Radon Risk Perception, Awareness and Knowledge

Subjects: Environmental Sciences

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Radon is a natural radioactive gas that is present in buildings and is the second cause of lung cancer after smoking. Risk perception has been studied from multiple perspectives, including social studies, anthropology, and medical disciplines, with psychology playing a primary role. Two main dimensions are involved in risk perception: a cognitive dimension, related to knowledge and understanding of risk, and an emotional dimension, which includes feelings; both are components of the reaction to risks, representations of immediate and/or future consequences and their implications, and how people decide how to behave accordingly. Perceived risk is therefore quantifiable and predictable: the psychometric paradigm has helped to clarify how certain elements and characteristics are specifically influential in people's perception of the dangerousness of an activity, such as controllability, voluntariness, threat to future generations, and responsibility. The research for the implementation of evidence-based radon communication programs is progressing rapidly. Many countries have issued regulations or recommendations to ensure that radon concentration levels do not exceed certain threshold values. Following the results of numerous epidemiological studies conducted two decades earlier, in 2009 the World Health Organization proposed a reference level of 100 Bq m^{-3} to minimize health risks from indoor radon, adding that if this level could not be achieved due to country-specific conditions, the chosen reference level should not exceed 300 Bq m^{-3}. According to the 2013 Euratom Directive, radon is an indoor pollutant monitored in workplaces and homes, with established limits and exposure control obligations but exposure continues to be very high in some situations.

Keywords: radon ; awareness ; knowledge ; risk perception

1. Background

Radon is a natural radioactive gas that is present in buildings and is the second cause of lung cancer after smoking [1][2]. For this reason, many countries have issued regulations or recommendations to limit radon concentration levels in workplaces and at home.

In 1988, the International Agency for Research on Cancer (IARC) listed radon and its decay products as Group 1: substances that are definitely carcinogenic to humans [3].

The perception of radon risk is of scientific interest due to its important role in lung cancer onset in the general population (attributable risk: 5–20%), ranked by the World Health Organization as the fifth leading cause of mortality in 2010 [1][4][5]. Radon exposure can contribute to other carcinogenic effects: the respiratory tract is the primary target, followed by the skin, and several studies have reported an association between radon presence and skin and blood cancers [6][7][8][9].

A study of an accurate database of national radon exposures for 66 countries estimated the lung cancer mortality attributable to radon. In 2012, there were an estimated 226,057 lung cancer deaths attributable to radon (an average of 3% of total cancer deaths) worldwide, confirming that residential radon is responsible for a high share of mortality due to this disease [10].

2. Risk Perception and Communication

Risk perception has been studied from multiple perspectives, including social studies, anthropology, and medical disciplines, with psychology playing a primary role. Two main dimensions are involved in risk perception: a cognitive dimension, related to knowledge and understanding of risk, and an emotional dimension, which includes feelings; both are components of the reaction to risks, representations of immediate and/or future consequences and their implications, and how people decide how to behave accordingly. Slovic, arguing about the well-known psychometric paradigm, states that experts and the general public are necessary in the assessment process and that comprehension of public perceptions is crucial for effective decision making [11]. Perceived risk is therefore quantifiable and predictable: the psychometric paradigm has helped to clarify how certain elements and characteristics are specifically influential in people's perception

of the dangerousness of an activity, such as controllability, voluntariness, threat to future generations, and responsibility [12].

In real life, the way people judge and evaluate risks is based on a combination of psychological and socio-cultural factors that shape their behavioral responses. There is no single way to process, understand, and react to risk information, as implied by one-way communication models. Therefore, the assessment of risks and their level of acceptance are highly dependent on attitudes and culture. These factors are influenced by differences between reference social groups within the same culture, resulting in different ways of understanding and responding to risks [13].

The psychological perspective is crucial to understanding the public's response to radon risk, particularly risk perception and management [14]. Indeed, rational behavior in which people receive information about the health risk and possible solutions and then simply apply them is unrealistic and rarely occurs. The process is more complex and "people may respond to health risk information in sub-rational ways, and such responses reflect both powerful unconscious and intentional psychological processes" [14][15][16][17]. Different hazards can have an impact on people depending on exposure and then become a risk, i.e., a measurable probability. Since risk perception is the process by which individuals attribute meaning and establish values to various threats, perceived risks are then informed by personal life history and past experiences in a specific community, shaping heuristics, which shape the approach to reality [18].

Various models and heuristics have been proposed to examine collective and individual responses to risks, which are useful for interpreting and placing risk perceptions in context in order to propose and promote effective risk reduction strategies [19][20][21][22]. The heuristics are: availability, i.e., the tendency to judge the probability of an event based on memories about similar facts (e.g., the association between cancer and radon); representativeness, which has to do with judgments about the probability of an event based on experiences or hypotheses (developing lung cancer at home is not part of the hypotheses or experiences); unrealistic optimism (e.g., when people are convinced that it cannot happen to them; in the case of radon, also due to an emotional attachment to the house, which generally gives a sense of security) [18].

Knowledge and its transmission focus on the importance of the social context: risk must be contextualized. If there is a lack of collective memory and knowledge, these can be built with appropriate tools and sharing, as some practical experiences show, even if related to risks of a very different nature [23]. Defining an area as a risk area could facilitate the public's acceptance of information or their curiosity and desire to receive comprehensive information that includes prevention. Risk perception and risk communication are indeed closely related. Communication can shape perception, and risk perception determines how and whether risk is communicated to communities. It is important to promote the construction of clear and reliable communication strategies, able to create effective messages, deliver them through the most convenient and relevant channels, and receive feedback [24].

Communications about health and environmental hazards tend to focus on the cognitive (rational and information-related) aspects; however, research shows that individuals' actions are also driven by the emotional aspects of risk. Information is the driver of behavior only if it is able to overcome the many biases that individuals have in processing risk information. Some psychological mechanisms, when risks threaten, drive people to action; others drive them to inaction. The radon hazard, due to its specific characteristics, can easily be downplayed to justify inaction. The perception of radon risk is subject to unconscious, cognitive, and emotional biases that influence the way information is processed: radon risk is perceived as distant, uncertain, and easily taken for granted; these biases may act to minimize risk perception [25].

Given these premises, it is not surprising that radon hazards fail to promote appropriate precautionary behavior: there are no immediate risks, and radon-related lung cancer occurs in the distant future. A multidisciplinary approach, involving continuous collaboration with experts in the field of psychology, is deemed essential to solve the problems associated with the lack of radon remediation. A key challenge for risk awareness programs is to inform the public in a way that does not create apathy, complacency, or overconfidence, without creating undue stress or alarmism [14][26][27].

Perceptions of radon risk were compared with perceptions of other sources of radiation risk, such as X-rays, nuclear energy, and nuclear waste. Individuals evaluate different types of radiation risk very differently. People perceive nuclear energy and what comes with it as a very high risk, while other sources, such as medical X-rays and natural radon gas, are considered to be of little risk. Most radiation experts see things differently. This perception gap shows that the acceptance of risk is conditioned by trust in those responsible for the technology and the evaluation of its benefits. The differences between the perceptions of lay persons and experts cannot be attributed only to the degree of knowledge: better information/communication about the possible consequences of radiation is needed [28][29].

Radiation risk is associated with a collective imagination linked to bombs and disasters: a risk that has no boundaries, penetrates the body, the environment and food, and never ends. As Slovic argues, “the lack of concern about radon seeping from the ground beneath dwellings seems to stem from the fact that it is of natural origin and occurs in a comfortable and familiar environment, with no one to blame”; moreover, it can never be eliminated completely. The public’s perception of risk and its acceptance are determined by the context in which radiation is used. Different uses provide information on the nature of perceptions and factors determining risk acceptability [29]. The social context matters in perception, because of its particular history, of how the interpersonal network responds to risk, of the norms with which the group identifies itself, of the type of information circulating, and of the trusted people who exist. If there is no collective action on radon, it is difficult for anyone to take the initiative on their behalf [30]. In communicating the radon risk, people should understand that there is a danger and deal with it. However, the fact that it is serious and relevant may frighten people and create awareness denial reactions; people at risk may be the most difficult to persuade if the message is too frightening.

It is interesting to note here that even the scientific world has not always been unanimous about the radon risk. In the late 1950s, this danger was unknown to most scholars, when Bengt Hultqvist performed the first set of radon measurement in an indoor environment in Sweden. During the 1970s, a quantitative estimation of lung cancer was calculated for miners exposed to radon, and the interest in indoor radon increased, but only in the 1990s epidemiological studies developed risk estimation on radon in dwellings and lung cancer [31].

There is still a scientific controversy about radon risk. There are thermal baths all over the world that are advertised for beneficial treatments in radon-rich waters, and radon has been used for medical treatments. This issue has been addressed in depth by a recent analysis of websites advertising spa treatments, trying to understand how such messages may influence public perceptions about radon [32]. Controversies in the scientific world are part of the knowledge landscape concerning many health risks caused by environmental determinants and certainly complicate the task of the authorities responsible for protecting public health [33].

For all those reasons, the research for the implementation of evidence-based radon communication programs is progressing rapidly: a recent paper proposed The Potsdam Radon Communication Manifesto in eight key steps to promote radon communication, based on the results of studies and experiences developed to date [34].

3. Regulatory Aspects

Although this research does not cover the analysis of the relationship between regulation of radon in dwellings and knowledge/awareness/willingness to remedy, some elements on regulation are given below. Many countries have issued regulations or recommendations to ensure that radon concentration levels do not exceed certain threshold values. The recommendation published in 1990 by the European Commission (CEC 90/143) indicated a reference level for radon of 400 Bq m^{-3} for homes, beyond which remedial actions to reduce radon concentration were recommended. Following the results of numerous epidemiological studies conducted two decades earlier, in 2009 the World Health Organization proposed a reference level of 100 Bq m^{-3} to minimize health risks from indoor radon, adding that if this level could not be achieved due to country-specific conditions, the chosen reference level should not exceed 300 Bq m^{-3} [1].

The World Health Organization report had a significant impact in the process of reviewing international regulations [35]. In particular, with regard to Europe, a reference level not exceeding 300 Bq m^{-3} was included in the European Directive on radiation protection (2013/59). Consequently, the 400 Bq m^{-3} reference level included in the European recommendation of 1990 must be considered outdated. According to the 2013 Euratom Directive [36], radon is an indoor pollutant monitored in workplaces and homes, with established limits and exposure control obligations.

Although public authorities in the United States focused on the problem in the 1990s and plans exist to address it, recent research shows that exposure continues to be very high in some situations. This is the case in many other countries in the world [37][38][39].

As a general remark, it is important to emphasize that the “reference level” is based on a much more complex concept than the previous “action level”. In fact, whereas the “action level” established the radon concentration above which corrective measures had to be taken, the “reference level” represents a guide to optimizing exposure, primarily above the level but also as an indication below it. These concepts and the associated operational guidance for protection against radon exposure are particularly important for the implementation of regulations in the highest risk areas [40].

References

1. Zeeb, H.; Shannoun, F. World Health Organization WHO Handbook on Indoor Radon: A Public Health Perspective; World Health Organization: Geneva, Switzerland, 2009.
2. Clement, C.H.; Hamada, N.; Lecomte, J.-F. International Commission on Radiological Protection Radiological Protection against Radon Exposure; SAGE: Thousand Oaks, CA, USA, 2014; ISBN 978-1-4739-1658-6.
3. International Agency for Research on Cancer. Man-made mineral fibres and radon: This publication represents the views and expert opinions of an IARC Working Group on the Evaluation of Carcinogenic Risks to Humans, which met in Lyon. In IARC Monographs on the Evaluation of Carcinogenic Risks to Humans; International Agency for Research on Cancer, Ed.; IARC: Lyon, France, 1988; ISBN 978-92-832-1243-0.
4. Morlier, J.P.; Morin, M.; Monchaux, G.; Fritsch, P.; Pineau, J.F.; Chameaud, J.; Lafuma, J.; Masse, R. Lung Cancer Incidence After Exposure of Rats to Low Doses of Radon: Influence of Dose Rate. Radiat. Prot. Dosim. 1994, 56, 93–97.
5. Darby, S.; Hill, D.; Auvinen, A.; Barros-Dios, J.M.; Baysson, H.; Bochicchio, F.; Deo, H.; Falk, R.; Forastiere, F.; Hakama, M.; et al. Radon in homes and risk of lung cancer: Collaborative analysis of individual data from 13 European case-control studies. BMJ 2005, 330, 223.
6. Vienneau, D.; de Hoogh, K.; Hauri, D.; Vicedo-Cabrera, A.M.; Schindler, C.; Huss, A.; Röösli, M. SNC Study Group Effects of Radon and UV Exposure on Skin Cancer Mortality in Switzerland. Environ. Health Perspect. 2017, 125, 067009.
7. Bräuner, E.V.; Loft, S.; Sørensen, M.; Jensen, A.; Andersen, C.E.; Ulbak, K.; Hertel, O.; Pedersen, C.; Tjønneland, A.; Krüger Kjær, S.; et al. Residential Radon Exposure and Skin Cancer Incidence in a Prospective Danish Cohort. PLoS ONE 2015, 10, e0135642.
8. Lubin, J.H.; Linet, M.S.; Boice, J.D.; Buckley, J.; Conrath, S.M.; Hatch, E.E.; Kleinerman, R.A.; Tarone, R.E.; Wacholder, S.; Robison, L.L. Case-control study of childhood acute lymphoblastic leukemia and residential radon exposure. J. Natl. Cancer Inst. 1998, 90, 294–300.
9. Tong, J.; Qin, L.; Cao, Y.; Li, J.; Zhang, J.; Nie, J.; An, Y. Environmental radon exposure and childhood leukemia. J. Toxicol. Environ. Health B Crit. Rev. 2012, 15, 332–347.
10. Gaskin, J.; Coyle, D.; Whyte, J.; Krewksi, D. Global Estimate of Lung Cancer Mortality Attributable to Residential Radon. Environ. Health Perspect. 2018, 126, 057009.
11. Slovic, P. Perception of risk: Reflections on the psychometric paradigm. In Social Theories of Risk; Krimsky, S., Golding, D., Eds.; Praeger: New York, NY, USA, 1992; pp. 117–152.
12. Slovic, P.; Fishhoff, B.; Lichtenstein, S. Facts and fears: Understanding perceived risk. In The Perceptio of Risk; Springer: Boston, MA, USA, 2000; pp. 220–231.
13. Renn, O.; Rohrmann, B. Cross-Cultural Risk Perception: A Survey of Empirical Studies; Springer: Boston, MA, USA, 2000; ISBN 978-1-4757-4891-8.
14. Hevey, D. Radon Risk and Remediation: A Psychological Perspective. Front. Public Health 2017, 5, 63.
15. Brown, V.J. Risk Perception: It's Personal. Environ. Health Perspect. 2014, 122.
16. Barton Laws, M.; Yeh, Y.; Reisner, E.; Stone, K.; Wang, T.; Brugge, D. Gender, Ethnicity and Environmental Risk Perception Revisited: The Importance of Residential Location. J. Community Health 2015, 40, 948–955.
17. Slovic, P. Perception of Risk. Science 1987, 236, 280–285.
18. Tversky, A.; Kahneman, D. Judgment under Uncertainty: Heuristics and Biases: Biases in judgments reveal some heuristics of thinking under uncertainty. Science 1974, 185, 1124–1131.
19. Covello, V.T. Risk comparisons and risk communication: Issues and problems in comparing health and environmental risks. In Communicating Risks to the Public: International Perspectives; Kasperson, R.E., Stallen, P.J.M., Eds.; Springer: Dordrecht, The Netherlands, 1991; pp. 79–124. ISBN 978-94-009-1952-5.
20. Walaski, P. Risk and Crisis Communications: Methods and Messages; John Wiley & Sons: Hoboken, NJ, USA, 2011; ISBN 978-0-470-59273-1.
21. Teuber, A. Justifing Risk. J. Am. Acad. Arts Sci. 1990, 4, 237–251.
22. Douglas, M.; Wildavsky, A. Risk and Culture: An Essay on the Selection of Technical and Environmental Dangers; University of California Press: Berkeley, CA, USA, 1982.
23. Arias, J.P.; Bronfman, N.C.; Cisternas, P.C.; Repetto, P.B. Hazard proximity and risk perception of tsunamis in coastal cities: Are people able to identify their risk? PLoS ONE 2017, 12, e0186455.

24. Kurita, T.; Arakida, M.; Colombage, S.R.N. Regional Characteristics of Tsunami Risk Perception among the Tsunami Affected Countries in the Indian Ocean. J. Nat. Disaster Sci. 2007, 29, 29–38.
25. Weinstein, N.D.; Klotz, M.L.; Sandman, P.M. Optimistic biases in public perceptions of the risk from radon. Am. J. Public Health 1988, 78, 796–800.
26. Fitzpatrick-Lewis, D.; Yost, J.; Ciliska, D.; Krishnaratne, S. Communication about environmental health risks: A systematic review. Environ. Health 2010, 9, 67.
27. Neznal, M.; Neznal, M. Human perception of radon risk and radon mitigation: Some remarks. Radiat. Prot. Dosim. 2008, 130, 85–87.
28. Slovic, P. The perception gap: Radiation and risk. Bull. At. Sci. 2012, 68, 67–75.
29. Halpern, M.T.; Warner, K.E. Radon risk perception and testing: Sociodemographic correlates. J. Environ. Health 1994, 56, 31–35.
30. Clifford, S.; Hevey, D.; Menezes, G. An investigation into the knowledge and attitudes towards radon testing among residents in a high radon area. J. Radiol. Prot. Off. J. Soc. Radiol. Prot. 2012, 32, N141–N147.
31. Swedjemark, G.A. The history of radon from a Swedish perspective. Radiat. Prot. Dosim. 2004, 109, 421–426.
32. Geysmans, R.; Perko, T.; Keser, M.; Pölzl-Viol, C.; Fojtíková, I.; Mihók, P. Cure or Carcinogen? A Framing Analysis of European Radon Spa Websites. Int. J. Public Health 2022, 67, 1604559.
33. Jasanoff, S. States of Knowledge: The Co-Production of Science and the Social Order; Taylor & Francis: Abingdon, UK, 2004; ISBN 978-0-203-41384-5.
34. Bouder, F.; Perko, T.; Lofstedt, R.; Renn, O.; Rossmann, C.; Hevey, D.; Siegrist, M.; Ringer, W.; Pölzl-Viol, C.; Dowdall, A.; et al. The Potsdam radon communication manifesto. J. Risk Res. 2021, 24, 909–912.
35. Bochicchio, F. The newest international trend about regulation of indoor radon. Radiat. Prot. Dosim. 2011, 146, 2–5.
36. The Council of the European Union. Council Directive 2013/59/Euratom of 5 December 2013 Laying down Basic Safety Standards for Protection against the Dangers Arising from Exposure to Ionising Radiation, and Repealing Directives 89/618/Euratom, 90/641/Euratom, 96/29/Euratom, 97/43/Euratom and 2003/122/Euratom. Available online: https://www.legislation.gov.uk/eudr/2013/59/contents (accessed on 20 July 2022).
37. Charles, M. UNSCEAR Report 2000: Sources and Effects of Ionizing Radiation. J. Radiol. Prot. 2001, 21, 83–85.
38. Chen, J.; Moir, D.; Schroth, E. Cross-Canada Survey of Radon Concentrations in Homes: Final Report; Health Canada: Ottawa, ON, Canada, 2012; ISBN 978-1-100-20115-3.
39. Duval, J.S.; Carson, J.M.; Holman, P.B.; Darnley, A.G. Terrestrial Radioactivity and Gamma-ray Exposure in the United States and Canada. US Geol. Surv. Open-File Rep. 2005, 1413, 2005.
40. Bochicchio, F.; Venoso, G.; Antignani, S.; Carpentieri, C. Radon reference levels and priority areas considering optimisation and avertable lung cancers. Radiat. Prot. Dosim. 2017, 177, 87–90.