and enthusiasm in radiological protection.

As the last few spots for early career researchers (ECRs) in the project are being filled, we are happy to announce that RadoNorm is not just fulfilling its goals of training a new generation in skills in radiological protection but also creating a space for enthusiasm and camaraderie amongst them.

The ECR council has been very much active since its inception in October 2022 and has been organising monthly meetings under its current leader, Å. Degenhardt from BfS. These monthly meetings have created a relaxed atmosphere to discuss their plans and findings, and receive feedback from a multi-disciplinary audience, which has given them new insights into their methodology and goals. The council also organised its training course titled "Transdisciplinary Communication in Radon and NORM" where participants met in Stockholm University and engaged in various workshops held by RadoNorm senior scientists on how to increase communicability of their research. It was a wonderful opportunity for new friendships, ideas and collaborations.

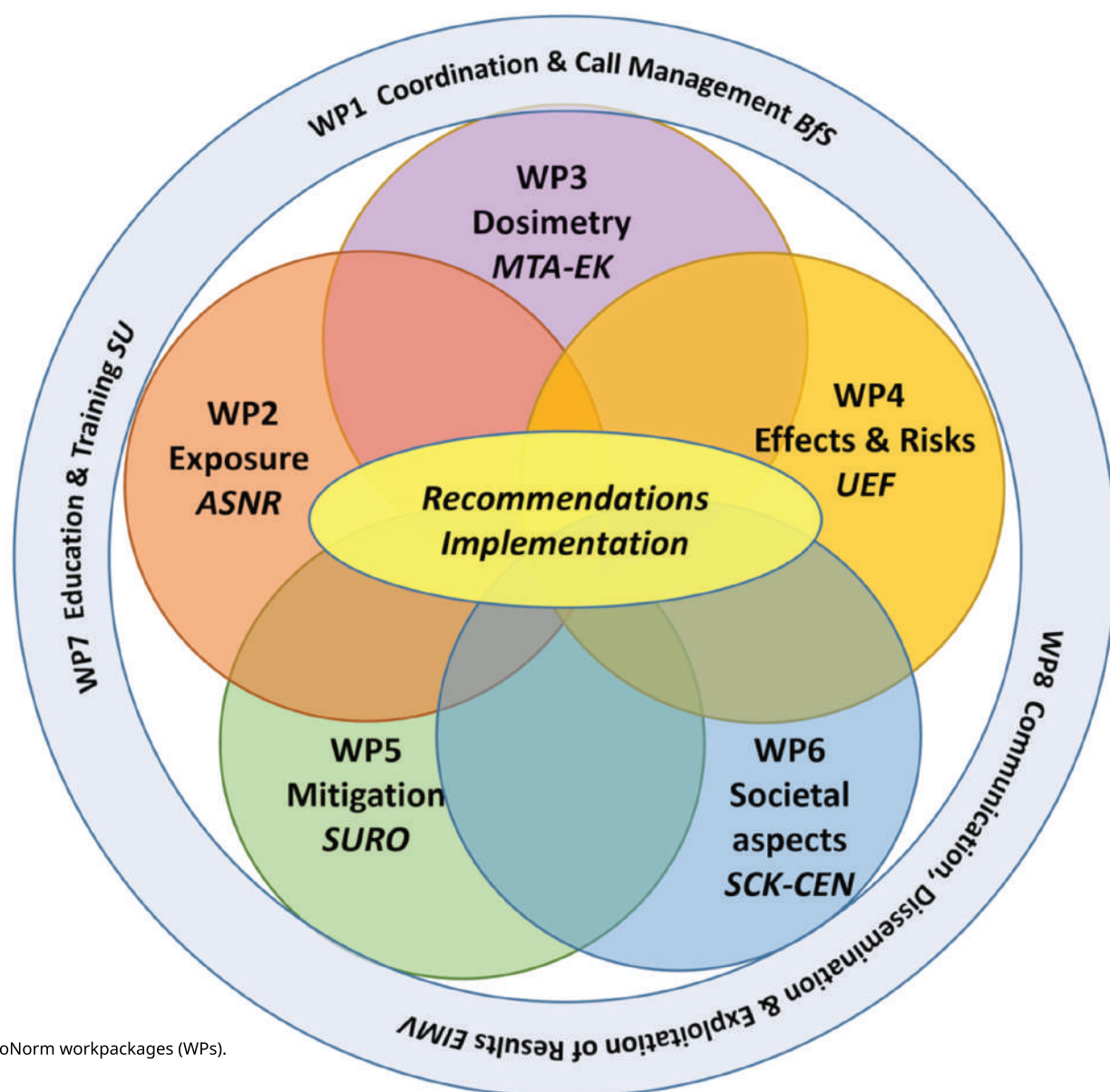
Our ECRs have also taken part in various conferences, training courses and exchange visits, where a total of 18 travel grants have been awarded since December 2022. We expect participation in various events to increase over the summer and autumn months. The 3rd Annual Meeting will also give our ECRs an opportunity to meet and interact with the greater consortium.

Moreover, four RadoNorm training courses will take place this year. Two of these were successfully conducted, one by the ECR council and the other by GIG (Naturally Occurring Radioactive Material – characterisation, inventory of related exposure situations and monitoring principles – stationary course). Two are yet to take place and will be organised by Uthe niversities of Aveiro and Porto (NORM impact assessment toolkit: from microorganisms to human cells) as well as by Stockholm University (Cellular effects of high and low LET ionising radiation – Introduction to radiation biology). More information about these courses can be found on our website.



Dr. Andrzej Wojcik, leader of Work Package 7, SU
Dr. Warren John, leader of Work Package 1, BfS





RadoNorm workpackages (WPs).

Latest deliverables and publications

New RadoNorm publications explore radon-related lung cancer, nuclear risks in war, sustainable radon barriers, NORM in cement, and public communication strategies. Studies offer novel insights into dose modelling, mitigation materials, stakeholder perspectives, and health impacts: advancing science and policy in radiological protection.

Many new papers have been published as part of the RadoNorm achievements:

The 2020 MELODI workshop on the effects of spatial and temporal variation in dose delivery

G. Madas, A. Wojcik

<https://doi.org/10.1007/s00411-022-01002-3>

A key activity of MELODI is to organise annual European meetings where scientific results and future directions and strategies of relevant research are discussed. The annual meetings, previously organised solely under the auspices of MELODI are, since 2016, jointly organised by the European platforms and referred to as European Radiation Protection Weeks (ERPW). In addition to ERPW meetings, MELODI organises, and finances annual workshops dedicated to specific topics. Outputs and recommendations from the meetings are published as review articles. The 2020 workshop focussed on one of the cross-cutting topics: the effects of spatial and temporal variation in dose delivery on disease risk. The current issue of REBS includes five review articles from the workshop on the effects of spatial and temporal variation in dose delivery and this editorial is a short summary of their content.

Effects of spatial variation in dose delivery: what can we learn from radon-related lung cancer studies?

G. Madas, J. Boei, N. Fenske, W. Hofmann, L. Mezquita

<https://doi.org/10.1007/s00411-022-00998-y>

Exposure to radon progeny results in heterogeneous dose distributions in many different spatial scales. The aim of this review is to provide an overview on the state of the art in epidemiology, clinical observations, cell biology, dosimetry, and modelling related to radon exposure and its association with lung cancer, along with priorities for future research. Particular attention is paid on the effects of spatial variation in dose delivery within the organs, a factor not considered in radiation protection. It is concluded that a multidisciplinary approach is required to improve risk assessment and mechanistic understanding of carcinogenesis related to radon exposure. To achieve these goals, important steps would be to clarify whether radon can cause other diseases than lung cancer, and to investigate radon-related health risks in children or persons at young ages. Also, a better understanding of the combined effects of radon and smoking is needed, which can be achieved by integrating epidemiological, clinical, pathological, and molecular oncology data to obtain a radon-associated signature. While in vitro models derived from primary human bronchial epithelial cells can help to identify new and corroborate existing biomarkers, they also allow to study the effects of heterogeneous dose distributions including the effects of locally high doses. These novel approaches can provide valuable input and validation data for mathematical models for risk assessment. These models can be applied to quantitatively translate the knowledge obtained from

radon exposure to other exposures resulting in heterogeneous dose distributions within an organ to support radiation protection in general.

Keywords: Carcinogenesis, Dosimetry, Mathematical modelling, Molecular mechanisms

War in Europe: health implications of environmental nuclear disaster amidst war

Jessica E Laine

<https://doi.org/10.1007/s10654-022-00862-9>

Recent incidents at nuclear facilities in Ukraine related to the attacks from Russian forces highlight the fragility of nuclear power plants and other nuclear facilities in war and the very real potential for another environmental nuclear disaster and associated health risks in Europe. Nuclear catastrophes from war can occur from radioactive materials released from war threatened nuclear power plants and other nuclear facilities in war zones, in addition to the direct threat from the deployment of nuclear weaponry and can result in immediate and long-term health impacts. Despite historical nuclear catastrophic events, including the Chernobyl nuclear power plant accident and atomic bombings of Hiroshima and Nagasaki, and that for more than a century epidemiologists have studied the consequences of radiation exposures, there are still major unanswered questions regarding radiation risks and human health. Epidemiologists will need to continue to quantify the health effects from exposure to environmental radiation, including background radiation, and are able to contribute to conversations about reliance on nuclear energy and alternative energy futures. As a society we are compelled to rethink our ties to nuclear energy, especially with the potential of increasing reliance on nuclear power amid oil and gas crisis and considering climate change, nuclear warfare, including nuclear weapon testing, and the fragility of humanity and health to even low doses of radiation from these and other natural and unnatural sources.

Sustainability assessment of waterproof membranes for radon mitigation in buildings

Felicioni, M. Jiránek and A. Lupíšek

<https://iopscience.iop.org/article/10.1088/1755-1315/1085/1/012056>

Gas radon is the main source of ionising radiation for humans and the second cause of lung cancer, just after smoking. Radon is present in the ground, and its concentration differs soil by soil according to the permeability and the mineral composition. Since radon mainly penetrates a building through cracks and fractures at the foundation level, it is necessary to focus on that area. The problem of high radon indoors concentration is present largely in Europe and in those countries where the heating indoors is privileged since there is a high-temperature difference between outdoors and indoors in winter.

The waterproof membranes placed continuously in the structures that are in contact with the soil are one of the cheapest and easy-to-install radon mitigation solutions. Membrane-based measures, like all remedial measures, represent operational and embodied environmental impacts; the last were more or less ignored so far. Still, as buildings are becoming energy-efficient and should ensure a high level of indoor comfort, the environmental impacts of these membranes are recognised as being noteworthy and shall be methodically examined. The paper aims to assess the contribution of embodied impacts of five macro-categories of membranes that could be installed to protect buildings against radon. The embodied impacts are calculated for the A1-A3 LCA stages and compared against each other in relation to one square meter and the radon resistance.

Usage of alternative cementitious binders containing naturally occurring radioactive by-products: The industry's perspective

Love, R. Geymans, S. Leroi-Werelds, T. Perko, R. Malina, W. Schroeyers

<https://www.sciencedirect.com/science/article/abs/pii/S0959652623000616?via%3Dihub>

In 2021, global cement production was responsible for around 7% of anthropogenic greenhouse gas (GHG) emissions. Alternative cementitious binders from secondary raw materials that replace traditional cement can reduce the need for the use of virgin raw materials and can thereby reduce GHGs associated with cement. Some of these secondary materials include industrial by-products categorised as NORM (Naturally Occurring Radioactive Material). While prior research has investigated the technical aspects of using NORM-contained by-products in cementitious binders, to date, no attention has been given to non-technical aspects such as perceived risks and concerns of the main stakeholders. This study brings novel insights into these overlooked aspects through a series of semi-structured interviews with concrete industry representatives in Belgium. Through a thematic analysis of the data, we found six themes that represent industry's concerns regarding the usage of NORM-contained cementitious binders: (1) availability of the by-products, (2) financial factors, (3) quality and performance, (4) common sustainability parameters, (5) customer demand, and (6) acceptance of NORM-contained by-products. Regulatory certainty was found to be a key driver in all six themes. With regard to the expected role of governments, we can synthesise three core expectations highlighted by interviewees: a) Policymakers need to revisit the current regulations regarding the performance and quality to facilitate innovation in the concrete industry such as the use of alternative cementitious binders. b) They should implement EU-level regulations that can provide a level playing field for the industry during their transition to net-zero targets, including import regulations and certification for the usage of NORM-contained by-products. c) As an important public buyer, the government should expedite the transition to alternative binders

through their procurement policies for governmental buildings and infrastructure projects.

Environmental impacts of waterproof membranes with respect to their radon resistance

Felicioni, M. Jiránek, A. Lupíšek

<https://www.sciencedirect.com/science/article/pii/S2214993722001555?via%3Dihub>

Gas radon is the main source of ionising radiation for humans and the second most common cause of lung cancer after tobacco smoke. Radon is present in the ground, and its concentration differs between different soils according to parameters such as permeability and mineral composition. As radon mainly penetrates buildings through cracks and fractures at the foundation level, this area requires research focus. This study aims to assess the contribution of the environmental embodied impacts of ten macro-categories of membranes that are installed to protect buildings against radon. This study aims to evaluate membranes because they are one of the cheapest and easiest radon level-reducing solutions for both new and existing buildings. The data used in the comparison were obtained from environmental product declarations (EPDs) downloaded from open-access databases. The environmental embodied impacts were calculated for the A1-A3 Life Cycle Assessment (LCA) stages and compared with each other in relation to one square meter and radon resistance, which are the parameters that highlight the performance of a membrane in terms of effectiveness for protection against radon. Finally, a comparison of the performance of the radon-proofing solutions with their environmental embodied impacts was conducted using the CML2001 methodology. The results of this investigation enable, for the first time, the selection of the most efficient and environmentally friendly radon-proof membrane at the design stage. Through this analysis (combining performance and environmental impacts), we found that polymeric membranes, such as HDPE and LDPE membranes, were the best options for achieving radon resistance in the range of 100–150 Ms/m in terms of environmental impacts, whereas the PVC membrane displayed the highest values of embodied impacts.

Clearing the air: A systematic review of mass media campaigns to increase indoor radon testing and remediation

Apers, H. Vandebosch, T. Perko

<https://www.degruyter.com/document/doi/10.1515/commun-2021-0141/html>

Indoor radon is a natural radioactive gas that enters homes through cracks in the foundations. It is one of the leading causes of lung cancer. Although radon can be detected with an indoor radon test and can be mitigated by means of either ventilation or professional measures, testing and mitigating rates of the at-risk population remain insufficient.

The objective of this study is to systematically review the current level of evidence regarding the design and effectiveness of mass media campaigns to address the health risks of indoor radon to homeowners. The results show that the informative tone of voices prevailed; other components, such as emotional or social components, were often not included. Furthermore, the focus was mostly on intention and less on behaviour itself, and on testing instead of mitigation. Further research is needed to test effective and innovative communication strategies to increase protective behaviour concerning indoor radon.

Machine intelligence for radiation science: summary of the Radiation Research Society 67th annual meeting symposium

Wilson, F. Kiffer, D. Berrios, A. Bryce-Atkinson, S. Costes, O. Gavaert, B. Matarèse, J. Miller, P. Mukherjee, K. Peach, P. Schofield, L. Slater, B. Langen
<https://doi.org/10.1080/09553002.2023.2173823>

The era of high-throughput techniques created big data in the medical field and research disciplines. Machine intelligence (MI) approaches can overcome critical limitations on how those large-scale data sets are processed, analysed, and interpreted. The 67th Annual Meeting of the Radiation Research Society featured a symposium on MI approaches to highlight recent advancements in the radiation sciences and their clinical applications. This article summarises three of those presentations regarding recent developments for metadata processing and ontological formalisation, data mining for radiation outcomes in pediatric oncology, and imaging in lung cancer.

Co-Designing Communication: A Design Thinking Approach Applied to Radon Health Communication

Apers, H. Vandebosch, T. Perko, N. Železnik
<https://www.mdpi.com/1660-4601/20/6/4965>

Indoor radon is a natural radioactive gas and is one of the leading causes of lung cancer. Despite multiple policy and communication interventions to increase radon testing and mitigation, the uptake of these measures remains insufficient. A participatory research design was applied in Belgium and Slovenia to probe the barriers and facilitators homeowners experience regarding radon protective behaviour on the one hand and co-designing communication tools on the other hand. The results show that there remains a need for interventions on all levels (i.e., policy, economic interventions, and communication). Moreover, results indicated a need for a communication strategy that follows the different steps between awareness and performing mitigation measures. Further, involving the target group in the early stages of intervention design was beneficial. Future research is needed to test the effectiveness of the proposed communication strategies in a controlled setting.

Influence of Dose Conversions, Equilibrium Factors, and Unattached Fractions on Radon Risk Assessment

in Operating and Show Underground Mines

Skubacz, K. Wołoszczuk, A. Grygier, K. Samolej
<https://www.mdpi.com/1660-4601/20/8/5482>

This paper compares the results of measurements taken in the underground workings of active and tourist mines. In these facilities, the aerosol size distributions of ambient aerosols at key workplaces and the distributions of radioactive aerosols containing radon decay products were determined. Based on these studies, dose conversions used for dose assessment and unattached fractions were determined. In addition, radon activity concentrations and potential alpha energy concentrations of short-lived progeny were also measured in the mines to determine the equilibrium factor. The dose conversions varied between 2–7 mSv/ (mJ × h × m⁻³). The unattached fraction measured in active coal mines ranged from 0.01–0.23, in tourist mines from 0.09–0.44, and in the tourist cave it was 0.43. The results showed significant discrepancies between the effective doses determined from current recommendations and legal regulations and those determined from direct measurements of parameters affecting exposure.

A methodology for the systematic identification of naturally occurring radioactive materials (NORM)

Michalik, A. Dvorzhak, R. Pereira, J. Lourenço, H. Haanes, C. Di Carlo, C. Nuccetelli, G. Venoso, F. Leonardi, R. Trevisi, F. Trotti, R. Ugolini, L. Pannecoucke, P. Blanchart, D. Perez-Sanchez, A. Real, A. Escibano, L. Fevrier, A. Kallio, L. Skipperud, J. Mrdakovic Popic
<https://www.sciencedirect.com/science/article/pii/S0048969723019435?via%3Dihub>

Naturally occurring radioactive materials (NORM) are present worldwide and, under certain circumstances (e.g., human activities), may give radiation exposure to workers, local public or occasional visitors and non-human biota (NHB) of the surrounding ecosystems. This may occur during planned or existing exposure situations which, under current radiation protection standards, require identification, management, and regulatory control as for other practices associated with man-made radionuclides that may result in the exposure of people and NHB. However, knowledge gaps exist with respect to the extent of global and European NORM exposure situations and their exposure scenario characteristics, including information on the presence of other physical hazards, such as chemical and biological ones. One of the main reasons for this is the wide variety of industries, practices and situations that may utilise NORM. Additionally, the lack of a comprehensive methodology for the identification of NORM exposure situations and the absence of tools to support a systematic characterisation and data collection at identified sites may also lead to a gap in knowledge.

Within the EURATOM Horizon 2020 RadoNorm project, a methodology for systematic NORM exposure identification has been developed. The methodology, containing consecutive tiers, comprehensively covers situations where NORM may occur (i.e., minerals and raw materials deposits, industrial activities, industrial products and residues and their applications, waste, legacies), and thus, allows detailed investigation and complete identification of situations where NORM may present a radiation protection concern in a country. Details of the tiered methodology, with practical examples on harmonised data collection using a variety of existing sources of information to establish NORM inventories, are presented in this paper. This methodology is flexible and thus applicable to a diversity of situations. It is intended to be used to make NORM inventory starting from scratch; however, it can also be used to systematise and complete existing data.

Tools for harmonised data collection at exposure situations with naturally occurring radioactive materials (NORM)

Mrdakovic Popic, H. Haanes, C. Di Carlo, C. Nuccetelli, G. Venoso, F. Leonardi, R. Trevisi, F. Trotti, R. Ugolini, A. Dvorzhak, A. Escribano, D. Perez Sanchez, A. Real, B. Michalik, L. Pannecoucke, P. Blanchart, A. Kallio, R. Pereira, J. Lourenço, L. Skipperud, L. Fevrier
<https://www.sciencedirect.com/science/article/pii/S0160412023002271?via%3Dihub>

Naturally occurring radioactive materials (NORM) contribute to the dose arising from radiation exposure for workers, the public and non-human biota in different working and environmental conditions. Within the EURATOM Horizon 2020 RadoNorm project, work is ongoing to identify NORM exposure situations and scenarios in European countries and to collect qualitative and quantitative data of relevance for radiation protection. The data obtained will contribute to improved understanding of the extent of activities involving NORM, radionuclide behaviours and the associated radiation exposure, and will provide an insight into related scientific, practical and regulatory challenges.

The development of a tiered methodology for identification of NORM exposure situations and complementary tools to support uniform data collection were the first activities in the mentioned project NORM work. While NORM identification methodology is given in Michalik et al., 2023, in this paper, the main details of tools for NORM data collection are presented and they are made publicly available.

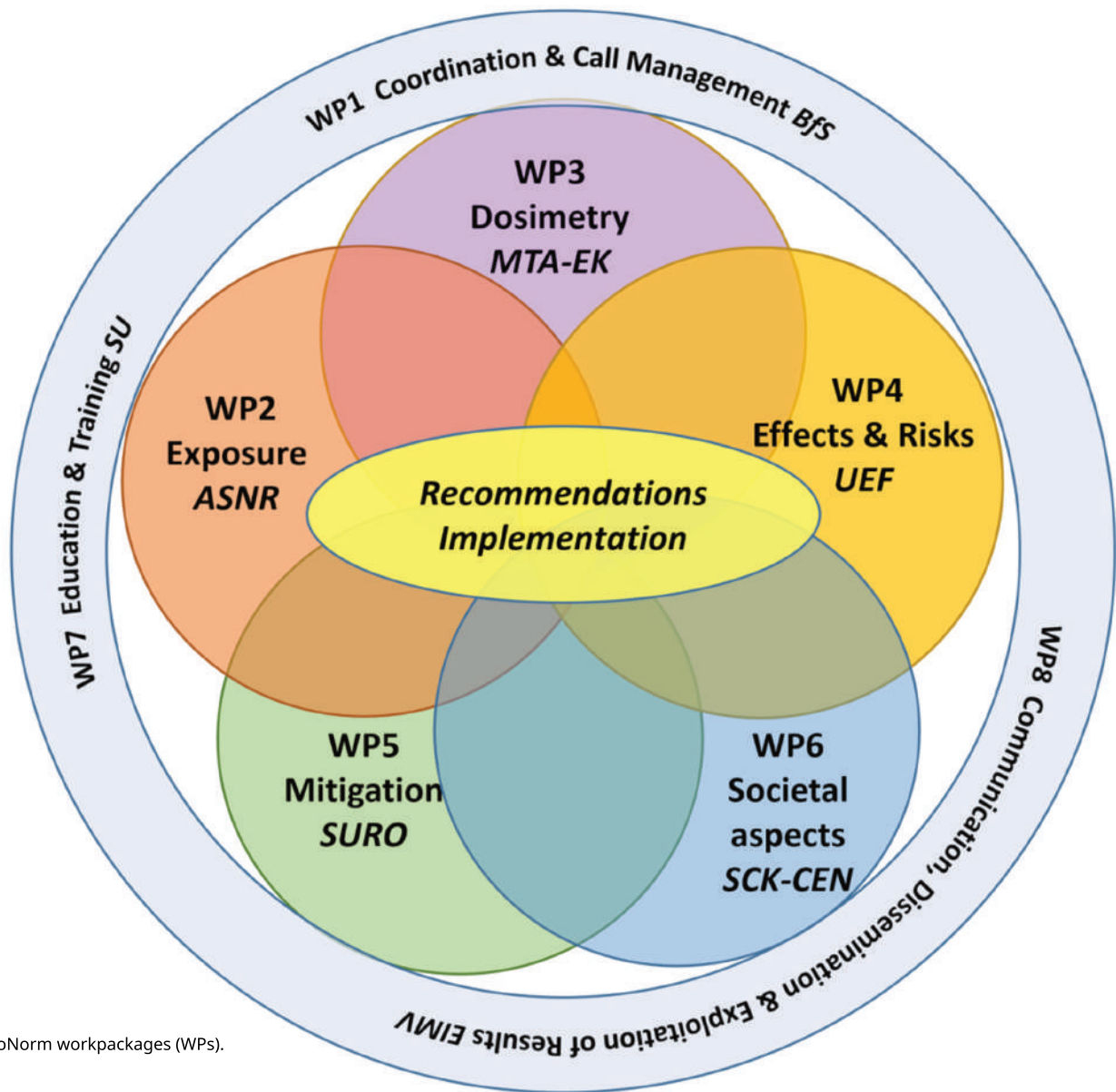
The tools are a series of NORM registers in Microsoft Excel form, that have been comprehensively designed to help (a) identify the main NORM issues of radiation protection concern at given exposure situations, (b) gain an overview of materials involved (i.e., raw materials, products, by-products, residues, effluents), c) collect qualitative and quantitative data on NORM, and (d) characterise multiple hazards exposure scenarios and make further steps towards development of an integrated risk and exposure

dose assessment for workers, public and non-human biota. Furthermore, the NORM registers ensure standardised and unified characterisation of NORM situations in a manner that supports and complements the effective management and regulatory control of NORM processes, products and wastes, and related exposures to natural radiation worldwide.

Changes induced in the human respiratory tract by chronic cigarette smoking can reduce the dose to the lungs from exposure to radon progeny

Honorio da Silva, E. Davesne, Y. Bonchuk, G. Ratia, B. Madas, V. Berkovsky, D. Broggio
<https://iopscience.iop.org/article/10.1088/1361-6498/acd3fa/meta>

Chronic cigarette smoking leads to changes in the respiratory tract that might affect the dose received from exposure to radon progeny. In this study, changes induced by cigarette smoking in the respiratory tract were collected from the literature and used for the calculation of the dose received by the lungs and organs outside the respiratory tract. Morphological and physiological parameters affected by chronic smoking were implemented in the human respiratory tract model (HRTM) used by the International Commission of Radiological Protection (ICRP). Smokers were found to receive lung doses 3% smaller than the ICRP reference worker (non-smoking reference adult male) in mines and 14% smaller in indoor workplaces and tourist caves. A similar dose reduction was found for the extrathoracic region of the HRTM. Conversely, kidneys, brain, and bone marrow of smokers were found to receive from 2.3- up to 3-fold of the dose received by the respective organ in the ICRP reference worker, although they remained at least two orders of magnitude smaller than the lung dose. These results indicate that the differences in the lung dose from radon progeny exposure in cigarette smokers and non-smokers are smaller than 15%.



RadoNorm workpackages (WPs).

Researchers in a spotlight

Spotlight on RadoNorm researchers: Boguslaw Michalik pioneers NORM safety in mining; Laura Mezquita links radon to lung cancer genetics; Edilaine Honorio da Silva explores smoking's impact on radon dose; and Kateřina Navrátilová Rovenská leads radon mitigation tech research for workplaces.

Boguslaw Michalik is a leading expert in natural radioactivity and NORM, with over 35 years of contributions to monitoring and research.

Boguslaw Michalik, D.Sc., on environmental engineering, studying the impact of the mining industry on environmental exposure to ionising radiation, is currently an associate professor at GIG (Central Mining Institute), engaged in the Silesian Centre for Environmental Radioactivity, Katowice, Poland.

Contrary to the majority of radiation protection researchers who are dealing with artificial radioactivity, Boguslaw started his professional career in radiation protection with natural radioactivity occurring in underground mines as radium in formation waters, as well as radon in the mine atmosphere. After hazards related to natural radioactivity had been well characterised in the eighties of the last century, together with the team of the then Laboratory of Radiometry, he developed the complex system of this hazard monitoring and related risk evaluation. The unique system created is working to date and meets nowadays requirements set by EC as well as IAEA.

Boguslaw has more than 35 years' experience in radiometry and radiation protection including measurement techniques like high resolution gamma spectrometry, TLD, LSC; investigation of NORM at workplaces (especially in underground mines) and in environment; investigation of natural and artificial radionuclides in soil, water, atmosphere, and the construction materials; exposure evaluation of non-human species inhabiting areas with enhanced level of natural radioactivity.

Since the beginning, Boguslaw has engaged in NORM symposia organised every three years, the last tenth in Utrecht, the Netherlands. Being a member of an originators group in 2018, he participated in the European NORM Association (ENA) founding. Based on experience gathered, Boguslaw contribute to IAEA projects in the field of NORM dealing with environmental aspects as well as occupational exposure.



Dr. Boguslaw Michalik, Central Mining Institute (GIG), Poland

Laura Mezquita focuses on the molecular profile of radon-induced lung cancer in nonsmokers, building on her expertise in oncology and radon research.

Laura Mezquita is a medical oncologist specialist in thoracic malignancies working at Hospital Clinic (Thoracic Oncology Group, Medical Oncology Department) and IDIBAPS (Laboratory of Translational Genomics) in Barcelona and focuses on 3 main research lines: Immunoncology, Precision Medicine in lung cancer and Molecular Epidemiology (impact of carcinogens and other risk factors). Her PhD was on Health Sciences, studying the impact of radon gas in the molecular subgroups of lung cancer. She finished her postdoc in Molecular Oncology (Gustave Roussy, France), studying the impact of risk factors in lung cancer profile, with special focus on the genetics (cancer predisposition genes) in lung cancer and radon gas, in collaboration with IRSN (Radon France study) and CEA (Radon-rats). She is now part of the RadoNorm consortium, co-leading task 4.5 of indoor radon and lung cancer in nonsmokers, working on the characterisation of the molecular profile of lung cancer induced by radon in rats, uranium miners, and patients exposed to indoor radon in Europe. She is also a co-principal investigator in BIORADON, sponsored by EORTC, which is a prospective study of 975 patients with lung cancer to study the correlation between the molecular profile and indoor radon in Europe.



Dr. Laura Mezquita MD, Laboratory of Translational Genomics (IDIBAPS), Spain

Edilaine Honorio da Silva is studying the effects of smoking on radon dose to lungs and assessing uncertainties in radon progeny dose estimates.

Edilaine Honorio da Silva is a post-doctoral scientist at the Institute for Radiation Protection and Nuclear Safety (IRSN, France), under the supervision of Dr. David Broggio, and she is contributing to two tasks of WP3 of RadoNorm. In task 3.1, together with colleagues from RPI (Ukraine) and CER (Hungary), she evaluated the influence of the changes in the respiratory tract caused by chronic cigarette smoking on the doses received from exposure to radon progeny. The results of this work, showing that smokers receive lower doses to their lungs than their non-smoking counterparts, have been published in the Journal of Radiological Protection. She is also contributing to task 3.4, in which the uncertainties in the radiation doses from radon exposure are under assessment. Her focus has been on the uncertainties arising from parameters relevant to radon progeny.



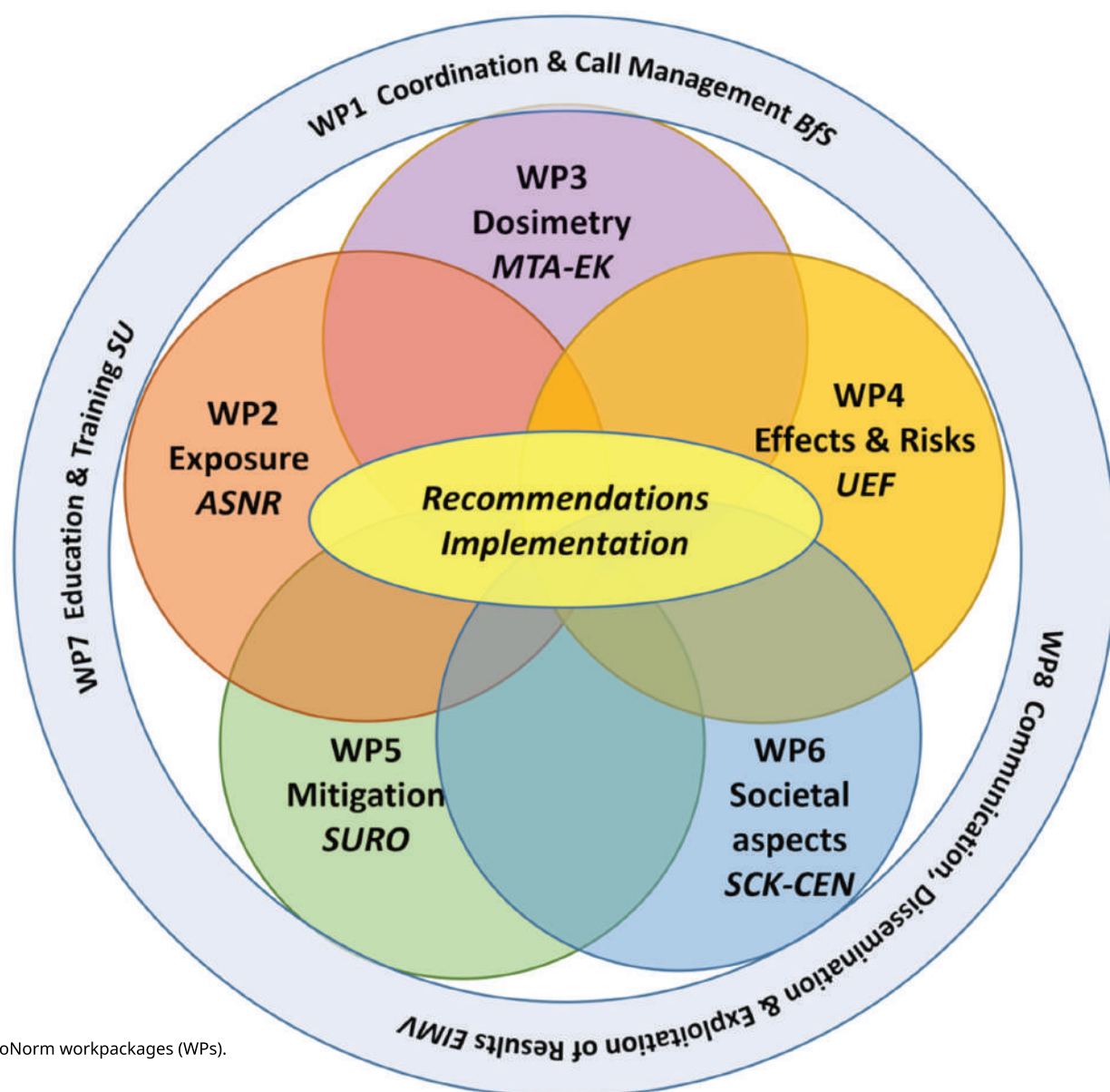
Dr. Edilaine Honorio da Silva, Institute for Radiation Protection and Nuclear Safety (IRSN), France

Kateřina Navrátilová Rovenská researches radon control in workplaces, performs detector tests and analyses data to enhance worker protection.

Kateřina Navrátilová Rovenská holds a PhD in Nuclear Engineering and has worked for more than 15 years as a senior researcher at the National Radiation Protection Institute (SURO), Czech Republic. Katerina is involved in environmental radioactivity measurement campaigns and monitoring programs mainly related to radon diagnostics and radon and NORM workplaces. Katerina is co-organiser of International Conference on Protection against Radon at Home and at Work for several years. She worked as a consultant for radon issues at the International Atomic Energy Agency. As a part of the RadoNorm consortium she leads task 5.4 (radon reducing and control technologies applied in underground and other specific workplaces) under which the team is carrying out various radon and radon progeny detector tests in labs and in the field to improve the understanding of their behaviour. In parallel, data and knowledge are collected to improve the protection of workers working at such workplaces affected by radon. All the activities are carried out in close collaboration with WP2.



Dr. Kateřina Navrátilová Rovenská, National Radiation Protection Institute (SURO), Czech Republic



RadoNorm workpackages (WPs).

RadoNorm engagement opportunities

The RadoNorm website and social media offer updates on project goals, results, and engagement opportunities. Stakeholders can join groups, receive newsletters, and participate in activities. The 3rd Annual Meeting (20–21 Sept 2023, near Katowice, Poland) is open to all, with hybrid access and limited financial support for selected participants.

RadoNorm offers updates, stakeholder engagement, newsletters, and invites all to its hybrid Annual Meeting in September 2023 near Katowice.

The RadoNorm website provides much information about the project, objectives, work programme, its development and results, interaction and engagement possibilities. RadoNorm on social media platforms LinkedIn, Twitter and YouTube, which are also accessible via the website, provides the latest news about the projects and their results. You are kindly invited to follow us.

RadoNorm established different engagement opportunities for the related and interested stakeholders. Several stakeholder groups are established for active involvement of different representatives in the project's activities, such as pilot testing of communication tools, development of new regulatory standards, discussions on scientific findings, or to be just informed about the RadoNorm results. You are most welcome to join the RadoNorm stakeholder groups. It is easy to submit your application.

The subscription to more information, like Newsletter issues, is also available. The RadoNorm partners, stakeholders and other groups are regularly informed about publications, news, events and calls. All developed contact databases are managed according to the RadoNorm Privacy policy.

The 3rd RadoNorm Annual meeting, open to all interested, will be held from the 20th to the 21st of September 2023 in the vicinity of Katowice, Poland. The meeting will be in a hybrid format to allow as many stakeholders as possible to attend. Topics will be organised into three themes / pillars titled "Environment", "Health" and "Society and Radiological Protection" and holistically addressed based on the new developments in the RadoNorm project. The stakeholder engagement is also foreseen to a great extent this year, as it was last year assessed to give very important added value.

The detailed programme and registration will be available soon. We kindly ask you to consider your participation in the event. We will, same as last year, financially support a limited number of stakeholders to participate and contribute to the event.



Dr. Nadja Železnik, leader of Work Package 8, EIMV

Sources



Short news from WPs

- ☼ International Workshop on Studies of Uranium Miners and Uranium Processing Workers, <https://uraniumminers.bfs-internationalworkshop-muc.de/>
- ☼ New publication, <https://iopscience.iop.org/article/10.1088/1361-6498/acd3fa/pdf>

Events and trainings: past and future

- ☼ Training courses, <https://www.radonorm.eu/calls/call-for-courses/>
- ☼ Website, <https://www.radonorm.eu/calls/call-for-courses/>

Latest publications

- ☼ New papers, <https://www.radonorm.eu/publications/scientific-papers/>
- ☼ Madas and Wojcik, <https://doi.org/10.1007/s00411-022-01002-3>
- ☼ Madas et al., <https://doi.org/10.1007/s00411-022-00998-y>
- ☼ E Laine, <https://doi.org/10.1007/s10654-022-00862-9>
- ☼ Feliconi et al., <https://iopscience.iop.org/article/10.1088/1755-1315/1085/1/012056>
- ☼ Love et al., <https://www.sciencedirect.com/science/article/abs/pii/S0959652623000616?via%3Dihub>
- ☼ Feliconi et al., <https://www.sciencedirect.com/science/article/pii/S2214993722001555?via%3Dihub>
- ☼ Apers et al., <https://www.degruyter.com/document/doi/10.1515/commun-2021-0141/html>
- ☼ Wilson et al., <https://doi.org/10.1080/09553002.2023.2173823>
- ☼ Aspers et al., <https://www.mdpi.com/1660-4601/20/6/4965>
- ☼ Skubacz et al., <https://www.mdpi.com/1660-4601/20/8/5482>
- ☼ Michalik et al., <https://www.sciencedirect.com/science/article/pii/S0048969723019435?via%3Dihub>
- ☼ Mrdakovic Popic et al., <https://www.sciencedirect.com/science/article/pii/S0160412023002271?via%3Dihub>
- ☼ Honorio da Silva et al., <https://iopscience.iop.org/article/10.1088/1361-6498/acd3fa/meta>

Researchers in a spotlight

- ☼ Smokers receive lower doses, <https://iopscience.iop.org/article/10.1088/1361-6498/acd3fa>

RadoNorm engagement opportunities

- ☼ RadoNorm website, <https://www.radonorm.eu/>
- ☼ LinkedIn, <https://www.linkedin.com/company/radonorm/>
- ☼ Twitter (now X), <https://twitter.com/RadoNorm>
- ☼ YouTube, <https://www.youtube.com/channel/UC6yCORiPX5DXgmu5AaGLn9Q>
- ☼ RadoNorm stakeholder, <https://www.radonorm.eu/stakeholders/>
- ☼ Subscription to more information, <https://www.radonorm.eu/newsletter/>
- ☼ RadoNorm Privacy policy, <https://www.radonorm.eu/privacy-policy/>
- ☼ The 3rd RadoNorm Annual meeting, https://www.radonorm.eu/wp-content/uploads/2023/07/RadoNorm-3rd-AM-Agenda_Version-13.07.2023.pdf

Key takeaways



- ☢ **RadoNorm is making significant breakthroughs in understanding radon's impact on health, the environment, and society, with numerous new publications and research results.**
- ☢ **Six selected citizen science projects across Europe are boosting public awareness and engagement in radon measurement and mitigation.**
 - ☢ **WP2 reports key findings on reducing uncertainties in radon measurements and characterising exposures in mines.**
 - ☢ **WP3 focuses on microdosimetry and uncertainties, supporting insights into radon's effects on lung tissue, including the influence of smoking.**
 - ☢ **WP4 continues research on radon-related lung cancer and tumour development mechanisms.**
 - ☢ **WP5 conducted an international intercomparison of instruments in mixed radon-thoron fields and tested new prototype devices for radon diffusion in materials.**
 - ☢ **WP6 finalised Europe's largest radon behaviour survey and analysed mitigation barriers and facilitators across four countries.**
 - ☢ **WP7 and the ECR Council continue to deliver training, foster collaboration, and strengthen the role of early career researchers.**
 - ☢ **RadoNorm has become a key platform connecting experts and stakeholders across disciplines in radiological protection.**
- ☢ **The Annual Meeting in Katowice (September 2023) will provide space for scientific exchange, presentations, and strong stakeholder engagement.**



RadoNorm
Managing risks from radon and NORM

RadoNorm

Newsletter

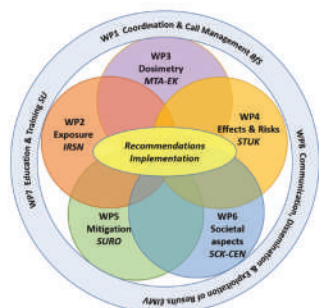
N°6 - December 2023



RadoNorm
Managing risks from radon and NORM

RadoNorm is strongly committed to open science

Increasing number of scientific publications



Dr. Jan Boei - Researcher in a spotlight

Investigates alpha radiation effects on human bronchial epithelial cells



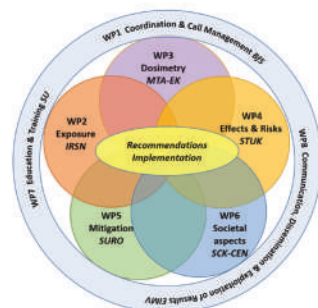
ECR Council

Early Career Researchers support peers with training, writing, and career development



4th RadoNorm Annual Meeting

Will be in Ljubljana, Slovenia, on 12th and 13th of June 2024



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RadoNorm Newsletter



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Editorial



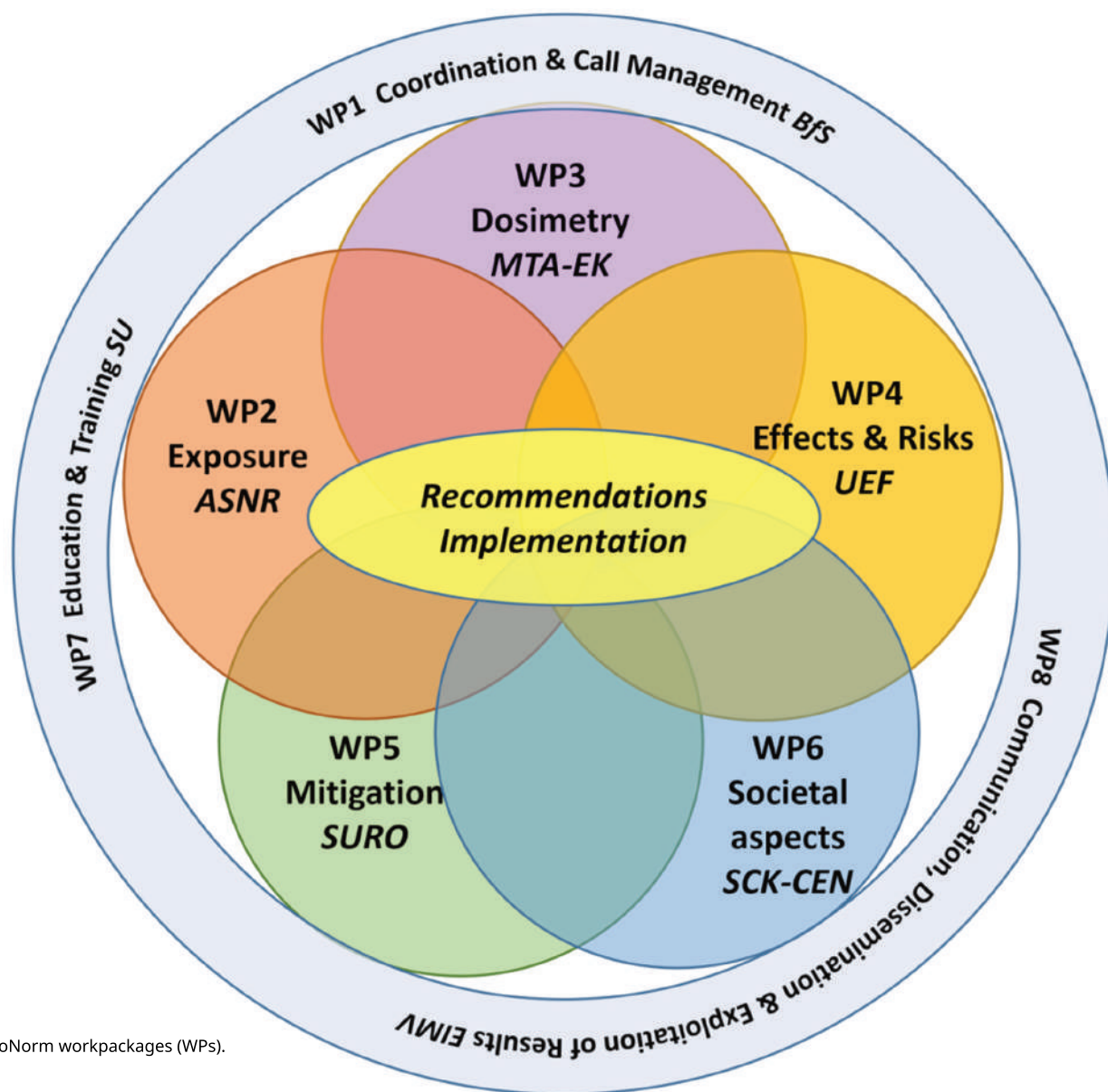
Dr. Nadja Železnik, leader of Work Package 8, EIMV

Dr. Nadja Železnik holds a BSc in Physics and an MSc in Reactor Physics from the Faculty of Mathematics and Physics, as well as a PhD in Psychology from the Faculty of Arts, all awarded by the University of Ljubljana, Slovenia. She is an expert in nuclear technology and radioactive waste management, with extensive experience in emergency preparedness and response, as well as in risk perception, communication, education, and training in environmental and nuclear projects.

She has acted as a civil society expert and knowledge manager in numerous European research initiatives, including EURAD-1 and -2, ECOSSENS, and RadoNorm. Her contributions include the development of national strategies, legislative frameworks, feasibility studies, safety and radiological assessments, and stakeholder engagement plans. She has authored communication strategies, training programmes, and information materials to foster public understanding and informed participation in the nuclear and environmental domains.

It is with great pleasure that we share this new issue of the RadoNorm Newsletter, marking the beginning of the project's fourth year and a new phase in its development. RadoNorm continues to build momentum, not only through scientific advances but also by reinforcing the strong connections between researchers, institutions, stakeholders, and society in addressing radon and NORM challenges.

This issue opens with reflections from our third Annual Meeting in Ustroń, Poland, where partners came together in an atmosphere of collaboration, openness, and shared purpose. The meeting showcased the project's interdisciplinary depth and growing cohesion across work packages, with a special emphasis on stakeholder dialogue, joint scientific outputs, and citizen engagement. Progress from across the project illustrates how RadoNorm is moving forward through new deliverables, published results, and the creative energy of early career researchers. From modelling exposures and refining measurement tools to exploring societal attitudes and promoting public participation, the project continues to bridge research excellence with real-world relevance.



Stepping in the RadoNorm year 4

RadoNorm strengthens its role in radiation protection, advancing radon and NORM research through collaboration, open science, stakeholder engagement, and citizen science. Highlights include a productive Annual Meeting, growing publications, and cross-sector dialogue, with continued progress expected in the coming years.

RadoNorm advances radiation protection through research, collaboration, and public engagement.

A further issue of this newsletter marks another milestone in the project. RadoNorm has solidified its position in the field of radiation protection as a significant contributor to understanding and mitigating risks towards radon and NORM, and the collaboration and camaraderie between our partners have never been more prosperous. This was plainly observed during our third Annual Meeting, organised by our gracious hosts, GIG, in the beautiful hills of Ustroń, Poland. We once again saw the essential interdisciplinarity, deepening friendships, and vital cooperation between European institutes and other stakeholders, thriving in the fertility of the project and ardently tackling the urgent questions that still need answering.

The result of all this is the impactful and ever-increasing number of scientific publications, a significant proportion of which are indeed co-created by multiple work packages. RadoNorm is strongly committed to open science, and we have made great efforts to ensure our publications are freely accessible to all interested parties, who could further use these outputs in meaningful ways. We have significantly grown our stakeholder involvement, to now also include companies that are simultaneously tackling

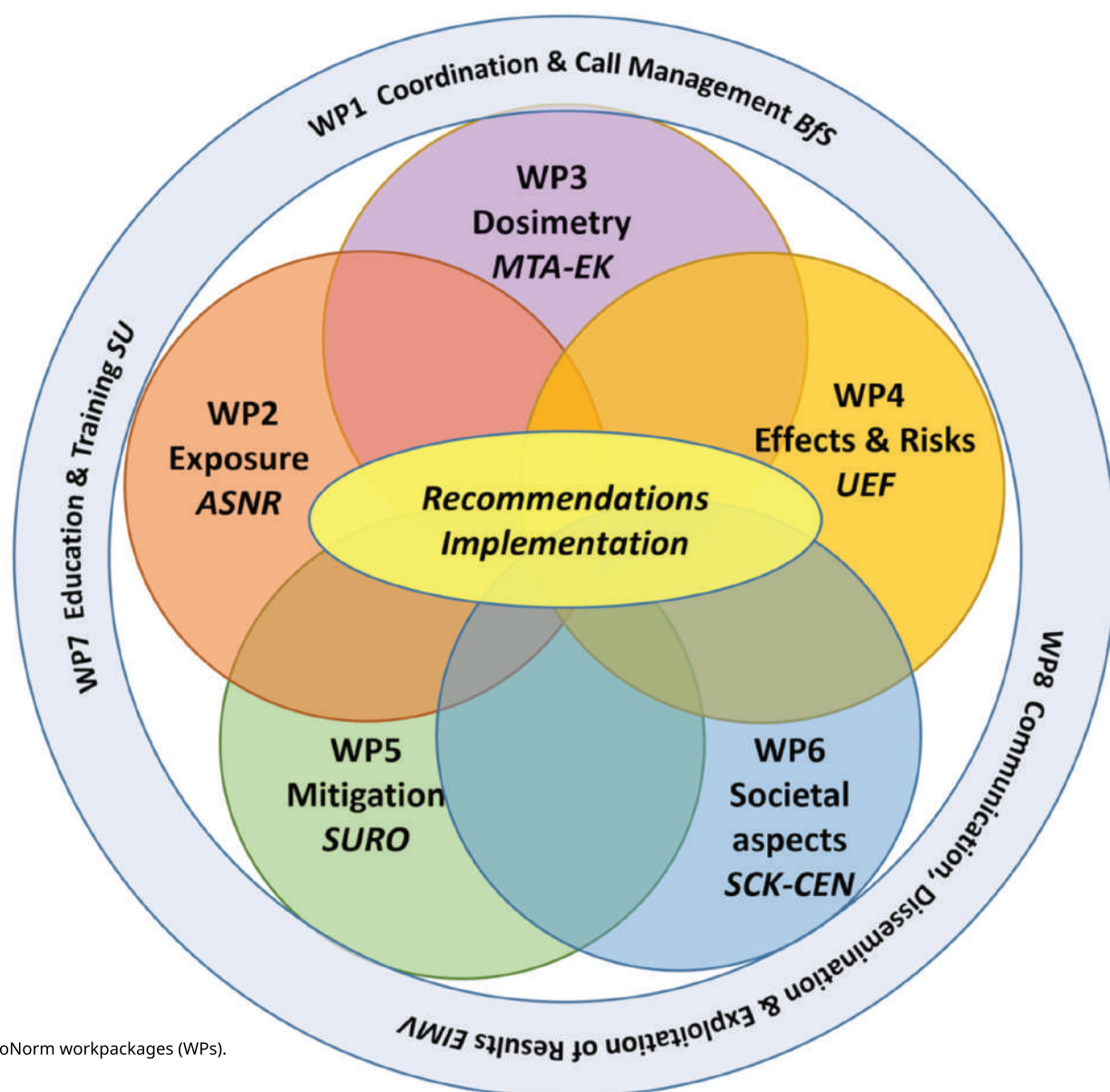
the same questions we are. Public engagement has also intensified through the launch of our new citizen science projects, as well as the success of our pilot projects, whose creativity continues to increase the relevance of radiation protection in society.

The Interest Group Meeting organised as part of the European Radiation Protection Week 2023 in Dublin, Ireland, to discuss the available and more affordable radon monitors on the market highlighted the fact that radiation protection is not only about science. The great interest from various stakeholders, such as regulatory authorities and members of the public, in addition to the manufacturers of the radon monitors themselves, showed that there is a demand for crosstalk and interaction between diverse stakeholders, and RadoNorm has in fact created the ideal platform for that.

As we wind down for the holiday season, we can be grateful for the successes and highlights of this year and also reflect on those areas where there is room for improvement. We eagerly look forward to the next two years of RadoNorm, where we hope to make even greater strides in addressing the EU's Basic Safety Standards and yielding more tangible results in radiation protection. RadoNorm hopes you enjoy reading the developments presented in this newsletter and wishes you a joyful Christmas season and a bright start to the new year.



Dr. Ulrike Kulka, RadoNorm coordinator, BfS



RadoNorm workpackages (WPs).

Short news from WPs

WPs created strong progress across scientific, technical, and societal dimensions, from radon exposure modelling and microdosimetry to new tools, stakeholder engagement, and citizen science. WP collaborations have intensified, key deliverables and milestones were achieved, and public involvement continues to expand across Europe.

WP2 advanced radon exposure science through key deliverables, cross-cutting collaboration, field and modelling studies.

WP2 presented its main outputs successfully at the 3rd annual meeting in Ustron and organised fruitful internal meetings on cross-cutting issues between tasks and other WPs, specifically with WP5. Two oral presentations have also been given at the Migration 2023 conference in Nantes, one as a plenary lecture on NORM and the other on the work performed in task 2.8 on the application of process-based models for understanding water flow processes as well as solute transport at a former uranium mining site.

WP2 is proud to have released its two first deliverables (D2.7 on “Workplace-type specific methods to assess the exposure of workers to radon – Focus on underground workplaces and itinerant workers” and D2.8 on “Approach to determine the contributions of local geology and other sources on the radon exposure in dwellings – scenarios and modelling of radon transport from soils to indoor-air”); whose contents are presented at the end of the Newsletter, and six milestones.

MS14 – “Field Measurements completed, analysis and datasets on ground exhalation and outdoor concentration” – presents a new methodology and its application to a

specific sampling location in the Fen complex (Norway) to assess the temporal variation (diurnal and seasonal) of radon and thoron exhalation from the ground, as well as the effect of the affecting factors. In addition, an article from Haanes et al. (2023) has assessed the dose rate contributions in Norwegian legacy mines with high natural background radiation in the cold season.

MS16 – “Simulations of radon products in forest environments complete and projected impact calculated. Verification of the ECORADON SVAT model and first scientific results” – presents the update of the model developed in Milestone MS15 up to a working level. MS16 also includes some model runs of spatial and temporal variability of radon and its daughters in the different soil and vegetation compartments that show that the model is giving meaningful scientific outputs. The model is now ready for case study application in the next phase of the project.

MS20 – “Review of statistical methods for the identification of buildings and areas with high radon levels, collection and harmonization of suitable data-sets from partners, and preliminary analysis of available data”. The report provides (1) a review of suitable statistical methods aimed to identify buildings and areas where high indoor radon concentrations might be found and (2) the description of suitable datasets potentially analysable with one or more selected methods among those described in the first part.

MS27 – “Modelling simulations to develop constant plant concentration approach ready” investigates the use of an alternative approach to describe soil-to-plant transfer of naturally occurring radionuclides based on the constant total element concentrations in plants, developed by the UEF.

MS 30 – “Completion of laboratory sorption and desorption experiments” completes the previous Milestone MS29 summarises the data obtained after applying laboratory experiments conducted to generate new knowledge and additional data in order to improve modelling to predict NOR interaction and subsequent mobility. Two approaches were explored. In the first one, sorption and desorption tests were applied to a collection of non-contaminated soils (> 30 soils) with different physicochemical properties to obtain new Kd (NOR) data and to enrich existing datasets to subsequently identify the parameters that govern the sorption of Ra, Po and U. The second approach aimed to determine if the nature of contamination and ageing influence retention parameters. To reach this objective, four different soils



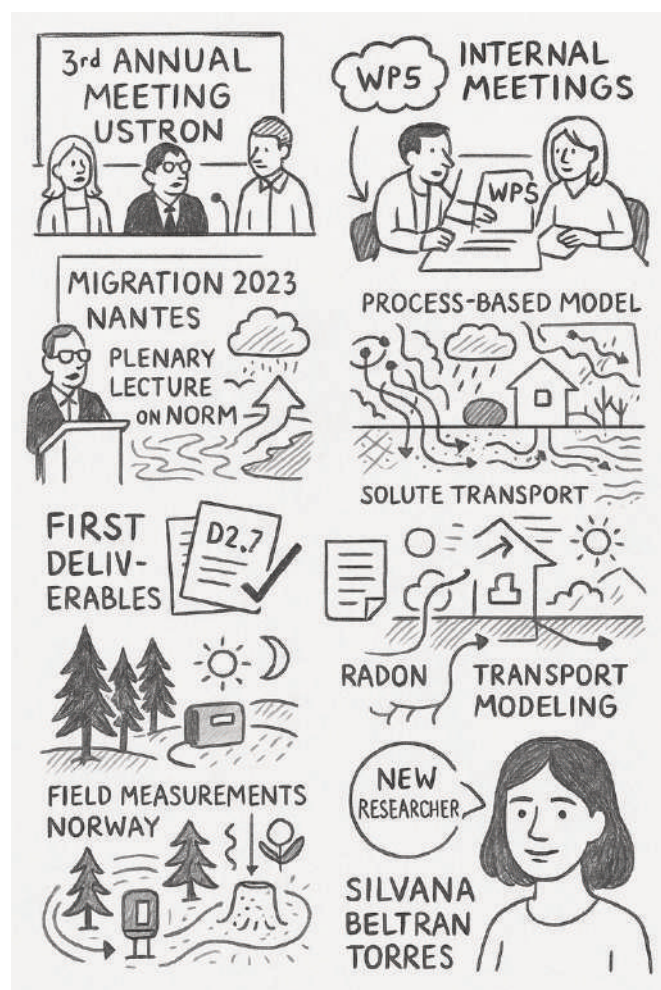
Dr. Laureline Fevrier, leader of Work Package 2, IRSN

Short news from WPs

were contaminated with ^{233}U added in liquid or organic form (previously contaminated plant material) and then incubated. Retention parameters were regularly measured during the incubation and compared to those of native ^{238}U .

MS31 – “Determination of site-specific K_d values” investigates a methodology for characterising the labile/remobilisable fraction of U and Ra, and to provide K_d values applicable to in situ condition. This work is being tested on soil / sediment taken from a wetland contaminated by past uranium mining activities at the Rophin site (France), with a focus on radium (Ra) and uranium (U). This work should help to develop a reactive transport model at the scale of the contaminated wetland in connection with Tasks 2.8.

Finally, WP2 is happy to welcome Silvana Beltran Torres, a new early career researcher who will work on the “Investigation of multiple hazards at NORM exposure sites” within task 2.5 at DSA. Her approach consists of exploring and identifying relationships between naturally occurring radionuclides (NOR), rare earth elements and other present hazards and environmental conditions at the Fen complex site in Norway. These relationships will be analysed at two levels of interactions: 1) analysis of the inter-relationship between identified hazards, and analysis of environmental parameters that impact on their transport and consequently on their availability to organisms and 2) evaluation of the level of uptake by living organisms with steps towards risk estimation. Statistical and spatial methods to identify relationships and patterns will be used. The main outcome of the work is planned to help in the development of the integrated approach for risk assessment for humans and non-human biota, as well as with respect to different, not necessarily radioactive contaminants commonly present at the NORM sites.



Computational microdosimetry and uncertainty analysis, advancing dose modelling and supporting experimental setups through simulations.

Two milestones and one deliverable were submitted by WP3 since the publication of the last Newsletter. The deliverable summarised the results of computational microdosimetry supporting the preparation and evaluation of experiments. These included simulations to estimate absorbed doses in different cell nuclei of the human and rat lungs in case of several exposure conditions. Considering the in vivo dose distributions, Monte Carlo simulations were performed to set up and evaluate in vitro experiments with organotypic tissue models and cell cultures. As those studies are still ongoing, we also continue our work tailoring our simulations for the experimental setups.

The milestones reported on the progress in the assessment of uncertainties affecting dosimetric calculations. One of them provides a detailed description of probability distributions of parameters to be used during uncertainty and sensitivity analysis. These parameters include those of the Human Respiratory Tract Model, the Human Alimentary Tract Model and the systemic model, as well as parameters related to the inhalation of radon progeny. In the other milestone, doses from radon and thoron progeny are compared.

We had several joint meetings with WP4, mostly during the Annual Meeting. The paper[1] published in May on the effects of smoking on absorbed doses was discussed during the Annual Meeting and later with a panel of epidemiologists involved in RadoNorm WP4. BfS has compared the Excess Relative Risk per Working Level Month (ERR per WLM) estimates of lung cancer by radon for smokers and non-smokers from different uranium miners' studies. In all studies, the ERR estimate for smokers was less than that for non-smokers. Having in mind that the ERR should be proportional to the lung dose, the results from epidemiology and dosimetry are consistent. However, several questions remain, which may be studied later.

[1] Honorio da Silva E., Davesne E., Bonchuk Y., Ratia G., Madas B., Berkovskyy V. and Broggio D. 2023. Changes induced in the human respiratory tract by chronic cigarette smoking can reduce the dose to the lungs from exposure to radon progeny. J Radiol Prot 43: 021509. <https://doi.org/10.1088/1361-6498/acd3fa>



Dr. Balázs Madas, leader of Work Package 3, EK

Childhood cancer, radon-induced lung tumours, dose distribution effects.

WP4 was well presented during the 3rd Annual Meeting in Poland. We had our General Meeting as well as several joint meetings with other WPs and presented our results in platform and poster sessions. Active participation of WP4 Early Career Researchers is also acknowledged.

Three milestones have been submitted during this Autumn:

“MS45: Cases (childhood leukaemia and brain tumours) and controls enrolled” gives information on the progress of the Finnish study on the effects of residential radon and natural background gamma on childhood cancer (Task 4.3).

“MS46: Molecular signature of lung cancers in rats exposed to radon” describes a retrospective analysis of lung primary tumours induced by radon from the lifespan experiments of CEA (Task 4.5). The results were also presented during the platform session at the Annual Meeting.

“MS48: Comparison of homogeneous and inhomogeneous dose distributions provided to Task 3.6” reports first results of studies testing the hypothesis that inhomogeneous alpha-particle exposure leads locally to relative high doses, sufficient to induce cell death, followed by a transient increase in basal cell proliferation (Task 4.5).

The leadership of Task 4.6 was recently reorganised inside IRSN, and Sophie Ancelet is now leading the task. A new postdoctoral fellow has also started to work in this task.



Dr. Päivi Roivainen, leader of Work Package 4, UEF

Tools for radon measurement and analysis, strengthened QA/QC collaboration with WP2, positive stakeholder feedback during ERPW's Meeting.

In order to summarise all the main outcomes of WP5 reached since the last issued Newsletter, I would start with a presentation of the current status of milestones and deliverables. Two deliverables and two milestones, described in detail further in this Newsletter in the section Latest deliverables and publications, were successfully accomplished and submitted to the coordinator.

MS67 : Data sets collected and analysis completed (DSA);

MS68 : In-situ comparison measurement campaign in selected underground workplaces (SURO);

D5.6 : Prototype of an advanced measurement device for determining the radon diffusion coefficient in waterproofing materials (CVUT); and

D5.3 : Software tool for evaluation of time variation of the total radon entry rate indoors based on Kalman filtering (SURO).

There were plenty of productive and successful meetings and discussions held as part of internal meetings during the 3rd AM in Ustron. Among them, I would point out a joint session of Tasks 5.5, 2.1, 5.4, and 2.3 focused on the QA/QC programs and procedures implemented in radon/thoron and its progeny activity concentration measurement utilizing continuous radon monitors (CRMs) both in laboratory and field measurement conditions, which clearly demonstrated intensified collaboration between WP5 and WP2, covering some significant cross-cutting issues raised during the project research activities implementation. WP 5 also actively participated in the topical sessions during the plenary meetings open to all stakeholders.

Moreover, I would also highlight the very positive feedback from the WP5 involvement in the above-mentioned workshop, the Interest Group Meeting, which was held as a side event of the ERPW in Dublin, emphasizing, among other things, the key role of QA/QC procedures, measurement standardization, and general metrological aspects in relation to electronic radon monitors.



Dr. Ales Fronka, leader of Work Package 5, SURO

Societal research through cross-country surveys, citizen science, stakeholder interviews, launched a data toolbox.

We are excited to share significant progress from WP6 in the investigation of societal aspects related to radon and NORM. Researchers have successfully concluded data collection through computer-assisted personal interviews in the final countries, with Norway completing the series. A total of 15 surveys have been conducted (Portugal pending), examining people's attitudes, behaviours, and opinions concerning the testing and radon mitigation of dwellings. Utilising a standardised questionnaire has enabled researchers not only to identify driving factors for testing and mitigation in each country but also to facilitate cross-country comparisons. National support from radon management authorities played a crucial role in facilitating most of the data collection.

In a major development, the RadoNorm toolbox, serving as an open data source, has been established in the STORE database, housing all data collected in WP6 through qualitative, quantitative, and mixed methods approaches.

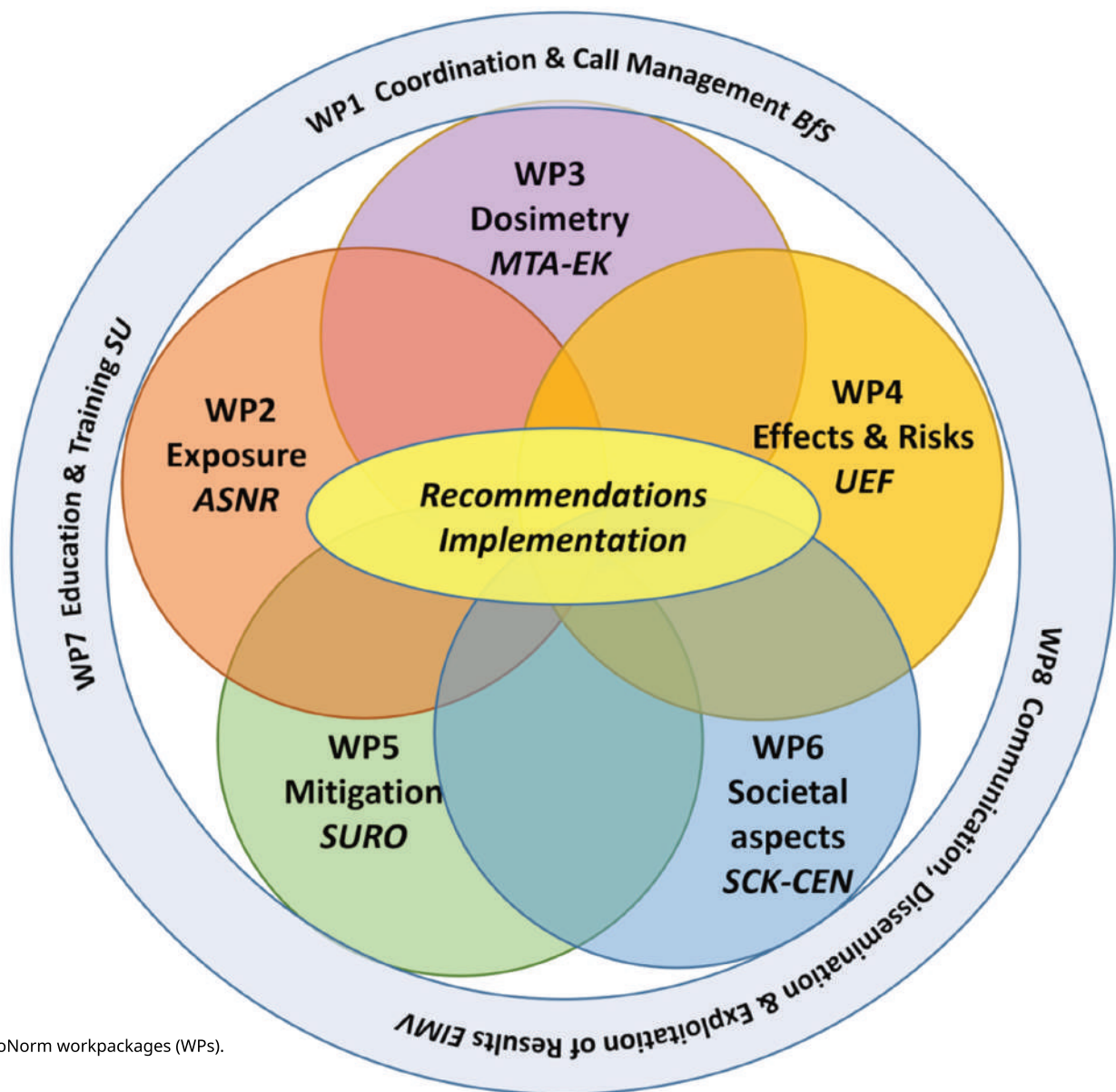
Exciting news comes from our communication team, which has developed social media communication tools aimed at motivating people to test and mitigate. Currently, these tools are in the testing phase in Slovenia, Belgium, Austria, and Ireland, with a planned large-scale deployment of social media campaigns in February in different countries.

RadoNorm continues to pioneer the investigation of radiation risk perception of NORM in geothermal installations. Interviews and workshops with workers, authorities, and managers in the industry have been conducted, with data currently in the analysis phase. Additionally, interviews with workers and visitors of radon spas in Austria and Germany have been completed to explore their perceptions of radon risks and benefits.

RadoNorm actively engages hundreds of citizens in seven distinct citizen science projects across Hungary, Poland, Portugal, Italy, Spain, Slovenia, and the Slovak Republic. Participants contribute significantly to the field of radiation protection from radon through various means, including the creation of measurement tools, conducting radon measurements at diverse locations, and developing do-it-yourself tools for radon mitigation.

WP6 has also made valuable contributions to the PIANOFORTE strategic research agenda in the field of social science and humanities (SSH). Furthermore, the team actively participated in a panel discussion at the RICOMET 2023 conference. During this discussion, our coordinator highlighted the significance of inclusion and collaboration with SSH in contributing to the success of project objectives. The RICOMET 2023 conference has been co-organised with the RadoNorm project also this year.





RadoNorm workpackages (WPs).

Events and trainings: past and future

WP7 awarded a record number of travel grants, supported active ECR engagement, hosted training events and panel discussions, and continued its successful course series. Many ECRs are concluding their terms, with several already securing positions within RadoNorm partner institutions, demonstrating the project's impact on career development.

Record ECR mobility, expanded council activities, successful training courses, new career opportunities within the RadoNorm network.

WP7 has seen its highest number of travel grants awarded this year, which has enabled our early career researchers (ECRs) to showcase their latest RadoNorm results and progress in various conferences and also participate in educational training courses. Also, the ECR council, initiated during the Annual Meeting in Munich in 2022, expanded their activity. Aside from their monthly meetings, which are still ongoing, they were also able to organise a meeting in person during the third Annual Meeting, which took place in Ustroń, Poland. Here, they could elect or re-elect their board members for the next year. The annual meeting also gave them the opportunity to organise a panel discussion as part of the plenary session on the topic of career perspectives in radiation protection, where diverse panellists were invited to discuss topics such as mentorship, career opportunities and essential skills needed in the field. The council additionally organised a training webinar on the topic of “Reference Managers” on 8th December 2023, where WP3 leader, B. Madas, gave an introduction to using Zotero. Moreover, the ECR council is preparing its second application for a course to be held in 2024.

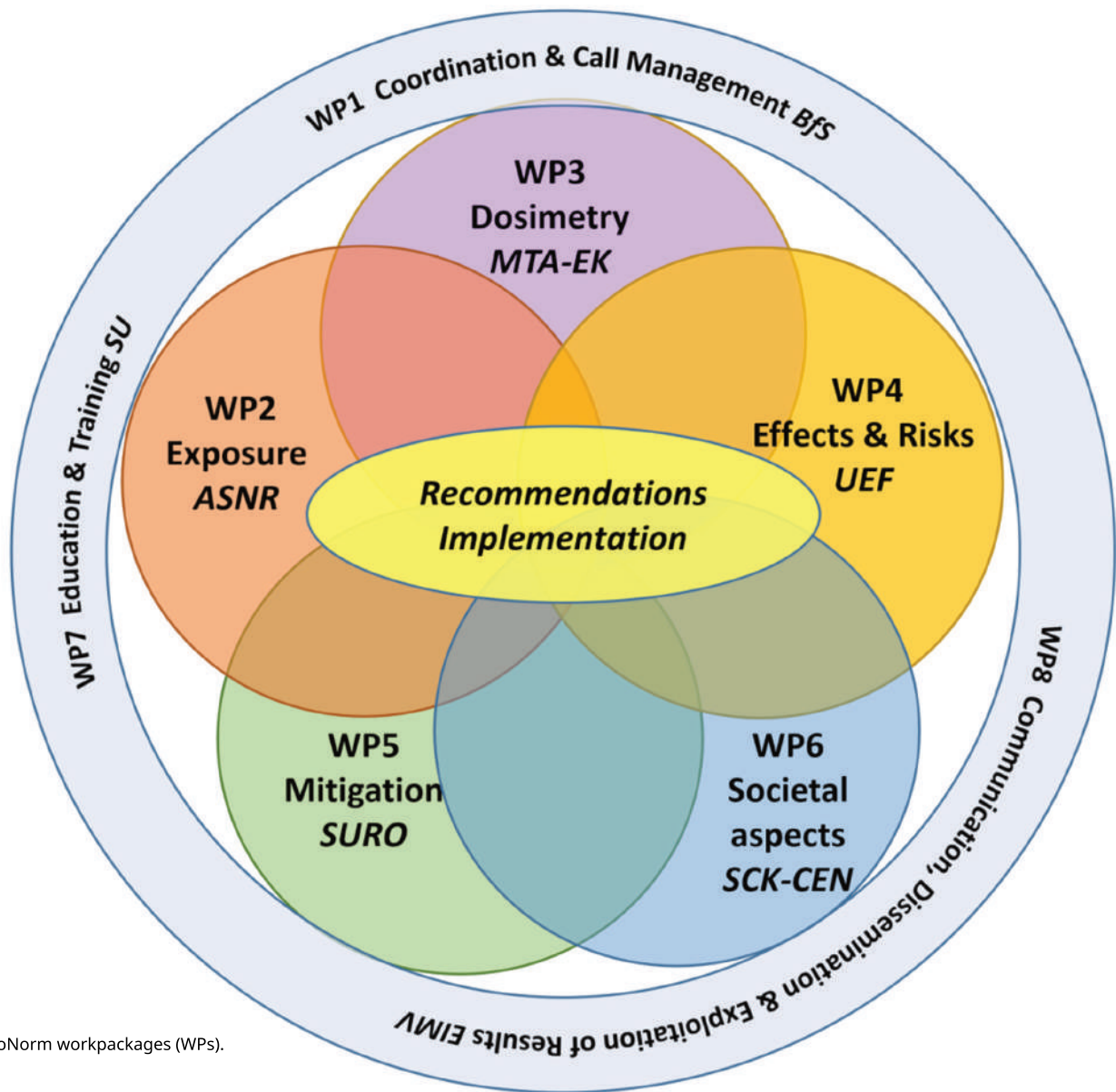
The last two training courses of the third series of courses organised in the framework of WP7 also took place. The course on the NORM impact assessment toolkit was jointly organised by the Universities of Porto and Aveiro in September 2023. At Stockholm University, the CELET course (Cellular effects of high and low LET ionising radiation) took place in November 2023. Both courses were offered for the third consecutive time after their previous successful rounds. Once again, feedback was overwhelmingly positive.

Many of our ECRs are coming to the end of their terms in RadoNorm. However, thanks to the networking opportunities that RadoNorm has provided, some of them have already found further employment opportunities in one or more RadoNorm partners. This highlights the success of RadoNorm in preserving competence in the field, and we hope that the trend continues.



Dr. Andrzej Wojcik, leader of Work Package 7, SU
Dr. Warren John, leader of Work Package 1, BfS





ECR Council

The ECR Council elected a new board for 2023–2024 and planned key activities, including a second training course on career management and new webinars. Following positive feedback, a second Zotero class is scheduled for January 2024, supporting ECRs in writing, stress management, and career development.



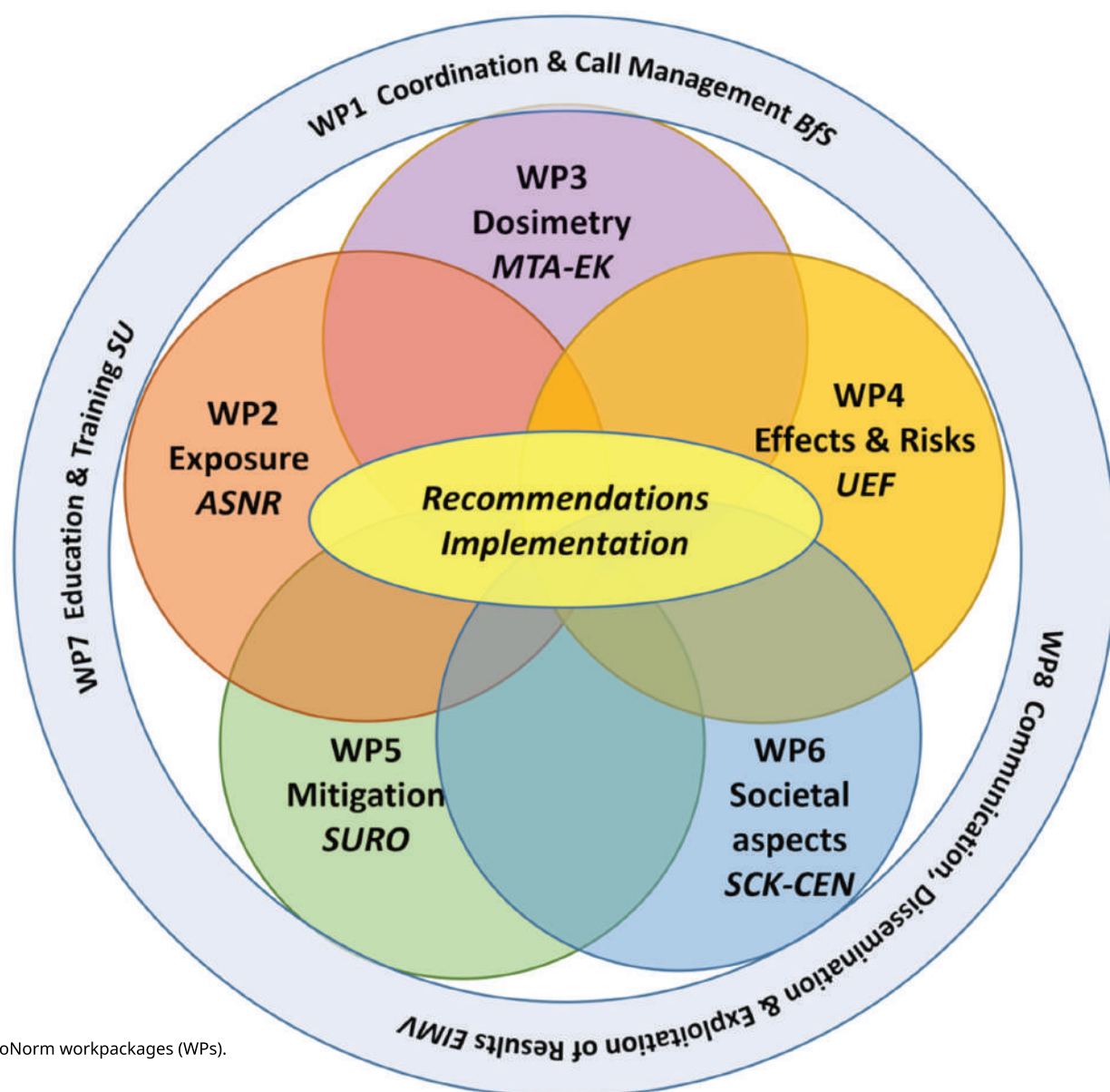
Dr. Ämilie Degenhardt, BFS

The ECR Council elected a new team and set plans for training, webinars, and a scientific publication. A second course on career management and additional Zotero training reflect strong engagement and support for ECR development.

During the 3rd Annual Meeting, the Early Career Researchers Council held elections for the term October 2023 – June 2024. The elected team is formed by the work package representatives Jaime Gomez Bolivar (WP2), Kim Sennhenn (WP3), Federica Turrisi (WP4), Agata Grygier (WP5), and Mabel Akosua Hoedoafia (WP6), the Scientific secretary Jad Abuhamed, and the Chair Ämilie Degenhardt. They also established activities to be developed during the term: a training course, webinars, and writing a scientific paper.

Due to the great success of the first training course organised by the council on “Transdisciplinary Communication in Radon and NORM” that took place in Stockholm in April 2023, the ECRs are planning a second training course. This time, the focus is on “Career management and perspectives in radon and NORM” which is planned to take place in Prague, hosted by the National Radiation Protection Institute (SURO) in April 2024. As the project approaches its conclusion (August 2025), many ECRs are finishing their PhD or their contracts as postdoctoral fellows. The course aims to help these ECRs manage time and stress due to thesis writing and deadlines. They will also learn how to improve their scientific writing, which will directly impact the quality of the publications on Radon and NORM, and more generally, on results from radiation research studies. Furthermore, they will learn strategies to prepare themselves and to apply for positions in the field of radiation protection and research, including radon and NORM.

Additionally, an online class on “How to use a reference manager software? – Training with Zotero” was organised by the ECR council and led by Balázs Madas (WP3) on the 8th of December 2023. Because of the positive feedback of the attendees and the great interest shown by the RadoNorm community, a second online class on the topic is planned on the 19th of January 2024.



RadoNorm workpackages (WPs).

Latest deliverables and publications

Several new RadoNorm publications address radon risk communication, radium and uranium in the environment, sensor performance, dose assessment, and radiation-induced health effects, showcasing interdisciplinary research and international collaboration.

The following deliverables are now available on the RadoNorm website:

Caroline Vignaud et al. (2023): Workplace-type specific methods to assess the exposure of workers to radon: Focus on underground workplaces and itinerant workers, D2.7:

Within the work package 2 dealing with “Exposure”, the task “Exposure to radon in buildings” aims at studying building materials (subtask 2.3.1), radon exposure in workplaces (subtask 2.3.2) and the contribution of other sources than local geology on radon exposure in buildings (subtask 2.3.3). This report concerns subtask 2.3.2 and presents the technical recommendations that might be taken into consideration to develop radon and radon progenies measurement protocols of some of member states and some non-European countries. The technical measurement recommendations are focused on underground workplaces and issues regarding itinerant workers. Some examples are given to illustrate the recommendations and to provide an overview of some countries’ practices. Measurements and tests in underground workplaces are still ongoing at the publication date of this report; thus, the resulting information will be analysed and published at the end of the project.

Nahla Mansouri et al. (2023): Approach to determine the contributions of local geology and other sources on the radon exposure in dwellings (scenarios and modelling of radon transport from soils to indoor air), D2.8:

Indoor radon activity concentration is the result of complex processes from different sources such as soil, building materials, gas and water supply. It is well known that the main source of radon in buildings is the soil underneath the building. In some situations, anthropogenic materials (such as uranium mill tailings from former uranium mines, phosphate mine tailings, etc.) can also be a source of radon and contribute to indoor exposure. This work aims to provide some answers to questions raised in the context of expert assessments carried out on exposure to radon of anthropogenic origin linked to the presence of radium-bearing waste. Such waste resulting from human activity can, in certain situations, constitute anthropogenic sources of radon in buildings and generate high radon exposure. The action consists of studying the possibility of using calculation tools (mathematical models), in addition, where appropriate, to in situ measurements (soil and building), to estimate the potential influence of anthropogenic sources on radon levels in the indoor air of houses.

Gabor Albrecht et al. (2023): Report on results of computational microdosimetry supporting the preparation and evaluation of experiments, D3.5:

The general aim of Task 3.5 is to support the biological experiments performed in Work Package 4. The specific aims are i) to quantify the in vivo dose distributions in human lungs in order to provide realistic exposure conditions for in vitro experiments with cell cultures and

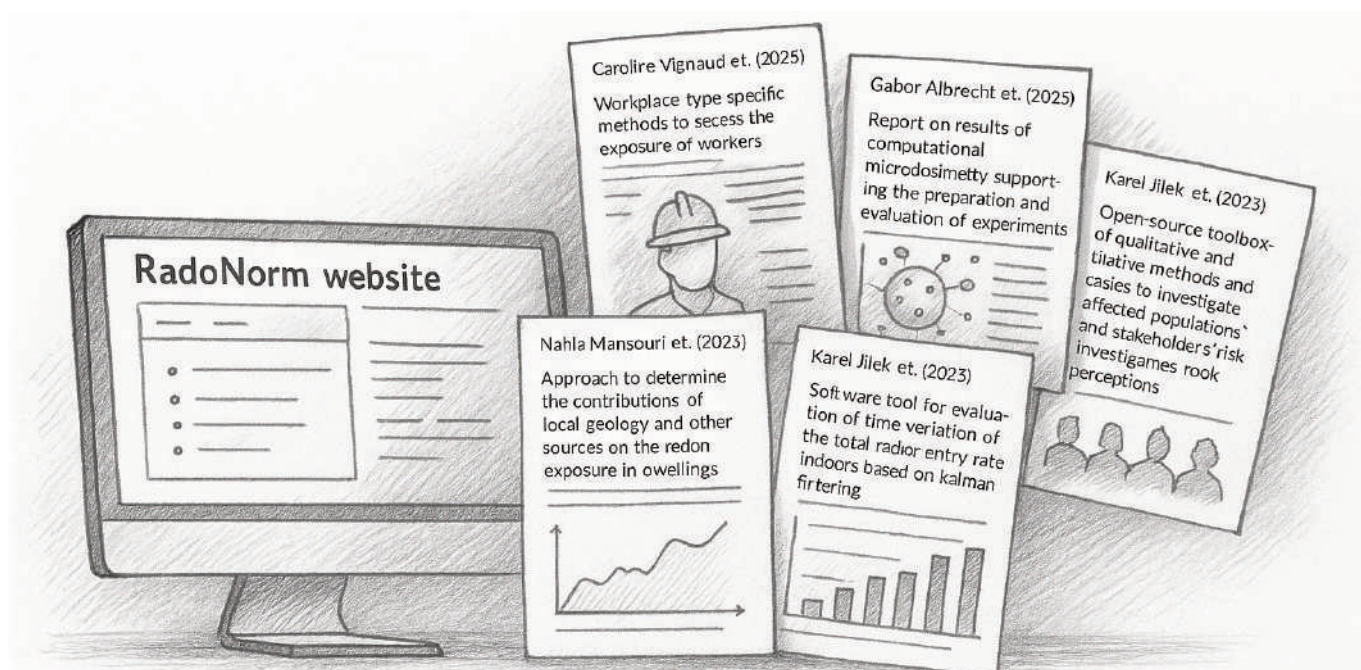
organotypic tissue models, ii) to quantify the dose distribution in rat lungs in order to support a retrospective rat study, and iii) to quantify the specific energy and hit distributions in in vitro experiments with cells and organotypic tissue models exposed to radon and solid alpha-sources. For these purposes, computational microdosimetry has been applied. Two computational modelling approaches were combined to estimate absorbed doses in different cell nuclei of the human lungs in the case of several exposure conditions, including home and uranium mine environments. Taking into account the spatially inhomogeneous dose distribution, both average doses in the bronchial airways and maximum doses in the deposition hot spots were estimated. Based on the simulations, recommendations were made to investigate the effects of 1 WLM exposure in the bronchial airways.

Karel Jílek et al. (2023): Software tool for evaluation of time variation of the total radon entry rate indoors based on the Kalman filtering, D5.3:

As a part of subtask 5.2 of the RadoNorm project, an open-source software tool for evaluation of time variation of the total radon entry rate indoors based on the Kalman filtering was developed. It serves for the simultaneous estimation of time-varying radon-entry rate (RER) and air-exchange rate (ACH) from the bivariate time series of measured radon and a tracer gas (where tracer entry rate is known). Statistical modelling is based on a new generation of the state-space model obtained by discretisation of a system of two ordinary differential equations, simply describing the underlying physics. The report describes the process of running the code in the R environment, the software requirements and the structure of the supplied data. The output data in .csv format can be further processed and output graphically. The attached example using actual measured data demonstrates the possibilities of using the script and understanding the outputs.

Jiránek M., Froňka A. (2023): Prototype of an advanced measurement device for determining the radon diffusion coefficient in waterproofing materials, D5.6:

As part of subtask 5.2 of the RadoNorm project, a prototype of an advanced measuring device was created to determine the radon diffusion coefficient in building materials. The device is intended for test methods based on determining the radon flux from the tested material. The device therefore enables the continuous measurement of the radon concentration on both surfaces of the material. It consists of several components (radon source, a set of source and receiver containers, radon concentration meters in the source and receiver containers and a flow pump). What is new compared to the current state is that these components are not firmly assembled into a single device, but their mutual arrangement can be freely changed according to the current need. The size and shape of the source and receiver containers can be changed according to the size of the test sample.



In addition, several samples can be measured at the same time, and their number can be changed as desired. A professional certified product or a homemade source can be used as a radon source.

Perko, T. and Martell, M. (2023): Open source toolbox of qualitative and quantitative methods and scales to investigate affected populations' and stakeholders' risk perceptions, views, opinions, motivations, attitudes and behaviour in radon areas and NORM exposures, including methodological guidelines, D6.2:

One of the objectives of the RadoNorm project is to develop an open source toolbox of qualitative and quantitative methods and scales, including a comprehensive database related to affected populations and stakeholders risk perception, view, attitudes and behaviour in radon and NORM exposures leading to integration of the radiation protection scientific community at EU level and a better coordination of social science and humanities research efforts. This deliverable (D6.2) describes the toolbox, its content and structure. This methodological toolbox is designed to enable social science researchers and practitioners in the field of radon communication to have access to the different methods and scales developed and used during the RadoNorm project to investigate different aspects related to radon risk, knowledge, attitudes, behaviour, etc.

New papers have been published as part of the RadoNorm achievements:

<https://doi.org/10.1093/rpd/ncad178>: Cold season dose rate contributions from gamma, radon, thoron or progeny in legacy mines with high natural background radiation,

Haanes et al.

<https://doi.org/10.3389/fpubh.2023.1252804>: A psychosocial-environmental lens on radon air pollutant: authorities', mitigation contractors', and residents' perceptions of barriers and facilitators to domestic radon mitigation, Hevey et al.

<https://doi.org/10.1016/j.scitotenv.2023.167065>: Assessing the exposure situations with naturally occurring radioactive materials across European countries by means of the e-NORM survey, Popic et al.

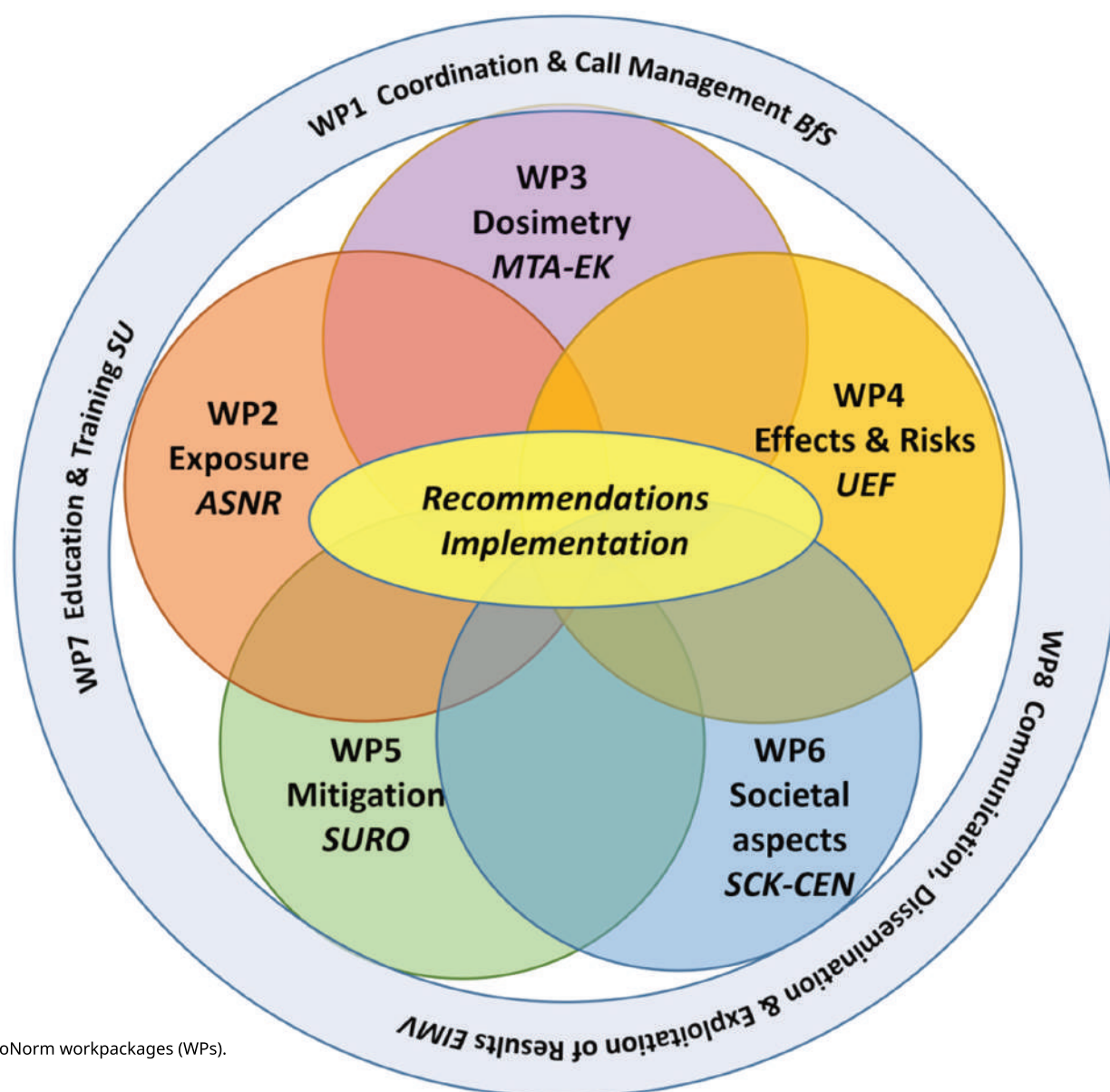
<https://doi.org/10.12688/openreseurope.15968.2>: When citizen science meets radon building diagnosis: Synthesis of a French pilot project developed in the framework of the European RadoNorm research project, Andresz et al.

<https://doi.org/10.3390/buildings13112706>: An Environmental Evaluation of Ventilation Systems Aimed at Reducing Indoor Radon Concentration, L Felicioni, M. Jiránek, B. Vlasatá, A. Lupíšek

<https://www.mdpi.com/1660-4601/20/23/7128>: Evaluation of Radon Action Plans: Searching for a Systematic and Standardised Method, Martell et al.

<https://iopscience.iop.org/article/10.1088/1742-6596/2600/15/152018>: Environmental assessment of several scenarios of active and passive radon control measures, Felicioni et al.

<https://doi.org/10.1016/j.jenvrad.2023.107355>: Measuring societal attitudes and behaviours towards radon indoors: A case study of Slovenia, Perko et al.



RadoNorm workpackages (WPs).

Researchers in a spotlight

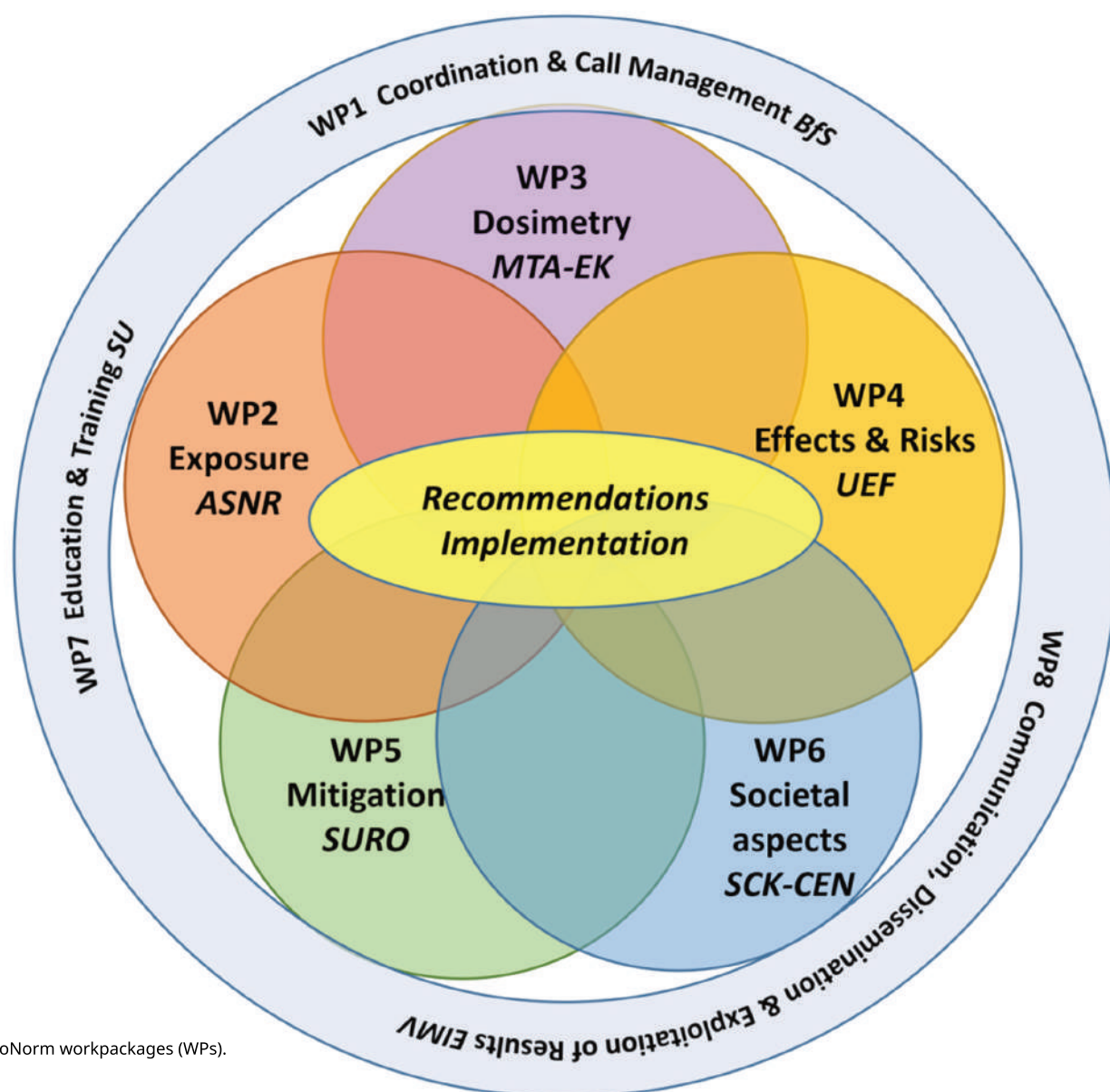
Jan Boei (LUMC) contributes to WP4 by studying how alpha-particle exposure affects bronchial epithelium in non-smokers. His work models lung responses, focusing on basal cell repair and proliferation under both uniform and inhomogeneous exposure, helping to predict biological effectiveness for RadoNorm.

Jan Boei (LUMC) studies how alpha-particle exposure affects bronchial epithelium, modelling lung response in non-smokers for WP4.

Jan Boei is a scientist at the Leiden University Medical Center and within the RadoNORM project he is contributing to WP4. In the framework of task 4.5 “Mechanisms of radiation action in lung cancer among never smokers” he investigates the biological consequences of homogeneous and heterogeneous alpha-particle exposure of bronchial epithelium, the principal tissue at risk upon radon inhalation. Hereto, primary human bronchial epithelial cells are differentiated at the air-liquid interface on tissue culture inserts to form an epithelial layer closely resembling the epithelium lining the human bronchi. Especially the effects of exposure on the basal cells present within this tissue are of interest. Under normal conditions most of these basal cells are not dividing but upon airway injury they are responsible for tissue regeneration and the maintenance of homeostasis. Therefore, investigations are focused on the repair of induced damage and the effects of exposure on the capacity of basal cell proliferation. The obtained insights on the impact of alpha particle exposure on cells within this relevant and complex tissue environment can be used to model and predict the relative biological effectiveness and are therefore shared with Task 3.6. In addition, inhalation of radon leads to an inhomogeneous exposure of the lungs with the epithelial layer lining the bronchial bifurcations receiving the highest dose. The air-exposed nature of the described lung models enables mimicking such an inhomogeneous exposure by partially shielding the models. Also repeated and chronic low dose rate exposure for several weeks are feasible using the in vitro models of reconstituted human bronchial epithelium. The consequences of such exposure scenarios are part of the current and future research performed within RadoNORM.



Dr. Jan Boei, Leiden University Medical center, Netherlands



RadoNorm workpackages (WPs).

RadoNorm engagement opportunities

The RadoNorm website and social media share project updates, results, and engagement opportunities. Stakeholders are invited to join groups, subscribe to the newsletter, and attend the 4th Annual Meeting in Ljubljana (June 2024), which will be held in hybrid format with limited financial support available for participants.

RadoNorm invites stakeholders to stay informed and engaged via its website, social media, newsletter, and upcoming hybrid Annual Meeting in June 2024.

The RadoNorm website provides much information about the project, objectives, work programme, its development and results, interaction and engagement possibilities. RadoNorm on social media platforms LinkedIn, Twitter (now X) and YouTube, which are also accessible via the website, provide the latest news about the projects and its results. You are kindly invited to follow us.

RadoNorm established different engagement opportunities for the related and interested stakeholders. Several stakeholder groups are established for active involvement of different representatives in the project's activities, such as pilot testing of communication tools, development of new regulatory standards, discussions on scientific findings, or to be just informed about the RadoNorm results. You are most welcome to join the RadoNorm stakeholder groups. It is easy to submit your application.

The subscription to more information, like Newsletter issues, is also available. The RadoNorm partners, stakeholders and other groups are regularly informed about publications, news, events and calls. All developed contact databases are managed according to the RadoNorm Privacy policy.

The 4th RadoNorm Annual Meeting will be held on 12th and 13th of June 2024 in Ljubljana, Slovenia, following the RadoNorm internal meetings on 10th and 11th of June 2024. The meeting will be in a hybrid format to allow as many stakeholders as possible to attend. The preliminary agenda and more organisational information will be shared soon. The stakeholder engagement is also foreseen as it has been assessed to be a big added value of the conference. We kindly ask you to consider your participation in the event. We will, same as last year, financially support a limited number of stakeholders to participate and contribute to the event.



Dr. Nadja Železnik, leader of Work Package 8, EIMV

Sources



Stepping in the RadoNorm year 4

- ⊕ 3rd Annual Meeting, <https://www.radonorm.eu/activities/3rd-annual-meeting/>
- ⊕ Citizen science projects, <https://www.radonorm.eu/activities/radonorm-citizen-science/>
- ⊕ Interest Group Meeting, <https://www.radonorm.eu/performance-testing-of-electronic-radon-monitors/>

Short news from WPs

- ⊕ Honorio da Silva et al., <https://doi.org/10.1088/1361-6498/acd3fa>

Events and trainings: past and future

- ⊕ Travel grants, <https://www.radonorm.eu/calls/call-for-travel-grant/>
- ⊕ Courses, <https://www.radonorm.eu/calls/call-for-courses/>
- ⊕ NORM impact assessment toolkit, https://www.radonorm.eu/wp-content/uploads/2023/05/Flyer-Advanced-course_v3.pdf
- ⊕ CELET course, <https://www.radonorm.eu/wp-content/uploads/2023/09/CELET-2023-flyer.pdf>

Latest publications

- ⊕ RadoNorm website, <https://www.radonorm.eu/publications/deliverables/>
- ⊕ New papers, <https://www.radonorm.eu/publications/scientific-papers/>
- ⊕ Haanes et al., <https://doi.org/10.1093/rpd/ncad178>
- ⊕ Hevey et al., <https://doi.org/10.3389/fpubh.2023.1252804>
- ⊕ Popic et al., <https://doi.org/10.1016/j.scitotenv.2023.167065>
- ⊕ Andresz et al., <https://doi.org/10.12688/openreseurope.15968.2>
- ⊕ Felicioni et al., <https://doi.org/10.3390/buildings13112706>
- ⊕ Martell et al., <https://www.mdpi.com/1660-4601/20/23/7128>
- ⊕ Felicioni et al., <https://iopscience.iop.org/article/10.1088/1742-6596/2600/15/152018>
- ⊕ Perko et al., <https://doi.org/10.1016/j.jenvrad.2023.107355>

RadoNorm engagement opportunities

- ⊕ RadoNorm website, <https://www.radonorm.eu/>
- ⊕ LinkedIn, <https://www.linkedin.com/company/radonorm/>
- ⊕ Twitter (now X), <https://twitter.com/RadoNorm>
- ⊕ YouTube, <https://www.youtube.com/channel/UC6yCORiPX5DXgmu5AaGLn9Q>
- ⊕ RadoNorm stakeholder, <https://www.radonorm.eu/stakeholders/>
- ⊕ Subscription to more information, <https://www.radonorm.eu/newsletter/>
- ⊕ RadoNorm Privacy policy, <https://www.radonorm.eu/privacy-policy/>
- ⊕ The 4th RadoNorm Annual Meeting, <https://www.radonorm.eu/activities/4th-annual-meeting/>

Key takeaways



- ☢ **WP2 delivered two major reports and six milestones, advancing radon/thoron modelling, workplace exposure assessments, and cross-cutting collaboration with WP5.**
- ☢ **WP3 progressed in computational microdosimetry and uncertainty analysis, supporting WP4's studies on lung dose impacts in smokers and non-smokers.**
- ☢ **WP4 delivered milestones on radon-induced childhood cancer and lung tumour mechanisms in rats.**
- ☢ **WP5 completed milestones on radon entry measurement and waterproofing tests, and enhanced QA/QC cooperation with WP2 during the ERPW Interest Group Meeting.**
- ☢ **WP6 finalised 15 national surveys and launched the RadoNorm social science data toolbox in the STORE database, enabling cross-country comparisons and risk perception studies.**
- ☢ **WP6 led seven citizen science projects across Europe and contributed to PIANOFORTE and RICOMET 2023, amplifying SSH integration in radiation protection.**
- ☢ **WP7 awarded a record number of travel grants, supported ECR-led training on Zotero and career development, and ran two international courses.**
- ☢ **The ECR Council planned new webinars, a training course in Prague for 2024, and continues supporting RadoNorm's next generation of researchers.**
- ☢ **Stakeholder engagement continues to expand, with open invitations to join RadoNorm groups and preparations for the hybrid 4th Annual Meeting in Ljubljana, June 2024.**



RadoNorm
Managing risks from radon and NORM

RadoNorm

Newsletter

N°7 - September 2024



Waterfall Pericnik, Slovenia
(photo B. Petkovsek)

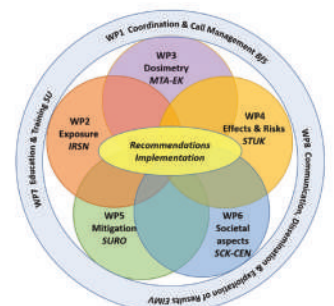
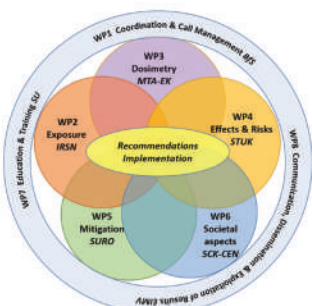
RadoNorm
Managing risks from radon and NORM

New project coordinator
Warren John replace Ulrike Kulka, we wish Ulrike all the best on her path

Dr. Augusto Giussani - Researcher in a spotlight
Models internal radiation doses from radionuclides for health protection.

Dr. Dariusz Aksamit - Researcher in a spotlight
Engages students in citizen science projects exploring natural radiation exposure.

Project's progress was reviewed by the European Commission
Exceptional results, significant impact



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RadoNorm Newsletter



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Editorial



Dr. Nadja Železnik, leader of Work Package 8, EIMV

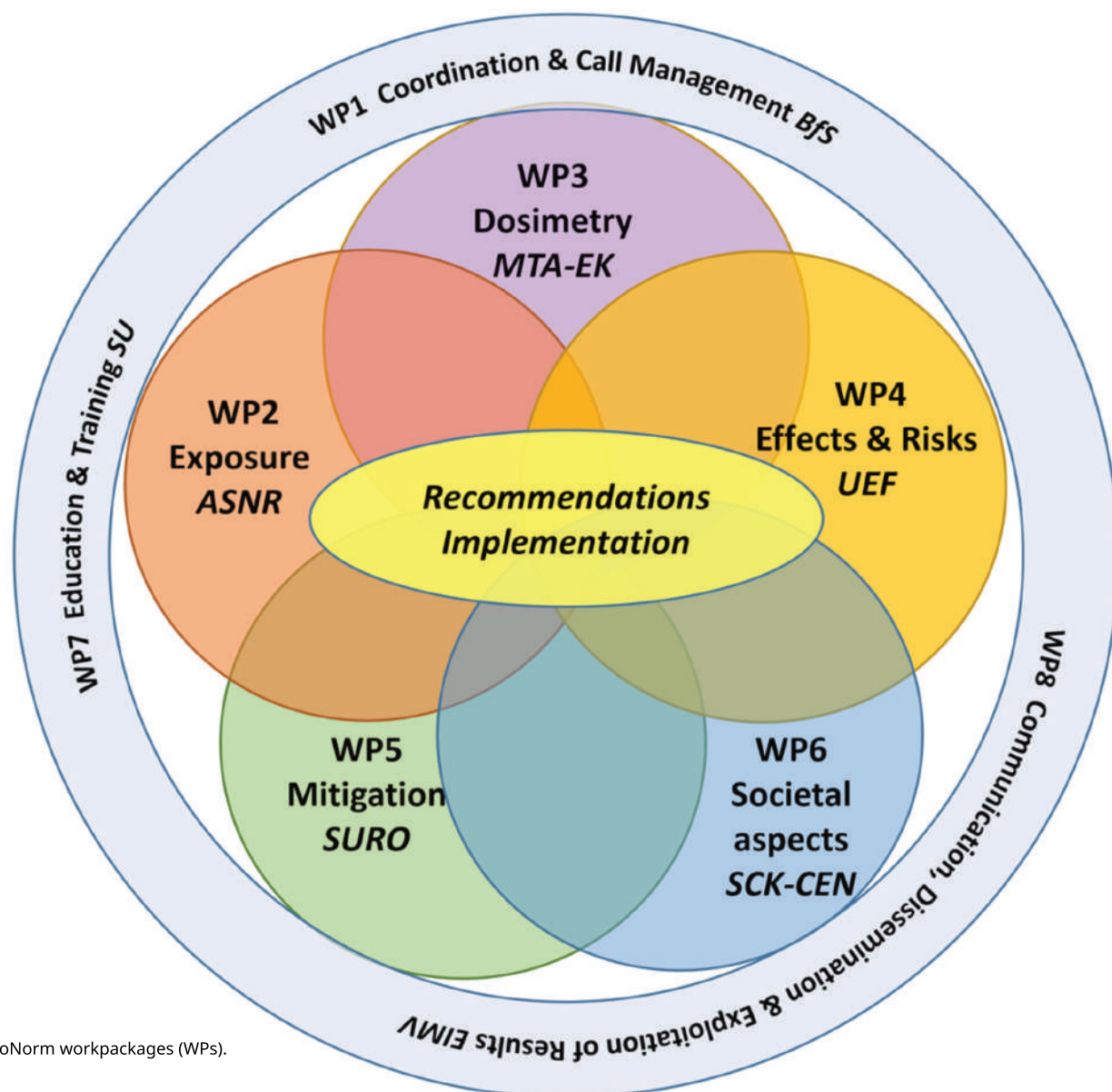
Dr. Nadja Železnik holds a BSc in Physics and an MSc in Reactor Physics from the Faculty of Mathematics and Physics, as well as a PhD in Psychology from the Faculty of Arts, all awarded by the University of Ljubljana, Slovenia. She is an expert in nuclear technology and radioactive waste management, with extensive experience in emergency preparedness and response, as well as in risk perception, communication, education, and training in environmental and nuclear projects.

She has acted as a civil society expert and knowledge manager in numerous European research initiatives, including EURAD-1 and -2, ECOSSENS, and RadoNorm. Her contributions include the development of national strategies, legislative frameworks, feasibility studies, safety and radiological assessments, and stakeholder engagement plans. She has authored communication strategies, training programmes, and information materials to foster public understanding and informed participation in the nuclear and environmental domains.

It is with great pleasure that we present the seventh issue of the RadoNorm Newsletter, offering a comprehensive look into the project's evolution as it enters the final stages of implementation. Now well into its fourth year, RadoNorm continues to mature, not only in terms of scientific achievement, but in how it brings together researchers, stakeholders, and the public to co-produce knowledge in the fields of radon and NORM.

This issue opens with reflections on the leadership transition and the European Commission's positive project review, reaffirming RadoNorm's continued momentum. The 4th Annual Meeting in Ljubljana, the most attended to date, showcased the project's interdisciplinary strength and societal relevance, complemented by the RICOMET conference's focus on social science integration and citizen engagement.

Highlights from across the work packages demonstrate progress in exposure science, dosimetry, mitigation, and social research. RadoNorm's collaborative efforts continue to bridge technical excellence with public involvement. With one year to go, we invite you to explore our latest publications and discover engagement opportunities.



Maturing RadoNorm – second half of year 4

In 2024, RadoNorm entered its fourth year with a new coordinator, Warren John. The EU review praised the project's exceptional results and impact in radiation protection. The Annual Meeting in Ljubljana highlighted interdisciplinary progress and strong public engagement, including award-nominated citizen science projects.

Leadership transition, receiving high praise in the EC review, and hosted its largest Annual Meeting in Ljubljana.

As RadoNorm entered its fourth year, 2024 marked a number of significant developments. In February, Ulrike Kulka stepped down as project coordinator and handed over her role to Warren John, who was previously undertaking the daily project management. The executive board of RadoNorm and the consortium members are deeply grateful to Ulrike for her expertise and insight in spearheading RadoNorm in its first three years, and the friendships she has let grow along the way. RadoNorm's objectives and priorities remain unchanged and the project continues to deliver on its initial ambitions.

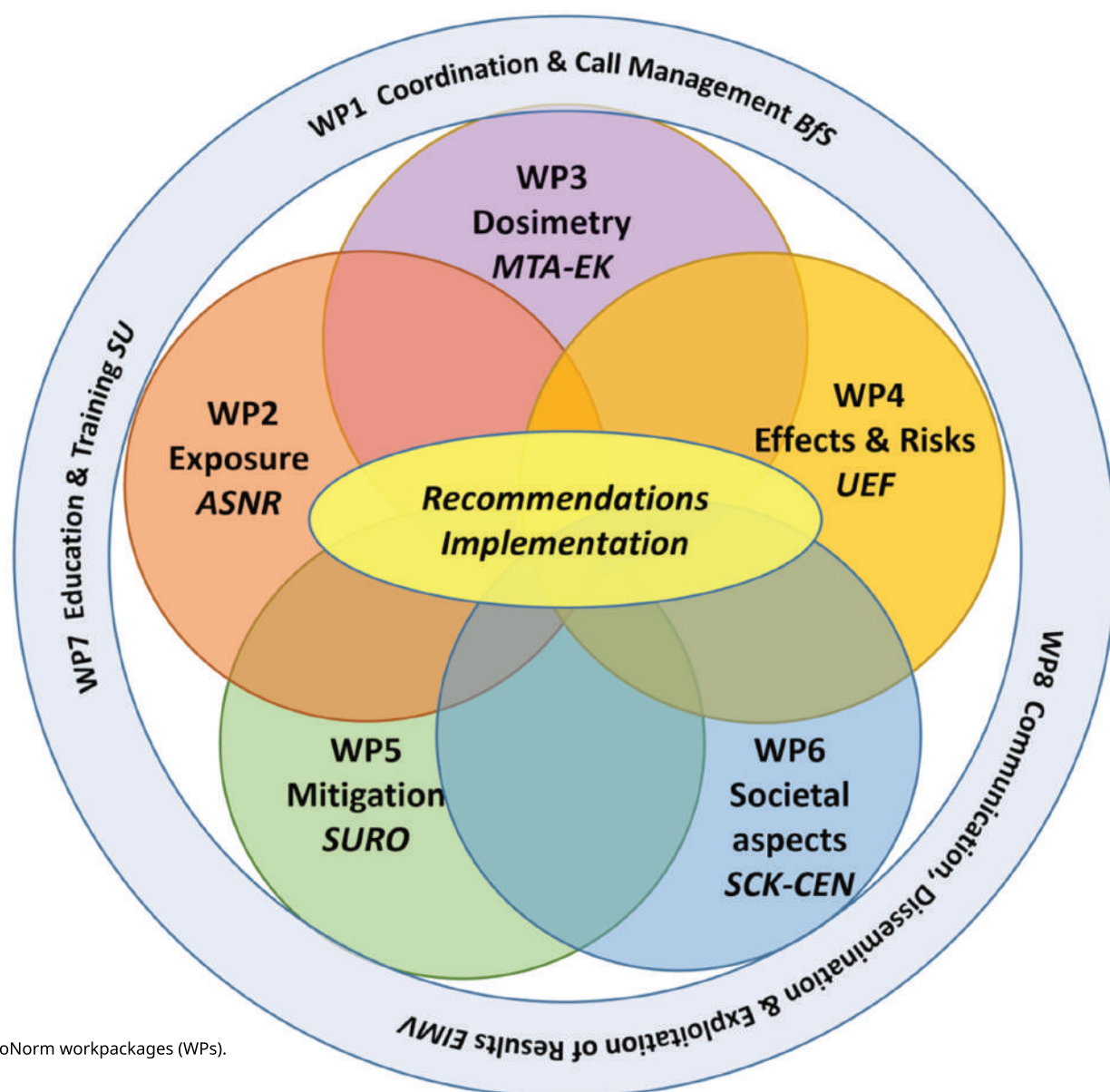
This was made especially clear by the project review conducted by the European Commission in January 2024. Here, the external reviewer, together with the project officer rated RadoNorm's progress positively, stating that the project has "delivered exceptional results with significant immediate or potential impact". RadoNorm's research was said to address vital questions in radiation protection and a lot of its outreach activities (education & training, dissemination, and citizen science, for example) were especially praised. In this light, the project also successfully concluded its 2nd periodic report at the beginning of the year.

To showcase RadoNorm's impact on society, the 4th Annual Meeting, held in June 2024 in Ljubljana, Slovenia, featured presentations from consortium members in three sessions titled "Fundamentals", "Recommendations" and "Applications & Implementation". It was the highest-attended annual meeting of the project, bringing together the consortium, stakeholders and distinguished guests from international organisations. Discussions with stakeholders revolved around the topics of radon communication, implementation of dose coefficients, and NORM in circular economy and building materials, to name a few. As the RICOMET 2024 conference was running parallel to the Annual Meeting this year, it also highlighted how RadoNorm integrates social sciences and humanities in its research portfolio. This integration was admirably exemplified through the funding of several citizen science projects encompassing radon testing and mitigation in radon-prone areas of Europe, thereby combining technical know-how and public engagement. The culmination of their activities was an honorary mention of the EU Prize for citizen science. The minutes of the meeting are already published.

RadoNorm continues to make progress and with each new question that its research answers, further avenues of research open up, which need to be addressed. The advancement of this massive pan-European consortium can be compared to a well-oiled machine, bringing together various disciplines in the field, effectively pushing the boundaries of radiation research and essentially demonstrating the importance of such a collaborative effort across Europe.



Dr. Warren John, leader of Work Package 1, BfS



RadoNorm workpackages (WPs).

Short news from WPs

WP2 made strong progress, achieving 6 deliverables, 8 milestones, and 6 scientific papers. Highlights include new models and methods for assessing radon/thoron exposure, building materials, plant uptake, and uranium behaviour. WP2 results were also shared at key events in Rome and Ljubljana.

WP2 marked a milestone period with significant scientific outputs, showcasing innovative methods and models across multiple exposure pathways.

A lot of progress has been done in WP2 since the last newsletter. Although a great deal of work is still in progress in WP 2, some tasks are nearing completion. The period was therefore marked by the achievement of 6 deliverable reports, 8 milestones and 6 scientific publications (Serra Ventura et al., 2024; Rey et al., 2024a, b; Galeone et al., 2024; Venoso et al., 2024 and Newman-Portela et al., 2024) referred at the end of this newsletter.

Deliverables released include:

D2.3 – Report and comprehensive database containing information on radon progeny activity concentration and aerosols characteristics in selected workplaces, which is the final report of subtask 2.1.3. After presenting the parameters necessary to make an effective dose evaluation and the different method available (from the measurement technique to the use of the Ventgraph model), the report provides the structure of a database that can help to compile all needed parameters to assess exposure to radon/thoron and their progeny in underground workplaces. Examples of applications are given.

D2.5 – Outdoor radon, thoron and their decay products –

exhalation, atmospheric transport and deposition, which is the final report of task 2.2. It includes the main outputs of this task, such as:

- The development and the application of a new method for determining the exhalation rate of radon and thoron with relatively short sampling integration in order to assess temporal variation of exhalation rate over short periods, like diurnally, and to assess for effects from hourly weather data.
- The analysis of temporal and spatial distributions and correlations of atmospheric radon at aerosol-monitoring system stations in Austria,
- The development and validation of a model to assess outdoor air radon across Europe
- The development and application of a soil-vegetation-atmospheric transfer model to assess exposure from radon and progeny to trees.

D2.6 – Methodology for the assessment of radon exhalation and gamma irradiation from building materials containing NORM and contribution of such materials to the indoor radon concentration, which is the final report of subtask 2.3.1. After a review of the approaches available in the literature for the assessment of building materials contribution to indoor radon concentration and gamma irradiation, the report presents measurement protocols to assess the radon exhalation rate from building materials, both in laboratory and in-situ conditions, as well as mathematical model of radon exhalation rate from building structures.

D2.14 – Recommendations for transfer parameters to plants, which is the final report of subtask 2.6.2. The report investigates the usability of the “constant plant concentration” approach as an alternative to the concentration ratio model classically used in radioecology to describe the soil-to-plant transfer of naturally occurring radionuclides (NOR). In cases where the “constant plant concentration”-approach is not suitable, the nonlinearity of the soil-to-plant transfer was investigated for several couples of plant and NORs.

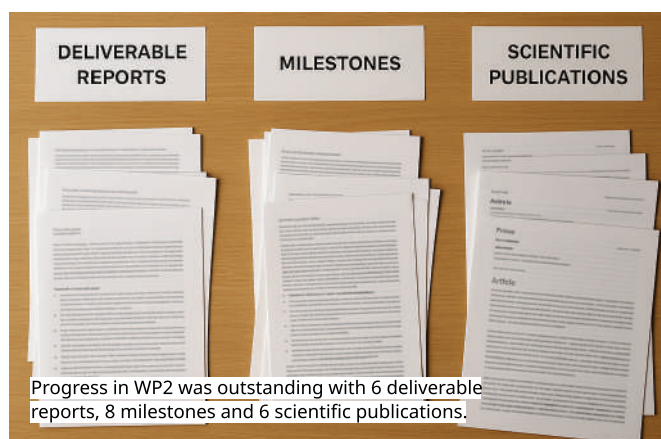
D2.15 – Report on the influence of microorganisms on the transport behaviour of uranium in mine waters, which is the final report of subtask 2.7.1. The deliverable reports results of experimental work to investigate the influence of the microbial activity of two mine waters on uranium speciation (more specifically on a possible reduction of soluble U(VI) species into a more immobile form of U) using a multidisciplinary approach combining microbiological, geochemical, microscopic and spectroscopic techniques.



Dr. Laureline Fevrier, leader of Work Package 2, IRSN

D2.16 – Laboratory sorption-desorption experiments and updated databases on soil sorption and desorption parameters for NOR, which is the final report of subtask 2.7.2. The report presents a series of complementary laboratory and in situ studies that have been completed in order to generate new knowledge and improve the models to predict the mobility of uranium (U), thorium (Th), polonium (Po) and radium (Ra) in soils.

Besides, WP2 activities have been presented at several conferences or meetings, such as the 3rd European NORM Association workshop last May in Rome, Italy, and the 4th RadoNorm Annual Meeting in Ljubljana in June.



Dr. Balázs Madas, leader of Work Package 3, EK

As RadoNorm enters its final year, many activities within WP3 are also approaching completion. The report on the effect of smoking on absorbed doses from radon exposure was submitted at the end of May, marking the formal completion of Task 3.1, although some related activities will continue. Task 3.4 is also nearing its conclusion, with one paper recently published and another manuscript currently under review. While Task 3.5 was formally completed last year, ongoing activities continue to support experiments in WP4. In the spring, Szabolcs Polgár, a PhD student, spent a month at Stockholm University to provide dosimetry support for in vitro experiments, thanks to a RadoNorm Research Stay Travel Grant.

Joint activities have also been strengthened in other tasks. In early May, Task 3.3 held a joint meeting with Task 4.3, where participants agreed on various actions. Among these, a webinar on radiation epidemiology is planned for early October. A brief follow-up meeting also took place during the annual meeting. Collaborations within Task 3.6 have intensified this year as well, with several meetings occurring between researchers at HUN-REN EK and GSI.

The RadoNorm Annual Meeting was a highlight of this period. We are proud that five Early Career Researchers presented their work during the plenary sessions. Additionally, we held a general meeting and several joint meetings with other tasks in Ljubljana.



Dr. Päivi Roivainen, leader of Work Package 4, UEF

WP4 held its annual General Meeting online in March. In addition, the tasks have had internal online and in-person meetings during the Spring and Summer. Collaboration with WP3 has remained active, also including research visits. The participation of WP4 members in the RadoNorm Annual Meeting is also acknowledged. The final year of the project will be busy, but all the tasks are on good track.

MS49: Combined effects of smoking and radon in separate cohorts were submitted in February 2024 by Task 4.1. This milestone reports on the investigation of the combined effect using the geometrical mixture model. The data originated from French and Czech cohorts of uranium miners.



Dr. Jonne Naarala, leader of Work Package 4, UEF



Mr. Valtteri Nieminen, co-leader of Work Package 4, UEF

The leader of WP4 changed in August as Päivi moved from UEF to another institute. She thanks all RadoNorm participants for their collaboration and wishes success for the final year of RadoNorm. The leadership remains at UEF and Professor Jonne Naarala will start as the new leader. Jonne is Professor of Radiation Biology and Head of the Department of Environmental and Biological Sciences. He will be assisted by a co-leader Mr. Valtteri Nieminen.

Intercomparison campaign in a Polish underground site, completion of deliverables on radon control, and a workshop on radon diffusion.

Several major achievements and deliverables were successfully accomplished within the WP5 that resulted from research activities carried out in close collaboration with all partners involved in individual Tasks and as a part of collaboration performed with subtask from WP2 Exposure. Some of the key results and outputs were presented during the 4th Annual Meeting in Ljubljana. I would like to highlight a particularly intensive collaboration on an intercomparison exercise that took place in an underground workplace in Poland. During this exercise, various detection equipment focused on radon activity concentration, equilibrium equivalent activity concentration, and attached and unattached fractions of radon progeny determination were tested at the Historic Silver mine in Tarnowskie Góry, from February 20th to 23rd, 2024. The Task 5.4 Radon reducing and control technologies applied in underground workplaces (mining industry; public access caves and mines; civil protection facilities etc.) has been completed recently, and both respective deliverables on measurement protocol of radon progeny attached and unattached fraction and the report on in-situ intercomparison measurement campaign have been submitted. A huge effort has been made on a consolidation of the deliverable D5.8 Report on Variability and Sustainability of Radon Prevention and Mitigation in Homes and Large Buildings, providing an in-depth analysis of the long-term effectiveness and variability of radon mitigation efforts across Europe. The report highlights that radon mitigation is effective in most situations, however, variability in outcomes is common due to differences in building types, technologies used, and maintenance practices differing in individual European countries. By doing this, Task 5.3 and all related research activities have finished, and the deliverable has been submitted to the EC for further evaluation. In addition, the Faculty of Civil Engineering, Czech Technical University, in collaboration with SURO, organised a special workshop on radon diffusion coefficient determination to discuss advanced techniques and procedures for determining the radon diffusion coefficient in waterproof materials. The workshop aimed to analyse and improve methods, particularly those related to ISO/TS 11665-13 for determining the radon diffusion coefficient. It also addressed measurement techniques and the correlation between measurement and calculation procedures. Fourteen representatives from nine organisations across five countries attended the workshop, sharing their experiences and methods for determining radon diffusion coefficients.



Dr. Ales Fronka, leader of Work Package 5, SURO

Course on qualitative methods, completion of a citizen science incubator involving 800+ participants across 10 countries.

For WP6, 2024 began with the organisation of a RadoNorm course on qualitative research methods. Spread over a two-week period, this course brought together renowned lecturers and a diverse group of international participants to discuss qualitative data gathering (e.g., focus groups, ethnography, interviews) and analysis (e.g., thematic analysis, framing analysis).

In February, WP6 held its annual meeting, focusing on the progress made over the past year and discussing the steps ahead as we enter the final project year. During this meeting, it became clear that significant progress had been made by the WP6 partners and that we are on course to complete all tasks within the planned timeline.

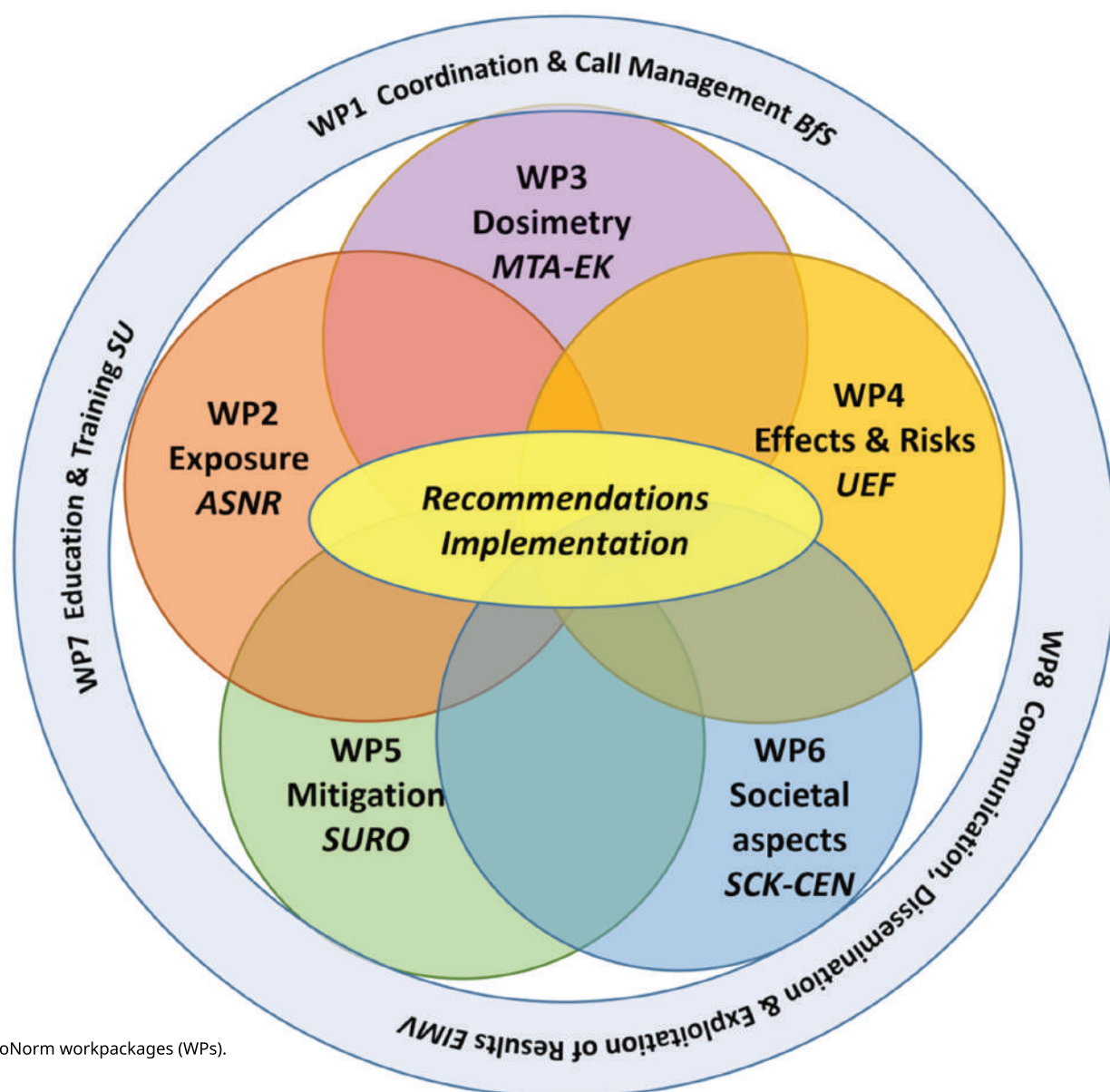
A particularly noteworthy activity in WP6 is the successful completion of a citizen science incubator. This incubator engages over 800 citizens in 10 countries and promotes collaboration between the public and experts to improve radiation protection practices across Europe. All of the citizen science coordinators and international citizen science expert Azby Brown met to exchange experiences and participate in a webinar during the 10th RICOMET conference, organised in Ljubljana in June.

Over the past months, the scientific outreach of WP6 was facilitated by the publication of various articles and book chapters, with contributions focusing on citizen science and radon communication. WP6 research was also presented at various scientific conferences and meetings, including those of the Society for Risk Analysis (SRA), the European NORM Association (ENA), the International Radiation Protection Association (IRPA), and RICOMET. Finally, on May 8th, a RadoNorm webinar was dedicated to WP6 research on NORM in the geothermal industry.



Dr. Tanja Perko, leader of Work Package 6, SCK CEN
Dr. Robbe Geysmans, leader of Work Package 6, SCK CEN





RadoNorm workpackages (WPs).

Events and trainings: past and future

In the first half of 2024, RadoNorm organised five diverse training courses and launched a new Research Stay Travel Grant to support ECR mobility and collaboration. One final course is scheduled for November, and a new call for 2024/2025 courses is open until 30 September, inviting proposals from RadoNorm partners.

Five training courses were delivered, a new mobility grant was launched, and the next course call is open until 30 September 2024.

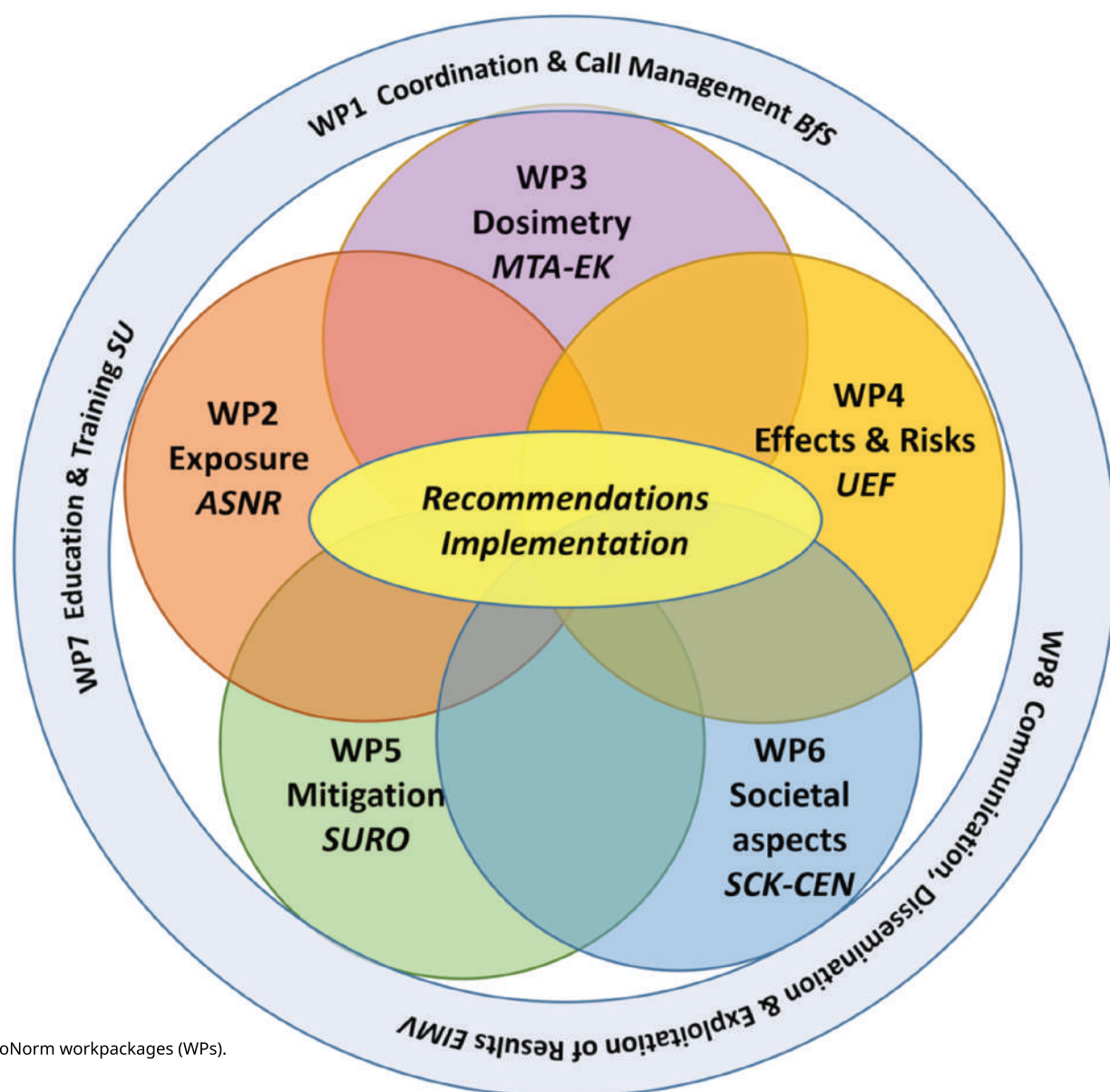
Five courses have been organised in RadoNorm in the first half of the year. They included different topics such as Qualitative research methods on the societal aspects of Radon and NORM: a hands-on experience, Career management and perspectives in radon and NORM, Interdisciplinary radiation research on radon, Naturally occurring radioactive material – characterisation, inventory of related exposure situations and monitoring principles, Workshop on translational and clinical oncology applied to environmental & occupational cancer: focus on radon. More details about the courses with fliers and programmes are available on the RadoNorm website. One training course on Cellular effects of high and low LET ionising radiation – Introduction to radiation biology will still be held from 11th to 22nd November 2024 at Stockholm University (Sweden). The deadline for applications is September 30th 2024, to andrzej.wojcik@su.se.

The next call for courses (2024/2025) in the Education and Training (E&T) programme is open until the 30th of September 2024 to RadoNorm Partners. The purpose of the training courses is to provide Education and Training covering all aspects of the scientific research areas relevant to RadoNorm in order to develop expertise in the field. The courses are primarily directed towards PhD students and early career researchers participating in RadoNorm but are also open to researchers from outside the project and to “citizen scientists” involved in WP6 of RadoNorm. All details can be found on the RadoNorm website. The future courses will be announced on the website and social media.

RadoNorm has also made available a new grant to encourage mobility and international exchange of its early career researchers, called the Research Stay Travel Grant. The goal of this grant is to fund longer-term exchange visits between RadoNorm partners or other relevant international institutions. Our ECRs have already been making use of this grant and are active in international collaboration.



Dr. Andrzej Wojcik, leader of Work Package 7, SU



RadoNorm workpackages (WPs).

Latest deliverables and publications

Several new RadoNorm publications address radon risk communication, radium and uranium in the environment, sensor performance, dose assessment, and radiation-induced health effects, showcasing interdisciplinary research and international collaboration.

New papers have been published as part of the RadoNorm achievements:

Perko, T., & Hevey, D. (2024). Communicating radon risks: the impact of different risk formulations on risk perception and protection intention. *Journal of Risk Research*, 1–19. <https://doi.org/10.1080/13669877.2024.2387346>

Serra-Ventura J., Vidal M., Rigol A. (2024). Construction and validation of parametric models to predict radium sorption in soils, *Science of the Total Environment*. <https://doi.org/10.1016/j.scitotenv.2024.173953>

Sixto-García, J., Pérez-Seijo, S., & García-Orosa, B. (Eds.). (2024). *Communicating Public Health Risk: The Case of Radon Gas* (1st ed.). Routledge. <https://doi.org/10.4324/9781032618180>

Galeone A., Devime F., Chapon V., Merroun M. L., Alban C., Ravanel S., Bourguignon J. (2024). Uranium-tolerant soil bacteria protect *Arabidopsis thaliana* seedling growth from uranium toxicity, *Environmental and Experimental Botany*, Volume 225, 2024, ISSN 0098-8472, <https://doi.org/10.1016/j.envexpbot.2024.105831>

Rey J. F., Meisser N., Licina D., Goyette Pernot J. (2024a). Evaluating the impact of indoor aerosols on the performance of real-time radon sensors, *Frontiers in Built Environment*, vol 10, <https://doi.org/10.3389/fbuil.2024.1407499>

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Tollefsen, K. E., Alonzo, F., Beresford, N. A., Brede, D. A., Dufourcq-Sekatcheff, E., Gilbin, R., ... Frelon, S. (2022). Adverse outcome pathways (AOPs) for radiation-induced reproductive effects in environmental species: state of science and identification of a consensus AOP network. *International Journal of Radiation Biology*, 98(12), 1816–1831. <https://doi.org/10.1080/09553002.2022.2110317>

Jaylet, T., Quintens, R., Benotmane, M. A., Luukkonen, J., Tanaka, I. B., Ibanez, C., ... Armant, O. (2022). Development of an adverse outcome pathway for radiation-induced microcephaly via expert consultation and machine learning. *International Journal of Radiation Biology*, 98(12), 1752–1762.

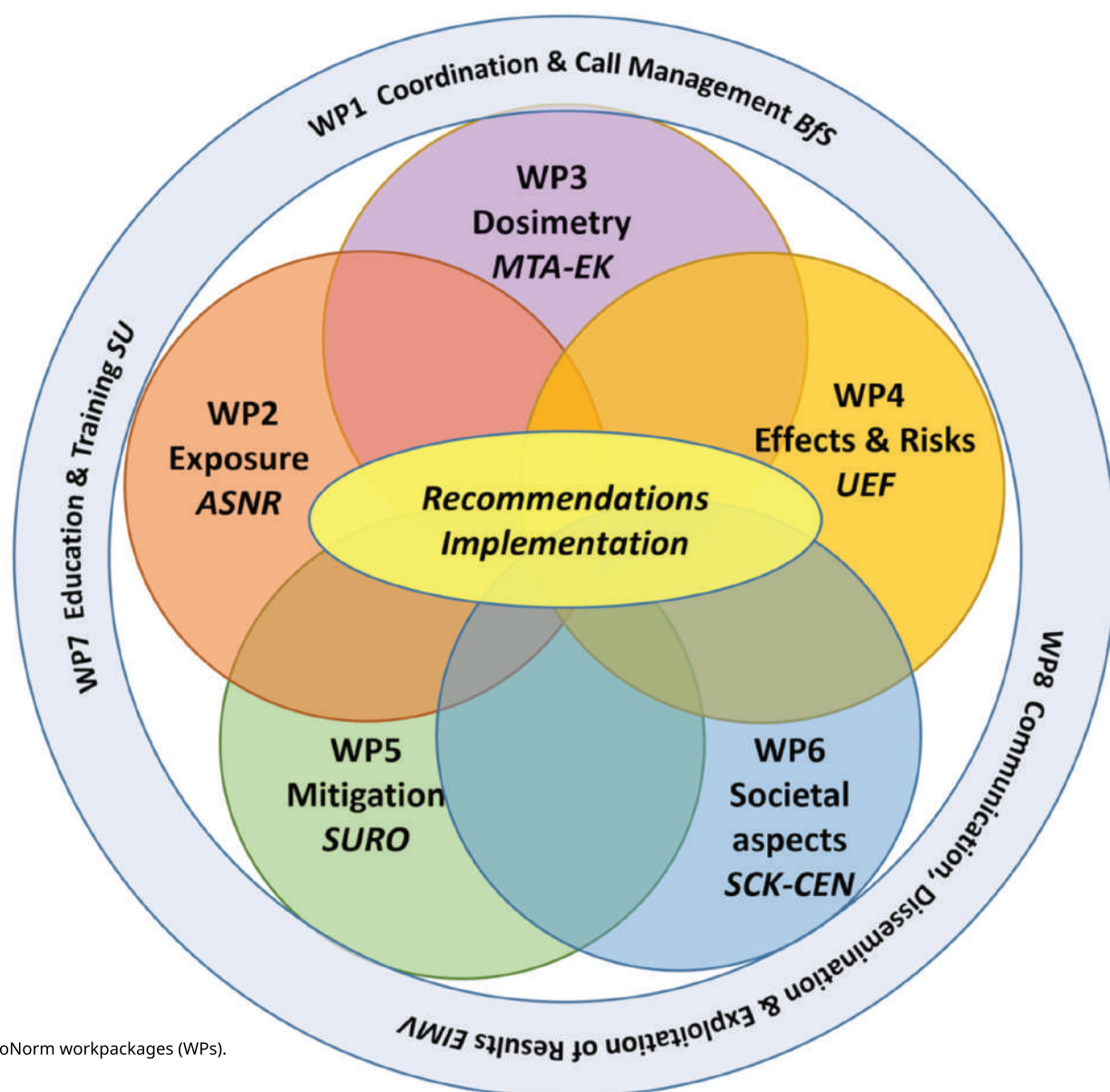
<https://doi.org/10.1080/09553002.2022.2110312>

Apers, S., Vandebosch, H. and Perko, T., (2024). Clearing the air: A systematic review of mass media campaigns to increase indoor radon testing and remediation, *Communications*, vol. 49, no. 1, pp. 144-165. <https://doi.org/10.1515/commun-2021-0141>

Rey J. F., Meisser N., Licina D., Goyette Pernot J. (2024b). Performance evaluation of radon active sensors and passive dosimeters at low and high radon concentrations, *Building and Environment*, Volume 250, <https://doi.org/10.1016/j.buildenv.2023.111154>

Venoso G., Nuccetelli C., Di Carlo C., Trotti F., Ugolini R., Trevisi R., Leonardi F., Urso L., (2024). Development of a methodology for assessing radiological dose due to use of NORM sludge as fertilizer, *Science of The Total Environment*, Volume 912, <https://doi.org/10.1016/j.scitotenv.2023.168934>

Newman-Portela A.M., Krawczyk-Bärsch E., Lopez-Fernandez M, Bok F., Kassahun A., Drobot B., Steudtner R., Stumpf T., Raff J., Merroun M.L. (2024). Biostimulation of indigenous microbes for uranium bioremediation in former U mine water: multidisciplinary approach assessment. *Environ Sci Pollut Res* 31, 7227–7245. <https://doi.org/10.1007/s11356-023-31530-4>



RadoNorm workpackages (WPs).

Researchers in a spotlight

Augusto Giussani (BfS) leads the development of models for radon dose assessment in sensitive population groups within RadoNorm WP3, while Dariusz Aksamit (Warsaw University of Technology) engaged high school students in the award-winning “AHS Radon Hunt” citizen science project, blending research, education, and outreach.

Augusto Giussani, expert in internal dosimetry and biokinetic modelling, leads research on radon dose assessment for sensitive populations in RadoNorm.

Augusto Giussani holds a Ph.D. from the Faculty of Physics of the Eberhard-Karls-Universität in Tübingen, Germany.

He started his research activity in the field of experimental physics, specifically in the development and application of nuclear activation techniques and mass spectrometry methods for the determination of stable isotopes in biological samples. These techniques were applied to study the biokinetics of radionuclides in humans using stable tracers. Using compartmental analysis, the results of these studies were used to develop biokinetic models and evaluate the internal dose resulting from the incorporation of radioactive substances.

After working at the Physics Department of the Università degli Studi di Milano in Italy and at the Institute of Radiation Protection of gsf (now Helmholtz Munich) in Germany, he is currently the head of the Unit "External and internal dosimetry, biokinetics" at the German Federal Office of Radiation Protection BfS. He has been the Scientific Secretary of EURADOS Working Group 7 "Internal Dosimetry", is a member of Committee 2 of the International Commission on Radiological Protection ICRP and leads the Task Group on "Dose to patients in diagnostic nuclear medicine". His main activity is now focused on compartmental modelling and internal dosimetry in nuclear medicine.

In RadoNorm, he is active in Work Package 3 "Dosimetry", where he leads Task 3.3 "Dose assessment for specific subgroups of the population". Within this work package, a comprehensive model for assessing the radon dose to the embryo and fetus is under development. Also, the effects of age-specific characteristics (such as sizes and morphology of organs, breathing rate) and of lung diseases on absorbed doses and dose distributions in the lungs are being investigated and quantified.



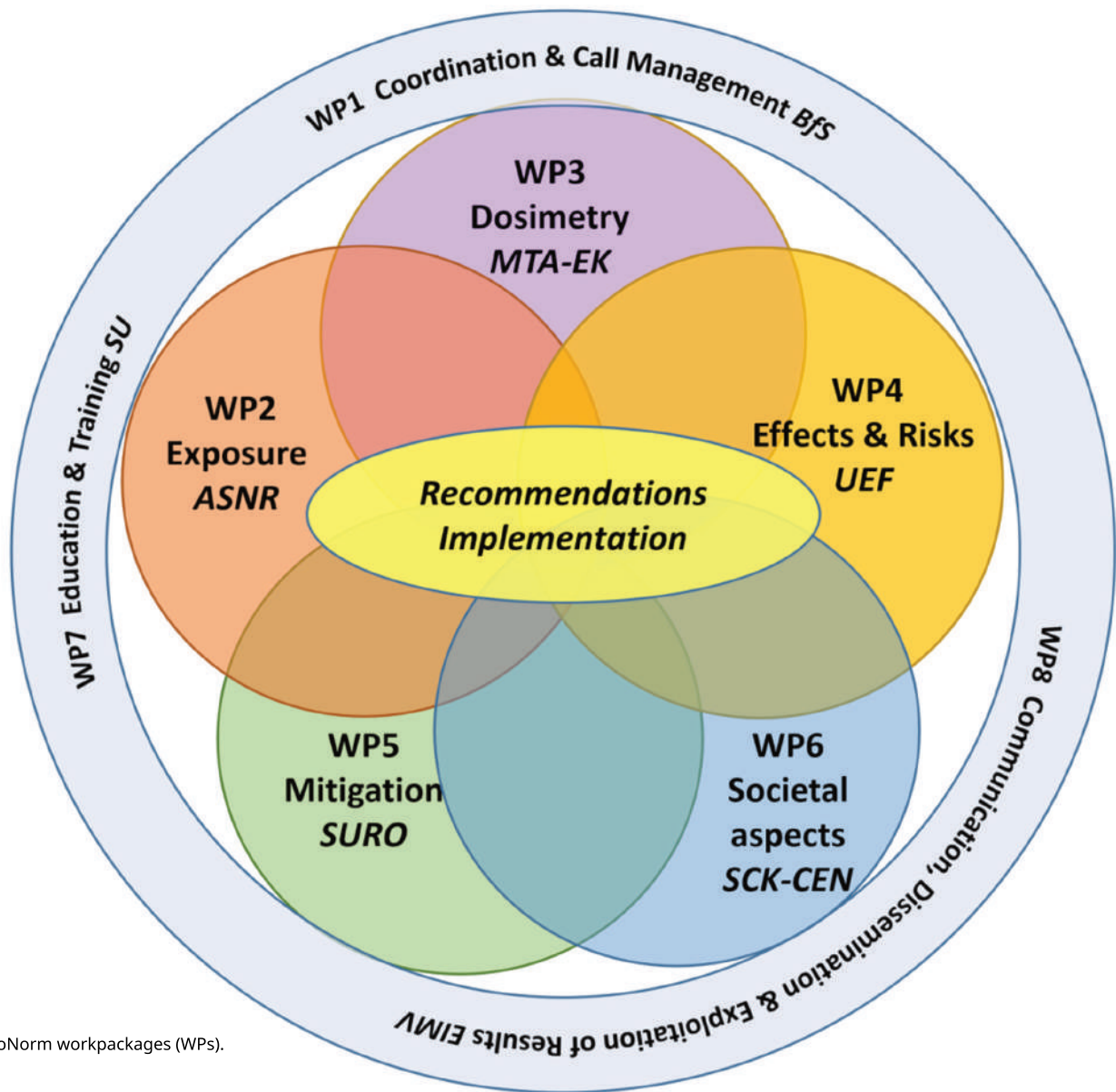
Dr. Augusto Giussani, BfS, Germany



Dariusz Aksamit combines research, teaching, and science communication in the award-winning “AHS Radon Hunt” citizen science project with students across Poland, supported by RadoNorm.

Dariusz Aksamit has multiple affiliations, switching roles from a researcher at Warsaw University of Technology, Faculty of Physics, to a physics teacher at Akademeia High School or a science communicator and pro-science activist in NGOs.

With the funding of RadoNorm WP6 he combined those roles by running the “AHS Radon Hunt” citizen science project with high school students. They performed active and passive measurements in air and water in various places around Poland and visited radiation-related places like dosimetric laboratories or depleted uranium mines, undergoing training or collecting samples. You can follow their adventure on a student-led TikTok account created for this project, as one of the aims of was to give students the agency and support peer-to-peer education about natural radiation. The abovementioned project was one of many developed within the RadoNorm citizen science incubator, which received Honorary Mentions in The European Union’s Citizen Science Prize 2024.



RadoNorm workpackages (WPs).

RadoNorm engagement opportunities

The RadoNorm website and social media offer access to project updates, publications, events, and stakeholder engagement opportunities. The 4th Annual Meeting in June 2024 in Ljubljana focused on translating research into societal impact, covering themes from radon regulation to environmental modelling and citizen involvement.

Cutting-edge radon research, stakeholder engagement, and practical applications were discussed at the 4th Annual Meeting in Ljubljana.

As it was already informed, the RadoNorm website provides much information about the project, objectives, work programme, its development and results, interaction and engagement possibilities. Please, have a look in particular to News, which informs about the major RadoNorm results, including deliverables, scientific papers and events with links to more details. RadoNorm is present on social media LinkedIn, Twitter (now X) and YouTube. You are kindly invited to follow us or even to become a RadoNorm stakeholder.

RadoNorm established different engagement opportunities for the related and interested stakeholders. Besides joining the stakeholders or attending the events, you can also be involved in RadoNorm activities. Depending on your active participation, RadoNorm might also offer support for reimbursement of direct costs.

The subscription to more information, like Newsletter issues, is also available. The RadoNorm partners, stakeholders and other groups are regularly informed about publications, news, events and calls. All developed contact databases are managed according to the RadoNorm Privacy policy.

The 4th RadoNorm Annual Meeting was held on 12th and 13th of June 2024 in Ljubljana, Slovenia, following the RadoNorm internal meetings on 10th and 11th of June 2024 and the RICOMET conference, also partly devoted to RadoNorm topics linked with societal issues. The Annual Meeting included three themes with RadoNorm: "Fundamentals," "Recommendations," and "Applications & Implementation," and included discussions highlighting the translation of RadoNorm research into societal applications. Presentations (available in this link) addressed topics such as radon exposure regulation, contributions of local geology to radon levels, radon modelling, and new insights into radionuclide sorption in soils.



Dr. Nadja Železnik, leader of Work Package 8, EIMV

Sources



Last year of RadoNorm

- 🌐 Deliverables, <https://www.radonorm.eu/publications/deliverables/>
- 🌐 Publications, <https://www.radonorm.eu/publications/scientific-papers/>
- 🌐 European Radiation Protection Week 2024, <https://www.erpw2024.eu/>
- 🌐 Software for model radon and thoron in confined spaces, <https://www.mdpi.com/1660-4601/19/24/16739>
- 🌐 Citizen science project in Hungary, <https://radonormcs.ek-cer.hu/>

WPs highlights

- 🌐 Deliverable D2.4, https://www.radonorm.eu/wp-content/uploads/file_exchange/D2.4_Report-on-proficiency-test-of-active-instrumentation_submitted28082024_watermarked.pdf
- 🌐 Beck et al., 2024, <https://www.mdpi.com/2073-4433/15/10/1180>
- 🌐 Grygier and Skubacz, 2024, <https://www.mdpi.com/2073-4433/15/9/1131>
- 🌐 Rey et al., 2024, <https://www.frontiersin.org/journals/public-health/articles/10.3389/fpubh.2024.1460295/full>
- 🌐 Vanhoudt et al., 2024, <https://www.sciencedirect.com/science/article/abs/pii/S0929139324003962?via%3Dihub>
- 🌐 Venoso et al., 2024, <https://www.sciencedirect.com/science/article/pii/S0048969723075630>
- 🌐 Deliverable D2.4, https://www.radonorm.eu/wp-content/uploads/file_exchange/D4.6_Health-effects-of-radon-uranium-and-other-NORM-in-drinking-water_submitted29082024_watermarked.pdf

Events and trainings

- 🌐 Six courses, <https://www.radonorm.eu/calls/call-for-courses/>

Latest deliverables and publications

- 🌐 RadoNorm website, <https://www.radonorm.eu/publications/deliverables/>
- 🌐 13 scientific papers, <https://www.radonorm.eu/publications/scientific-papers/>

RadoNorm engagement opportunities

- 🌐 RadoNorm website, <https://www.radonorm.eu/>
- 🌐 News, <https://www.radonorm.eu/news/>
- 🌐 LinkedIn, <https://www.linkedin.com/company/radonorm/>
- 🌐 Twitter (now X), <https://twitter.com/RadoNorm>
- 🌐 YouTube, <https://www.youtube.com/channel/UC6yCORiPX5DXgmu5AaGLn9Q>
- 🌐 RadoNorm stakeholder, <https://www.radonorm.eu/stakeholders/>
- 🌐 RadoNorm activities, <https://www.radonorm.eu/activities/>
- 🌐 Subscription to more information, <https://www.radonorm.eu/newsletter/>
- 🌐 RadoNorm Privacy policy, <https://www.radonorm.eu/privacy-policy/>
- 🌐 RadoNorm website, <https://www.radonorm.eu/activities/>
- 🌐 5th RadoNorm Annual Meeting, <https://all.accor.com/hotel/6151/index.en.shtml>

Key takeaways



- ☢ **Received excellent evaluation by the European Commission, with reviewers praising RadoNorm's "exceptional results with significant immediate or potential impact."**
- ☢ **WP2 achieved 6 deliverables, 8 milestones, and 6 scientific publications, advancing methods for radon/thoron exposure assessment in workplaces and outdoors.**
- ☢ **Developed advanced dosimetric models in WP3 & WP4, including dose assessments for foetuses, vulnerable groups, and patients with lung conditions.**
- ☢ **Completed a major intercomparison campaign in an underground Polish mine, testing radon detection methods under real conditions (WP5).**
- ☢ **Published insights on the long-term performance of radon mitigation in buildings, highlighting regional variability in effectiveness (WP5).**
- ☢ **WP6 engaged over 800 citizens in 10 countries through its citizen science incubator, earning an honorary mention in the 2024 EU Prize for Citizen Science.**
- ☢ **Delivered five international training courses on topics from translational oncology to qualitative methods, with another upcoming in November 2024.**
- ☢ **Launched a mobility grant programme supporting extended research visits for early career researchers between RadoNorm and external partners.**
- ☢ **Published 13+ peer-reviewed articles, covering uranium transport, sensor performance, risk communication, plant transfer, and social aspects of exposure.**
- ☢ **Strengthened stakeholder dialogue and societal impact, with the 4th Annual Meeting in Ljubljana and the RICOMET 2024 conference highlighting interdisciplinary translation of RadoNorm research.**



RadoNorm
Managing risks from radon and NORM

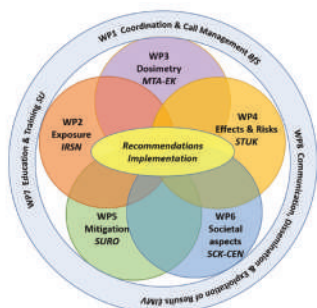
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Newsletter

N°8 - December 2024



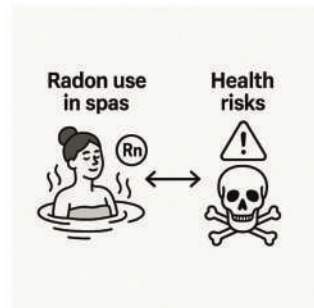
Last year of RadoNorm
Achievements and the impact on research and managing Ra-risks



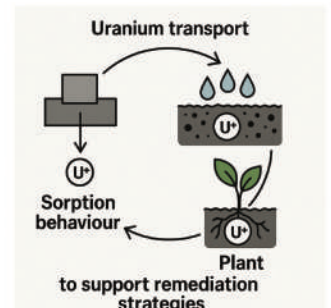
Confirmed vulnerability to radon in sensitive groups
Children, pregnant women...



Controversies around radon use in spas
Health vs. health risks, advocating for balanced EU-level communication



Remediation strategies
Advanced understanding of uranium transport, sorption behaviour, and plant transfer



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RadoNorm Newsletter



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Editorial



Dr. Nadja Železnik holds a BSc in Physics and an MSc in Reactor Physics from the Faculty of Mathematics and Physics, as well as a PhD in Psychology from the Faculty of Arts, all awarded by the University of Ljubljana, Slovenia. She is an expert in nuclear technology and radioactive waste management, with extensive experience in emergency preparedness and response, as well as in risk perception, communication, education, and training in environmental and nuclear projects.

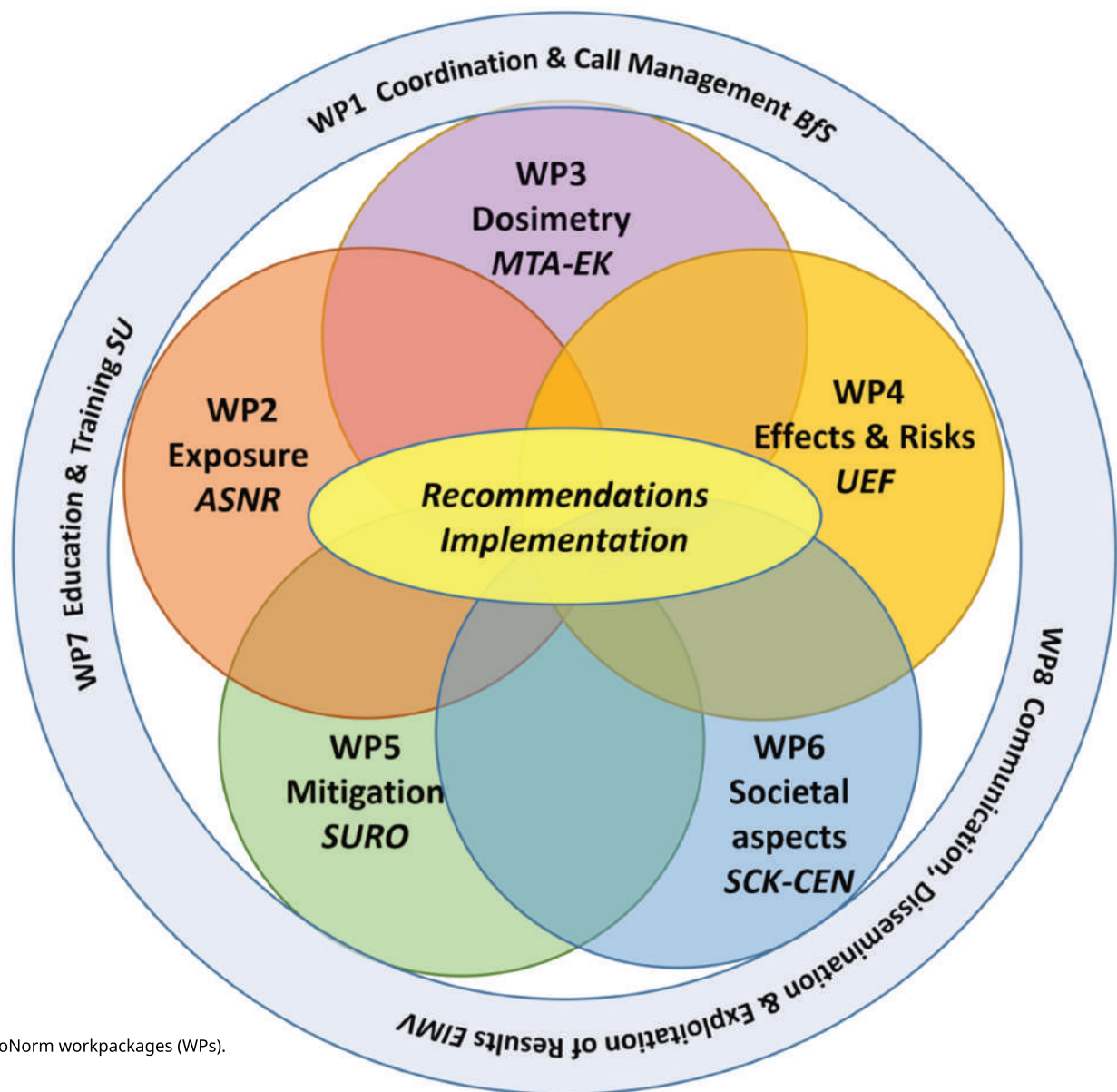
She has acted as a civil society expert and knowledge manager in numerous European research initiatives, including EURAD-1 and -2, ECOSSENS, and RadoNorm. Her contributions include the development of national strategies, legislative frameworks, feasibility studies, safety and radiological assessments, and stakeholder engagement plans. She has authored communication strategies, training programmes, and information materials to foster public understanding and informed participation in the nuclear and environmental domains.

It is with great pleasure that we present the eighth issue of the RadoNorm Newsletter, highlighting key recent developments as the project nears its final stages. This edition reflects the growing engagement of researchers, stakeholders and citizens in shaping better understanding and protection strategies around radon and NORM.

The issue covers the third Stakeholder and End-User Workshop, where participants discussed remediation, communication and training in radiation protection. Early career researchers are also featured for their contributions following the 8th International Symposium on NORM.

Citizen involvement remains central, with school-based radon measurements in Romania and Hungary, and the first Citizens' Jury on radon policy held in Portugal.

The issue encourages reflection on knowledge's role in protecting health and the environment.



RadoNorm workpackages (WPs).

Last year of RadoNorm

RadoNorm concludes 2024 with key scientific recommendations on radon and NORM, showcased at ERPW in Rome. Highlights include citizen science, new modelling tools, and stakeholder engagement. A final 2025 meeting in Brussels will present results and shape future research.

Scientific recommendations on radon and NORM, new modelling tools, citizen science achievements, consortium expansion...

At the beginning of the project, RadoNorm promised to deliver science-based recommendations to manage risks for radon- and NORM-exposure situations, and 2024 has seen the fulfilment of this promise in various aspects of radiation protection. In the form of deliverables and publications, recommendations have been provided for the use of active radon monitors at home (D2.4), dosimetric calculations for radon and thoron in underground mines (D3.4), radionuclide transfer parameters to plants (D2.14), health effects of radionuclides from drinking water (D4.6), radon mitigation measures for buildings (D5.8) and addressing controversies between radon as a treatment, i.e. in health spas, and radon as a threat (D6.14), to name a few. Such recommendations are geared to shape future research and also help policy makers, authorities, and other stakeholders in their decision making.

Consequently, we proudly presented our achievements at the European Radiation Protection Week 2024, which took place in Rome, Italy. Being the last of the conferences that would be organised in the span of RadoNorm, two sessions were devoted to radon and NORM research and it

was clear that RadoNorm research has had a vital impact in radiation protection research. The conference featured a tech sharing corner, where we presented our software for model radon and thoron in confined spaces, as well as one of the prototypes that was built by the high school students of the citizen science project in Hungary.

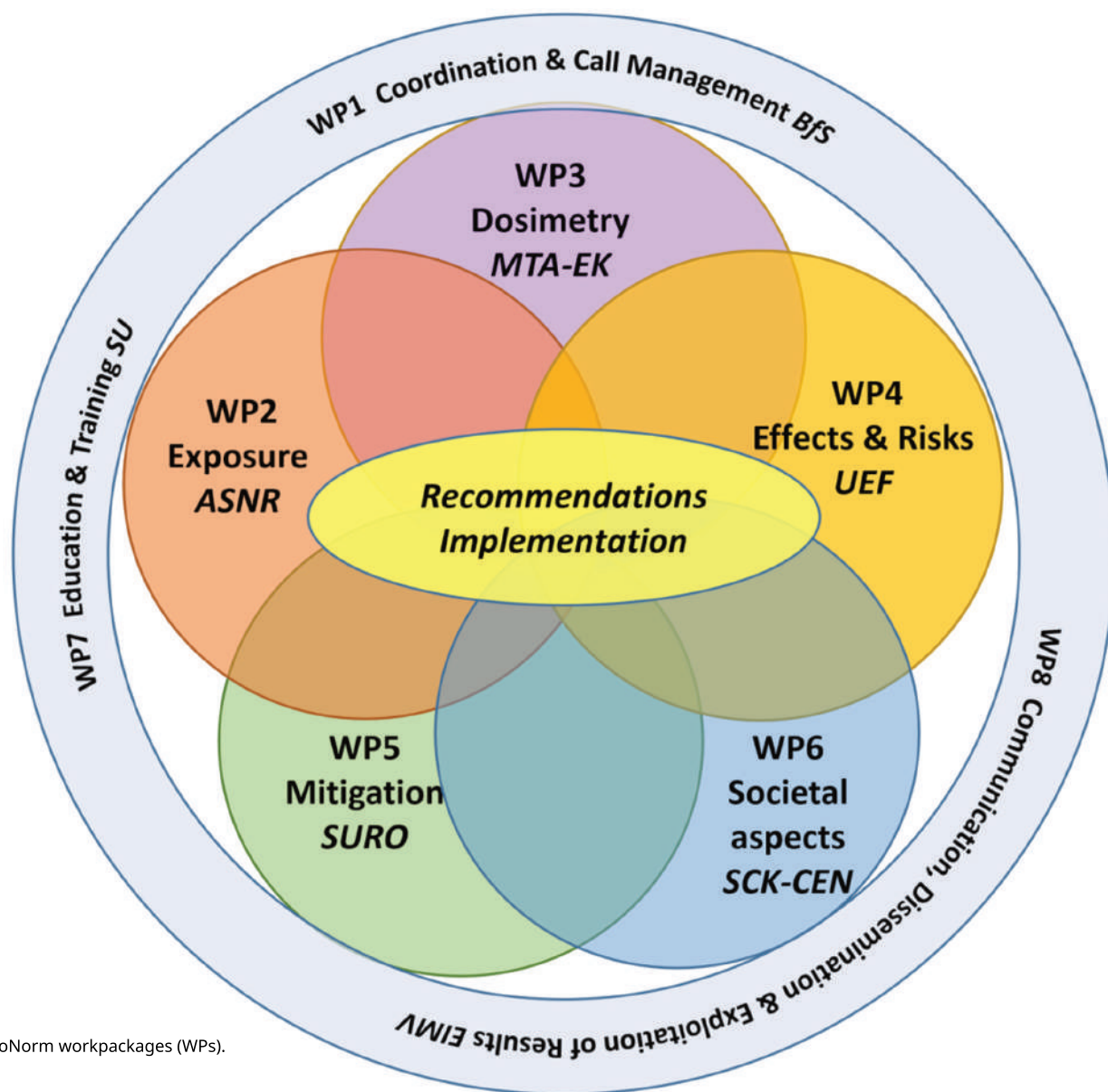
Moreover, the University of Gothenburg joined the RadoNorm consortium as a new partner and continues to work on NORM exposure sites in Greenland. We are glad to welcome our new partner and are thankful to the University of Aarhus, which is leaving the consortium, for their collaboration on the project.

As several tasks are now coming to an end and the main achievements of the project are being published, we look to also maximise their impact by actively entering into discussions with stakeholders. A “Showcase Meeting” is being planned in Brussels in 2025 to convey to the European Commission that RadoNorm has been and still is a major contributor to radiation protection research and the implementation of the basic safety standards. At this meeting, we hope to also engage participation from international organisations and the European platforms and partnerships to find out what research still needs to be done and how we can progress.

But for the moment, we can look back on 2024 with heads held high, taking pride in our accomplishments thus far and our successful efforts to bring together organisations in Europe and collectively drive research forward. We wish all our partners and collaborators a joyful Christmas season and a well-deserved relaxing holiday time.



Dr. Warren John, leader of Work Package 1, BfS



RadoNorm workpackages (WPs).

WPs highlights

Since the last update, WPs 2 to 6 have published major deliverables and 13 scientific papers. ECRs presented at key conferences and completed research stays. WP4 held a general meeting, while WP6 showcased Citizen Science results. Preparations began for new measurement campaigns and training courses, and WP3 released two impactful studies.

WP2 continues to finalise and publicise its main activities, with the release of an additional deliverable (D2.4 (Report on proficiency test of active instrumentation, including a practical guideline that will introduce into essential measures of quality control, reflecting requirements from normative documents)) and 5 scientific articles (Beck et al., 2024; Grygier and Skubacz, 2024; Rey et al., 2024; Vanhoudt et al., 2024, Venoso et al., 2024).

The main outcomes of WP2 regarding research on NORM has been successfully presented at the 6th ICRER conference (International Conference on Radioecology and Environmental Radioactivity) end of November in Marseille (France), which has gathered around 300 participants.



Dr. Laureline Fevrier, leader of Work Package 2, IRSN



Dr. Balázs Madas, leader of Work Package 3, EK

Two deliverables were submitted this year. In one of them, the effect of smoking on absorbed doses from radon exposure was presented. It included a publication in the Journal of Radiological Protection, “Changes induced in the human respiratory tract by chronic cigarette smoking can reduce the dose to the lungs from exposure to radon progeny”, which was shortlisted for the Bernard Wheatley Award. Although the paper was not the winner in the end, it is still a great recognition. The first author of the paper – a former RadoNorm Early Career Researcher (ECR) – became a professor at the University of São Paulo this year.

The other deliverable focused on uncertainties affecting dosimetric calculations for the intake of radon and thoron progeny in underground mines. The analysis highlighted the urgent need for improved safety measures in underground mining. The authors found that stricter ventilation standards, mandatory personal protective equipment and Increased monitoring are essential to reduce miners’ exposure to radiation hazards and associated lung cancer risks.

We are proud of the achievements of our ECRs, who presented their finding at the Annual Meeting in Ljubljana and several other conferences, including the European Radiation Protection Week. The successful completion of research stays of ECRs was also a highlight of the year. One of them contributed to a manuscript already submitted, while another manuscript is under preparation, with most contributions from two WP3 ECRs.

WPs highlights



BieNaarala, leader of Work Package 4, UEF
eri Nieminen, leader of Work Package 4, UEF

A successful WP4 General Meeting was arranged on September 30, 2024, to have an update and discussion on tasks' statuses and to introduce the new leaders of the WP.

Three milestones and one deliverable (MS47 (Radon measurements completed), MS50 (Environmental pathways to the development of childhood leukemia), MS55 (Reducing uncertainty of lung cancer risk inference by integration of molecular profiles into radio-epidemiology with biologically-based risk models), and D4.6 (Health effects of radon, uranium and other NORM in drinking water, also addressing combined effects of radiation and chemical toxicity)) were submitted to European Commission.

There were several important research activities carried out since the last RadoNorm annual meeting. I would like to highlight the work that has been devoted to planning the NRPI inter-comparison air-exchange rate measurement campaign in a house. This unique opportunity to measure and compare air-exchange rates in situ using tracer gas techniques will take place in selected dwellings in Czechia, commencing with the installation of detection systems in January 2025. In addition, there was intensified work on a deliverable, D5.13, and the continuation of research work on continuous radon monitors' performance testing in the radon calibration facility. RadoNorm course preparation. From radon measurement to optimised mitigation has been commenced, which focuses on radon diagnosis, radon remedial measures design and implementation and will be held in May 2025 in Prague in collaboration between SURO and CTU Faculty of Civil Engineering.



Dr. Ales Fronka, leader of Work Package 5, SURO



Dr. Tanja Perko, leader of Work Package 6, SCK CEN
Dr. Robbe Geysmans, leader of Work Package 6, SCK CEN

Various WP6 partners presented their RadoNorm research at the 2024 ERPW in Rome, with presentations on NORM in building materials, the RadoNorm citizen science incubator, and the use of radon in spas.

The impact of the citizen science projects conducted in WP6 is still clearly tangible, with, among others, presentations by Dariusz Aksamit and Yevgeniya Tomkiv at ICRER 2024 in Marseille and the showcase of a prototype radon and air quality measuring device stemming from the Hungarian citizen science project at ERPW 2024.

On November 21st a RadoNorm research seminar was organised at which WP6 researchers presented their study on 'Understanding radon in the context of health spas: framings, perceptions and enactments'.

WP6 research on marketing and societal challenges of NORM in building materials is being finalised, with the public PhD defence of Nazanin Love being planned on January 17th 2025.



Events and trainings

In 2025, RadoNorm will offer six specialised courses covering radon therapy, mitigation, NORM characterisation, and AI in science.

The Early Career Researcher Council, formed in 2022, fosters collaboration among 35 young researchers. In 2024, new leadership was elected to support networking and transdisciplinary exchange across work packages.

2025 RadoNorm courses

Six courses will be organised by RadoNorm in 2025:

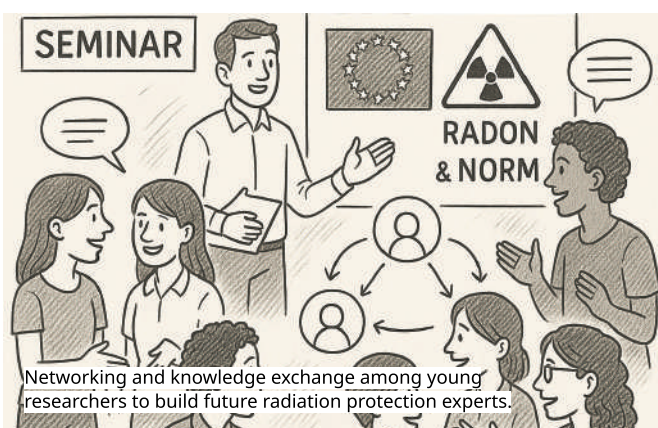
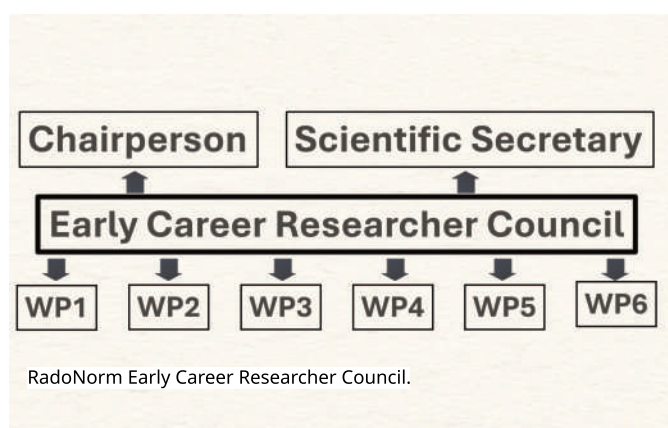
- ▶ “Radon therapy: theory and practice, benefits and health risks” organised by SU and EK,
- ▶ “From radon measurement to optimised mitigation” organised by SURO and CTU,
- ▶ “II Synergy Workshop on Translational & Clinical Oncology applied to Environmental & Occupational Cancer: Focus on Radon Interrad” organised by FCRB – IDIBAPS,
- ▶ “Application of liquid scintillation counting (LSC) and alpha spectrometry for NORM characterisation” organised by GIG,
- ▶ “Naturally occurring radioactive material – characterisation, inventory of related exposure situations and monitoring principles – stationary course” organised by GIG and
- ▶ “AI in Science: Key knowledge, applications and challenges” organised by GSI, Uni Granada, BfS and (HZDR).

DATE	COURSE	INSTITUT	FLYER / LINK
10th to 12th March 2025	II Synergy Workshop on Translational & Clinical Oncology applied to Environmental & Occupational Cancer: Focus on Radon	FCRB - IDIBAPS	Flyer
7th to 11th April 2025	Radon therapy: theory and practice, benefits and health risks - RATH	Stockholm University	Flyer
5th to 16th May 2025	From radon measurement to optimized mitigation	SURO & CTU	Flyer
31st March – 12th April 2025	Naturally occurring radioactive material - characterisation, inventory of related exposure situations and monitoring principles - stationary course	GIG (Poland)	Flyer
12th to 23rd May 2025	Application of liquid scintillation counting (LSC) and alpha spectrometry for NORM characterisation	GIG (Poland)	Flyer
17th to 20th March 2025	AI in Science: Key knowledge, applications and challenges	GSI & University of Granada	Flyer



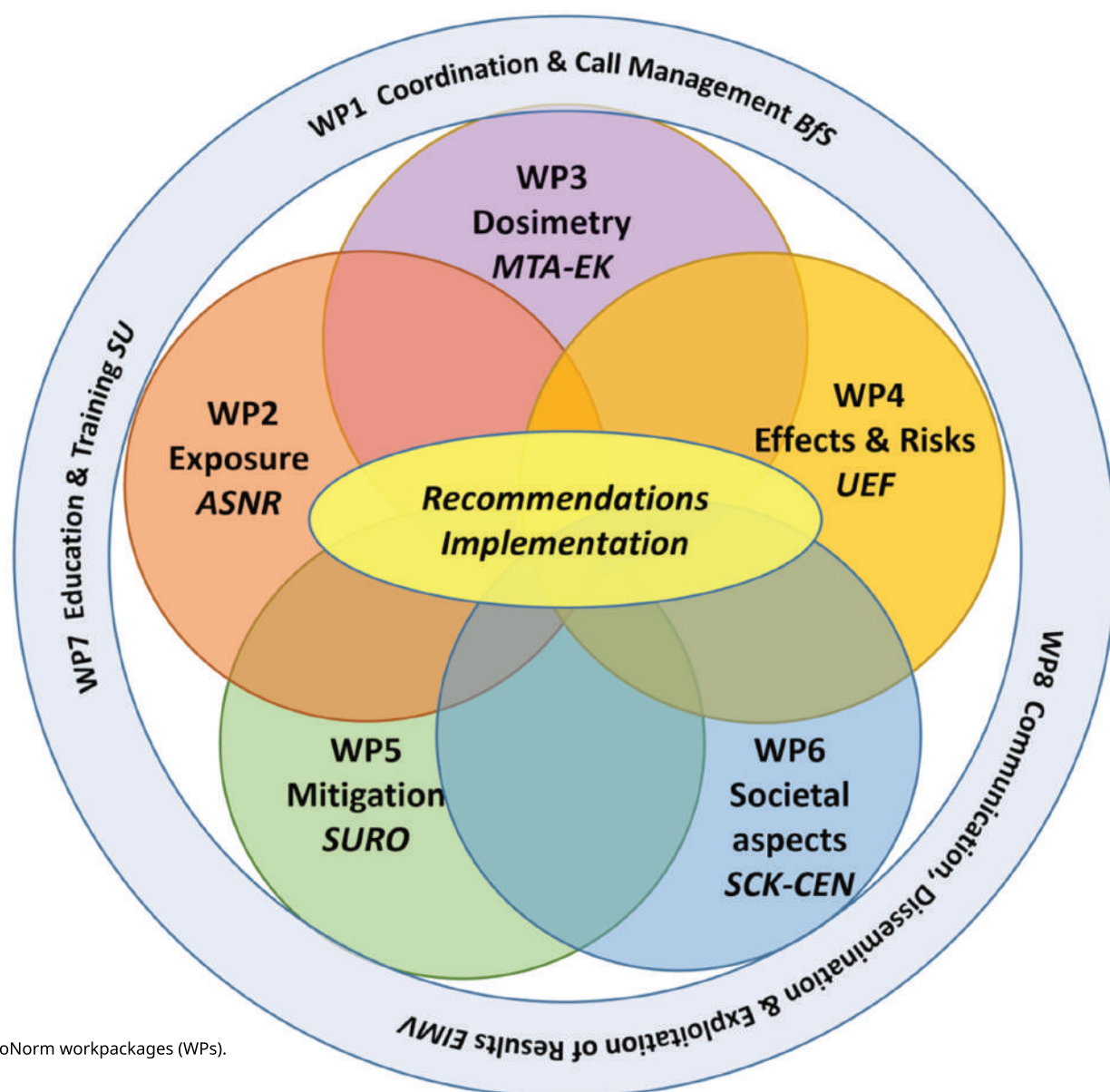
Dr. Andrzej Wojcik, leader of Work Package 7, SU

A total of 23 PhD students and 12 postdoctoral researchers (collectively referred to as early career researchers) are funded by RadoNorm during the duration of the project. On 2022 10 05, during the second annual meeting in Munich, the ECR met and set up a RadoNorm Early Career Researcher Council (ECRC). The aim of the ECRC is to allow closer contacts and networking of young researchers that form the basis of future European Union experts in the field of radiation protection related to radon and NORM.



The plan is to organise regular seminars and meetings with the aim of explaining the research questions tackled within each WP to members of other WPs in a way that will facilitate transdisciplinary collaboration. The council is composed of the chairperson, the scientific secretary and the representatives of RadoNorm work packages: Warren John (BfS) for WP1, Andrea Maiorana (ISS) for WP2, Alok Dhaundiya (EK) for WP3, Wafa Alimam (TUNI) for WP4,

Hubert Makula (GIG) for WP5 and Melisa Muric (UAntwerpen/SCKCEN) for WP6. In June 2024, in the annual meeting in Ljubljana, there was a leading board change in the ECRC: chairperson, Ämilie Degenhardt, and the Scientific Secretary, Jad Abuhamed, stepped down to give the opportunity to other ECRs to gain leadership experience. The new chairperson is Kim Sennhenn (GSI), and the new scientific secretary is Francesca Tugnoli (BfS).



RadoNorm workpackages (WPs).

Latest deliverables and publications

Since the last update, WPs 2 to 6 have published major deliverables and 13 scientific papers. ECRs presented at key conferences and completed research stays. WP4 held a general meeting, while WP6 showcased Citizen Science results. Preparations began for new measurement campaigns and training courses, and WP3 released two impactful studies.

The following new deliverables are now available on the RadoNorm website:

14 (Recommendations for transfer parameters to plants): The report presents recommendations for soil-to-plant transfer parameters of radionuclides, emphasising the need for accurate predictive models. It evaluates the effectiveness of traditional concentration ratios and introduces a “constant plant concentration” approach. Challenges in data selection and nonlinearity of transfer are discussed, with suggestions for further investigation.

15 (Report on the influence of microorganisms on the transport behaviour of uranium in mine waters): The report investigates how microorganisms influence uranium transport in mine waters. It combines microbiological, geochemical, and spectroscopy techniques to analyse water samples from two former uranium mines. Findings highlight the role of microbial diversity in uranium reduction, particularly identifying effective electron donors for bioremediation strategies, enhancing understanding of uranium mobility.

16 (Laboratory sorption-desorption experiments and updated databases on soil sorption and desorption parameters for NOR): The report outlines laboratory sorption-desorption experiments on naturally occurring radionuclides (NOR), including uranium and radium, to enhance predictive models of soil mobility. It details field studies, experiments on sorption mechanisms, and findings about the behaviour and mobility of NOR, contributing to improved environmental assessments and remediation strategies.

6 (Health effects of radon, uranium and other NORM in drinking water, also addressing combined effects of radiation and chemical toxicity): The report assesses studies on high concentrations of radionuclides in groundwater, which are not effectively mitigated in private wells. The evidence reviewed indicates that, although there is inconsistency in ecological studies, there is a possibility of a modest increase in cancer risk from ingested radionuclides, particularly from uranium-238 and radium-226.

10 (Report on In-situ Intercomparison measurement campaign): The report outlines a framework for measuring and assessing radon in homes and workplaces to protect public health. It emphasises standardised methods, short- and long-term monitoring, training personnel, and public awareness. Aimed at guiding stakeholders, it supports effective radon management policies.

11 (Report on available solutions and technologies applicable for legacy site remediation, NORM involving industries and treatment of radioactivity in water): The report provides recommendations for mitigating radon exposure in buildings, emphasising health risks from prolonged exposure. It outlines assessment methods,

remediation strategies like sealing, ventilation, and sub-slab depressurisation, and stresses post-remediation monitoring. Case studies and engagement with occupants support implementation, aiding stakeholders in effective radon management.

12 (Feasibility study into application of selected radioecological model for evaluation of NORM treatment options and NORM legacy remediation): The report addresses radiation protection for NORM, assessing mitigation impacts in industries and legacy sites. It examines dose assessment methodologies and exposure scenarios using simple and advanced models. Case studies on titanium dioxide production and mining remediation highlight tailored approaches for managing NORM, promoting safer practices and effective remediation.

8 (Report on variability and sustainability of radon prevention and mitigation in homes and in large buildings): The report analyses the effectiveness and reliability of radon mitigation in homes and workplaces. It highlights the variability in long-term efficiency due to maintenance and building changes, emphasising combined techniques like radon sumps and ventilation. Ongoing monitoring, maintenance, and homeowner education are essential for sustained success.

9 (Measurement protocol of radon progeny attached and unattached fraction: Focus on graded approach to measurement on underground and specific types of workplaces): The report emphasises standardised methods for accurate radon exposure assessments, focusing on workplace conditions and regulatory needs. It details methodologies for radon progeny measurement, highlights technology gaps, and stresses instrument calibration and quality control. A collaborative effort, it supports improved workplace radiation protection.

12 (Scientific article on societal aspects of radiation protection related to radon in geothermal energy): The report examines societal perceptions and radiological risks of geothermal energy, focusing on NORM in Europe. It combines technical radon assessments with societal research, finding risks manageable but requiring communication strategies. Emphasising transparency and public education, it aims to improve safety and confidence in geothermal projects and supports future research dissemination.

14 (Report on controversies between “radon as treatment in radon spas” and “radon as threat in health communication campaigns): The report highlights gaps in social science research on radon spas, noting legal inconsistencies in radon level regulations across Europe. It examines contrasting spa marketing and health messaging, identifying five framing themes. Recommendations emphasise balanced communication to address controversies, fostering better understanding and management of radon’s risks and benefits.

Since Newsletter 7, there have been 13 scientific papers published as part of the RadoNorm achievements:

Rey, J.F.; Antignani, S.; Baumann, S.; Di Carlo, C.; Loret, N.; Gréau, C.; Gruber, V.; Goyette Pernot, J.; Bochicchio, F. Systematic Review of Statistical Methods for the Identification of Buildings and Areas with High Radon Levels. *Public Health* 2024, 12, 1460295, doi:10.3389/fpubh.2024.1460295.

Hoedoafia, M.A.; Martell, M.; Perko, T. Evaluating Citizen Science Projects: Insights from Radon Research. *Environ. Sci.* 2024, 12, 1436283, doi:10.3389/fenvs.2024.1436283.

Henyoh, A.M.S.; Laurent, O.; Mandin, C.; Clero, E. Radon Exposure and Potential Health Effects Other than Lung Cancer: A Systematic Review and Meta-Analysis. *Public Health* 2024, 12, 1439355, doi:10.3389/fpubh.2024.1439355.

Jiránek, M.; Kačmaříková, V.; Svoboda, Z. The Influence of Radon Penetration through Joints on the Overall Radon Barrier Properties of Waterproof Membranes. *Build. Eng.* 2024, 96, 110604, doi:10.1016/j.job.2024.110604.

Boroumand, N.; Baghdissar, C.; Elihn, K.; Lundholm, L. Nicotine Interacts with DNA Lesions Induced by Alpha Radiation Which May Contribute to Erroneous Repair in Human Lung Epithelial Cells. *Environ. Saf.* 2024, 284, 117009, doi:10.1016/j.ecoenv.2024.117009.

Makumbi, T.; Breustedt, B.; Raskob, W.; Ottenburger, S.S. Application of INTDOSKIT Tool for Assessment of Uncertainties on Dose Coefficients for Ingestion of Uranium by Workers. *Phys. Chem.* 2025, 226, 112247, doi:10.1016/j.radphyschem.2024.112247.

Grygier, A.; Skubacz, K. Radon Equilibrium Factor and the Assessment of the Annual Effective Dose at Underground Workplaces. *Atmosphere* 2024, 15, 1131, doi:10.3390/atmos15091131.

Beck, T.R.; Foerster, E.; Biel, M.; Feige, S. Measurement Performance of Electronic Radon Monitors. *Atmosphere* 2024, 15, 1180, doi:10.3390/atmos15101180.

Jaylet, T.; Coustillet, T.; Smith, N.M.; Viviani, B.; Lindeman, B.; Vergauwen, L.; Myhre, O.; Yazar, N.; Gostner, J.M.; Monfort-Lanzas, P.; et al. Comprehensive Mapping of the AOP-Wiki Database: Identifying Biological and Disease Gaps. *Toxicol.* 2024, 6, 1285768, doi:10.3389/ftox.2024.1285768.

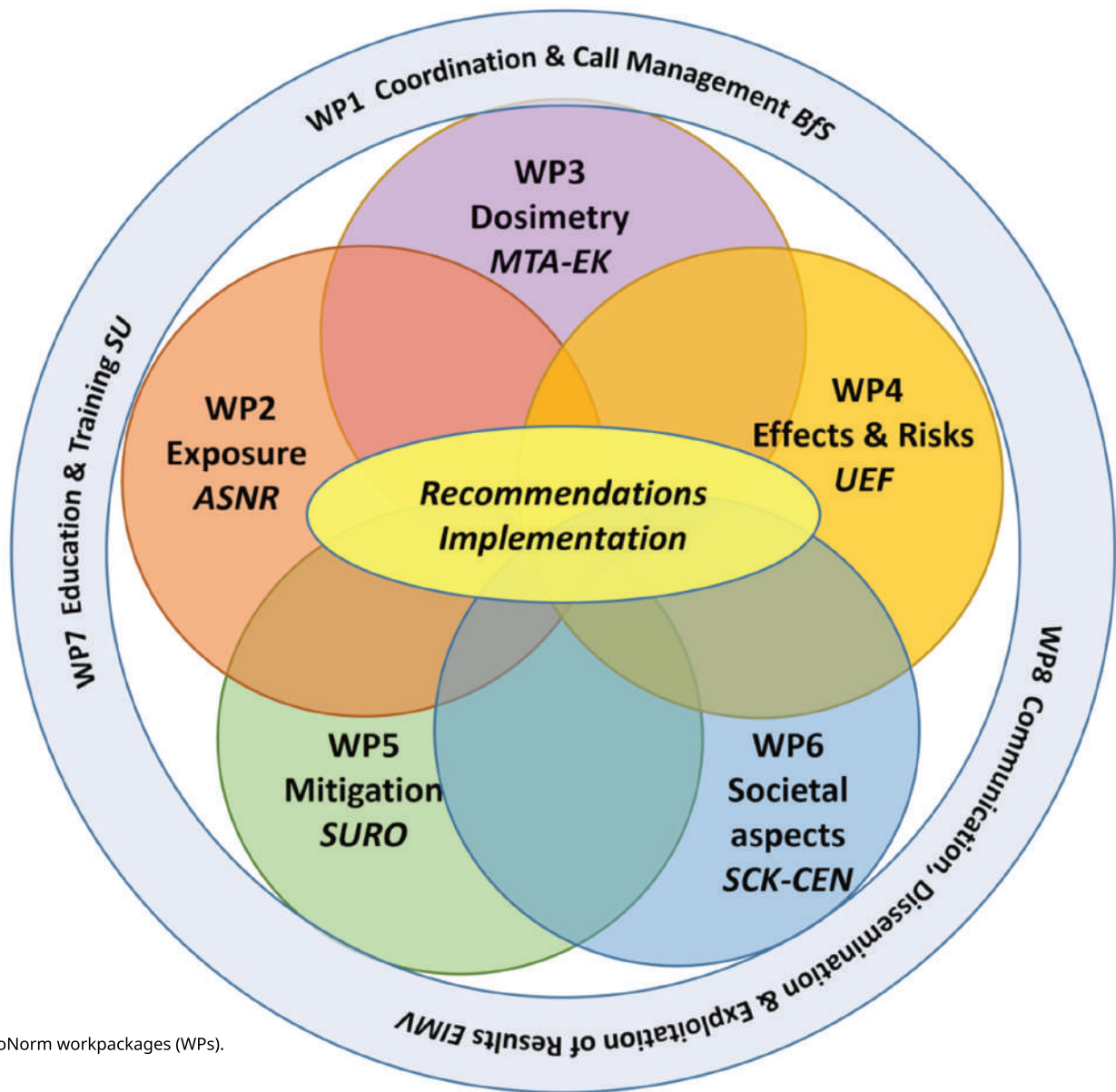
Jaylet, T.; Coustillet, T.; Jornod, F.; Margaritte-Jeannin, P.; Audouze, K. AOP-helpFinder 2.0: Integration of an Event-Event Searches Module. *Int.* 2023, 177, 108017, doi:10.1016/j.envint.2023.108017.

Fialova, E.; Otahal, P.P.S. Determination of the Radon

Progeny Activity Size Distribution in Laboratory Conditions. *Atmosphere* 2024, 15, 1262, doi:10.3390/atmos15111262.

Vanhoudt, N.; Wannijn, J.; Nauts, R.; Gompel, A.V.; Mijndendonckx, K.; Impens, N. Influence of Earthworms on the Mobility and Bioavailability of Metals, Metalloids and Radionuclides in Historically Contaminated Soil. *Appl. Soil Ecol.* 2024, 203, 105665, doi:https://doi.org/10.1016/j.apsoil.2024.105665.

Venoso, G.; Nuccetelli, C.; Di Carlo, C.; Trotti, F.; Ugolini, R.; Trevisi, R.; Leonardi, F.; Urso, L. Development of a Methodology for Assessing Radiological Dose Due to Use of NORM Sludge as Fertilizer. *Sci. Total Environ.* 2024, 912, 168934, doi:10.1016/j.scitotenv.2023.168934.



RadoNorm workpackages (WPs).

RadoNorm engagement opportunities

RadoNorm shares results, news, and events via its website, newsletters, and social media, and invites stakeholder participation. Public events in 2025 include the Showcase Meeting in Brussels (27 March) and the Annual Meeting in Budapest (2–6 June), with travel support available for active contributors.

Updates, results, upcoming events, and engagement opportunities are on the website, social media, and newsletters.

All facts about activities and developments are available on the RadoNorm website, with information about the project, objectives, work programme, its development and results, interaction and engagement possibilities. Please, have a look in particular to News, which informs about the major RadoNorm results, including deliverables, scientific papers and events with links to more details. RadoNorm is present on social media LinkedIn, Twitter (now X) and YouTube. You are kindly invited to follow us or even to become a RadoNorm stakeholder.

RadoNorm established different engagement opportunities for the related and interested stakeholders. Besides joining the stakeholders or attending the events, you can also be involved in RadoNorm activities. Depending on your active participation, RadoNorm might also offer support for reimbursement of direct costs.

The subscription to more information, like Newsletter issues, is also available. The RadoNorm partners, stakeholders and other groups are regularly informed about publications, news, events and calls. All developed contact databases are managed according to the RadoNorm Privacy policy.

RadoNorm is now planning several public events before the end of the project in August 2025:

- RadoNorm's Showcase Meeting will take place on 27th of March 2025 in Brussels: The meeting will bring together members of the European Commission, international organisations and European Platforms and Partnerships, among others. The main achievements of RadoNorm will be showcased, their implementation in society highlighted, and discussions facilitated on the way forward, addressing open questions stemming from the project. More information will be provided on the RadoNorm website.
- The 5th RadoNorm Annual Meeting will be held in the 23rd calendar week of 2025 (2nd to 6th June) in Budapest, Hungary. Please save the date in your calendars. As usually, travel grants will be available for the active participation of our stakeholders.



Dr. Nadja Železnik, leader of Work Package 8, EIMV

Sources



Last year of RadoNorm

- ✚ Deliverables, <https://www.radonorm.eu/publications/deliverables/>
- ✚ Publications, <https://www.radonorm.eu/publications/scientific-papers/>
- ✚ European Radiation Protection Week 2024, <https://www.erpw2024.eu/>
- ✚ Software for model radon and thoron in confined spaces, <https://www.mdpi.com/1660-4601/19/24/16739>
- ✚ Citizen science project in Hungary, <https://radonormcs.ek-cer.hu/>

WPs highlights

- ✚ Deliverable D2.4, https://www.radonorm.eu/wp-content/uploads/file_exchange/D2.4_Report-on-proficiency-test-of-active-instrumentation_submitted28082024_watermarked.pdf
- ✚ Beck et al., 2024, <https://www.mdpi.com/2073-4433/15/10/1180>
- ✚ Grygier and Skubacz, 2024, <https://www.mdpi.com/2073-4433/15/9/1131>
- ✚ Rey et al., 2024, <https://www.frontiersin.org/journals/public-health/articles/10.3389/fpubh.2024.1460295/full>
- ✚ Vanhoudt et al., 2024, <https://www.sciencedirect.com/science/article/abs/pii/S0929139324003962?via%3Dihub>
- ✚ Venoso et al., 2024, <https://www.sciencedirect.com/science/article/pii/S0048969723075630>
- ✚ Deliverable D2.4, https://www.radonorm.eu/wp-content/uploads/file_exchange/D4.6_Health-effects-of-radon-uranium-and-other-NORM-in-drinking-water_submitted29082024_watermarked.pdf

Events and trainings

- ✚ Six courses, <https://www.radonorm.eu/calls/call-for-courses/>

Latest deliverables and publications

- ✚ RadoNorm website, <https://www.radonorm.eu/publications/deliverables/>
- ✚ 13 scientific papers, <https://www.radonorm.eu/publications/scientific-papers/>

RadoNorm engagement opportunities

- ✚ RadoNorm website, <https://www.radonorm.eu/>
- ✚ News, <https://www.radonorm.eu/news/>
- ✚ LinkedIn, <https://www.linkedin.com/company/radonorm/>
- ✚ Twitter (now X), <https://twitter.com/RadoNorm>
- ✚ YouTube, <https://www.youtube.com/channel/UC6yCORiPX5DXgmu5AaGLn9Q>
- ✚ RadoNorm stakeholder, <https://www.radonorm.eu/stakeholders/>
- ✚ RadoNorm activities, <https://www.radonorm.eu/activities/>
- ✚ Subscription to more information, <https://www.radonorm.eu/newsletter/>
- ✚ RadoNorm Privacy policy, <https://www.radonorm.eu/privacy-policy/>
- ✚ RadoNorm website, <https://www.radonorm.eu/activities/>
- ✚ 5th RadoNorm Annual Meeting, <https://all.accor.com/hotel/6151/index.en.shtml>

Key takeaways



- ☢ **Delivered science-based recommendations for managing radon and NORM exposure in homes, mines, water, and agriculture.**
- ☢ **Developed and tested innovative tools – from low-cost radon monitors to advanced dosimetric models and lifecycle risk tools.**
- ☢ **Confirmed vulnerability to radon in sensitive groups: children, pregnant women, and individuals with lung conditions.**
- ☢ **Integrated citizen science in 10+ actions, empowering communities and students to co-develop solutions and devices.**
- ☢ **Demonstrated that social norms and emotions often outweigh statistics in radon risk communication.**
- ☢ **Advanced understanding of uranium transport, sorption behaviour, and plant transfer to support remediation strategies.**
- ☢ **Identified smoking's influence on lung dose from radon and its implications for radiation protection.**
- ☢ **Enabled cross-border training and knowledge transfer via 6+ expert-led courses and early career researcher exchange.**
- ☢ **Strengthened stakeholder engagement and policy relevance through open deliverables, public events, and EC outreach.**
- ☢ **Highlighted controversies around radon use in spas vs. health risks, advocating for balanced EU-level communication.**
- ☢ **Published 13+ peer-reviewed scientific papers spanning technical, environmental, and societal dimensions of radon and NORM.**



WE WISH YOU A
HAPPY NEW YEAR

2025!



RadoNorm
Managing risks from radon and NORM

RadoNorm

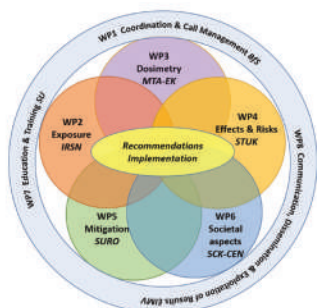
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N°9 - May 2025



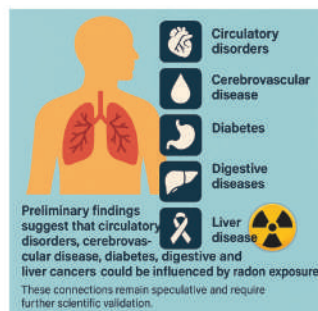
RadoNorm Showcase Meeting

Achievements and the impact on research and managing Ra-risks



Health impact of radon exposure

Investigating cancer and non-cancer effects, and other diseases



Protection against radon at work and at home

Improving radiation protection strategies with budget-friendly monitors



NORM and circular economy

New screening levels proposed for sludge reuse in agriculture



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RadoNorm Newsletter



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Editorial



Dr. Nadja Železnik, leader of Work Package 8, EIMV

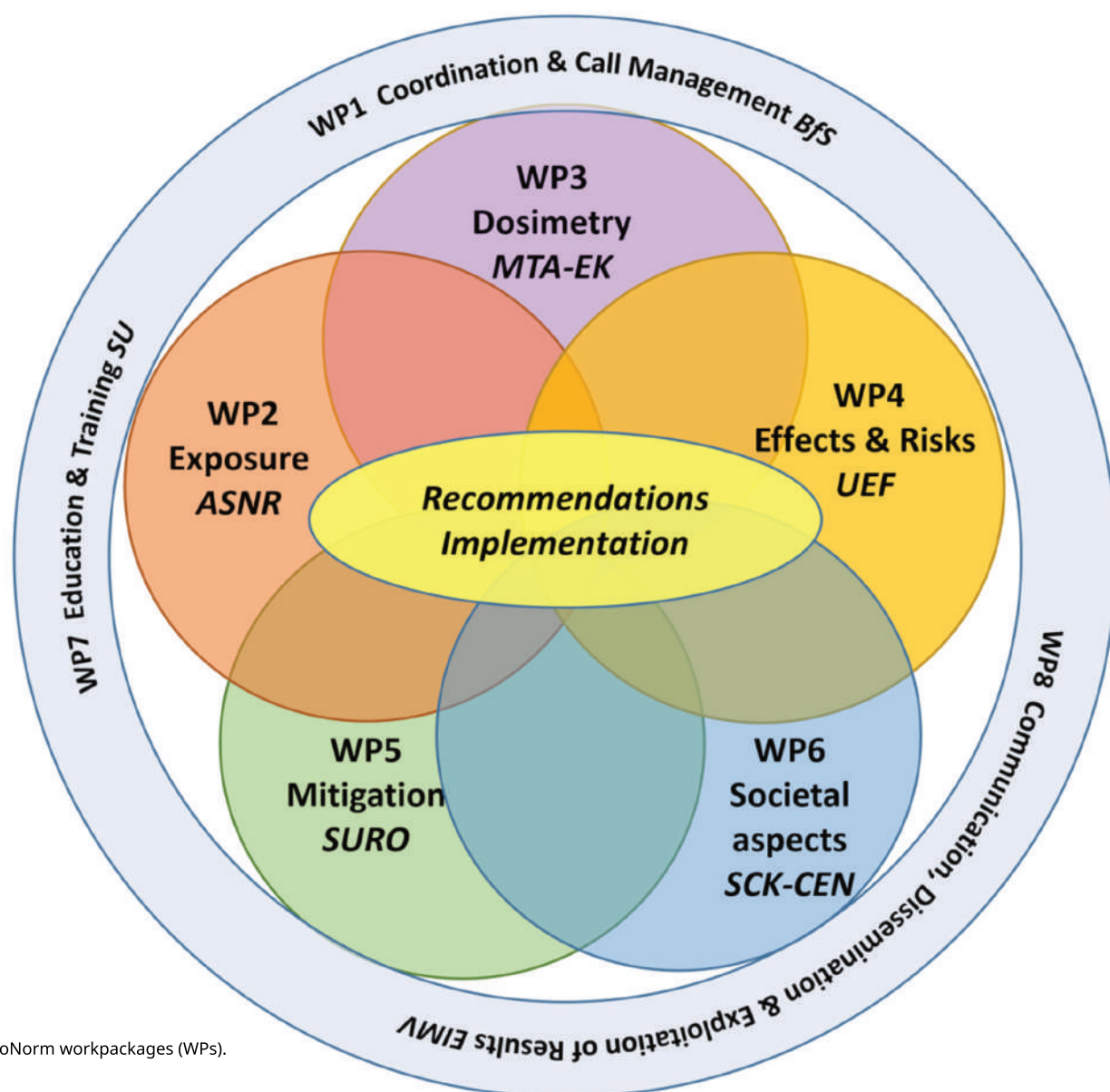
Dr. Nadja Železnik holds a BSc in Physics and an MSc in Reactor Physics from the Faculty of Mathematics and Physics, as well as a PhD in Psychology from the Faculty of Arts, all awarded by the University of Ljubljana, Slovenia. She is an expert in nuclear technology and radioactive waste management, with extensive experience in emergency preparedness and response, as well as in risk perception, communication, education, and training in environmental and nuclear projects.

She has acted as a civil society expert and knowledge manager in numerous European research initiatives, including EURAD-1 and -2, ECOSENS, and RadoNorm. Her contributions include the development of national strategies, legislative frameworks, feasibility studies, safety and radiological assessments, and stakeholder engagement plans. She has authored communication strategies, training programmes, and information materials to foster public understanding and informed participation in the nuclear and environmental domains.

It is with great pride that we present the ninth issue of the RadoNorm Newsletter, highlighting the key scientific and societal achievements of our project as it reaches the conclusion of five years of collaboration. During this time, our community of researchers, professionals, policymakers and citizens has set new standards in understanding and managing the risks associated with radon and NORM.

This issue brings together major research results on health effects, measurement improvements, protection strategies in buildings and workplaces, public risk perception, and the potential for material reuse within a circular economy. Special emphasis is placed on citizens who have actively contributed as co-creators of science through various measurement and awareness activities.

At the same time, this newsletter serves as an invitation to reflect on the future: which challenges still lie ahead, how we can retain and build upon the knowledge gained, and how to ensure sustainable protection of health and the environment.



RadoNorm workpackages (WPs).

RadoNorm Showcase Meeting

The RadoNorm Showcase Meeting presented key achievements in radon and NORM research. Experts, policymakers, and stakeholders discussed health risks, mitigation, and societal aspects. The event offered insights for future research and regulation, setting the stage for RadoNorm's Final Meeting.

The RadoNorm Showcase Meeting highlighted key research contributions and paved the way for the Final Meeting, which will focus on results and future directions in sustainable radiation protection.

The RadoNorm Showcase Meeting, held on 27th March 2025 at the Institute of Natural Sciences in Brussels, highlighted the project's achievements and the impact of the RadoNorm project in advancing research and managing risks associated with radon and naturally occurring radioactive materials (NORM).

The event brought together scientists, policymakers, EU officials, and stakeholders from across Europe to evaluate scientific results, technological innovations, and societal engagement activities developed throughout the project.

Through presentations and panel discussions, the meeting showcased progress in understanding radon-related health effects, improving measurement and mitigation strategies, and enhancing communication and citizen participation. It also served as a platform to identify remaining challenges and to provide concrete recommendations for future research, regulation, and implementation efforts in radiation protection.

Among the speakers addressing nearly 40 participants at the RadoNorm Showcase meeting was the Slovenian Member of the European Parliament, Vladimir Prebilič,

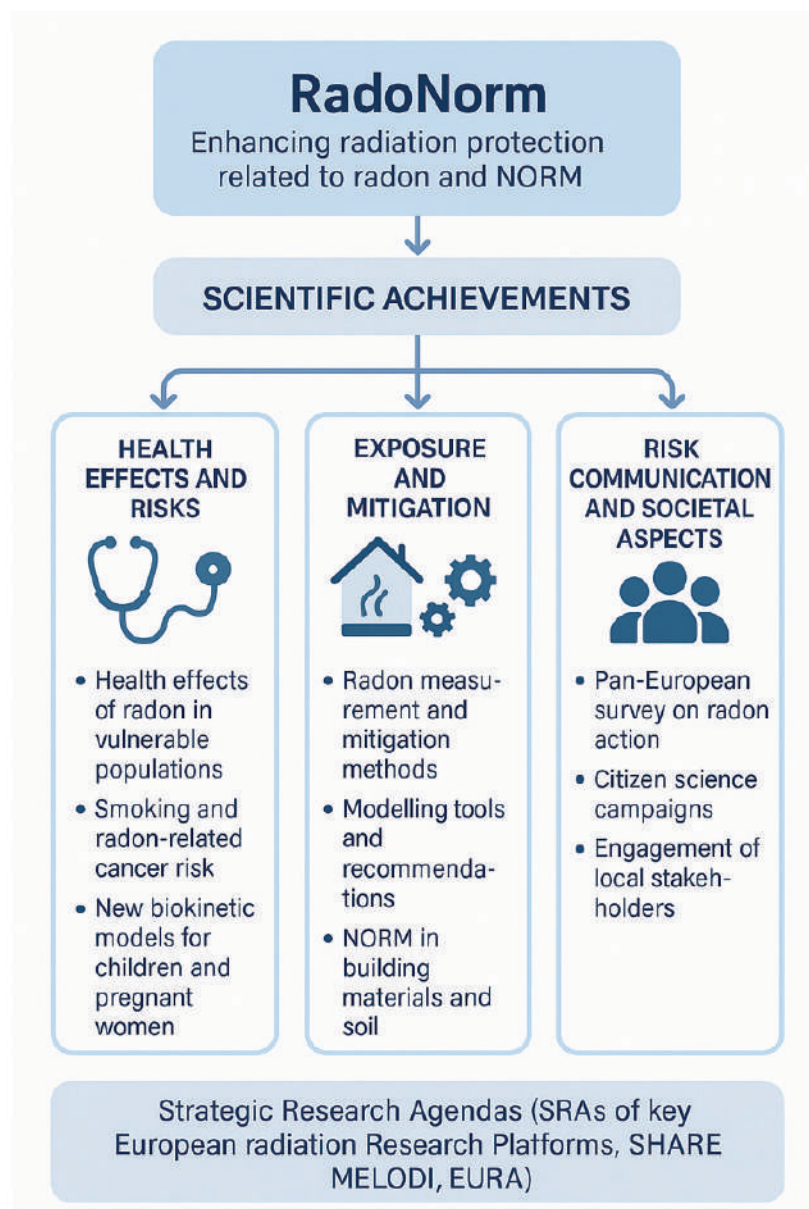
who shared his experiences in raising radon awareness in the Municipality of Kočevje, Slovenia. His contribution was complemented by presentations from other key figures in the field, including Domenico Rossetti, Deputy Head of Unit for Euratom Research, who presented the European Commission's Research Actions in Radiation Protection, and Florian Rauser, Vice President of the Federal Office for Radiation Protection (BfS), who also contributed to the discussions.

The meeting featured three panel discussions and a summary discussion with an outlook on the future. The focus of the main panel discussions was on "health effects and risks", "exposure and mitigation", and "risk communication and societal aspects", highlighting the relevance of RadoNorm's progress and its impact on radiation research and implementation. These discussions provided insights into how RadoNorm's findings could be implemented and what future research areas need to be addressed based on the project's progress.

The Showcase Meeting underscored RadoNorm's significant contributions to radiation protection research and set the stage for its upcoming Final Meeting, where the latest results will be highlighted,

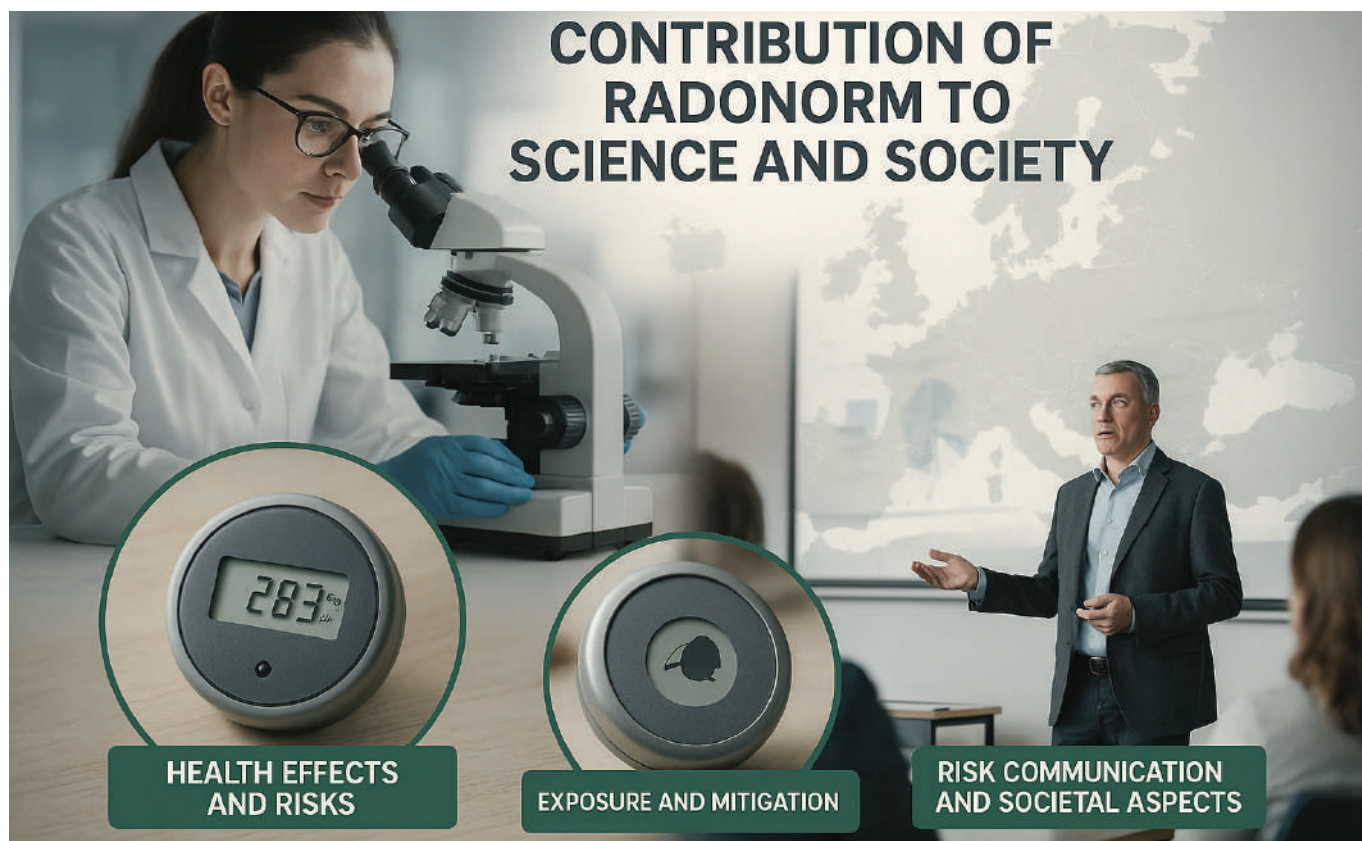


RadoNORM Showcase Meeting participants.



Contribution of RadoNorm to science and society

RadoNorm advanced radiation protection on radon and NORM through groundbreaking research on health effects, exposure, mitigation, and societal aspects. The project developed new tools, models, and strategies aligned with the Strategic Research Agendas of the key European Radiation Research Platform, shaping policies and empowering stakeholders across Europe.



The RadoNorm project has significantly enhanced radiation protection related to radon and NORM. The project's wide-ranging scientific achievements, particularly under the themes of health effects and risks, exposure and mitigation, and risk communication and societal aspects, are well aligned with the Strategic Research Agendas of key European Radiation Research Platforms (ERRPs), including MELODI, EURADOS, ALLIANCE, and SHARE.

Groundbreaking work was conducted on the health effects of radon exposure, particularly in vulnerable populations such as children and individuals with respiratory conditions. RadoNorm also revealed how smoking alters radon-related dose distribution and cancer risk, and explored new biokinetic models for children and pregnant women. These insights are crucial for improving personalised dosimetry and public health strategies.

In the realm of exposure and mitigation, the project delivered extensive testing and validation of radon measurement technologies and mitigation methods, from residential settings to high-risk workplaces like underground mines. Innovative modelling tools and recommendations were developed for indoor and outdoor radon exposure, gamma radiation, and NORM in building materials and soil. These efforts have advanced the regulatory framework and practical guidelines for radiation protection.

The societal dimension of radiation protection was also central to RadoNorm. A pan-European survey revealed that simply increasing awareness is not enough to spur action against radon; emotional and social cues play a stronger role. Novel communication strategies, citizen science campaigns, and social science tools were successfully piloted to engage the public and empower local stakeholders in Slovenia and across Europe.

The contributions made during the RadoNorm project not only inform European policies like the Basic Safety Standards Directive but also offer practical tools and strategies for national authorities, industry, and the public. Through its interdisciplinary approach and collaborative research mode, RadoNorm has set a new standard for integrated radiation protection and risk communication in Europe.



Assessment of health risks

RadoNorm revealed radon-related lung cancer mutations, developed predictive models, and advanced understanding of smoking effects. Vulnerable groups, children, pregnant women, and those with asthma or COPD, receive higher doses. These insights support personalised risk assessment and targeted protection strategies.

Under the RadoNorm project, significant progress has been made in understanding the cancer-related health risks associated with radon exposure. One of the most notable achievements is the identification of a distinct gene mutation fingerprint for radon-induced lung cancer, first observed in rats and now also confirmed in uranium miners. Among the affected genetic pathways, the RTK-RAS pathway emerged as the most commonly altered, underscoring its key role in radon-related carcinogenesis.

To complement these molecular findings, researchers have been developing a predictive model known as the Multi-Stage Clonal Expansion Model. This model is designed to estimate both the number and size of lesions that occur during lung carcinogenesis, particularly in conditions of high radon exposure and varying exposure rates. It provides two crucial temporal indicators: latency time (the period between the emergence of the first surviving cancer cell and clinical detection) and sojourn time (the interval from the appearance of the first premalignant cell to the formation of the first malignant cancer cell).

While the predictive model is still undergoing refinement, particularly in translating findings from animal models to human contexts, its results show promise for enhancing early detection efforts. Specifically, the ability to quantify preneoplastic lesions could inform lung cancer screening programmes in areas with elevated radon exposure. These advances mark a significant step forward in establishing the biological mechanisms of radon-induced lung cancer and open pathways for improved and potentially simplified diagnostic approaches.

The RadoNorm project has made important strides in uncovering how smoking interacts with radon exposure in ways that affect lung cancer risk. Surprisingly, dosimetric

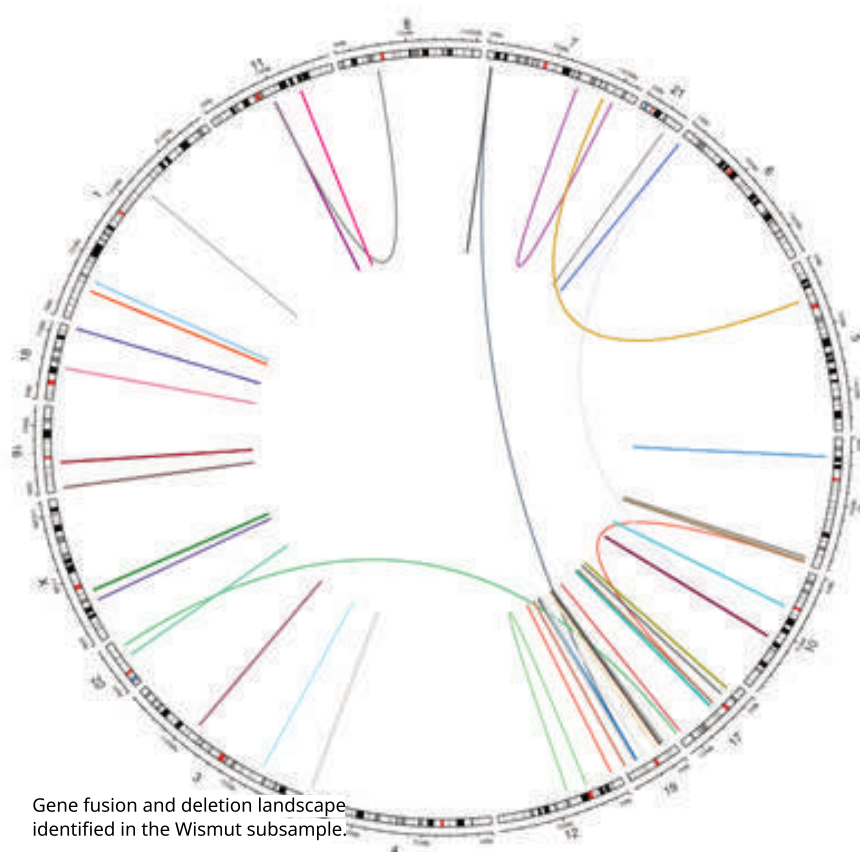
modelling revealed that smoking may reduce the dose of radon to the lungs, while simultaneously increasing it to other organs (Honorio da Silva et al., 2023; shortlisted for the Bernard Wheatley Award of the Journal of Radiological Protection). This counterintuitive outcome is likely due to physiological changes in smokers, such as a thicker mucus lining and slower mucus clearance, which might shield the bronchial epithelial cells from alpha radiation. However, these findings need further verification using experimental data, especially in the context of evolving smoking habits like vaping.

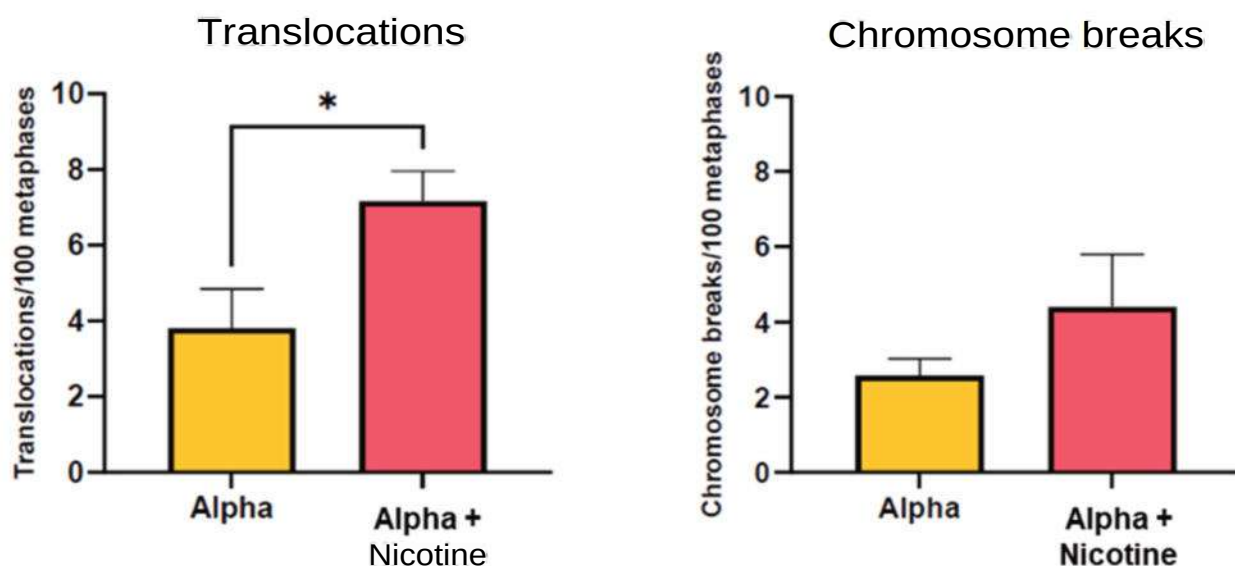
Experimental research also demonstrated that nicotine alters DNA repair processes (Boroumand et al., 2024). In bronchial epithelial cells exposed to alpha radiation, nicotine increases the rate of DNA repair (but potentially in a harmful way). The elevated repair activity is thought to be more error-prone,

which can lead to more genetic mutations. These findings are supported by chromosomal analyses showing increased translocations and breaks when nicotine is present alongside alpha particle exposure.

To deepen understanding of particle behaviour in smokers' lungs, RadoNorm researchers enhanced the Stochastic Lung Model (SLM) to incorporate the effects of coagulation on particle deposition. This improved model allows more accurate simulation of particle interactions and deposition dynamics in both smokers and non-smokers, offering a more precise estimate of lung dosimetry in realistic scenarios.

The advancements in the created knowledge of the impact of smoking and radon on the human organism bring us closer to a mechanistic explanation of how





Modified figure from Boroumand et al. 2024.

27 h after 2 Gy alpha irradiation

smoking and radon jointly contribute to lung cancer, and they emphasise the need to consider smoking behaviour when assessing radon-related health risks. Future studies should continue to refine these models and investigate the implications for modern smoking trends, including electronic cigarettes and vaping.

While the primary health impact of radon exposure remains lung cancer, the RadoNorm project has begun to explore the potential for non-cancer effects and other diseases, though current evidence is still limited. A comprehensive literature review revealed only minor support for associations between radon and diseases beyond lung cancer (Henyoh et al., 2024). However, some links are beginning to emerge.

Preliminary findings suggest that circulatory disorders, cerebrovascular disease, diabetes, digestive and liver diseases, and possibly other cancers could be influenced by radon exposure. These connections remain speculative and require further scientific validation. The need for more robust experimental and epidemiological strategies to assess these associations has been strongly emphasised in recent publications.

A particularly novel development is the use of Adverse Outcome Pathways (AOPs) to explore the effects of radiation beyond cancer. One such effort under RadoNorm involved mapping pathways for radiation-induced microcephaly based on existing literature (Jaylet et al., 2022, 2023). This opens up new avenues for investigating developmental and neurological outcomes of radiation exposure, especially in vulnerable populations.

Epidemiological work findings not only expand the scope

of radon-related research but also highlight the importance of targeted communication strategies for informing specific at-risk groups, depending on disease type, exposure history, and demographic vulnerabilities.

Ultimately, continued investigation is essential to determine how radon may contribute to a broader range of health outcomes and how this knowledge can inform both risk assessment and public health policy.

The RadoNorm project has placed special emphasis on assessing the effects of radon exposure in vulnerable populations, particularly children, pregnant women, and individuals with pre-existing lung conditions. This focus has helped to refine dose modelling and guide tailored protection strategies.

Epidemiological studies conducted in Norway revealed a statistically significant association between radon exposure in homes and increased cancer incidence among children. This finding underscores the need for targeted mitigation in domestic environments where children are present. In parallel, lung dosimetry studies have shown that children, due to their smaller airways and thinner mucus layers, absorb higher doses of radon compared to adults when exposed to the same concentration (Deliverable D3.3).

RadoNorm has also developed a biokinetic model for pregnant women, which shows that acute radon exposure results in low doses to foetal tissue, providing early reassurance. However, additional work is ongoing to expand the model to cover radon progeny, which may behave differently in the maternal-foetal system.

Further, lung dosimetry modelling has revealed that individuals with asthma and chronic obstructive pulmonary disease (COPD) receive higher absorbed lung doses from the same radon concentration than healthy individuals. This is due to disease-related changes in airway morphology and mucus dynamics, which increase particle deposition (Deliverable D3.1).

The findings support the urgent need for personalised dose assessment and protective measures that account for physiological variability across different population groups, prioritising children, pregnant women, and people with respiratory diseases, and ensuring that radiation protection is equitable and evidence-based.



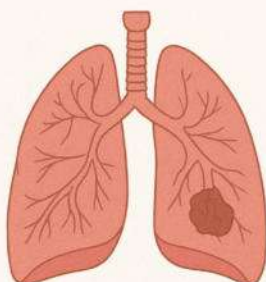
Summary

Assessment of Health Risks

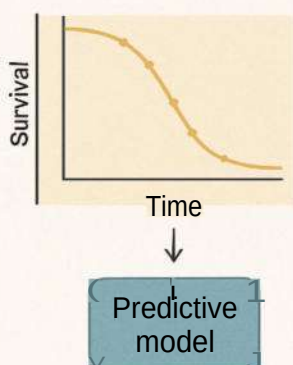
Gene mutation fingerprint



Lung cancer



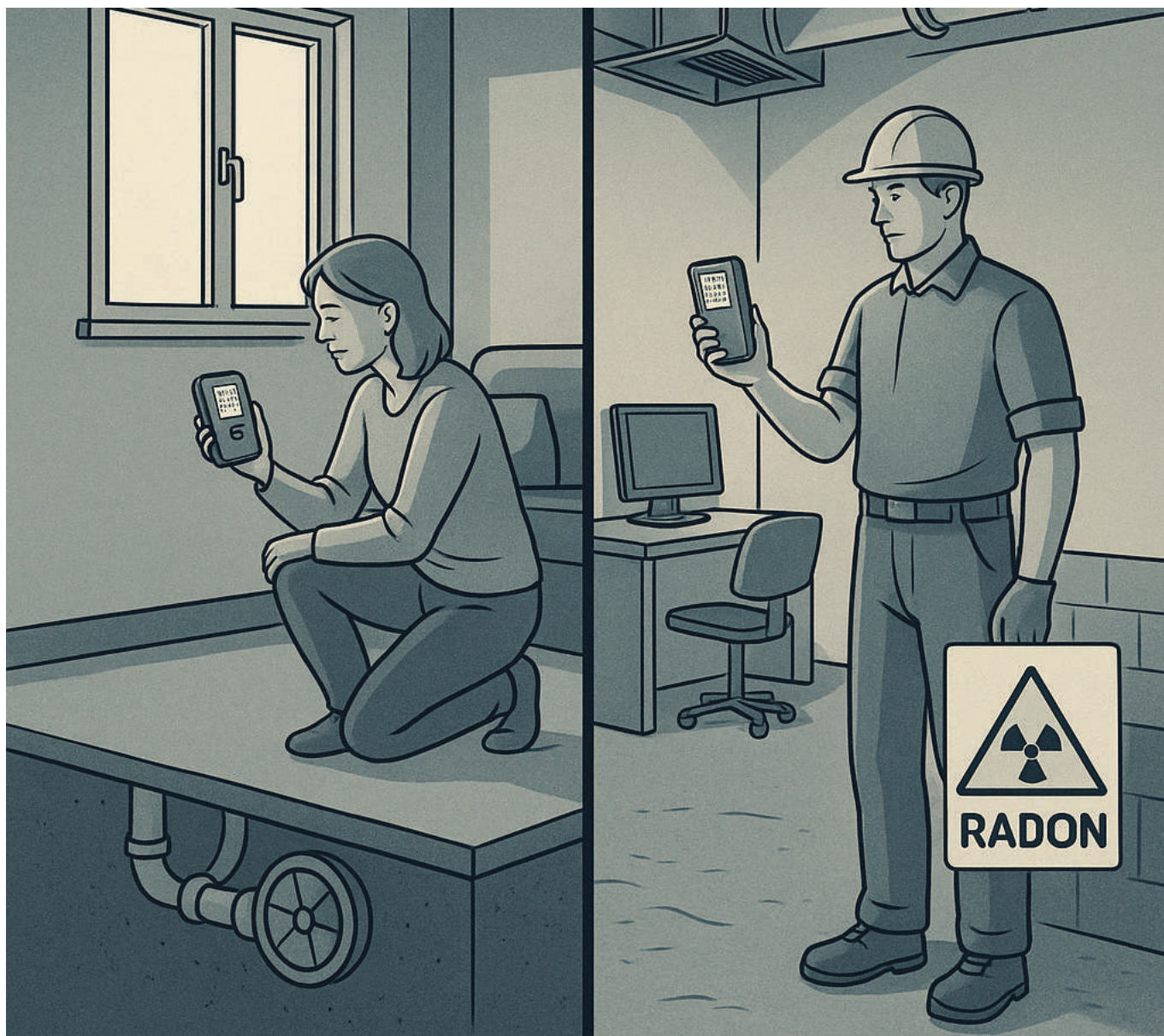
Predictive model



Smoking interaction



The RadoNorm project has significantly advanced the understanding of radon-related health risks by identifying a distinct gene mutation fingerprint for lung cancer, first observed in rats and now confirmed in uranium miners. This discovery, along with the development of the Multi-Stage Clonal Expansion Model to estimate lesion growth and key temporal indicators such as latency and sojourn time, lays the groundwork for improved early detection of radon-induced lung cancer. At the same time, research into the interaction between smoking and radon exposure has revealed that smoking may reduce radon doses to the lungs while increasing radiation exposure to other organs, likely due to physiological changes such as thicker mucus layers and slower clearance. Nicotine was also found to disrupt DNA repair processes in bronchial cells, leading to more frequent and potentially harmful genetic mutations. These findings, supported by enhancements to the Stochastic Lung Model for simulating particle behaviour, provide deeper insight into how particles deposit differently in the lungs of smokers and non-smokers. Although lung cancer remains the primary concern, preliminary evidence suggests that radon exposure might also be linked to circulatory disorders, cerebrovascular disease, diabetes, and digestive or liver conditions, prompting further investigation through tools like Adverse Outcome Pathways. Special attention has been given to vulnerable groups such as children, pregnant women, and individuals with asthma or chronic obstructive pulmonary disease (COPD), who absorb higher radon doses due to their specific physiological traits. Altogether, the scientific developments pave the way for more accurate risk assessment and the design of equitable, evidence-based public health strategies.



Protection against radon at work and at home

RadoNorm improves radon protection at home and work through accurate measurements, enhanced detectors, and clear guidance. Using simulation tools and direct thoron assessment, it supports effective mitigation. Research on materials, ventilation, and underground exposure aims to ensure safer living and working environments.

RadoNorm's work on measuring radon and thoron has significantly contributed to improving radiation protection strategies at home and in workplaces. A key aspect of this effort has been the evaluation of both budget-friendly (Beck et al., 2024; Deliverable D2.4) and research-grade continuous radon monitors (Deliverable D5.9), with emphasis on the need for standardisation and quality assurance/quality control (QA/QC) procedures. These are essential to ensure data reliability and to prevent the common "garbage in, garbage out" (GIGO) pitfalls in follow-up risk management and mitigation measures.

One major advancement involves the independent assessment of radon entry rates and air exchange rates using tracer gas methods. These approaches help refine the design of mitigation systems and enable the implementation of highly efficient, targeted corrective actions. They are especially valuable in identifying problem areas within buildings and optimising ventilation

and sealing strategies.

In contrast to radon (Rn-222), thoron (Rn-220) presents unique challenges for measurement and dose assessment. Due to its much shorter half-life and high spatial variability, thoron concentration can vary greatly depending on the distance from its source. Therefore, conventional radon monitoring methods and assumptions, such as using a single measurement point or relying on equilibrium factor estimates, do not hold for thoron.

For effective thoron risk assessment, RadoNorm recommends measuring its decay products (which have longer half-lives) rather than thoron gas itself when estimating dose. However, if the goal is to locate thoron sources within an indoor space, direct thoron measurements at multiple distances from suspected sources are appropriate.

RadoNorm has made significant contributions to the field of radon measurement by enhancing the

quality and reliability of monitoring practices. This includes the improvement of commercially available radon detectors, ensuring more accessible and precise tools for both professionals and the public. Additionally, the project has enabled more accurate and differentiated dose assessments for both radon and thoron, accounting for their distinct behaviours and risks. Equally important, RadoNorm has provided clearer guidance to the public and regulatory authorities, helping them to better interpret measurement results and implement appropriate responses.

Together, this work enhances the reliability of exposure assessments and supports the broader goal of reducing health risks through smarter, data-driven protective measures.



Radon monitors.

Protection against radon at work and at home

The RadoNorm project has strengthened protection measures for underground workplaces, such as mines, where radon and thoron exposure present unique challenges. To improve risk estimation and control in the underground environments, simulation tools like Ventgraph and RadoThor were used to model gas distribution and variability in confined spaces (Deliverable D2.3). These tools enable scenario testing and ventilation planning under dynamic conditions.

Measurements in Polish mines revealed that the equilibrium factor (F), the ratio between radon and its progeny, varies significantly across sites, making dose estimation based on standard values unreliable. To address this, RadoNorm recommends that dose assessments be based on direct measurements of potential alpha energy concentration rather than assumed equilibrium factors, ensuring greater accuracy and site specificity (Grygier & Skubacz, 2024).

Further, the project developed the INTDOSKIT toolkit, designed to calculate dose coefficients for inhaled radionuclides. This tool allows for uncertainty and sensitivity analyses through Monte Carlo simulations, helping to assess intake scenarios with improved precision (Makumbi et al., 2024).

Crucially, RadoNorm's findings underscore the importance of ventilation and drilling techniques. Simulations show that dry drilling under poor ventilation results in higher radiation doses than wet drilling with good ventilation, primarily due to increased airborne progeny particles. This has significant biological implications, as it could contribute to elevated lung cancer risk in poorly ventilated settings.

In response, new recommendations have been published for radon measurement protocols in underground workplaces. The recommendations include tailored approaches for varying mine

conditions and reinforce the need for high-quality, environment-specific monitoring to support occupational health standards (Skubacz et al., 2023, Deliverable D2.7, Deliverable D5.9).

The advancements in radon-related underground knowledge offer a robust foundation for regulatory improvements, protective equipment guidelines, and worker safety training, ensuring radon and thoron risks are properly managed in some of the most challenging exposure environments.



RadoNorm improved radon mitigation by modelling radon entry, using direct measurements, and identifying effective sealing materials like HDPE.

RadoNorm's research on radon in buildings has contributed valuable insights and practical tools for predicting and mitigating indoor radon exposure. One of the core developments is a model for radon transport from soil into indoor air, which has proven feasible in simulating radon behaviour in various building configurations (Deliverable D2.8). This helps identify structures most at risk and supports smarter planning and remediation.

To improve accuracy in assessing radon sources within construction materials, the project introduced direct measurement techniques using the SIREN apparatus. The direct measurements were found to be more reliable than those derived from existing predictive models, marking a step forward in material-specific radon risk assessment (PhD Thesis A. Maiorana).

Importantly, RadoNorm examined the efficacy of radon-proofing methods, emphasising that not only the membrane material but also joints and sealing methods play a crucial role. For example, sealing tapes were found to be ineffective, whereas torched bitumen membranes and welded polymer joints offered excellent radon resistance (Jiranek et al., 2024). Among the tested materials, HDPE (high-density polyethylene) stood out as the most promising membrane, combining performance with low environmental impact (Felicioni et al., 2023).

The role of air handling systems (HVAC) as a radon mitigation strategy was also investigated. While HVAC systems can reduce indoor radon concentrations, they may interfere with energy-saving goals and indoor air quality management, presenting a complex trade-off between radiation protection and environmental sustainability.

The advancements in knowledge about radon in buildings support more robust building standards, enhance measurement reliability, and guide sustainable mitigation practices, ultimately contributing to healthier indoor environments across Europe.





Radon risk communication

RadoNorm research shows that raising awareness alone is not enough to prompt radon testing or mitigation. Key psychological drivers (social norms, perceived risk, and emotional engagement) strongly influence behaviour. Narrative and culturally tailored strategies are more effective than statistics in motivating protective actions.

The RadoNorm project has placed a strong focus on understanding and improving radon risk communication, particularly through the lens of public perception and behavioural psychology. While general awareness of radon exists across Europe, the data show that awareness alone has a weak influence on whether individuals actually test for or mitigate radon in their homes. This gap between knowledge and action was explored in depth using data from the European Radon Behavioural Atlas, which mapped attitudes across 16 countries (DOI: 10.20348/STOREDB/1179/1274).

Through this research, several key psychological determinants were identified as the strongest predictors of protective behaviour (Perko et al., 2024):

- **Subjective norms:** People's belief that important individuals or social groups expect them to act (e.g., test for radon) significantly influences behaviour.
- **Descriptive norms:** Individuals are more likely to act when they perceive radon testing as a common behaviour in their community or peer group.

- **Severity:** The perceived seriousness of health outcomes caused by radon exposure plays a major role in shaping motivation to act.

- **Susceptibility:** People who perceive themselves or their families as vulnerable to radon-related health effects are more likely to take preventative steps.

- **Affective response:** Emotional reactions, such as fear, anxiety, or concern, triggered by radon-related information, can catalyse decisions to test or remediate.

To support tailored communication strategies, RadoNorm also developed a social science toolbox composed of qualitative and quantitative methods. This resource helps authorities assess public perception more effectively and design targeted interventions (DOI: 10.20348/STOREDB/1180).

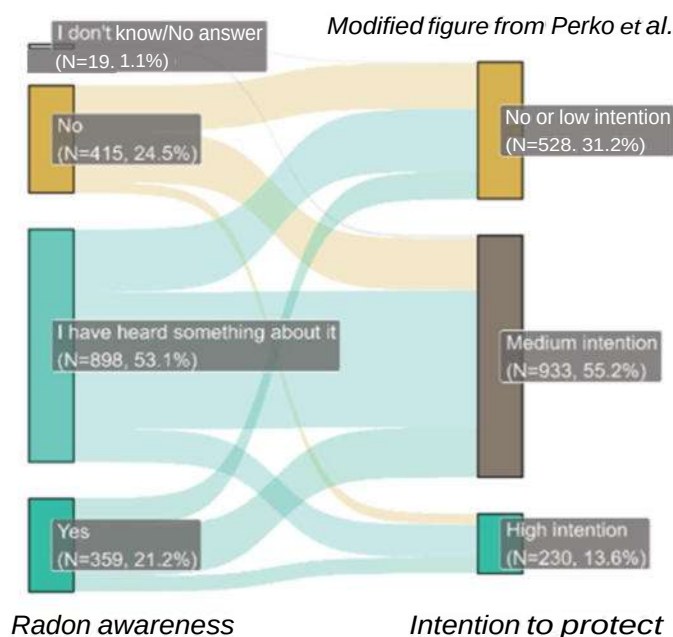
Ultimately, the risk perception findings suggest that effective radon communication must go beyond raising awareness. It must leverage social norms, emotional engagement, and perceived vulnerability to motivate action, especially in areas where radon exposure is high but public response remains low.

RadoNorm's findings on radon risk communication highlight the importance of emotionally engaging, personally relevant approaches over purely statistical messaging. Research shows that narrative communication, such as sharing real-life stories of individuals affected by radon-related lung cancer, leads to significantly greater intention to test, seek information, and take mitigation measures compared to abstract statistics. For example, while people may read that 7-8% of lung cancer cases in Belgium are attributable to radon, it is the personal story of a young, terminally ill patient like Nathalie Dubois that truly motivates action.

In addition to narrative, other emotional communication strategies, such as the use of humour and social norm nudges, can enhance message effectiveness. However, these methods are not universally applicable and must be tailored to national or cultural contexts to ensure resonance with the target audience.

RadoNorm also emphasises the need to address the dual reality of radon's identity. On one hand, radon is a known health hazard and a cause of lung cancer; on the other hand, it is used in radon therapy for certain medical conditions. Communication strategies must transparently address both the risks and benefits associated with radon. This involves clearly presenting each perspective, providing contextual explanations to help audiences understand the dual nature of radon, and actively engaging trusted stakeholders, such as healthcare professionals, to ensure messages are credible and effectively delivered (Deliverable D6.14).

The project encourages risk communicators and public authorities to adopt evidence-based, psychologically informed practices when designing campaigns.





Citizen science

RadoNorm showed that citizen science can effectively support radon risk assessment and mitigation. Ten European projects engaged diverse citizens in radon measurement, raising awareness, empowering communities, and prompting local action. The initiative earned EU recognition and offers a strong model for future environmental health efforts.

RadoNorm's citizen science projects effectively empowered communities across Europe to understand and address radon risks.

RadoNorm has successfully demonstrated the potential of citizen science to contribute meaningfully to radon risk assessment and mitigation at the community level (Hoedoafia et al., 2024). Through ten distinct projects across Europe, citizens, ranging from high school students to senior participants, were actively involved in measuring radon levels and interpreting results using a variety of detectors and techniques.

Participants received hands-on training not only in technical measurement procedures but also in applying them across diverse contexts, including homes, schools, and even natural settings like caves. These projects significantly empowered individuals and communities by enhancing their understanding of radon risks and engaging them directly in the monitoring process.

The initiative's impact was acknowledged through an "honorary mention" at the EU Prize for Citizen Science, recognising its innovative approach and societal value. Most importantly, these projects proved to be highly effective in raising awareness and fostering a sense of responsibility at the local level. The increased knowledge and engagement among citizens also encouraged local authorities to take further action, promoting more structured mitigation efforts and improved communication.

By directly involving the public, citizen science under RadoNorm not only delivered reliable data for research purposes but also achieved a key goal of motivating communities to remediate and take ownership of indoor air quality. It stands as a promising model for future environmental health initiatives seeking both scientific and societal impact.





Environmental protection

RadoNorm advanced understanding of NORM mobility by modelling radium and uranium behaviour in soil and ecosystems, highlighting bioremediation and phytoremediation potential. These findings improve environmental risk assessments and support sustainable remediation of legacy and mining-impacted sites across Europe.

RadoNorm has developed models and bioremediation strategies that significantly enhance environmental risk assessment and remediation.

RadoNorm's environmental protection work has yielded significant advances in understanding the mobility and impact of naturally occurring radioactive materials (NORM), especially in areas affected by mining and legacy contamination.

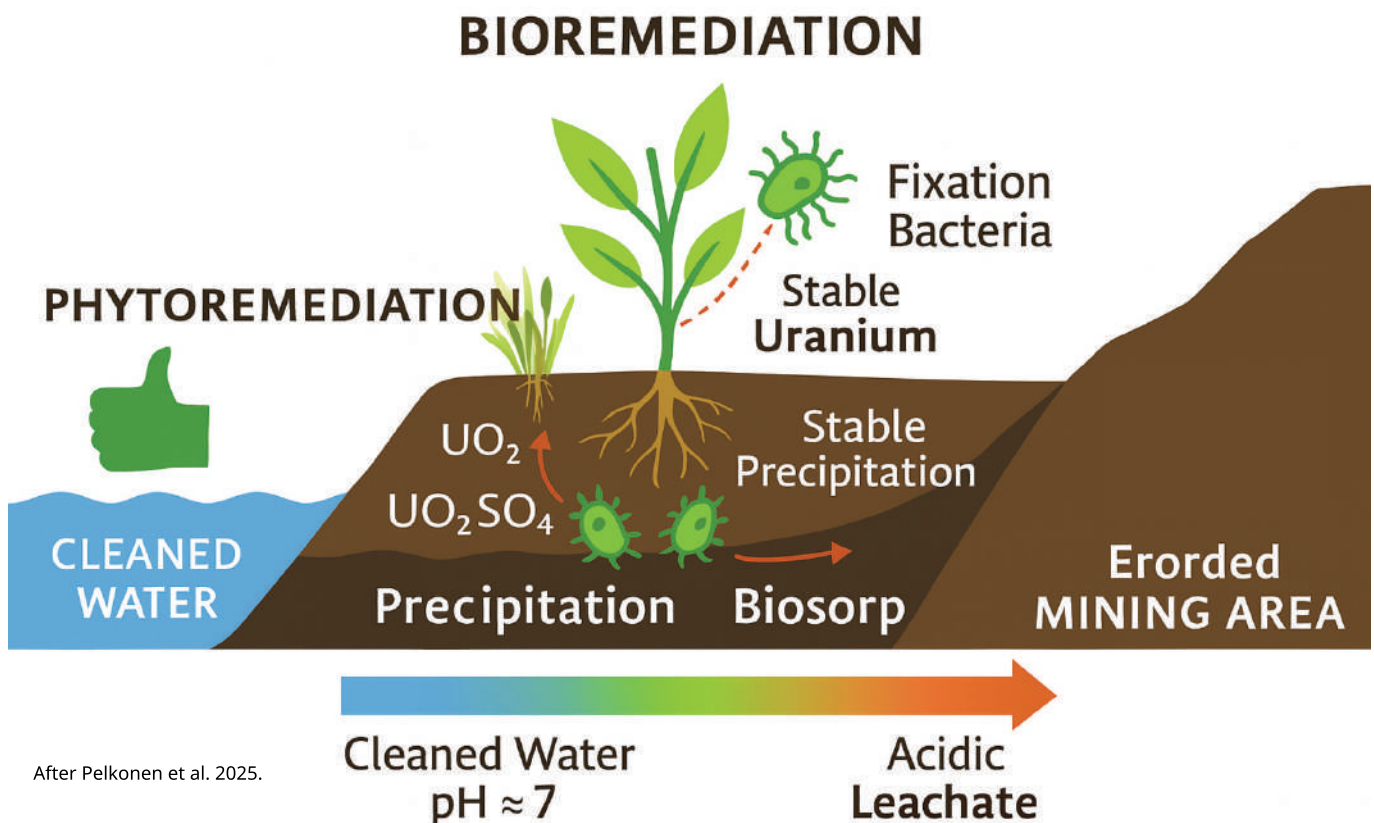
A central achievement is the development of a model for radium migration in soil, which identifies key parameters influencing the movement of radium and enables the prediction of sorption and desorption processes across different soil compartments. This model offers critical insight for environmental risk assessment, especially in areas with varying physico-chemical soil properties (Serra-Ventura et al., 2024).

Parallel investigations into uranium mobility have highlighted the importance of site-specific conditions. At alum shale sites in Norway, factors affecting uranium transport were systematically explored (Pelkonen et al., 2025), while research into symbiotic interactions between plants and bacteria demonstrated their influence on uranium behaviour in soil (Galeone et al., 2024). These findings, particularly from Galeone et al., are directly applicable to phytoremediation strategies, where native plant-bacteria systems can be harnessed for sustainable environmental cleanup.

RadoNorm also extended environmental modelling into forest ecosystems, simulating radon migration through soil layers (Vives i Batlle, 2025). In addition, the combined effects of ionising radiation and chemical pollutants on wildlife populations were modelled, offering a comprehensive view of ecosystem-level risk (Vives i Batlle, 2025b).

Another notable contribution is the demonstration that native microbial populations can be stimulated to immobilise uranium in contaminated mine water, suggesting a promising bioremediation approach for legacy NORM sites (Newman-Portela et al., 2024).

Together, these efforts improve risk assessments for non-human biota, particularly in regions where mining is ongoing or planned (Norway), and lay the foundation for more feasible and ecologically sound remediation strategies.





NORM management

RadoNorm improved NORM management by developing lifecycle-based risk assessment tools and open activity registers. It proposed new dose-based screening levels for material reuse (e.g. fertiliser) and introduced a tiered framework to track exposure risks, supporting safer, regulation-aligned reuse of NORM in circular economy contexts.

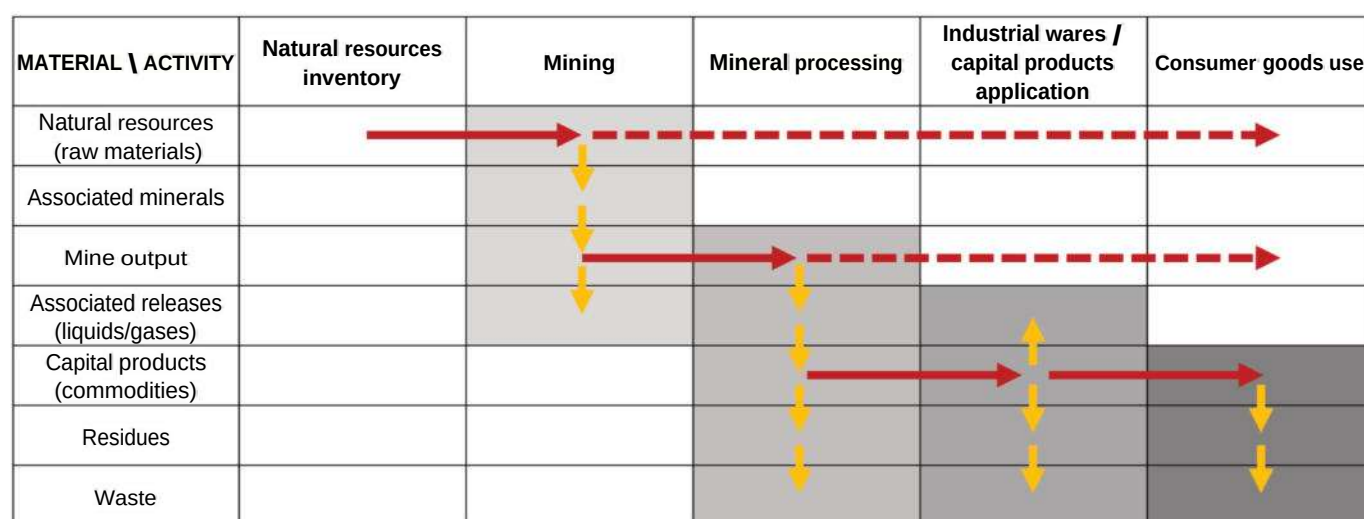
Open activity registers, proposed dose-based reuse criteria, and the lifecycle risk framework support safe and sustainable circular economy practices.

RadoNorm has made substantial progress in improving the management of NORM by developing systematic tools for risk assessment throughout the industrial lifecycle of these materials (Michalik et al., 2023; Mrdakovic Popic et al., 2023). A key achievement includes the creation of open NORM activity registers, which help industries identify and assess potential radiological risks at various stages, from raw material extraction to product use and waste disposal. The registers, now available via the RadoNorm website, offer a structured approach to track exposure risks and facilitate regulatory oversight.

As the principles of the circular economy increasingly shape industrial and environmental practices across sectors, the project also addressed the reuse of NORM-containing materials, such as sludge from groundwater filtration facilities, which can be repurposed in agriculture. New screening levels based on dose criteria (e.g., 1 mSv/year or 0.3 mSv/year) were proposed for evaluating whether such sludge can be safely used as fertiliser, especially in scenarios not currently covered by existing guidelines (Venoso et al., 2023). This enables more informed decisions about recycling NORM materials while protecting public and environmental health.

Furthermore, RadoNorm developed a tiered framework (from natural resource inventory to consumer use) for tracking and evaluating NORM across the full lifecycle of industrial operations. This methodology provides a clearer picture of how radiation risks evolve and accumulate across production chains, enhancing the governance of NORM in sectors like mining, water treatment, and agriculture.

The advancements in NORM management knowledge lead to more precise risk assessments and support the development of better-targeted legislation, ensuring NORM is handled, processed, and reused responsibly and in compliance with radiological protection standards.



Red: subsequent industry sectors. Orange: processed material fate at each level. After Popic et al. 2023.



Stakeholder perceptions governing NORM use

RadoNorm explored stakeholder views on using NORM by-products in construction, identifying key drivers (e.g. regulation, CO₂ incentives) and concerns (e.g. health risks). Findings stress the need for harmonised EU rules, clear communication, and certification to support safe, circular use of NORM and improve societal acceptance.

Clear regulation, transparent communication, and stakeholder trust are key to enabling the safe and circular use of NORM by-products in industry.

As part of integrating Social Sciences and Humanities (SSH) activities, RadoNorm has investigated stakeholder perceptions surrounding the use of NORM-containing by-products, particularly in the cement and construction industries. The goal was to understand the barriers and enablers to integrating alternative materials derived from NORM into industrial processes that support a circular economy.

Research involving both industrial professionals and end-users revealed a range of influential factors. Key motivators for NORM material use include regulatory certainty, customer demand, quality and performance assurance, and financial incentives, such as CO₂ taxation schemes favouring sustainable materials (Love et al., 2023). However, significant concerns remain, especially regarding health risks, material performance, and economic viability. The concerns vary from country to country, reflecting diverse regulatory frameworks and market readiness for the adoption of NORM-containing materials (Love et al., 2025).

A conceptual framework developed by the project outlines how these issues interlink, highlighting the importance of harmonised EU regulations, common sustainability parameters, and transparent certification mechanisms for new NORM-based products.

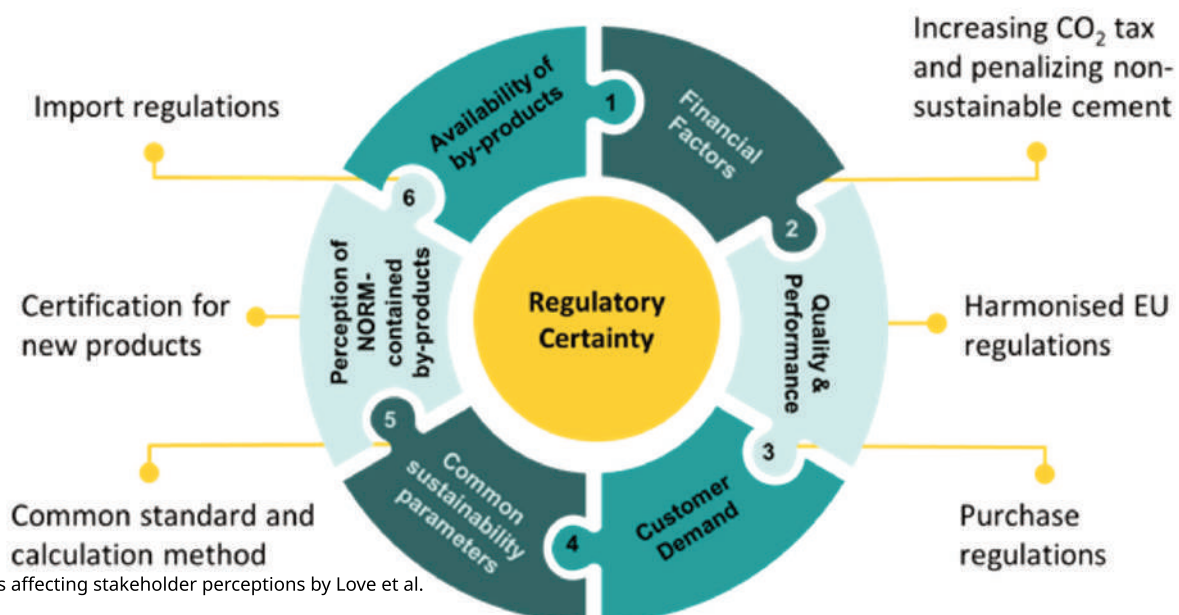
A critical insight from the evaluation of stakeholder

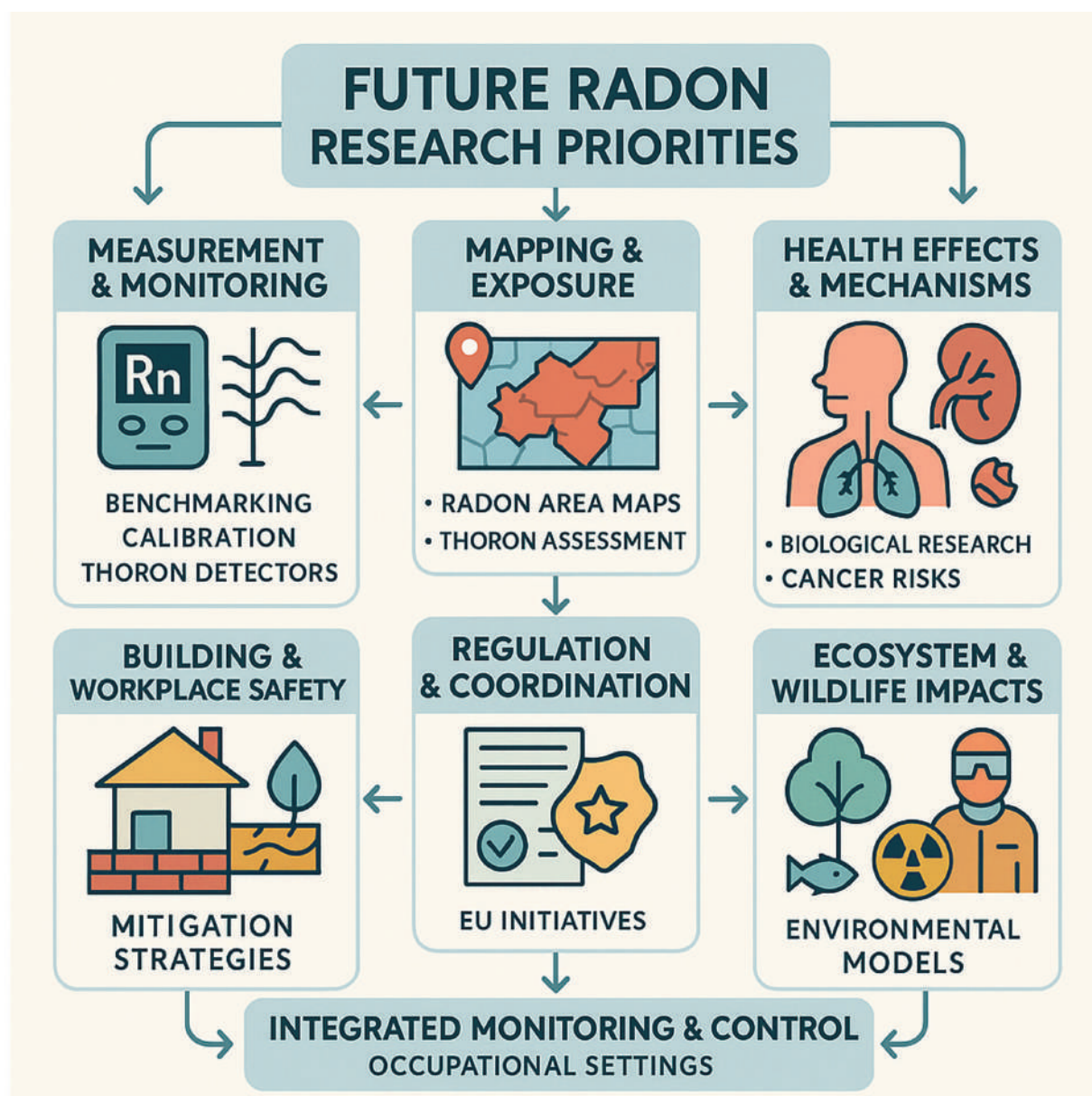
perceptions of NORM is the strong need for clear, standardised communication and guidance on the safe use of NORM by-products. Public and industry perceptions around radiation safety must be addressed to gain trust and improve uptake.

These findings directly contribute to:

- Promoting a more robust governance structure for NORM-containing products,
- Supporting carbon footprint reduction in the construction industry, and
- Advancing more circular, resource-efficient practices within NORM sectors.

The insights developed during the RadoNorm project strengthen the link between technological innovation and societal acceptance, laying the groundwork for sustainable and regulated integration of NORM in mainstream industrial applications.





Prospects for radon research

Future radon research must address measurement, health effects, building safety, and policy integration, with a focus on improving monitoring, understanding health risks, supporting mitigation, and aligning with EU initiatives, which requires multidisciplinary collaboration for effective radon risk reduction.



Future radon research in the nuclear and environmental health fields must address a complex array of scientific, technical, and regulatory challenges, all aimed at better understanding and mitigating its risks to human and ecological health. One of the foremost priorities is improving measurement and monitoring systems. This includes setting benchmarking standards for radon detectors, refining calibration and testing methods, and enhancing techniques for thoron and its progeny. Special attention is being given to workplaces where conventional models fail to predict radon progeny concentrations, necessitating the development of new approaches to accurately measure attached fractions.

Efforts in mapping and exposure assessment are equally critical, focusing on updating radon-prone area maps by leveraging national indoor radon databases and geological risk models. These updates also call for more inclusive national surveys that factor in thoron exposure and radon exhalation from buildings. Simultaneously, health effects and mechanisms research are deepening our understanding of how radon and thoron impact organs such as the lungs, bronchi, and kidneys over the long term. This involves refining biokinetic and dosimetric models and investigating biological mechanisms, particularly those involving the immune system, metabolism, and epigenetic changes.

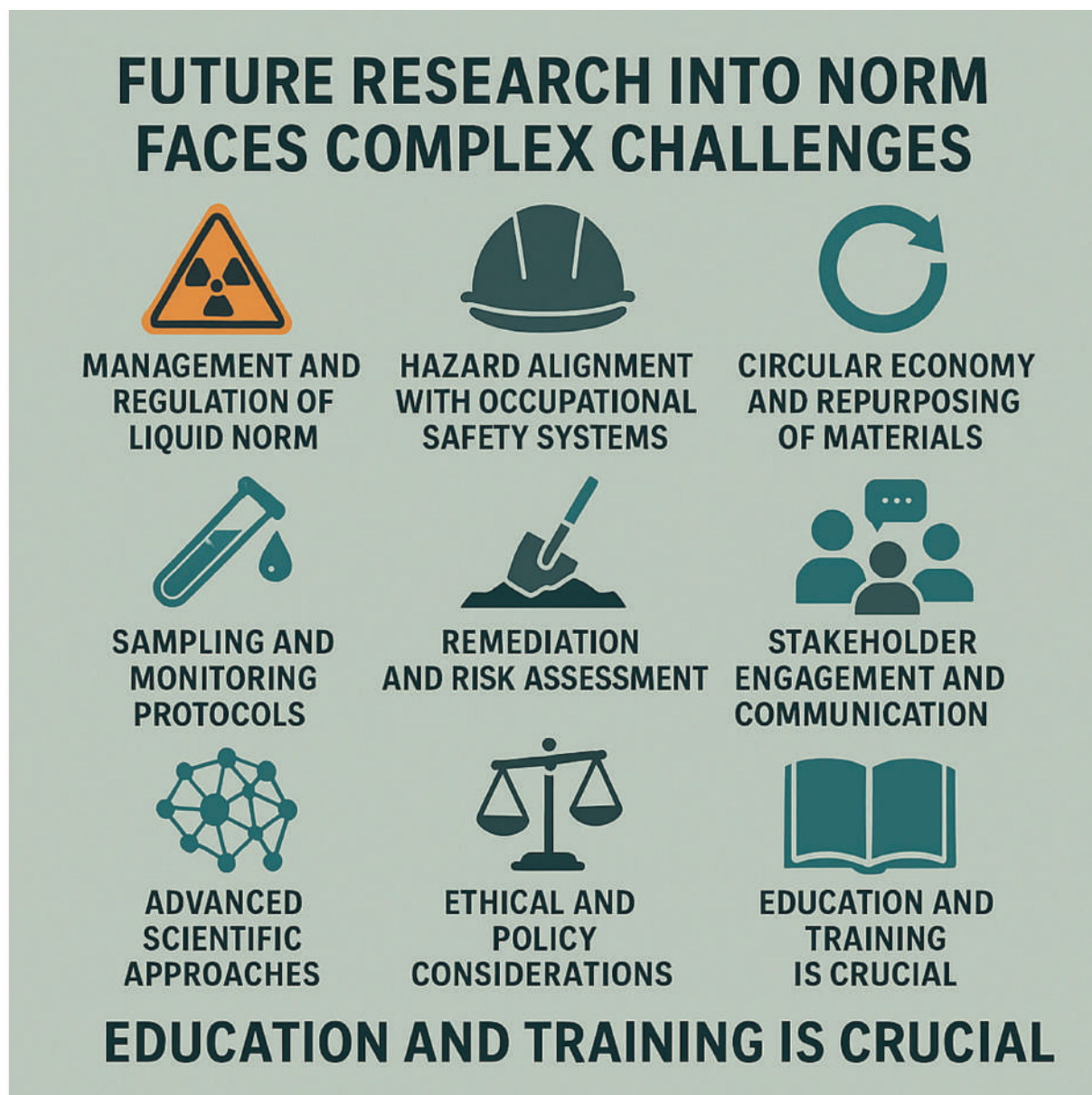
Another important frontier lies in examining cancer and non-cancer risks. Researchers are probing connections between radon exposure and various cancers, including lymphoma, stomach, liver, skin, and breast cancer, as well as non-cancer outcomes like cardiovascular disease. The interplay between radon and lifestyle factors such as smoking and vaping is of increasing interest, especially in

the context of precision medicine and the development of targeted therapies.

On the building and workplace safety front, efforts are being made to implement standardised radon barriers and engage professionals through training and strategic tools that enhance mitigation. In terms of ecosystem and wildlife impacts, radon's influence at a macroscopic level is being modelled, with validation through targeted field studies. These findings contribute to a broader understanding of how radon affects biodiversity and environmental health.

At the policy level, regulation and coordination are being aligned with major EU initiatives like the "EU Beating Cancer Plan", indoor air quality programs, and the EU Bauhaus movement. Ethical research supports these efforts by assessing policy impacts and ensuring robust data protection practices. Finally, a significant long-term objective is the establishment of integrated monitoring and control systems. These would simultaneously track radon and other Naturally Occurring Radioactive substances in occupational settings, ensuring a comprehensive approach to radiation safety.

All open radon challenges together underscore the need for multidisciplinary collaboration, technological innovation, and policy alignment to ensure effective radon risk reduction across diverse settings



Prospects for NORM research

Future NORM research must improve liquid NORM regulation, enable safe reuse in line with circular economy goals, enhance monitoring and remediation, and integrate social, ethical, and policy aspects. Continued training and interdisciplinary collaboration are key to sustaining expertise and ensuring effective radiation protection.



Future research into NORM faces a wide range of interlinked challenges, spanning technical, environmental, social, and ethical dimensions. One of the central priorities is improving management and regulation strategies for liquid NORM under diverse exposure scenarios and ecological conditions. This includes aligning hazard management with occupational health and safety systems while developing science-based clearance level guidelines informed by Life Cycle Assessment (LCA) methodologies.

Through the circular economy paradigm, researchers are tasked with finding ways to repurpose NORM-containing materials (e.g., in agriculture and construction) in line with zero-waste and environmental goals, all while gauging and enhancing public and industrial acceptance of such practices. At the same time, sampling and monitoring protocols must evolve. Efforts are underway to refine guidance for sampling and characterisation, create reliable reference materials, and develop cost-efficient monitoring solutions that better capture the transport and impact of NORM in the environment.

The remediation and risk assessment sphere demands innovative and economical strategies, including the use of bioremediation, tailored approaches for rare earth element recovery, and more precise risk assessment tools that incorporate long-term exposure and dosimetry. Equally important is stakeholder engagement and communication, which focuses on making field studies more accessible to the local public, improving the communication of health risks, and contributing to the validation of predictive radioecological models.

In parallel, advanced scientific approaches are being explored to address the complexity of NORM impacts. These include the integration of toxicokinetic-

toxicodynamic modelling, artificial intelligence, and adverse outcome pathways to analyse the effects of mixed contaminants. Finally, ethical and policy considerations require sustained attention. This involves conducting research to evaluate the societal impacts of policies, ensuring transparent data availability, and complying with EU open science and data protection standards.

Non-resolved challenges addressing NORM emphasise the need for interdisciplinary collaboration, innovative methodologies, and proactive stakeholder involvement to ensure responsible and effective management of NORM in the evolving nuclear landscape.

However, the most important future work for society and the environment is the continuation of education and training programs to sustain the expertise developed under RadoNorm.

Both radon and NORM recommendations for future work chart a comprehensive path forward for advancing both scientific knowledge and practical radiation protection measures across Europe.

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Key takeaways



- ☢ Identified radon-specific gene mutations and developed predictive cancer models.
- ☢ Developed low-cost radon monitors and validated protective materials for buildings.
- ☢ Showed that emotions and social norms are more powerful than statistics in radon communication.
- ☢ Confirmed higher radon doses in children, pregnant women, and people with lung conditions.
- ☢ Empowered communities through 10+ citizen science actions across Europe.
- ☢ Proposed safe reuse guidelines for NORM in agriculture and construction.
- ☢ Created lifecycle risk tools and open activity registers for NORM industries.
- ☢ Highlighted the need for harmonised EU regulation, trust-building, and stakeholder engagement.



RadoNorm
Managing risks from radon and NORM

RadoNorm

Newsletter

N°10 - August 2025

RadoNorm Statistics

Spanning from September 2020 to August 2025, the RadoNorm project has achieved a range of scientific, societal, and educational milestones. The focus of RadoNorm is on the management of Naturally Occurring Radioactive Material (NORM) risk.

Deliverables and milestones



58

DELIVERABLES

87

MILESTONES

71

PEERS REVIEWED
SCIENTIFIC ARTICLES

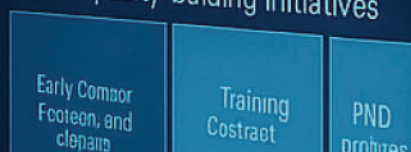
77

CITATIONS

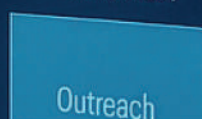
200+

CITATIONS

Capacity-building initiatives



Outreach



People engaged



RadoNorm
Managing risks from radon and NORM

Impact of RadoNorm

Advanced science, policy, monitoring, and public engagement on radon and NORM across Europe

Open challenges: radon

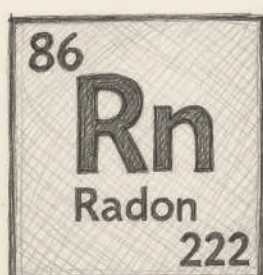
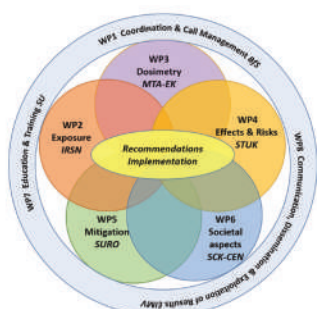
Improve measurements, health models, thoron assessment, mitigation, and policy integration

Open challenges: NORM

Demand sustainable management, ethical practice, stakeholder trust, circular economy models

RadoNorm legacy

High-impact research, education, transparency, public engagement, and policy-relevant results



NORM
Naturally Occurring
Radioactive
Materials



Content

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RadoNorm Newsletter



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Editorial



Dr. Nadja Železnik, leader of Work Package 8, EIMV

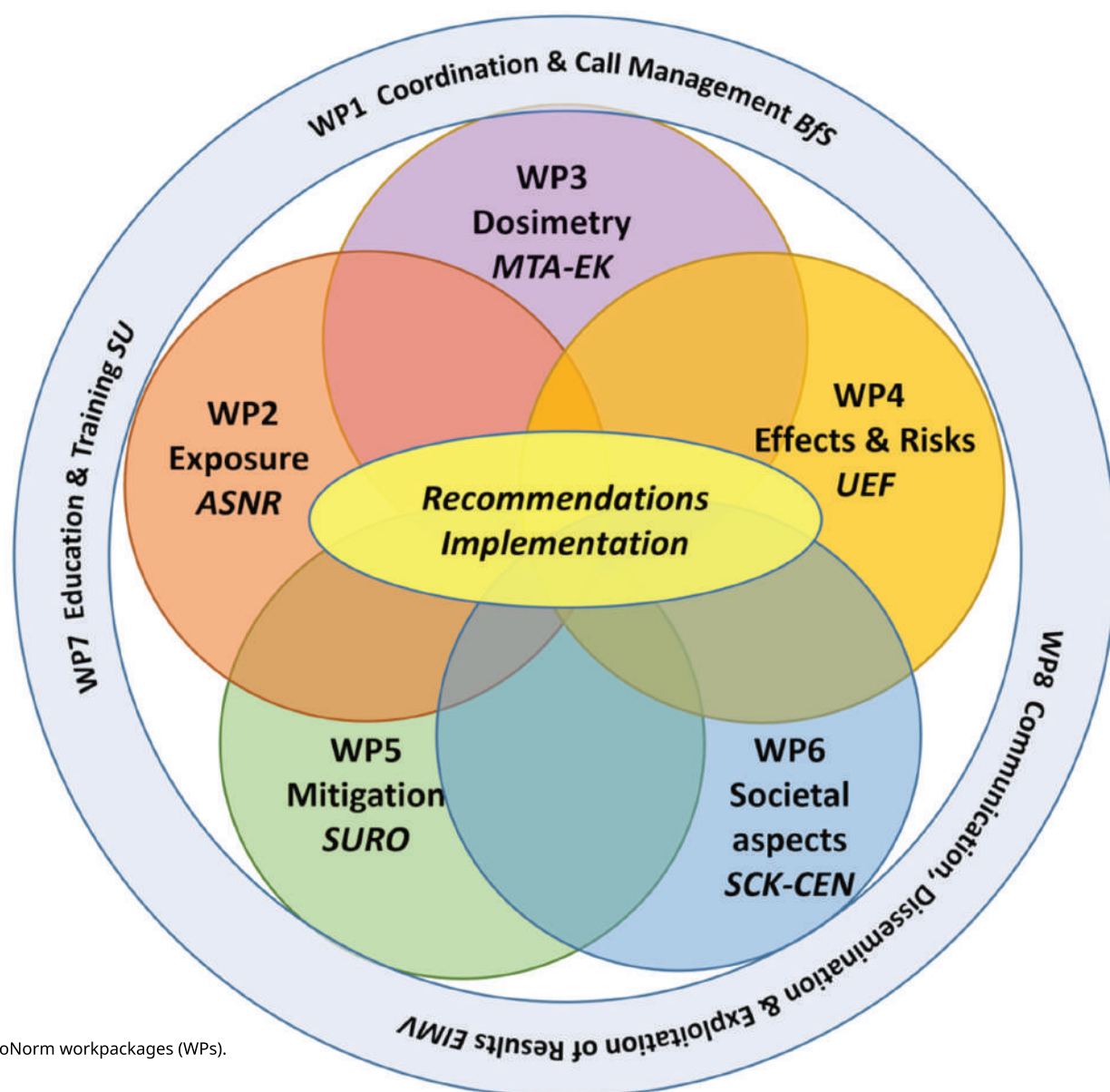
Dr. Nadja Železnik holds a BSc in Physics and an MSc in Reactor Physics from the Faculty of Mathematics and Physics, as well as a PhD in Psychology from the Faculty of Arts, all awarded by the University of Ljubljana, Slovenia. She is an expert in nuclear technology and radioactive waste management, with extensive experience in emergency preparedness and response, as well as in risk perception, communication, education, and training in environmental and nuclear projects.

She has acted as a civil society expert and knowledge manager in numerous European research initiatives, including EURAD-1 and -2, ECOSSENS, and RadoNorm. Her contributions include the development of national strategies, legislative frameworks, feasibility studies, safety and radiological assessments, and stakeholder engagement plans. She has authored communication strategies, training programmes, and information materials to foster public understanding and informed participation in the nuclear and environmental domains.

It is with great appreciation that we share this editorial summary of RadoNorm's remarkable progress at the threshold of its final project phase. Over five years, the consortium has delivered impactful scientific, societal, and educational outcomes, transforming how Europe approaches radon and NORM risk management.

This reflection celebrates advances in health research, including gene-level understanding of radon-induced diseases, innovations in low-cost monitoring and protective construction, citizen engagement through science and outreach, and strong contributions to EU policy goals such as the Green Deal and Mission on Cancer. The commitment to open science, with over 60 publications and publicly accessible tools, underlines RadoNorm's transparency and long-term vision.

Yet, as we look ahead, important questions remain: how can we close gaps in thoron assessment, ensure broader regulatory uptake of our findings, and strengthen stakeholder trust? This moment invites continued collaboration to carry forward RadoNorm's legacy in protecting people and the environment from radiological risks.



RadoNorm workpackages (WPs).

RadoNorm Statistics

From 2020 to 2025, RadoNorm delivered 58 deliverables, 87 milestones, 71 peer-reviewed articles, and major advances in radon/NORM research, education, and public engagement.

The project promoted FAIR data, trained 25 PhDs, funded 132 mobilities, supported EU policy goals, and fostered scientific, societal, and regulatory impact across Europe.

RadoNorm delivered major scientific advances, 71 publications, 25 PhDs, extensive training and outreach, and strong policy impact across Europe.

Spanning from September 2020 to August 2025 funded under the Euratom Research and Training Programme 2019–2020 (Grant Agreement No. 900009), the RadoNorm project has achieved outstanding quantitative and qualitative output across scientific, societal, and educational dimensions in the fields of radon and naturally occurring radioactive material (NORM) risk management.

RadoNorm is on track to approach its promised 85 deliverables and 99 milestones. The breadth of research output by July 2025 is evident in the publication of 71 peer-reviewed scientific articles, with more than 190 citations and 61 instances of open access to research data and publications, reflecting a strong commitment to scientific transparency and FAIR data principles (Findable, accessible, interoperable, retrievable). The project's commitment to open science was further substantiated by a focused audit of 50 randomly selected RadoNorm publications, aimed at evaluating research data availability and repository use, which showed widespread inclusion of data availability statements but limited use of public repositories, underscoring both progress and persistent challenges in FAIR data implementation.

The project is still ongoing and is expected to generate further results in its final phase. A special issue dedicated to RadoNorm publications is currently open (by invitation only) in *Radiation and Environmental Biophysics* (Springer Nature), under the Health and environmental risks from radon and NORM exposure situations. Therefore, the

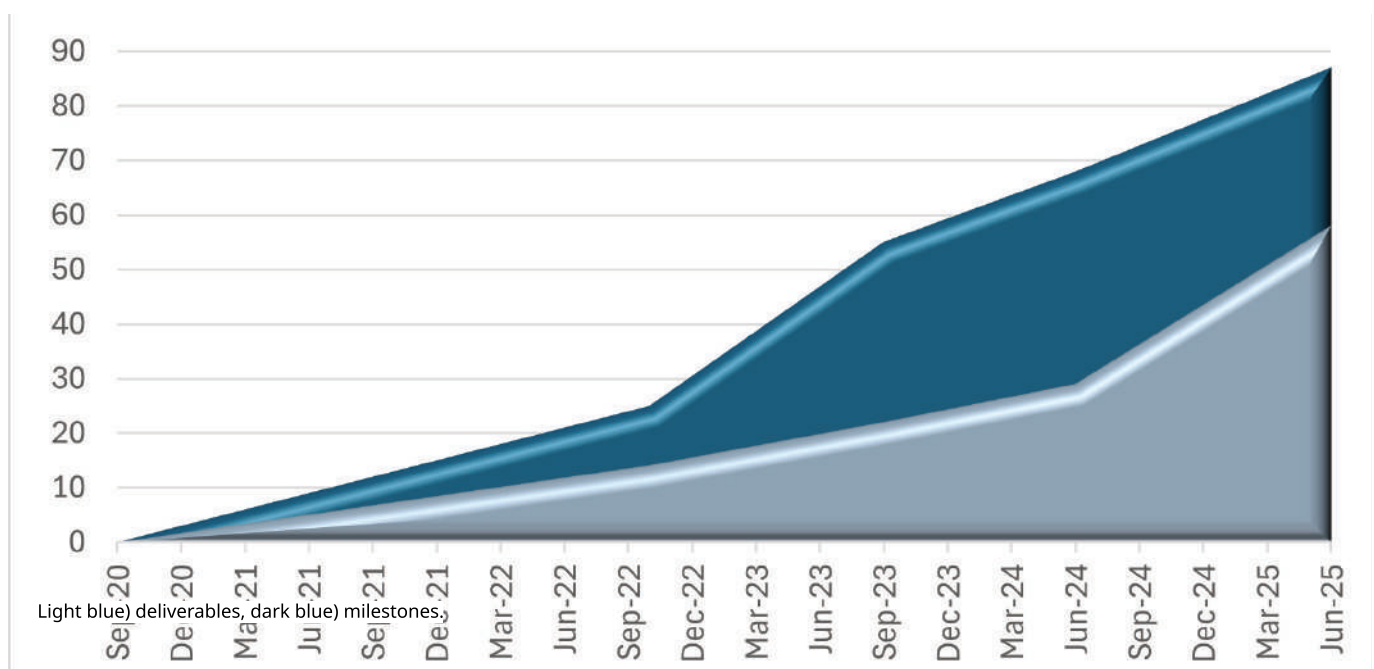
highest number of peer-reviewed publications is anticipated in 2025.

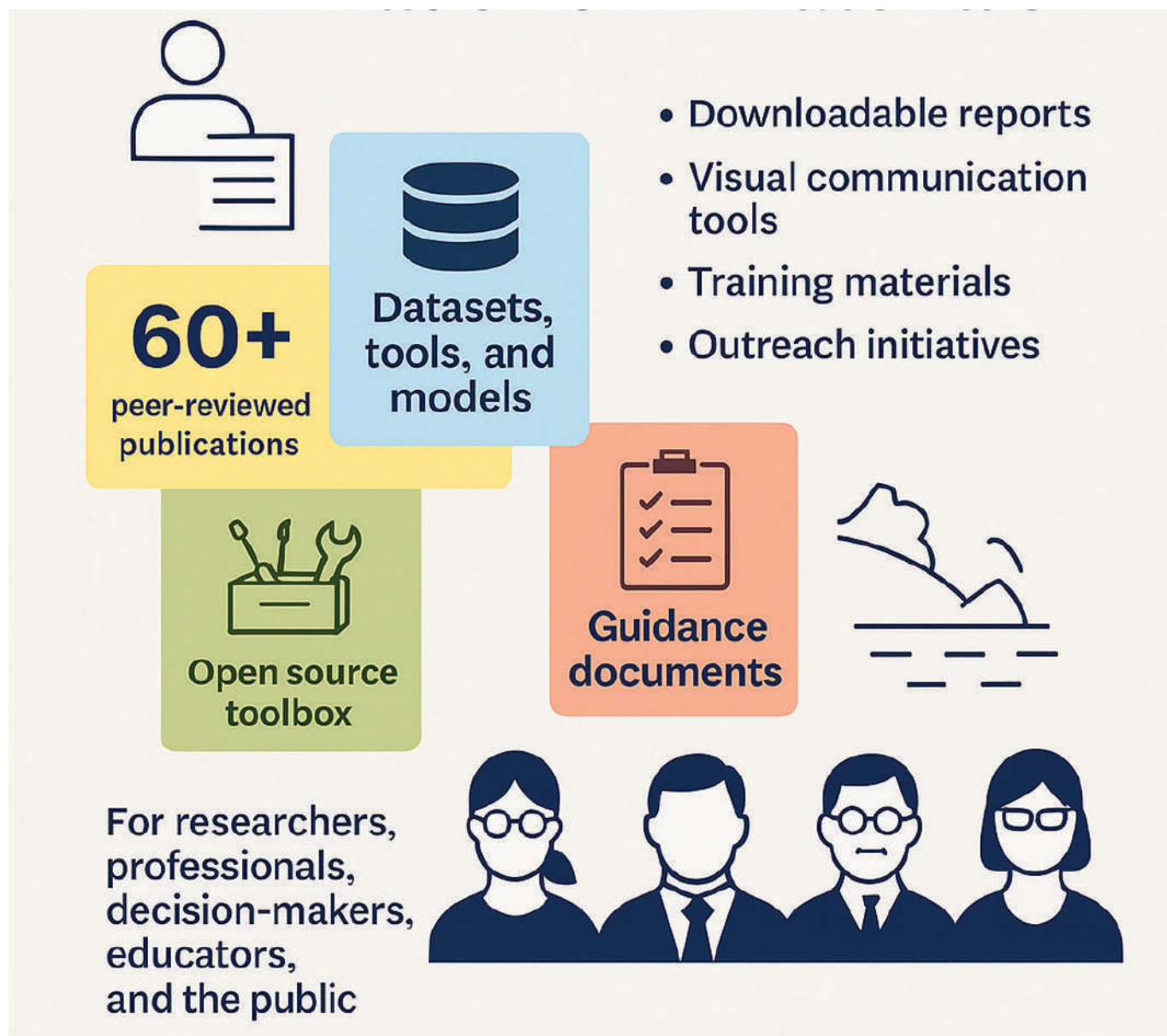
Education and capacity-building were also crucial in the RadoNorm project. The consortium organised 25 training courses, engaging over 200 participants, and funded 25 PhD projects, many of which were already successfully defended. The Early Career Researcher (ECR) Council, composed of PhD candidates, initiated annual courses and secured a sustainable future through its transition to the ECRad platform under the PIANOFORTE programme.

In terms of mobility and exchange, the project awarded 132 travel grants and 13 research stay grants through 18 competitive calls, facilitating extensive international collaboration and knowledge exchange.

RadoNorm actively contributed to EU policy goals such as the Green Deal, the EU Mission on Cancer, and the New European Bauhaus. Outreach initiatives reached over 800 citizens, while 30 public engagement activities and media coverage helped raise awareness and foster dialogue about radon risks and mitigation.

Lastly, RadoNorm provided a vital networking platform through its presence at major events such as the European Radiation Protection Week (ERPW) 2024 in Rome, Italy, and the RadoNorm Showcase Meeting in Brussels (March 2025). These forums highlighted landmark findings, such as the genetic fingerprint of radon-induced lung cancer, citizen science engagement, and radon-risk communication tailored to building energy efficiency.





Publicly Accessible RadoNorm Materials

RadoNorm (2020–2025) produced 60+ open-access publications, tools, datasets, training materials, and policy resources on radon and NORM. With strong focus on open science, it supported 25 PhDs, citizen science, and capacity-building, ensuring lasting impact on research, regulation, and public engagement across Europe.



The RadoNorm project has generated a rich collection of publicly accessible resources aimed at advancing science, informing policy, and supporting stakeholders across Europe in matters related to radon and NORM. In alignment with open science principles and EU transparency objectives, a substantial part of the project's outputs has been made openly available for researchers, professionals, decision-makers, educators, and the general public.

These publicly accessible materials include over 60 peer-reviewed scientific publications, which have more than 190 citations. Datasets, tools, and models developed during the project are stored in structured repositories and data portals to ensure the reusability and reproducibility of results. Among the standout resources are educational tools like guidance documents for radon measurement and mitigation, and software such as RadoThor for modelling radon and thoron behaviour in indoor and underground environments.

The project has also delivered many deliverables that are publicly downloadable, covering topics such as health risk modelling, social science insights, communication strategies, and environmental protection approaches. Visual communication tools, such as the European Radon Behavioural Atlas, and training materials from 19 courses, including e-learning modules, are likewise accessible for capacity-building across disciplines.

In addition, RadoNorm supported 25 PhD projects and numerous outreach initiatives, including citizen science

programmes and policy briefings, many of which are documented and available to the public. These efforts collectively reflect the project's commitment to transparency, engagement, and long-term knowledge transfer within and beyond the scientific community.

As a central repository, a RadoNorm project website was designed to allow sharing all public documents developed during the project with RadoNorm, where all information about the project and the activities was made available and promoted, and opportunities for interaction were provided. The external communication strategy was based on a synergetic combination of several channels and tools:

- A project website linked with social media networks (LinkedIn, X and YouTube),
- Regular news, newsletters and other information materials (e.g. event material),
- Two-way interaction tools and channels with different stakeholders,
- A calendar of conferences and other events that are of RadoNorm interest (RadoNorm events, RadoNorm-related events and internal project events for members only) with material,
- Publications, including deliverables, peer-reviewed scientific journal papers, popular science publications and others,
- Website folder with past and ongoing RadoNorm activities which were important for partners, project stakeholders and all others interested.

The RadoNorm website will also be available in the future to allow for the use and reuse of all output of the project.



Impact of RadoNorm

RadoNorm advanced radon and NORM science by linking health research, monitoring tools, policy support, and citizen engagement. Its findings on cancer, measurement, and risk communication set new standards for protection and sustainability across Europe.

The RadoNorm project has had a profound impact on the scientific, societal, and policy dimensions of radon and NORM research. By systematically addressing health risks, improving measurement techniques, advancing stakeholder issues and engagement, and developing sustainable management strategies, the project has created a robust foundation for future research, regulatory refinement, and public communication in Europe and beyond.

One of the most significant scientific achievements of RadoNorm is its contribution to the mechanistic understanding of radon-induced diseases, particularly lung cancer. Groundbreaking work has shown gene mutation fingerprints in both animal models and human cohorts, such as uranium miners, offering insights into the RTK-RAS pathway's involvement in cancer development. The gene mutation knowledge is complemented by novel biokinetic and dosimetric models that help explain the latency and progression of radon-induced cancers. Intriguingly, research into the role of smoking and nicotine has revealed unexpected effects on radon dosimetry, with smoking decreasing lung dose but increasing systemic exposure, while also affecting DNA repair mechanisms in exposed bronchial cells.

Beyond cancer, the project has expanded knowledge on non-cancer health effects, including the development of adverse outcome pathways for conditions such as microcephaly. Research into the impacts of radon on children and individuals with respiratory conditions like asthma and COPD has demonstrated that these groups receive significantly higher radiation doses under similar exposure conditions. As a result, compelling findings are paving the way for personalised protection strategies for vulnerable populations.

The project also tackled measurement and monitoring challenges with vigour. It evaluated both budget and research-grade radon monitors and introduced software tools such as Ventgraph and RadoThor for simulating radon behaviour in complex settings. Notably, discrepancies in equilibrium factors for radon and its progeny in Polish mines highlighted the need for direct measurements in occupational environments. Further, the INTDOSKIT toolkit was developed to support dose assessment with uncertainty analysis, and recommendations were issued for radon measurement protocols in underground workplaces.

In terms of built environment and mitigation, RadoNorm evaluated radon-proofing strategies in construction, identifying high-performance materials and techniques. This work not only informs building codes but also addresses the environmental impacts of mitigation technologies. Importantly, the research uncovered the trade-offs between radon remediation systems and energy efficiency strategies in heating, ventilation and air-conditioning (HVAC) design.

A distinct and innovative aspect of the project lies in its social science contributions. RadoNorm's behavioural and communication studies, such as the European Radon Behavioural Atlas, showed that subjective norms, perceived susceptibility, and affective responses were key predictors of public willingness to test for and remediate radon. Communication strategies using storytelling and humour, tailored to national cultures, were shown to significantly enhance public engagement. Complementing this was a successful citizen science programme, engaging diverse demographics and winning EU-level recognition, thereby empowering communities and influencing local policies.

On the environmental and NORM side, RadoNorm provided new modelling tools to evaluate uranium and radium mobility in soil and explored bioremediation via microbial pathways. The project examined how combined radiological and chemical stressors affect ecosystems, advancing environmental risk assessment for wildlife, especially in mining areas like Norway. Registries and screening levels for NORM reuse in sectors such as agriculture and construction were also developed, helping to close regulatory gaps and foster circular economy practices.

The impact of RadoNorm further extends to policy and education. The project's alignment with EU policy objectives, including the Green Deal and EU Beating Cancer Plan, reflects its strategic relevance. It has delivered over 70 peer-reviewed publications, a plethora of novel methodologies and technologies, and a large body of open-access data. Through training courses, PhD funding, and new educational resources, including the RadoNorm Toolbox, the initiative has substantially enhanced European competence in radiation protection, particularly among early-career researchers through its ECR council.

In summary, RadoNorm has not only advanced the frontiers of radon and NORM science but has also catalysed a paradigm shift in public engagement, policy development, and sustainable innovation. Its legacy is a well-integrated framework that spans molecular biology to societal behaviour, setting a new standard for interdisciplinary radiation research in Europe.



RadoNorm Open Challenges

RadoNorm research shows that raising awareness alone is not enough to prompt radon testing or mitigation. Key psychological drivers (social norms, perceived risk, and emotional engagement) strongly influence behaviour. Narrative and culturally tailored strategies are more effective than statistics in motivating protective actions.

The RadoNorm project outlined several pressing challenges in the domain of radon research that demand future scientific attention. At the forefront lies the need to improve measurement and monitoring, particularly through the creation of rigorous standards for radon and thoron monitors, as well as the development of better calibration methods and testing protocols for progeny standards. There is also a significant gap in accurate thoron assessment, which necessitates advanced measurement tools that can reliably detect attached fractions of thoron in indoor environments. Mapping and exposure assessment remain essential, as existing national databases often fail to comprehensively integrate thoron exposure, necessitating updated radon-prone area maps and broader survey initiatives. In terms of human health, a deeper understanding of thoron's impact on organs such as the lungs and kidneys is vital, especially regarding biokinetic and dosimetric modelling and its effects on the immune system and epigenetic mechanisms. The potential co-effects of radon with smoking and vaping, alongside cancer and non-cancer risks, including impacts on the circulatory system, are areas where research must expand, particularly for precision medicine. Additionally, stakeholder training and the development of advanced mitigation strategies in buildings are crucial for enhancing workplace safety. Broader considerations include the ecological impact of radon at the wildlife level, as well as the integration of radon risk reduction within EU policy initiatives. A final strategic priority lies in establishing integrated monitoring systems that combine radon with other NORM substances in occupational settings.

In parallel, research into NORM presents its own suite of challenges, particularly regarding regulation, sustainability, and stakeholder involvement. Effective strategies are needed to manage liquid NORM across diverse environmental and occupational scenarios, incorporating hazard assessments and life cycle analysis to support regulatory decisions. There is growing interest in the potential for circular economy models to support the reuse of NORM materials, which calls for sustainability assessments that also consider the societal implications of such reuse. Engaging with stakeholders, from field technicians to affected communities, is vital for improving communication around health risks and for fostering trust in radiological models. Scientific advancements must also prioritise toxicodynamic and toxicokinetic approaches to assess health risks from mixed exposures, such as through adverse outcome pathways. Ethical research practices must underpin all of this work, with an emphasis on open science and data protection principles aligned with EU standards.



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- ☼ Stakeholders, www.radonorm.eu/stakeholders/
- ☼ Events, www.radonorm.eu/event/
- ☼ Events' material, www.radonorm.eu/event/event-material/
- ☼ Publications, www.radonorm.eu/publications/
- ☼ Activities, www.radonorm.eu/activities/

Key takeaways



- ☢ **Established cross-disciplinary research bridges linking genetics, measurement science & social insight.**
- ☢ **Strengthened open science practices and FAIR data via audits, repositories & open-access publication.**
- ☢ **Advanced predictive health models using gene mutations and biokinetic radon dosimetry research.**
- ☢ **Enabled capacity-building through 25 PhDs and 200+ trained participants across EU institutions.**
- ☢ **Developed tools like Ventgraph, RadoThor & INTDOSKIT for risk modelling in indoor, underground, and workplace settings.**
- ☢ **Created lifecycle risk tools and open activity registers for NORM industries.**
- ☢ **Highlighted the need for harmonised EU regulation, trust-building, and stakeholder engagement.**
- ☢ **Highlighted communication strategies: emotions & social norms trump raw statistics.**
- ☢ **Reached 800+ citizens and ran award-winning citizen science programmes across 10+ countries.**
- ☢ **Shaped building practices with validated low-cost monitors & high-performance radon barriers.**
- ☢ **Offered NORM reuse guidelines, registers & lifecycle tools for the circular economy pathway.**
- ☢ **Informed EU strategies on cancer, sustainability, the Green Deal, and energy-efficient construction.**



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This publication uses dual pagination to reflect both the structure of the collective proceedings and the original numbering of individual issues.

Example: 13 | iv-5 indicates page 13 of the proceedings, and page 5 of issue iv (4).

Each issue within this volume contains its own table of contents and pagination.
Page numbers in these tables refer only to the original issue, not to the overall proceedings.



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