Understanding Radon Management in French Homes: Barriers and Facilitators from Two Regions

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Acronyms

ARS: Regional Health Agency; **ASN**: Nuclear Safety Authority; **DMP**: Data Management Plan; **EAF**: Ethical Application Form; **ICRP**: International Commission on Radiological Protection; **LPA**: Local Public Administration; **NORM**: Naturally Occurring Radioactive Materials; **PMA**: Pays de Montbéliard Agglomération; **RAP** : (national) Radon Action Plan; **RPMT**: Revised Protection Motivation Theory; **SMOC**: Swiss Model for Outcome Classification in Health Promotion and Prevention; **SWOT**: Strength Weakness Opportunities Threat; **WHO:** World Health Organization; **WP**: Work Package

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ABSTRACT

Background. Indoor radioactive radon gas stands as a prominent contributor to lung cancer, a threat that can be readily identified and addressed. Despite the accessibility of testing and mitigation measures, their adoption rates remain disproportionately low. There is a research gap in understanding why people hesitate to test and mitigate radon. Qualitative research is crucial to identify motivations, barriers, and facilitators, serving as a valuable tool in addressing this knowledge gap and improving radon management practices.

Objective. This article presents the methodology of a qualitative research study developed in the framework of the RadoNorm European research project and applied in two French regions to investigate the barriers and facilitators in radon management in homes from the dual perspective of representatives of local public administrations (LPA) who have implemented a radon management action and inhabitants who engaged in radon management activities.

Design. Two groups of respondents were identified and recruited with a combination of strategies. Individual interviews were performed based on an open-ended interview method. Theoretical models helped to design the questions, cover the range of possible answers, and provide a practical approach for the qualitative analysis. Data management and ethical considerations were addressed.

Results. Together 13 barriers/facilitators were identified for the LPA and 9 for inhabitants, all supported by tangible elements, and then classified in a Strength Weakness Opportunities Threat (SWOT) matrix. The collection of a dual point of views allows cross-discussion on common topics: radon communication, temporality, and follow-up.

Conclusion. The research provides a methodologically-sound approach to investigate the barriers and facilitators in radon management in French homes. The results can be used by different parties to implement effective and experience-based improvements of the process of radon management, notably with the development of qualitative indicators for efficiency, improved follow-up of the exposed/concerned inhabitants in the long run and engaging reflection for minimising the cost and the complexity of radon mitigation.

Key words: Radon in homes; Radon management action; Perceived barriers, Perceived facilitators, Open-ended interview; Theoretical model

INTRODUCTION

The RadoNorm project

RadoNorm[1] is a Euratom Horizon 2020 research project gathering 57 organizations in Europe with the aim to strengthen the scientific and technical basis of the management of radon risk and reducing the exposure from naturally occurring radioactive materials (NORM). Work Package 6 (WP6) is dedicated to Societal Aspects of radon and NORM and the task includes "*to develop and test qualitative tools addressing the risk perceptions, views, opinions, motivations, attitudes and behaviours associated with radon*" (task 6.1.3) [1]. From a methodological standpoint, "qualitative" research is a type of research that aims to gather and analyse non-numerical (descriptive) data to gain an understanding of individuals' social reality, including understanding their attitudes, beliefs, and motivations [2]. In contrast, "quantitative" research is the process of collecting and analysing numerical data to find patterns and averages, make predictions, test causal relationships, and generalize results to wider populations.

Partners from RadoNorm WP6 located in six countries (Ireland, Belgium, Slovenia, Czech Republic, Germany and France) were invited to develop a qualitative research project on radon management adapted to their national context. Methodological support was provided by task Leaders who organized regular meetings, internal workshops/trainings and by other RadoNorm partners who published a literature review on social and human research in the field of radon and NORM [3].

[1] https://www.radonorm.eu

We define barriers as factors (be it human, regulation, contextual, …) that hinders or impede the implementation or the engagement in a radon management action and facilitators as factor that help and the implementation/engagement. The objective of this article is to present the research questions developed by CEPN tuned to the French context regarding the barriers and facilitators for the management of radon at home, the methodological tenets to address the research questions and the results obtained.

Context

The current French national strategy for the management of radon is provided in the 4th National Radon Action Plan (RAP) 2020–2024[2] whose application for radon at homes focuses essentially on supporting local actions implemented voluntarily by "local public administrations" (LPA), meaning cities, municipalities, federations of municipalities or counties to raise awareness on radon risk and associated "radon management actions" such as distribution of radon test kits, public information meetings and support for post-measurement steps:

1. the building diagnosis (i.e. to identify the entry points and transfer mechanisms of radon in the house, generally performed by a trained building professionals),
2. mitigation work (combination of sealing and ventilation of the basement and/or the living areas),
3. and the re-test for efficiency evaluation.

[2] National action plan 2020-2024 for management of the radon risk (synthesis in English), Nuclear Safety Authority, 2021 https://www.french-nuclear-safety.fr/asn-informs/news-releases/radon-a-naturally-occurring-radioactive-gas [access January 2024].

The recurrent feedback is that the participants very rarely commit into the step of mitigation and building diagnosis and remediation rates remains extremely low [4]. Whilst some LPA have covered the cost of the diagnosis, this practice cannot be generalized because of budgetary constraints and the scarcity of trained professionals. Facing this issue, the LPA Pays de Montbéliard Agglomération (PMA, East of France) organized a technical workshop (circa 2 h) where volunteering inhabitants with elevated radon concentration at home measured during the winter of 2017-2018[3] received detailed information on radon mitigation and were able to interact with professionals with experience in radon diagnosis/mitigation.

[3] In France, radon in homes is generally measured using solid state nuclear track detectors installed in living areas during minimum 2 months of the heating season (October year N – April year N+1). The results are available in Spring N+1 and a public meeting for presenting the results 'and possibly the technical workshop to discuss mitigation), took place in Autumn N+1.

METHODS

Research objectives

The aim of the research was to understand the reasons and motivations why some LPA have chosen to initiate a radon management action, to describe their approach and their results and to identify the barriers and facilitators from these experiences, particularly since the promoters of radon management actions have hardly been the subject of qualitative research [3].

Local inhabitants who participated to in radon management actions were interviewed to understand, as a mirror of the LPA, the reasons to engage in radon management action, their experience and the barriers and the facilitators they have met. This research was also meant to gain a better grasp of why in general very few local inhabitants tend to engage in post-measurement steps and if the technical workshop acted was a facilitator in radon mitigation and how it interplays with the other facilitators and barriers.

Research design overview

Two groups were defined:

- Group A: representatives of LPA with experience in radon management actions. Two administrative regions were selected: Bourgogne Franche Comté and Pays de la Loire.
- Group B: inhabitants of PMA who participated to the 2017-2018 radon measurement campaign.

The research questions for each group were the following (Table 1).

Table 1. – Research questions

Research questions for LPA (group A)	Research questions for inhabitants of PMA (group B)
1. For which reasons/motivation the LPA chose to initiate radon management actions? 2. What approaches have been followed and what were their results? 3. What are the barriers faced by the LPA in initiating radon management actions, what can be done to overcome them, and, conversely, what can favor radon management actions?	1. For which reasons/motivation the inhabitants choose (or not): a. to attend the public workshop? b. to host an on-site radon diagnosis? c. to implement radon mitigation work? d. to assess these actions? 2. How did the inhabitants perceive the public meeting and the technical workshop? Was it helpful and what are the areas of improvement? 3. What are the barriers they have faced? What can be done to overcome them, and, conversely, what can favor radon management actions?

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139 The researchers from CEPN chose to collect data through individual interviews. The research
140 questions are of a qualitative nature, therefore using closed questions was not deemed
141 relevant. Meanwhile, the steps in developing a radon management action for LPA and
142 engaging radon management actions for inhabitants are following a specific order calling for
143 the questions to be asked in a specific order too, thus rejecting an informal interview
144 method. To ensure a minimum level of consistency in the data, limiting the bias and

increase comparability of responses for their analysis, a standardized open-ended interview method was preferred.

Theoretical models

Although not systematic, qualitative researches often make use of a theoretical model coming from behavioural science to help map the research domain, consider all the possible facets, define the qualitative research problems more clearly, and guide the research design. Two theoretical models were selected and used to guide the formulation of the questions, comprehensively cover possible answers of facilitators and barriers and facilitated the data analysis involving coding the responses into themes and sub-themes [2].

- **For LPA**, the literature review [3] identified only two articles where LPA were the subjects of qualitative research, yet neither of them employed a model. The researchers selected the Swiss Model for Outcome Classification in Health Promotion and Prevention (SMOC, [5]) which is a logical model embracing (all) the elements of any health or prevention programme distributed in a 4 levels scheme: activities, factors, effects and benefits. SMOC can be used either to design a programme/project or an *ex-post* analysis tool and was applied by Swiss cantons in numerous fields, including the strategy against lung cancer from tobacco, which related well with radon management actions.
- **For inhabitants**, the selected model is the Revised Protection Motivation Theory (RMPT, [6]), a model developed for the understanding of the health behavior of individuals based on the source of information, the mediative process it initiates and the resulting coping mode. RMPT was selected among other possible models as being the most general in encompassing not only threat appraisal but also wider

168 social and cultural factors affecting the response probability, whose influence in
169 radon management at local level was identified by previous research [7].

170 Based on the models, two lists of questions and associated probes (a probe is a question
171 with more detailed/specificities than the main question and is used to initiate or redirect
172 the discussion) to be addressed to each group were created. The lists of questions and
173 probes are presented in § 1-4 of the Supplementary Materials.

174 **Sampling**

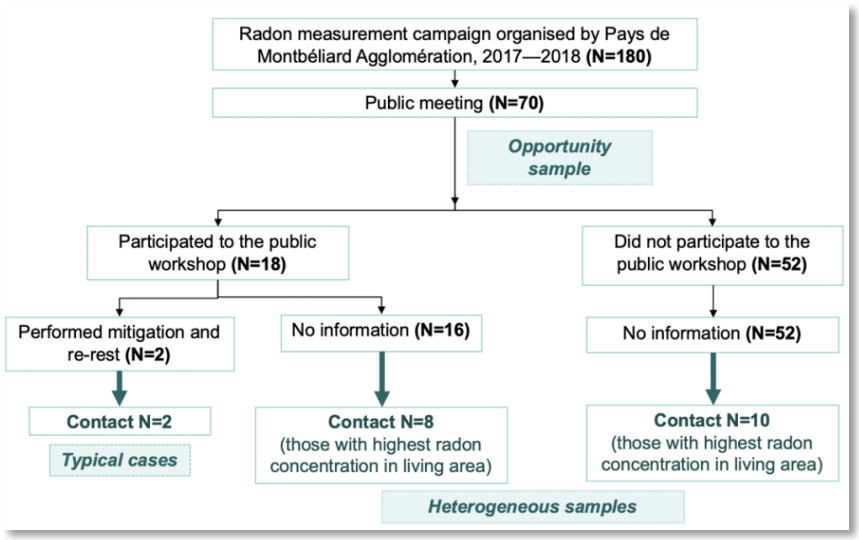
175 It is worthwhile to recall here that in qualitative research the sampling is not driven by
176 statistic/representativity (like in quantitative research) but by its richness and explanatory
177 value of the data. Sample sizes looks generally small (< 20) but allow for data completeness
178 to answer the research question providing the selection/sampling is purposeful and cannot
179 be compared with the size of group sampled for quantitative research aiming for
180 representativeness.

181 To constitute **Group A**, the Health Regional Agency of Bourgogne Franche Comté (ARS) and
182 the Nuclear Safety Authority (ASN) of Bourgogne Franche Comté and Pays de la Loire were
183 contacted in May 2022 to obtain contact information for representatives of LPA who had
184 engaged in radon management actions. Six names were provided. These representatives
185 were invited to take part in an interview or, if they declined, they were asked to propose a
186 new name, employing a *snowball sampling* technique. The intended objective was to
187 interview 6 representatives.

188 **Group B** was formed by filtering the list of the participants to the PMA 2017-2018 action to
189 identify the participants with the highest radon concentration in living areas and constitute

two sub-groups: one with those who took part to the public workshop and one with those who did not (*heterogenous sample* to consider the effect of the public workshop on mitigation intention). In addition, participants known by PMA to have performed mitigation and re-test (*typical cases sampling*) were identified. The intended objective was to interview 20 inhabitants in total. Figure 1 is a schematic of the sampling strategy.

Figure 1. Sampling strategy for Group B.



The recruitment of LPA started in September 2022 and those of inhabitants in January 2023 after the interviews with LPA were finished. Initial contact was performed by email by presenting the context of the project, the objectives of the interview and a consent form (available in § 5 of the Supplementary Materials). Participants could access the Data Management Plan (DMP) and the Ethical Application Form (EAF) of the research on request.

By March 2023, the objective to interview 6 representatives of LPA was met but only 7 out of 20 interviews with inhabitants were conducted, despite several reminders. The characteristics of the participants are presented in § 6 of the Supplementary Materials).

Data collection and analysis

Each question was meant to be asked to the interviewee and the probe was used in the case the interviewee would not elaborate. Yet in practice, the exchanges were very fluent, and the interviewees often answered several questions at once, so the interviews were mainly conversational and situational.

The collected answers were interpreted by coding the themes and the sub-themes, facilitated by the theoretical models which provided a reading grid. The sub-themes were classified as facilitators or barriers according to their effect on radon management action. The facilitators were then classified as Strengths or Opportunities and the barriers as Weaknesses or Threats under the SWOT matrix, which provides a deeper level of analysis.

RESULTS AND DISCUSSION

Detailed results.

The detailed results, including the elements explaining each theme and sub-theme with quotes from the participants, are presented in the § 7–8 of the Supplementary Materials.

Identified barriers and facilitators

The barriers and facilitators for LPA are presented in Table 2 and those for inhabitants in Table 3.

Table 2. Themes and sub-themes for local public administrations (Group A)

Themes	Sub-themes: facilitators (+) and barriers (–)
Initial motive	(+) A former history with radon
	(–) Radon not a priority
Development of health and prevention promoting services*	(+) Different approaches adapted to the local context
	(+) Raising awareness through multiple channels
	(–) Several difficulties in communication
Advocacy, cooperation of organizations*	(+) Including radon in existing plan/program
	(+) Engagement of decision makers/key persons
	(+) Organizational insights
Social mobilization*	(+) The importance of follow-up
	(–) No clear vision beyond awareness

	(–) Lack of intermediary players
Development of individual skills*	(–) Difficulty in accessing information and knowledge
	(–) Lack of skills for building professionals

*The themes indicated with * are the promotion measures of the SMOC model [5]) and the 'initial motive' theme is an emerging theme.*

Table 3. Themes and sub-themes for inhabitants (Group B)

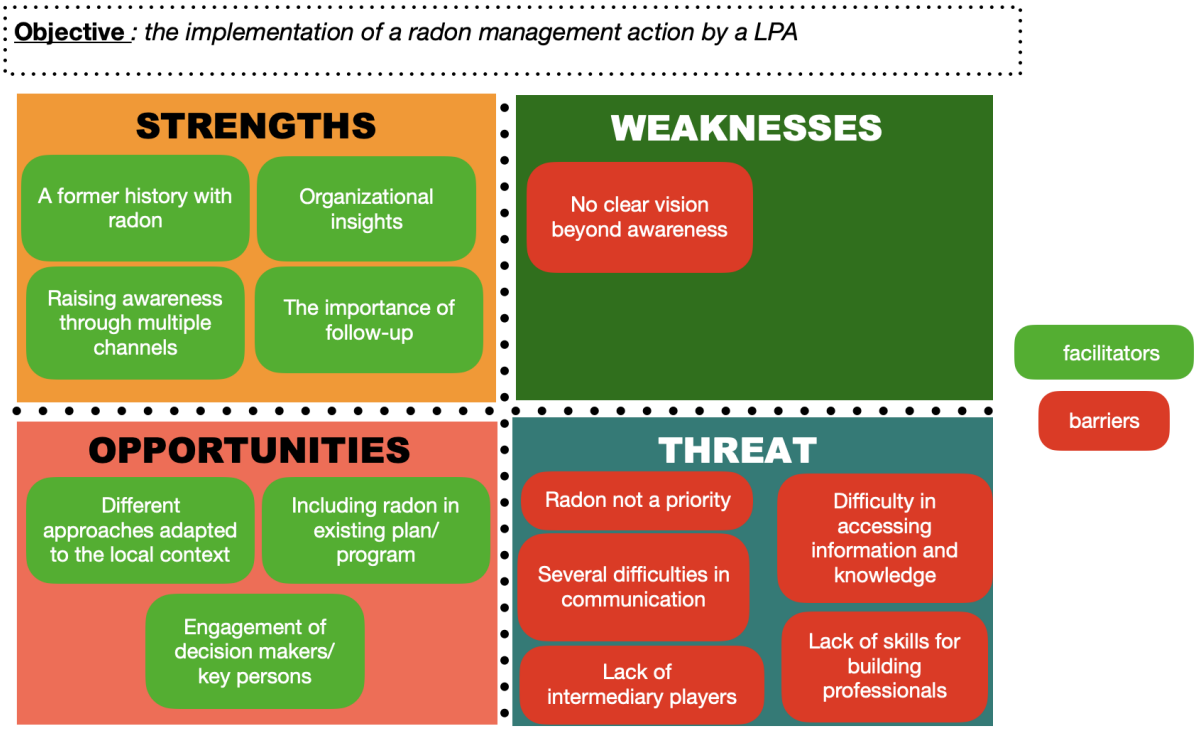
Themes	Sub-themes: facilitators (+) and barriers (–)
Source of information*	(+) A panoply of sources of information
	(+) Engagement fostered by an individual history
	(+) Public meetings and technical workshops to deliver insights about radon mitigation
Cognitive mediating process*	(+) A personal and qualitative appreciation of the risk
	(+) Understanding of the general concepts of radon risk management
	(–) Cost and complexity of mitigation works
Coping modes*	(+) Natural ventilation: a change in behavior
	(+) Implementation of simple action at controlled cost
	(–) Lack of follow-up overtime

*The themes indicated with * are the themes in the RPMT [6].*

A SWOT reading of the results

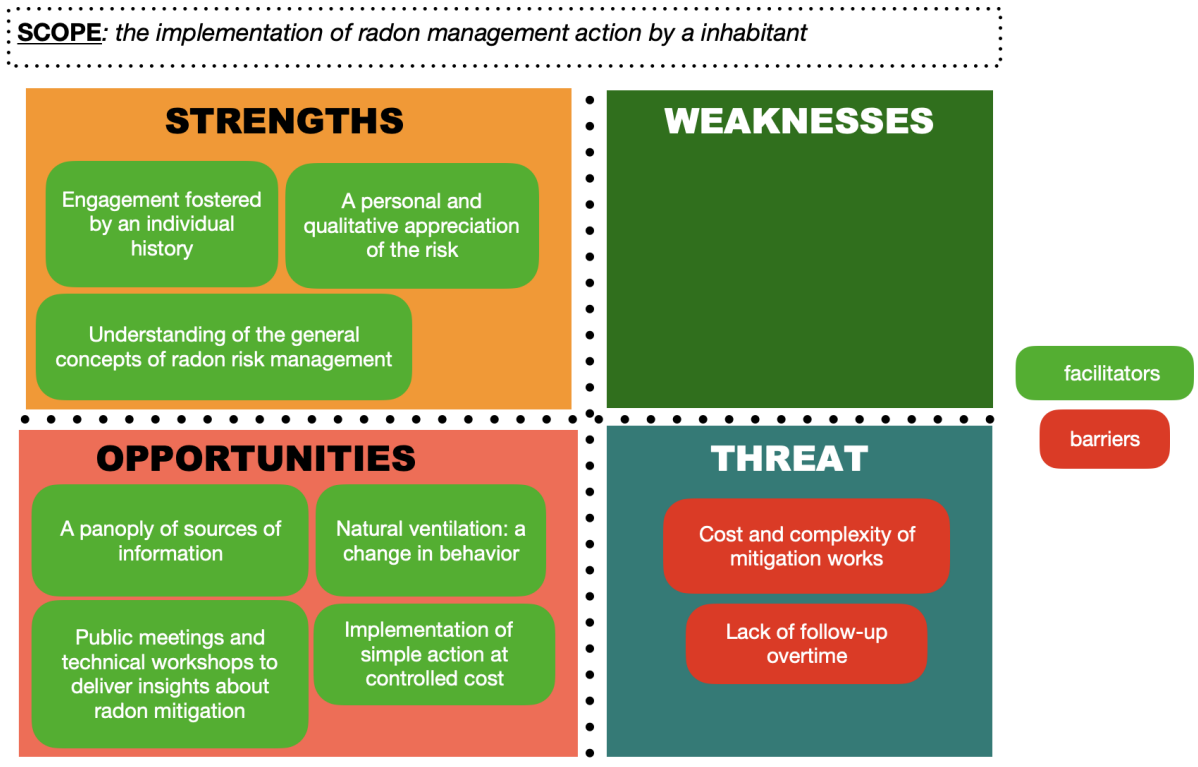
For each group, the barriers and facilitators have been classified under a SWOT analysis, whose results are displayed in Figures 1 and 2.

231 **Figure 2. SWOT analysis for LPA (group A)**



232

233 **Figure 3. SWOT analysis for inhabitants (group B)**



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For LPA, the internal and external factors that are favorable in achieving the intended objective of implementing the radon management actions are confronted with several unfavorable elements, predominantly external (*threats*), underscoring the need to strengthen the external support of the LPA who engage in radon initiatives.

For inhabitants, despite the numerous internal strengths and the external opportunities they have taken, SWOT reveals two barriers of external nature: the cost and complexity of the mitigation and the lack of follow-up and support over time. Consequently, both deserve specific attention.

The use of theoretical models

The application of SMOC for coding the LPA's data was sometimes difficult and equivocal and most of the factors within SMOC remained unidentified in the data collected and a new theme ("initial motive") had to be introduced. The creators of SMOC acknowledged that the model is not universal, and its application may be "*problematic*" in some cases and radon being potentially one of them. Conversely, no issue was met in applying RPMT to explain the behavior of the inhabitants.

Should comparable research be conducted in another region or country, it is suggested to adapt SMOC, develop a new model (for example, a model constructed upon the system from the International Commission on Radiological Protection [8] and recommendations from the World Health Organization [9]) or not use any predefined model and inferring it from the interviews.

Limits

The inhabitants who did not answer were mostly those who did not take part in the technical workshop (see Figure 1) consequently, the relative importance of it cannot be thoroughly investigated. In addition, this research has probably collected more facilitators than barriers; the latter will be the most difficult to identify because these are associated with the least motivated inhabitants and/or those confronted with difficult situations (for example, low financial means).

The research has been performed in 2 administrative regions with a high number of radon priority areas and up to 7 different radon management actions have been identified (described in § 9 of the Supplementary Materials). Data saturation (additional data are not yielding new insights) have been reached for Groups A and B. Whilst this research does not encompass all the possible situations, it covers a part of the spectrum, and the results (barriers and facilitators) might be applicable in other French regions. Recent research has identified facilitators and barriers in radon mitigation in four different European countries [10] and it will be interesting to investigate, which results are transferable to other countries, those who are not e.g. due to regulatory and other contextual differences (with the caveats of representativity and potential sensitivity to bias [11]).

Issues in radon communication

This research collected the view of both the emitters and the receptors of radon awareness materials. LPA distributed information through multiple channels (e.g. flyer, town hall office, event, press, social media, website, etc.) and the inhabitants reported having been informed through different means, supporting the current multi-channels approach. The public meeting and workshop with the presence of officials and building professionals were also deemed very important to convey information and should be pursued.

Several stakeholders such as mayors, landlords, family physician, pharmacists and building professionals (architects; …) can play a role to relay information, but this remains mainly at a proposal stage.

Observing different but complementary viewpoints on the content of the communication by LPA and inhabitants is noteworthy. LPA indicated that they encountered some difficulties in finding information to craft their messages. They struggled to find a balance between giving a 'health' or a 'building' perspective to the message, leading to confusion regarding whom to involve in promoting the message ("*it is not up to the mayor to be more pressing about radon, but is it the Ministry of Health or the Ministry of Ecological Transition? I do not know but there is a topic here*"). Inhabitants, on the other hand, reported concerns at different level: finding radon messages to be "*inaudible*" and potentially contradicting with energy saving campaigns. All these factors combined suggest that harmonized messages on radon, clear in their approach (health vs. building) and taking into account current policies (energy saving, building retrofitting, …) should be developed by national administration and, if already existing, promote them. This pre-defined messages would not only save time and resources of the LPA but also allow them to concentrate on radon management and especially the post-measurement steps.

Tuning the follow-up for post-measurement steps

This research revealed that indicators of qualitative nature, to direct a local radon management action, assess it's outcomes and adapt/improve it for a next time are missing. Lack of structured efficiency indicators were similarly observed for the evaluation of the effectiveness of media campaigns to address the health risks of indoor radon to

homeowners [12] and the results of the implementation of national RAPs [13], confirming that indicators are a “blind spot” in most radon management activities.

These observations promote the development of a structured follow-up of local actions, with indicators of quantitative and qualitative nature as appropriate and extending over a long period, spanning several years from the start. These developments are essential to support motivated inhabitants, contribute to continuous improvement and comprehensively assess the success (and the justification) of radon management actions.

Almost insuperable barriers

Clearly, the main obstacles on radon management lie in the post-measurement steps. Even though the LPA have integrated radon into existing plans/programmes and have involved elected representatives and other stakeholders, inhabitants have interpreted the radon results and mitigation work very well, but mitigation work is deemed costly and complicated: (“*it is very complicated to perform the mitigation in an old house*”; “*the financial aspect was a barrier*”). LPA cannot allocate a budget to support inhabitants precisely because radon is an added item in existing plans/programmes and is not granted with a specific budget. In addition, building professionals with training/experience in radon are missing to take over the complicated part of the mitigation and consequently only simple actions at controlled costs are implemented by the inhabitants. The simplest action of all being opening the windows more often.

Proposed remedies by the interviewees go two ways: creating a specific financial support by rerouting a small part of the budget available for building energy retrofit and training building professionals on radon management. But important uncertainties about the cost and the efficiency of the mitigation works [14] make the evaluation of a budget difficult for

both the inhabitants and the LPA. Circling the cost-efficiency ratio of radon classical mitigation work implemented in typical building settings certainly constitutes a fruitful prospect of research. Developing training on radon addressed to building professionals does not fall within the responsibility of LPA, nor its accreditation or implementation. Nevertheless, radon trainings addressed to building professionals are becoming available by regional networks/association in Bourgogne Franche Comté[4] and Bretagne[5], as well as at national level[6].

[4] Since 2023, a French Swiss diploma at university level on radon risk and indoor air quality is proposed: https://www.heia-fr.ch/fr/formation-continue/risque-radon-et-qualite-de-l-air-dans-le-batiment-diplome-inter-universitaire-diu-franco-suisse-2024/

[5] Since 2013, the association Approche Éco Habitat has created a radon and indoor air group address to professionals who wish to gain information and progressively build competence on radon mitigation. https://radonbretagne.fr/professionnel-se-former-au-radon.html#top.

[6] The Scientific and Technical Centre for Building (CSTB) proposed two training sessions on the protection of the buildings against gaseous pollutants from the ground. https://formations.cstb.fr/formations/?etp=347

Conclusion

This research aimed to identify the reasons and motivations, facilitators and barriers in radon management, from the dual points of view of local public administrations who decided to implement a radon management action and inhabitants who decided to take part in measuring radon measurement. To our knowledge, these groups have hardly been the subject of qualitative research in France, notably the viewpoint of local public administration has never been collected/analysed despite that they are identified as the lead promoter of local radon management actions in the National Radon Action Plan. Our approach consisted in performing individual open ended interviews with questions based on two theoretical models: the Swiss Model for Outcome Classification in Health Promotion and Prevention (SMOC) for the questions addressed to local public administration recruited through snowball sampling in two administrative regions with radon priority areas, and the Revised Protection Motivation Theory (RPMT) for the questions addressed to the inhabitants recruited through opportunistic and heterogenous samplings in a community with experience in radon management actions. Overall, seven (different) radon management actions, implemented at different levels (district, city, community etc.) were subject of the analysis.

While we recruited the expected number of local public administrations, the recruitment of the inhabitants proved to be difficult and the sample size is smaller than the intended objective; it is possible that only the radon-interested individuals stepped forward for the interview, limiting the potential for identification of the possible barriers.

The results obtained through the qualitative analysis contribute firstly to understanding the application of radon management actions in French homes (from the perspective of two

355 administrative regions), how the actions/activities have been perceived and what are the
356 barriers and facilitators for each group, their location in the process and their possible
357 relationships and their effect in the process.

358 Secondly, the results help in identifying the origins and characteristics of the facilitators (to
359 be supported) and barriers (to be reduced/bypassed). The identification of barriers of
360 external nature (*threats*) suggests that other stakeholders: building professionals, national
361 administrations and other parties have a role in the achievement of local radon
362 management actions.

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408 **Supplementary data**

409 Store DB: STOREDB:STUDYXX RadoNorm Subtask 6.1.3 - A French perspective on the
410 barriers and facilitators in the management of radon in homes – Supplementary materials
411 https://doi.org/10.20348/STOREDB/1194.

412 The supplementary data contains the following:

413 • Questions addressed to local public administration (group A)
414 • Connection between the questions in the survey instruments addressed to local
415 public administration (group A) and the Swiss Model for Outcomes Classification for
416 health and prevention measures (SMOC)
417 • Questions addressed to inhabitants (group B)
418 • Connection between the questions addressed to the inhabitants (group B) and the
419 themes of the revised protection motivation theory model (RPMT)
420 • Information on the project addressed to local public administration and the
421 inhabitants and consent form to participate
422 • Characteristics of the participants
423 • Detailed results for the local public administration
424 • Detailed results for the inhabitants
425 • Key characteristics of the radon management actions implemented by the local
426 public administration
427