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BRAZILIAN JOURNAL OF RADIATION SCIENCES

doi.org/10.15392/2319-0612.2025.2869
Braz. J. Radiat. Sci., Rio de Janeiro
2025, 13(3) | 01-17 | e2869
Editor: Prof. Dr. Bernardo Maranhão Dantas
Editor: Prof. Dr. Alfredo Lopes Ferreira Filho
Submitted: 2025-02-27
Accepted: 2025-05-13

Effective social participation in radiation protection: a necessary approach to indoor radon programs in Brazil

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Abstract: Effective social involvement in nuclear science and radiation protection remains a challenge, particularly in managing natural radiation exposure, such as radon gas – the largest contributor to human exposure from natural sources. This paper addresses the first Brazilian attempt to actively engage the public in a 6-month indoor radon monitoring campaign in Poços de Caldas, a region with high natural radioactivity. The study aimed to raise awareness and foster voluntary participation through a communication campaign, incorporating educational content, strategic messaging, and both virtual and in-person engagement. Despite a modest voluntary participation rate of 17%, the study found strong commitment among participants and demonstrated the effectiveness of local partnerships, digital tools, and community-driven efforts. The findings underscore the importance of tailored communication strategies and collaborative engagement to overcome barriers in public health initiatives, suggesting a need for culturally appropriate approaches to radon risk management in Brazil. Future work should focus on refining engagement strategies and assessing long-term impacts to ensure sustainable public participation in radon exposure control.

Keywords: Radon exposure, public engagement, health communication, behavioral change, community participation.

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Participação social eficaz na proteção radiológica: uma abordagem necessária para os programas de radônio *indoor* no Brasil

Resumo: O envolvimento social eficaz na ciência nuclear e na proteção radiológica permanece um desafio, especialmente no que diz respeito à gestão da exposição à radiação natural, como o gás radônio – o principal responsável pela exposição humana proveniente de fontes naturais. Este artigo examina a primeira tentativa brasileira de envolver ativamente o público em uma campanha de monitoramento de radônio em ambientes internos, com duração de seis meses, realizada em Poços de Caldas, uma região de alta radioatividade natural. O estudo teve como objetivo sensibilizar a população e fomentar a participação voluntária por meio de uma campanha de comunicação, que combinou conteúdo educativo, mensagens estratégicas e formas de engajamento tanto virtuais quanto presenciais. Embora a taxa de participação voluntária tenha sido modesta, com 17%, o estudo revelou um forte comprometimento por parte dos participantes, demonstrando a eficácia das parcerias locais, ferramentas digitais e iniciativas comunitárias. Os resultados destacam a relevância de estratégias de comunicação sob medida e de um engajamento colaborativo para superar barreiras em iniciativas de saúde pública, sugerindo a necessidade de abordagens culturalmente apropriadas para a gestão do risco de radônio no Brasil. Trabalhos futuros devem priorizar o aprimoramento das estratégias de engajamento e a avaliação dos impactos a longo prazo, a fim de garantir a participação pública sustentável no controle da exposição ao radônio.

Palavras-chave: Exposição ao radônio, engajamento público, comunicação em saúde, mudança comportamental, participação comunitária.

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1. INTRODUCTION

Effective social involvement is, without a doubt, an essential element to the advancement of today's nuclear science and radiation protection. However, it is a goal not yet achieved in the field [1]. Lack of public interest or sufficient knowledge on the themes of ionizing radiation; negative perceptions of nuclear energy rooted in worldwide culture (and stimulated by mainstream media); and mistrust in governmental policies and institutional actions remain as historical barriers to the voluntary involvement of society on self-protective efforts against exposure to radiation. The decades-long communication challenges the nuclear field faces reflect its resistance to the full embracing of multidisciplinary approaches and the integration of social, health and environmental data in radiation protection. While stakeholder involvement (in the form of public acceptance) is admitted as critical to the development of nuclear energy production and remediation of legacy sites – and as such has been addressed in the last two decades – close consideration to societal aspects in the management of other sources of exposure to natural radiation is still highly overlooked and only very recently has become the subject of scientific research [2-5].

Public involvement is especially relevant to the management of exposure due to indoor radon gas – which, along its progeny, is the largest contributor from natural sources of ionizing radiation, accounting for 50% of the annual dose received by humans (due to all sources). Chronic exposure to the gas, which happens in high frequency indoor environments (workplaces, schools/childcare facilities and dwellings) and responds for 3-14% of lung cancer cases worldwide, is considered a public health issue – to be approached through national monitoring programmes (or so-called 'radon action plans') [6,7]. As such, lack of direct involvement of the public in the process hinders the full potential of large-scale initiatives. Low rates of voluntary action in well-established national radon programs point

to a situation known as value-action gap, in which values and attitudes of people do not correlate to their actions [2]. Because public health campaigns do not automatically prompt behavioural change, authors look at radon risk remediation as a socio-political and psychological issue rather than a technical or scientific one [8]. Thus, the neglect of sociological perspectives and effective communication protocols are clear constraints to the full understanding of radon risk for modern societies and its current risk perceptions as well as to the development of sustainable control measures.

Radon action plans or large-scale indoor radon studies are not a reality in Latin America [9]. In countries of continental proportions such as Brazil, with a population of 212 million and area of 8,4 million km^2, challenges are multiple, ranging from scarcity of resources for dedicated long term and large-scale projects (economical); absence of internal coordination and harmonization of approaches developed (managerial); disregard of radon exposure as a public health problem and prioritization of other population needs seen as more urgent (political) to lack of public interest and knowledge on the themes of natural radiation (educational); and devaluing of science as fundamental for socioeconomic development (cultural) [10]. Moreover, environmental, geological, socioeconomic & cultural diversities that conform Brazil as a country add yet another layer to the constraints to the design of a nationwide effort to assess indoor risk.

Brazil has a record of local studies of indoor radon measurements in dwellings, concentrated in the southeast [11] and northeast regions [12, 13], with a few carried out in other areas of particular interest due to their uranium-rich geology. Despite all technical efforts aimed at assessing indoor radon exposure, identifying radon prone areas and creating conditions for the development of a national program (if necessary), Brazilian studies that take into account any human and social factors are nowhere to be found.

The most comprehensive project on indoor radon assessment conducted in the country results from a joint institutional effort led by the Brazilian National Commission for

Nuclear Energy-Laboratory of Poços de Caldas (CNEN-LAPOC), along the National Cancer Institute (INCA) and Health Secretariat of the State of Minas Gerais (SES-MG). The program covered 700 dwellings from 4 municipalities of the Poços de Caldas Plateau Region, along two seasonal exposure campaigns executed within one year. Despite the efficient logistics – which were based on the mobilization of teams of local community health workers responsible for visiting the targeted homes and installing passive detectors – the project did not envision an approach of direct involvement of dwellers in the process. While it successfully relied on public trust previously built by local community health workers in their practice as a facilitator to the participation (which was not compulsory), it did not promote the interest or action of participants beyond agreeing to have their homes monitored during the campaign [11].

This paper discusses the first Brazilian experience on seeking active participation of the public in indoor radon measurements in dwellings. The study, conducted in a region known worldwide for its high levels of natural radioactivity, aimed to involve a local population by attracting its interest to the issues of natural radioactivity and motivating the voluntary (and active) participation of individuals in a 6-month indoor radon monitoring campaign. The strategy was based on the design of a communication campaign; production of educational content with messages inspired by the Extended Parallel Process Model (EPPM) [14]; and the encouragement of community-like efforts in a way to stimulate group participation and local cooperation. Subtitle

2. MATERIALS AND METHODS

2.1 Area of study

The study was conducted in two adjacent census sectors (approximately 9 km²) within the municipality of Poços de Caldas, southeastern Brazil. The selected area comprises

roughly 250 households (~1,000 inhabitants) and is geographically isolated by natural boundaries. The region is historically linked to uranium mining and high natural radioactivity levels, factors contributing to heightened local risk perception and community mistrust towards institutional actors. These social and geographical characteristics were considered strategic for piloting a public engagement approach for indoor radon monitoring.

2.2 Communication Strategy and Implementation

The study adopted a communication-centered approach to promote voluntary participation in a 6-month indoor radon monitoring campaign. The strategy included the development and distribution of educational content addressing radon risks, health impacts, detection methods, and protective actions. Materials were produced in both digital (social media posts, short videos) and printed formats (pamphlets, posters), with content presented in accessible language along strategic messages to foster public understanding and interest. A visual identity was also created for the campaign to support message recognition and coherence across materials.

Engagement activities involved door-to-door visits for material distribution and device installation, formation of a participants WhatsApp group, and the establishment of online platforms (Instagram and Facebook) providing instructions, campaign updates, and direct communication with the research team. Logistics were designed to simplify participation: residents received passive radon detector kits, printed instructions, and access to technical support.

3. RESULTS AND DISCUSSIONS

The first Brazilian exploratory initiative of public engagement in an indoor radon monitoring campaign yielded a number of insightful findings regarding public response and the importance of communication strategies. A voluntary participation response rate of 17%

was recorded in the area where engagement strategies were applied, compared to a 0% response rate in the census sector where no such practices were implemented. This contrast highlights the potential effectiveness of carefully designed public engagement in motivating citizen participation in environmental health initiatives.

To guide the communication approach, the Extended Parallel Processing Model (EPPM)—often referred to as "threat or fear management theory"—was utilized. This model combines emotional reactions (such as fear of health threats) with cognitive factors (such as beliefs in self-efficacy) to explain how individuals decide to act in the face of risks. According to the EPPM, behavioral decisions are influenced by a balance between perceived threat (including perceived severity and susceptibility) and efficacy (including response efficacy and self-efficacy). The feeling of threat captures attention and motivates action, while the belief in one's own ability to effectively address the risk is what ultimately drives behavior. Previous applications of EPPM in health communication campaigns, including radon control efforts, have demonstrated its utility in shaping effective messaging [14]. However, the current campaign also accounted for sociocultural dimensions: Whittaker [15] argues that unequal power dynamics in society can lead to heightened fear and anxiety, which may in turn diminish individuals' self-efficacy. Conversely, Hevey [16] and Perko [17] caution that when radon is communicated as a natural, low-threat source, public concern can be insufficient, potentially limiting engagement. These perspectives informed the campaign's nuanced communication strategy.

Accordingly, the campaign materials were developed to present the risks of radon in a transparent yet non-alarmist manner. Emotional appeals focused on protecting one's family, and emphasis was placed on both individual and collective power to act. The materials also included a clear call to action, step-by-step instructions for participation, and user-friendly explanations of the scientific methods for measuring radon. This integrated approach aimed not only to raise awareness but also to empower participants to take

meaningful action, reinforcing both perceived threat and perceived efficacy in line with EPPM principles.

This first Brazilian exploratory initiative also revealed promising levels of participant commitment and provided key insights into the effectiveness of different engagement strategies. Once enrolled in the project, participants demonstrated a high degree of responsibility and follow-through, with less than 1% of radon detectors either unexposed or not returned. Individuals successfully completed a range of tasks with minimal support, including filling out digital questionnaires, joining a WhatsApp group, managing visit scheduling, installing detectors themselves, and returning them on time. This level of autonomy suggests that, when given clear guidance, community members are fully capable of independently carrying out technical procedures within citizen science and public health contexts.

Interaction within the WhatsApp communication platform further illustrated participants' engagement and interest. When prompted, individuals actively contributed to discussions, posed technical questions, praised the initiative, and reported sharing campaign materials within their personal networks. The influence of peer participation became evident, as waves of new involvement followed visible online interactions and local word-of-mouth. In contrast, social media engagement - despite deliberate content production and investment in promotional strategies - remained low. Participants did not significantly interact with posts or use the social media platforms for communication, highlighting WhatsApp's practicality as a direct, user-friendly channel for dialogue and coordination.

The benefits of stakeholder engagement in radon risk management are known, this case study also reinforces the growing importance of digital communication platforms as tools for public involvement [2, 17]. As noted by Turcanu et al., online platforms tailored to user preferences in design, transparency, and interactivity can foster more favorable attitudes toward participation [2]. In this Brazilian context, both digital and in-person approaches were combined to optimize engagement. The campaign utilized Facebook and Instagram pages

titled Projeto Radônio e Ciência, designed to be easily discoverable and informative. These pages included clear messaging about the project's objectives, multiple contact options, instructions for participation, and content ranging from Q&As to short videos and myth-busting materials - enhancing transparency and public trust.

Complementary in-person outreach efforts were carried out through visits to the target area, distribution of pamphlets, and face-to-face recruitment. After volunteer groups were established, additional visits were made to deliver detector kits and provide procedural instructions. Media involvement also contributed to visibility: a regional outlet produced a news segment featuring a researcher and participant demonstrating a radon detector installation, further legitimizing the initiative and expanding public awareness.

This study also highlighted the critical role of collective engagement and trusted relationships in promoting public participation in indoor radon monitoring. Building on evidence that social context and community involvement enhance risk perception and health action [16], the campaign actively partnered with local leaders, healthcare workers, and university-affiliated residents to establish trust and legitimacy. The involvement of academics—professors and researchers living in the area—further reinforced the project's credibility and helped foster a sense of shared purpose.

Communication efforts emphasized both personal agency and the collective importance of participation. Messages were designed to validate each individual's role in the success of the initiative, while promoting the idea of a broader, united effort. This approach aligned with best practices in participatory public health messaging.

To support engagement, campaign logistics were streamlined: door-to-door outreach, free delivery and collection of detector kits, printed and digital instructions, open researcher communication, a dedicated WhatsApp group, and an online data collection system. These tools facilitated participation and encouraged community interaction. A comparative approach in a similar neighborhood—where only brochures were mailed and no active

engagement occurred—yielded no responses, underscoring the importance of relationship-building and interactive communication over passive outreach methods.

This experience highlights the importance of integrating both digital tools and face-to-face engagement to build trust, encourage participation, and ensure sustained involvement in public health initiatives. The findings demonstrate that communication strategies, when tailored to the technological preferences and cultural context of the target audience, can significantly improve the effectiveness of citizen-centered campaigns. By combining theory-driven messaging with local sensitivity, the study underscores the critical role of stakeholder engagement in enhancing public participation in environmental health initiatives. These insights lay the foundation for future large-scale campaigns in Brazil, emphasizing that fostering trust, promoting a shared sense of purpose, and simplifying participation logistics are key to the success of community-based health efforts.

4. CONCLUSIONS AND FUTURE CHALLENGES

Despite the relatively low response rate observed in this first Brazilian indoor radon communication campaign, the results offer valuable insights into the potential for public engagement in environmental health initiatives, especially in regions with limited infrastructure and historical skepticism about radioactivity. Conducted without a dedicated team of multidisciplinary experts or substantial human and financial resources, this pilot initiative demonstrates that, even in challenging contexts, public engagement can be achieved. The study suggests that residents were more likely to participate when they felt part of a collective effort, were presented with engaging and approachable content, and received clear, user-friendly guidance supported by digital tools.

Collaborative partnerships and close community ties played a crucial role in fostering trust and involvement, further reinforcing findings from the literature about the importance

of community-based approaches. The use of social media, while powerful in today's digital world, requires sustained efforts and financial investment to be effective, as the landscape is saturated with competing messages. This campaign showed that a balanced combination of digital and face-to-face interactions is key to building a robust and multidimensional stakeholder engagement strategy.

Additionally, the application of behavior change communication models like the Extended Parallel Processing Model (EPPM) provided a solid foundation for structuring the campaign's messaging. While further studies are needed to refine these approaches, they offer valuable insights into how to design and deliver effective public health messages. A critical area for future work will be developing methods for assessing the long-term impacts of such initiatives and establishing protocols for measuring success.

In conclusion, this exploratory initiative demonstrates that voluntary participation is essential for the successful implementation of large-scale radon control actions in Brazil. However, this cannot be achieved without a well-designed social involvement strategy tailored to the economic, political, and cultural realities of the country. Future efforts should continue to refine and expand upon the lessons learned here, paving the way for more effective public health campaigns in Brazil and beyond.

ACKNOWLEDGMENT

This work was facilitated by a partnership between the Brazilian Commission for Nuclear Energy-Poços de Caldas (CNEN-LAPOC) and the State University of Campinas-Institute of Geosciences (UNICAMP-IG). The authors would also like to thank CNEN-SEFESP for support and acknowledge colleagues Hugo Teixeira (UNICAMP) and Carolina Del Roveri (UNIFAL).

FUNDING

This work was funded by the Brazilian Commission for Nuclear Energy-Poços de Caldas (CNEN-LAPOC) and the State University of Campinas-Institute of Geosciences (UNICAMP-IG).

CONFLICT OF INTEREST

All authors declare that they have no conflicts of interest.

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APPENDICES

I. Visual identity of the communication campaign "Project Science & Radon"

Figura 1: (a)Campaign logo and (b) Campaign cover and motto

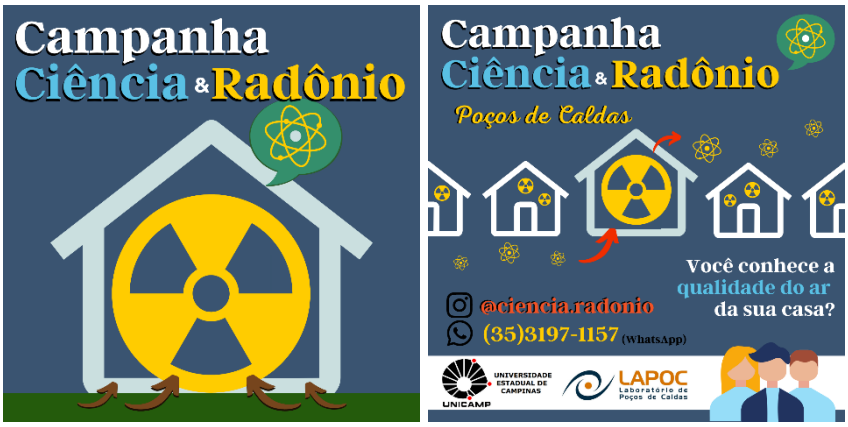
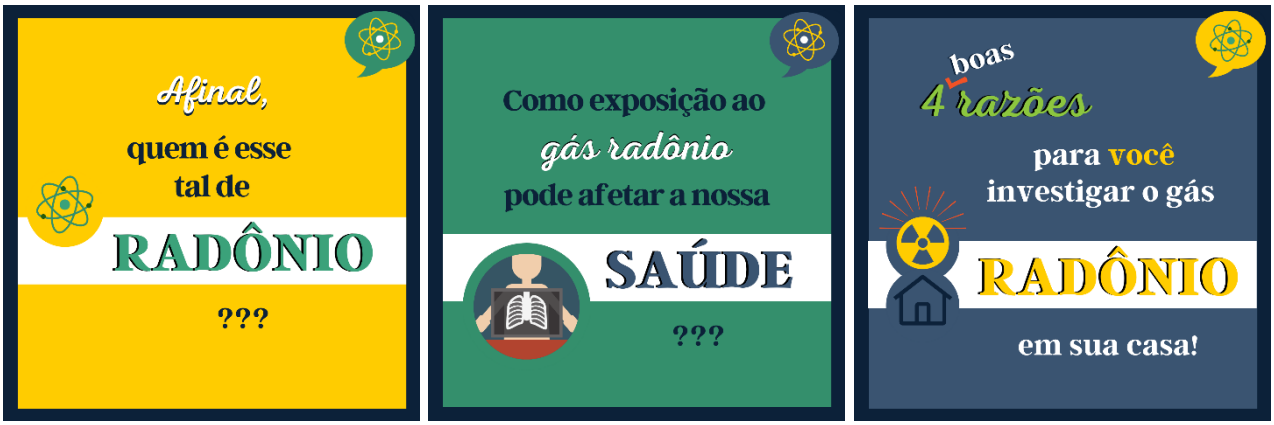


Figure 1(c): Post covers for social media; color scheme



II. Examples of materials designed for the communication campaign "Project Science & Radon"

Figure 2: (a)Poster (for impression)

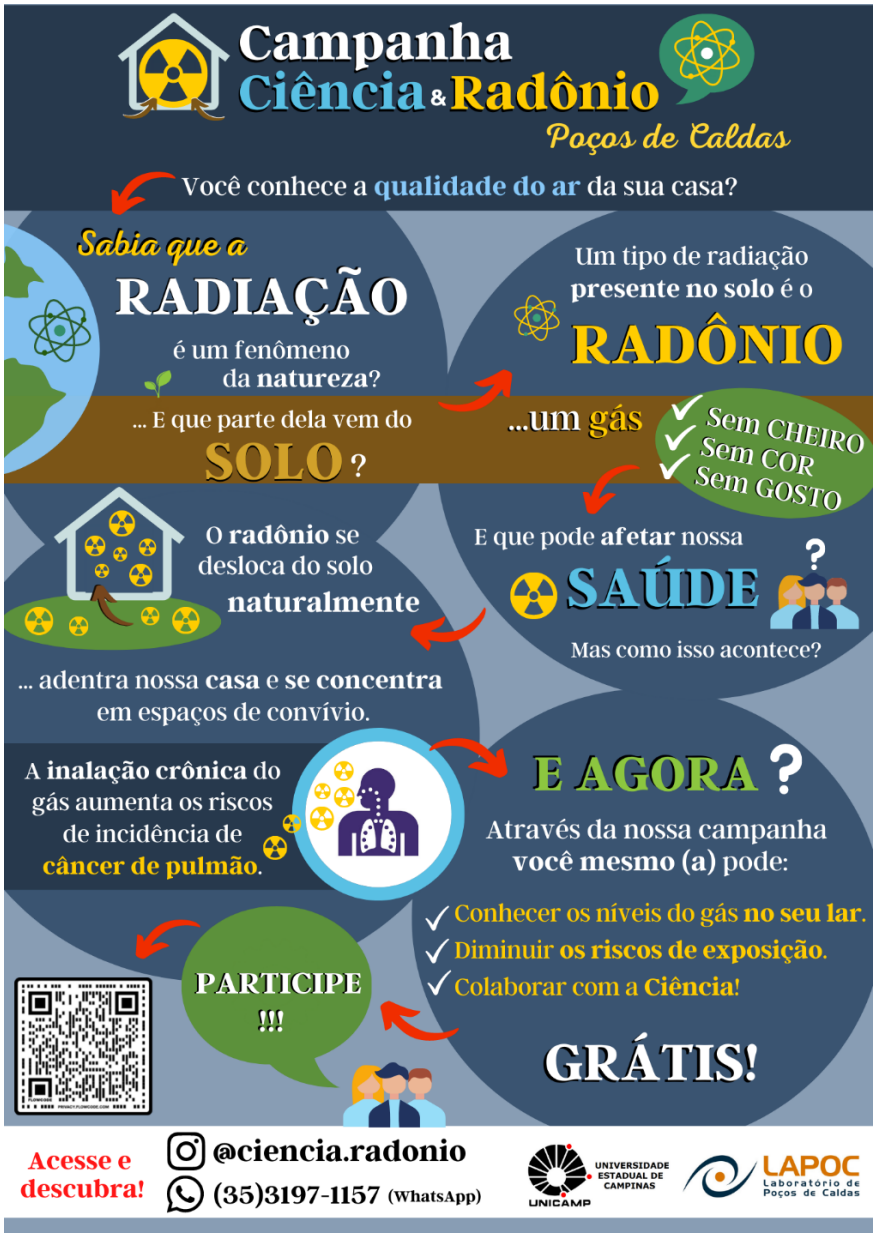
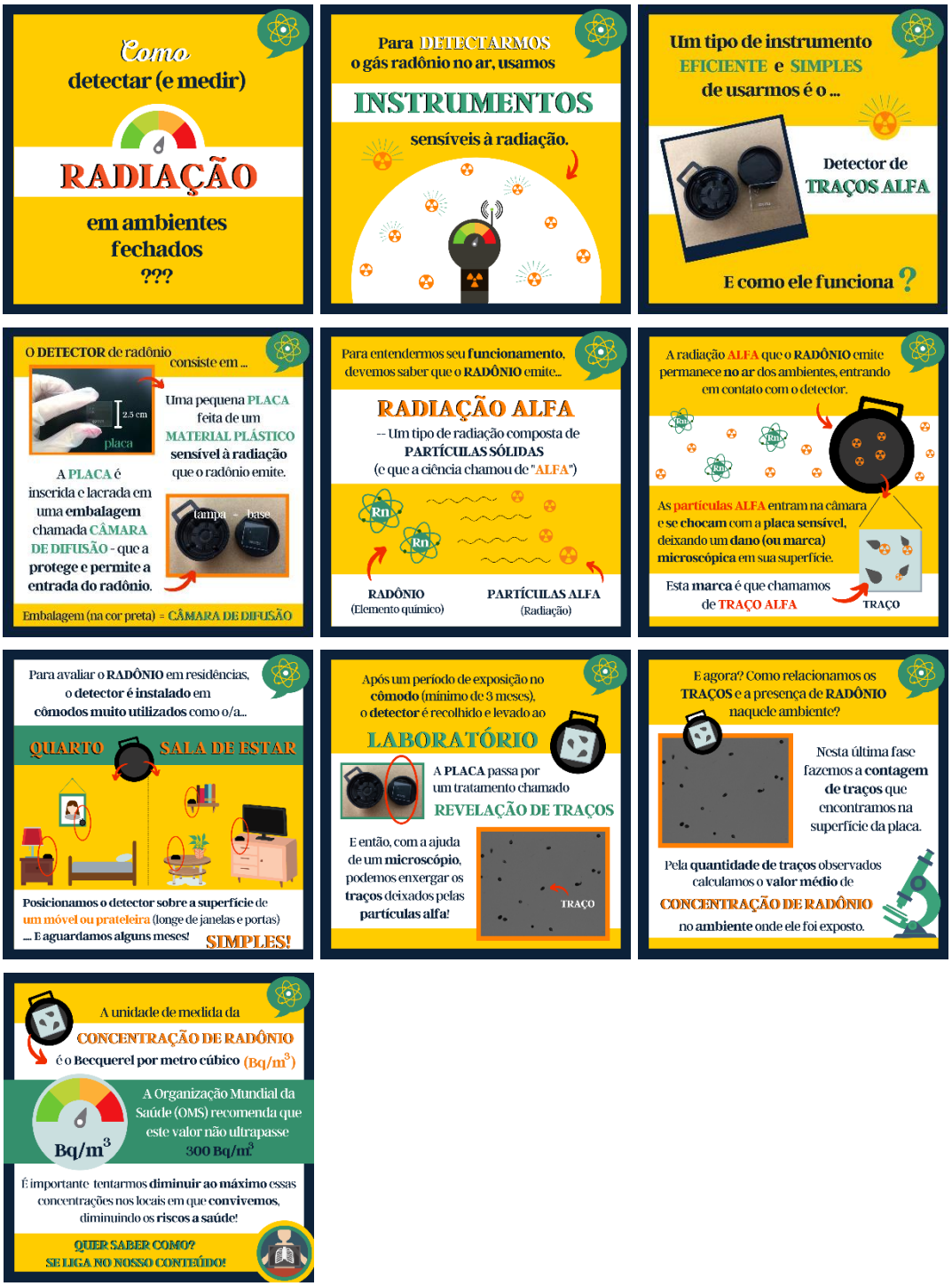


Figure 2: (b) Example of complete material for social media.
Theme: "how to measure radon indoors"



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