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Article

Digital News Blindspot: Radon Awareness in Portuguese Digital Media

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Abstract: This study addresses the underrepresentation of radon gas within the media discourse, particularly in Portugal. Employing a comprehensive mixed-methods approach, this paper examines how major Portuguese digital newspapers have covered radon gas, aiming to deepen our understanding of this critical issue. The findings reveal a significant lack of coverage on radon gas over 24 years in the selected newspapers. Surprisingly, only a few articles were identified, failing to convey its importance effectively. Despite identifying some risk communication strategies, their impact was statistically insignificant, indicating a clear discrepancy in attention. This study emphasizes the urgent need for balanced reporting on public health risks like radon gas and offers insights into enhancing risk communication strategies. Ultimately, it contributes to advocating for more comprehensive coverage of critical public health issues in the media.

Keywords: radon gas; carcinogenic substance; media representation; risk communication; public health; environmental concerns; Portugal; digital newspapers; mixed-methods approach; risk perception

1. Introduction

Radon gas poses a significant health risk to human beings and occurs naturally in the soil in various regions across the globe. Recently, specific areas highly affected by radon gas have been identified in Portugal. This article aims to evaluate how the major digital newspapers in the country report on radon gas and the extent to which they utilize risk communication strategies to inform the public about its harmful effects and presence.

To achieve this, the study employs the risk communication framework proposed by Beck (2014) and Giddens and Sutton (2017), along with insights from Bouder et al. (2021), Dametto et al. (2023), Lundgren and McMakin (2018), Sellnow et al. (2009), and a comprehensive report on risk communication that includes the effects of radon in gas-affected villages in the United Kingdom (Petts et al. 2001) and in the Galician area in Spain (Negreira-Rey and Vázquez-Herrero 2022).

Using a mixed-methods approach, comprising both quantitative and qualitative methods, this study seeks to understand the extent and manner of radon gas coverage in major digital newspapers in Portugal. Additionally, it aims to conduct a comparative analysis of the quantity of radon-related publications over the years. All publications containing the term "radon" were identified in the major digital newspapers of Portugal, the first being in 1998 by Público newspaper, and the research was compared with other related terms. Based on these data, the radon-related news articles were categorized into eight distinct categories for in-depth analysis, employing a model based on Glik's (2007) studies.

This study contributes to the understanding of risk communication practices and media coverage related to radon gas. The findings shed light on the strategies employed in risk communication and the overall quantity of coverage in the selected newspapers. The results are valuable in enhancing public awareness and effective communication about the risks associated with radon gas.

The term risk has been extracted from its everyday usage, where taking risks or engaging in controlled risky behaviors is a common part of human life. However, as

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a sociological and communication concept, it has evolved with some differences from its predecessor. The sociological use refers to the social conditions and ways in which industrial societies reflect on the detrimental aspects of modernity, being introduced in topics such as health, crime and deviance, environment, and social theory (Giddens and Sutton 2017).

There is also a sense of crisis stemming from the collapse of an entire cultural system. New research methods challenge the stability of the world previously provided by religion, offering instead the possibility of revisable and therefore fluid research, breaking the paradigm of fixed relationships between images and philosophical, theological, or historical meanings that have ultimately lost their stability (Eco 2006).

The concept of risk is central to interpreting these contexts of contemporary societies, as they encompass a series of social transformations such as increased insecurity regarding employment stability, the erosion of traditions' influence on personal identity, the breakdown of traditional family paradigms, and the democratization of personal relationships. Thus, the future for individuals becomes increasingly unstable compared to the past, and even simple decisions like what to eat are announced in a context where conflicting information about the advantages and disadvantages of food exists, representing new risks for individuals.

The concept of risk can be even broader, as Beck (2014) argues that there is a new configuration of society called the risk society, replacing the slowly dying industrial society. The risk society is characterized by awareness of risks and how to avoid them, with particular emphasis on environmental issues.

Following a comprehensive description, Lundgren and McMakin (2018, p. 3) define risk communication as follows: "Risk communication is a subset of technical communication. As such, it has its own characteristics. At its most basic, it is the communication of some risk". They highlight the difficulty that the presence of emotions, or lack of them, can generate in the public's association with a risk, causing noise in its communication. According to the authors, the social amplification of risk theory states that social activities will magnify the consequences of a risk event, often in unexpected ways:

Risk information "vacuum" is most likely to blame for the social amplification of risks. That is, when experts refuse to provide information, a hungry public will fill the void, often with rumors, supposition, and less-than-scientific theories. Silence from experts and decision makers, particularly regulatory agencies, breeds fear and suspicion among those at risk and makes later risk communication much more difficult (Lundgren and McMakin 2018, p. 15)

Perceptions of risk can be defined as individuals' subjective assessments that determine whether the risk is man-made, whether it can cause illness or medical conditions, whether it is localized in a specific geographic area, whether it is a source of disagreement among experts, whether it is difficult to detect, or whether it is beyond people's control (Glik 2007). In this type of assessment, mass media can be a beneficial tool for the general population, assisting in the process of risk perception and the implementation of necessary safety or precautionary measures.

Due to its foundation in calculations and interpretations, the majority of scenarios involving risk communication are characterized by the active involvement of technical experts disseminating multiple messages, each contending for acceptance. The inherent uncertainty and ambiguity intrinsic to risk situations necessitate thorough deliberation as an integral facet of risk communication (Sellnow et al. 2009).

Uncertainty, originating from an inadequacy of information, prompts risk messages to mitigate this uncertainty through the generation and evaluation of the credibility associated with available evidence. Ambiguity materializes when the accessible information allows for more than one interpretation, leading to debates concerning the quality and appropriate application of this evidence. In response to ambiguity, risk messages advocate for a particular interpretation of existing evidence, asserting its superiority over alternative perspectives (Sellnow et al. 2009).

This perspective limits the mass media's effect on risk communication, as they can only attenuate or amplify a risk if it resonates with a pre-existing public sentiment (Petts et al. 2001). Additionally, individuals' pre-existing emotional states can also influence their reactions to crisis communication. Individuals who are sad, anxious, or angry have lower capacities to absorb new information (Glik 2007). Risk communication has transitioned from an initial stage of understanding what people think to an appreciation of how information and knowledge are exchanged within and between individuals and groups (Beck 2014).

Effective communication strategies for radon risk should target specific dimensions. Firstly, there is a need for empowerment, involving assistance for individuals at risk in making informed decisions regarding radon exposure. Secondly, enlightenment efforts should focus on fostering public understanding of radon risks, aiming to cultivate a "risk-literate" population through educational initiatives. Additionally, trust-building measures are crucial, involving support for radon risk management institutions in establishing and sustaining trust through transparent communication and demonstrating competence. Finally, conflict resolution plays a vital role, requiring assistance through involving major stakeholders and affected parties in the radon risk management process to ensure a collaborative and inclusive approach that addresses conflicts of interest and enhances the overall effectiveness of risk management initiatives. (Bouder et al. 2021).

Humans coexist daily with radon, which accounts for about 55% of all radiation a human being receives in their lifetime, as indicated by the following chart (Figure 1) prepared by the Natural Radioactivity Laboratory of Rio Grande do Norte, LARANA, at the Federal University of Rio Grande do Norte:

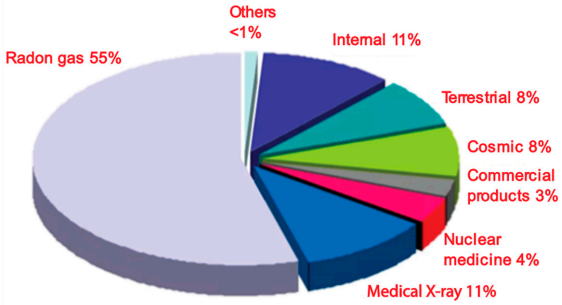

Figure 1. Radiation received by a human during their lifetime—https://pt.slideshare.net/restinpeaceAMEM/larana-cartilha-radonio (accessed on 27 June 2024) (Campus 2010).

The Portuguese Environment Agency, APA, also illustrates with a slight difference the amount of radiation a human receives per year, as explained in the following chart (Figure 2):

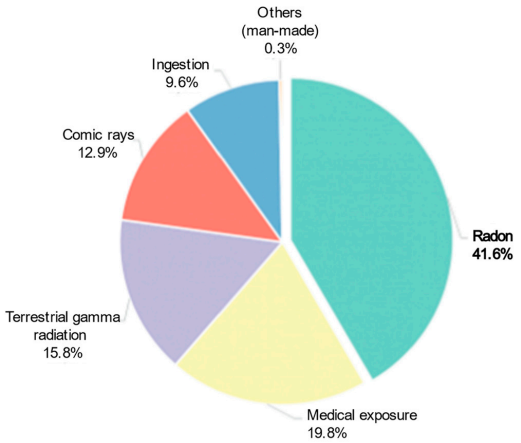

Figure 2. Percentage of the annual dose received by the world population—https://apambiente.pt/radao (accessed on 27 June 2024) (APA 2021).

Although differing in the exact numbers, both agree that radon is the primary radioactive agent to which a human being is exposed throughout the year.

Radon is a noble gas formed naturally through the decay of uranium and thorium present in the soil, which characterizes the gas as radioactive and carcinogenic. Its decay generates solid byproducts that can be inhaled and adhere to sensitive parts of the lungs. The rapid decay of these byproducts can expose these lung areas to radiation, destroying cells or affecting their DNA (CETESB 2018).

The elements that generate radon can be present in any type of soil, potentially causing harmful effects worldwide, but it is the concentration that affects how harmful this gas can be to human health.

The pressure and temperature differences in buildings cause air from the soil, contaminated with radon, to mix with the cold air entering homes. Since it is a tasteless, odorless, and colorless element, there is no natural way for a human being to sense its presence, and its concentration can cause serious health damage (CETESB 2018).

Radon is the leading cause of lung cancer development among non-smokers, estimated to cause about 21,000 lung cancer deaths per year (WHO 2009; Lacchia et al. 2020).

Although considered a serious health problem, the presence of the gas and its effects are relatively unknown to the general population. While prolonged exposure to radon is one of the most significant risk factors for lung cancer, public awareness and willingness to mitigate the risk are typically low, even in regions with high radon concentrations (Dametto et al. 2023). According to a British study on risk communication related to radon, when people are informed about the new risk, there is a strong tendency to rationalize:

> "When confronted with information about a risk they were unfamiliar with—Radon—they showed strong tendencies to rationalize, trying to make sense of why they hadn't heard about it, searching for explanations in the absence of (acute) evident deaths and even in the possibility that it was an invented issue designed to 'take money from people'". (Petts et al. 2001, p. 8)

It is inevitable that this process of rationalization requires people to resort to various and mixed sources of information, including mass media, but not limited to it, as there is also a search for non-mediated information. When people tried to find out about this "new" potential risk, they had difficulty relating the mediated knowledge provided by researchers to their everyday life (Petts et al. 2001; Skotnes et al. 2021).

As a result, analogies are commonly made to understand the problem. The study showed that people tended to process the danger of radon by comparing it to pollution, in addition to having high financial concerns about who would pay for radon tests and who is responsible for alerting the population about these dangers (Petts et al. 2001).

Portugal is a country already identified as problematic regarding radon, especially in its northern part. In 2020, the Portuguese Environment Agency conducted a major study in collaboration with the University of Coimbra to develop a detailed radon susceptibility map, along with a table specifically showing the incidence level by regions (Figure 3):[1]

Along with the study, communication materials and lectures were developed to contribute to raising awareness of the problem (Azeredo et al. 2022). The most recent information is that the APA is currently developing a national radon plan (PNR); in a study conducted by Silva and Dinis (2022), it was revealed that a significant majority of European Union member states, approximately 65%, have implemented a national radon plan.

The objective of this work is to understand the representation of radon risk in Portugal by the main digital media outlets, from the perspective of risk communication.

To achieve this objective, we formulated two hypotheses that will help fulfill this goal:

(a) The media does not use risk communication strategies to report on events related to radon.
(b) The danger of radon is underrepresented by digital media outlets in the country.

The investigation was carried out exclusively with online newspapers using the search bar of each of the highlighted portals, using the word "Radão" (radon in Portuguese).

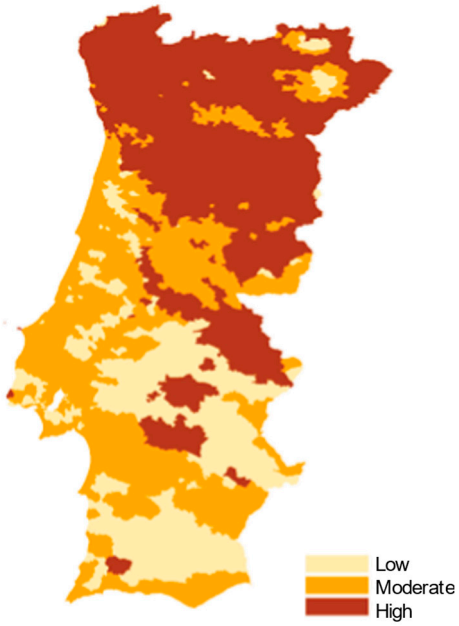

Figure 3. Radon susceptibility map—https://apambiente.pt/prevencao-e-gestao-de-riscos/mapa-de-suscetibilidade-ao-radao (accessed on 27 June 2024) (APA 2021).

2. Materials and Methods

To identify the major national digital news portals in Portugal, we used data from the 2015 study on audiences and media consumption conducted by the Regulatory Authority for the Media (ERC) (Públicos e Consumos de Média 2015). This study identified Jornal de Notícias, Correio da Manhã, Público, and Diário de Notícias as the most prominent national digital news portals in Portugal. Additionally, a more recent study by Cardoso et al. (2021) updated these findings, recognizing Expresso as another significant digital news source in the country.

For this analysis, we chose to exclude specialized newspapers from our selection, even if they appeared among the most accessed, as they were deemed not relevant to the topic of radon. This decision ensures that our focus remains on general news portals that are more likely to engage in broader public discourse and risk communication strategies relevant to radon gas exposure.

To refine the search results further, only articles that contained the word "radão" in their body were considered, as there were also news results that had similar words like "rádio" or "Rada".

A total of 85 articles were identified from all the newspaper databases, covering a period of 24 years. The search encompassed all entries of the term "radon" from 1998, the year of the earliest article found, to 2022. Notably, none of the analyzed news portals published any articles containing the term "radon" in their body text in 2023, up until the time of this study.

We initiated our study with a comprehensive content analysis, adhering to the framework established by Jensen (2021). This methodological approach allowed us to systematically evaluate the extracted news articles, ensuring an examination of how radon-related information was presented in the major national newspapers over the period:

> "In traditional content analyses, the researcher first decides on a unit of analysis (e.g., full news articles, individual sentences, headlines, words, or images). Next, the researcher develops a codebook, which is a guide to categorizing material. In general, codes should be non-overlapping and exhaustive, so as to identify and include all relevant categories". (Jensen 2021, p. 273)

Next, we categorized all the news articles into distinct frames, as outlined by Jensen (2021), with a focus on their value in shaping risk perception. This categorization was

guided by the risk communication models presented to better understand how the topic was framed and communicated.

> "The concept of a frame suggests that an item of information—whether arising from one's perception of the environment, from other people, or from media technologies—only makes sense once it is placed in a context of additional information [. . .]. We select some information from potentially endless masses of information; we bracket that information in a particular way, which constitutes a frame. Frames are, at once, mental and social categories—the outcome of both interpretation and interaction, a product as well as a process of framing ". (Jensen 2021, p. 169)

The 85 publications we found were divided into 8 categories, ranging from raising awareness about the dangers of the gas to human health, to categories where the gas is mentioned in the article but there is no relationship with awareness or its natural presence in Portugal. The categories also include specific situations that brought the problem to the forefront momentarily and were then forgotten. The categories are as follows (Table 1):

Table 1. Categorization.

Category	Number of News	Period
Relation of radon with mines	24	2003–2017
Relation of radon with earthquakes	9	2006–2021
Gas in schools	11	2004–2017
Lack of mandatory audits	5	2004–2017
Others (unrelated)	8	2009–2021
Others (marginally related)	12	2017–2022
Amplifier of risk perception (localized)	10	2007–2017
Amplifier of risk perception	6	1998–2020
Total: 8 categories	85	1998–2022

Based on this categorization, we will conduct a qualitative analysis to identify key points regarding risk communication strategy and their news potential (Glik 2007; Lundgren and McMakin 2018; Quivy and Van Campenhoudt 2005).

This qualitative analysis will be supported by a quantitative analysis of the representation of the term radon in comparison with other related terms. This arrangement sets up the proposed mixed method of analysis and guarantees a broader insight into the representation of the problem in the country's digital newspapers with the contribution of the percentage of this representation.

In order to have a comparison parameter for the representation of the subject in the country, we counted the results of this research and compared them with the results of other searches using the keywords "Poluição" (Pollution), which, according to Petts et al. (2001), people tend to rationalize the danger of radon through the perspective of pollution; "Aquecimento Global" (global warming), as it is a problem highly focused on by risk communication, as pointed out by Beck (2014); "Dióxido de Carbono" (carbon dioxide), as it is also a gas but with a stronger connection to global warming; and "COVID-19", the extreme global emergency that captured the attention of the news and can provide an interesting comparison parameter. The proposed results with a mixed qualitative and quantitative approach allows us, respectively, to understand how radon is being portrayed and the exact representation of the subject in the country's digital journalism.

The categories were divided based on affinity and according to the scope of the work, as can be seen below:

Category 1—relation of radon with mines: This totaled 24 news articles covering the period from 2003 to 2017. Within this category, there is a specific case that resulted in 16 news articles, which is the abandonment of the uranium mine in Urgeiriça, in the parish of Canas de Senhorim, that raised radiation levels in the region. The problem persists but is always treated in a very localized way, related to the mine. This relation of radon

with mines distances the idea of awareness or amplification of risk perception, especially considering that these are national newspapers.

Category 2—relation of radon with earthquakes: This included 9 news articles covering the period from 2006 to 2021. Within this category, there is a specific case that resulted in 4 news articles, which is the earthquake in the L'Aquila region in Italy. There was a scientist who managed to predict the earthquake due to high concentrations of radon in the region days before the event. Another factor that drove news coverage of this case was the arrest of scientists responsible for "predicting" earthquakes, the ability or inability to predict earthquakes is a theme in several news articles in this category. This relation of radon with earthquakes distances the idea of awareness or amplification of risk perception, as they are relatively rare events.

Category 3—gas in schools: This included 11 news articles, one from 2004, nine from 2015, and one from 2017. The episode that drew attention in 2015 was a measurement of gas in schools conducted by the University of Porto, which revealed high levels of radon and other gases in these environments, along with the reaction of some local authorities and school boards to the findings. However, the news articles did not provide information about the gas itself, focusing mainly on the levels of carbon dioxide revealed in the studies. Radon appeared only as a secondary or tangential element.

Category 4—lack of mandatory audits: This included 5 news articles, one from 2004 and four from 2017. It was noted that mandatory audits on air quality in environments such as schools, hospitals, gyms, and shopping centers had been lacking for 4 years and were no longer compulsory. The articles mention radon as one of the elements to be checked, which can be harmful to human health, but they focus mainly on the legislative aspect.

Category 5—others (unrelated): This included 8 news articles from 2009 to 2021. In this category, we gathered articles that mentioned radon but did not relate it to a public health issue.

Category 6—others (marginally related): This included 12 news articles from 2017 to 2022. This category includes articles where radon is merely mentioned. Out of these, 9 news articles are about lung cancer, with radon only alluded to as one of its causes, without further explanations about the origin or methods of prevention for radon exposure.

Category 7—amplifier of risk perception (localized): This totaled 10 news articles from 2007 to 2017. This is a category of interest for the study that considers radon as a harmful gas and seeks to increase awareness of the risk. However, these articles were all localized to a specific municipality or district and do not generalize the risk to all affected areas.

Category 8—amplifier of risk perception: This included 6 news articles from 1998 to 2020. This category is also of major interest for the study, as these articles seek to classify radon as a harmful gas in a particularly affected country. The mentioned study by the Portuguese Environment Agency in 2020 resulted in only two articles that increase awareness of the risk.

Our qualitative analysis was grounded in the framework established by Glik (2007), which emphasizes the concept of subjective assessment and the media's role in facilitating this process. To support our analysis, we drew on various sources, including Petts et al. (2001), Bouder et al. (2021), Pulimeno et al. (2020), Săpoi et al. (2023), and the discussions of social amplification by Lundgren and McMakin (2018).

By applying these theoretical perspectives, we aimed to examine the presence or absence of key elements within the news articles. Specifically, we focused on how these elements contribute to shaping public perception of risk. This part of our study involved categorizing the articles into distinct frames based on Jensen (2021) methodology, and then evaluating them for key points of subjective assessment as discussed in the aforementioned studies.

Based on this approach, we formulated the following questions that we will examine in the news articles and discuss its presence, partial presence (presence*), or absence, point by point, category by category:

Is the risk caused by human activities?

Can it cause illness or some type of medical condition?
Is the risk localized in a specific geographic area?
Is it a subject of disagreement among experts?
Is it difficult to detect?
Is it beyond people's control?
Are there statistical data available on the risk?

These questions serve as analytical criteria to assess how the media presents and discusses the topic of radon gas in relation to public perception of risk. The following Table 2 was compiled to analyze the presence of these subjective assessment conditions in the selected texts, thereby providing a detailed understanding of how risk communication strategies were employed by the media.

Table 2. Analysis table.

Category X: Category Name	X News Articles
Is the risk caused by humans?	Present/Present*/Absent
Can it cause illness or some type of medical condition?	Present/Present*/Absent
Is the risk localized in a specific geographic area?	Present/Present*/Absent
Is it a source of disagreement among experts?	Present/Present*/Absent
Is it difficult to detect?	Present/Present*/Absent
Is it beyond people's control?	Present/Present*/Absent
Are there statistical data on the risk?	Present/Present*/Absent

3. Results

(1) Relation of radon with mines:

The 24 news articles in this category are dominated by events in Urgeiriça, Canas de Senhorim. Portugal was one of the largest producers of uranium at a time when the harmful effects of radioactivity were not well understood. After the decline in demand for this material, the country's mines were left abandoned, and only in 2003 did the first concerns about radiation arise from the news article (ID3), stating that researchers would analyze the residues from Portuguese uranium mines. The results were astonishing, and for this reason, 12 out of the 24 news articles cover the period from 2003 to 2008 when the issue was being discussed. The details of Category 1 are presented in the (Table 3) below:

Table 3. Category 1.

Category 1: Relation of Radon with Mines	24 News Articles
Is the risk caused by humans?	Present*
Can it cause illness or some type of medical condition?	Present
Is the risk localized in a specific geographic area?	Present*
Is it a source of disagreement among experts?	Absent
Is it difficult to detect?	Present
Is it beyond people's control?	Present*
Are there statistical data on the risk?	Absent

All the highlighted texts mentioned the presence of radon gas in the mine debris. However, they fail to explain the natural occurrence of radon gas, limiting it to mining activities.

Although the effects mentioned in the texts are often associated with radiation in a broader sense, not necessarily radon gas specifically, the news articles explain the toxicity to which mine workers were exposed and even showed the demand at the time of these workers for oncological screening.

The criticism to be pointed out is that the problem seems to be confined only to mining activities and specific regions. There is no explanation of other areas that could also be affected by the gas.

There are no debates among experts presented in any of the texts.

The texts mention the qualities that make the gas difficult to detect, highlighting the government's radiation detection program in the area, which has been a subject of debate among the miners.

There are no clear indications of combating the presence of the gas; the texts focus mainly on building refurbishments and sealing of the mines.

There is no presentation of statistical data on the incidence of diseases or even the presence of the gas in the region.

(2) Relation of radon with earthquakes:

In this category, which includes nine news articles from 2006 to 2021, we have the case of the earthquake in L'Aquila, Italy, which generated four direct news articles, with ID14 being an opinion article. A constant theme in this group is the debate about whether it is possible or not to predict earthquakes. Italian scientist Giampaolo Giuliani claimed to have predicted the earthquake that occurred, warning the locals to evacuate the city before the earthquake. He argued that the levels of radon had increased and that this was an indication that a major earthquake would occur. On the other hand, scientists debate this idea by presenting places with high seismic activity where radon levels rise but no earthquake occurs, as evidence that the events are not directly related. According to ID84, the best available technology for earthquake prediction is the installation of sensors at sea, so that authorities can have a few seconds of advance warning before the earthquake, which would be enough time to "open doors, shut off gas, or make elevators stop at the right places". The details of Category 2 are presented in the (Table 4) below:

Table 4. Category 2.

Category 2: Relation of Radon with Earthquakes	9 News Articles
Is the risk caused by humans?	Present
Can it cause illness or some type of medical condition?	Absent
Is the risk localized in a specific geographic area?	Present
Is it a source of disagreement among experts?	Present
Is it difficult to detect?	Present
Is it beyond people's control?	Present
Are there statistical data on the risk?	Absent

Regarding earthquakes, it is evident that the risk is not caused by humans, so the articles focus on what happened in the case of the earthquake in Italy or on its prevention.

The various traumas that earthquakes can cause are not covered in the articles. When radon is mentioned, there is no explanation of its toxicity to people.

When discussing the earthquakes that occurred, there is a distinction in terms of location. When the articles focus on prevention, it becomes difficult to pinpoint an exact location, although they mention seismological activity in the Azores and even in Lisbon.

Even if prediction is possible, it is clear that there are no available means of controlling earthquakes.

There is no statistical information available in the articles about earthquakes or radon.

(3) Gas in schools:

This category includes 11 news articles, with nine of them from 23 and 24 September 2015. On that occasion, a study revealed significantly higher levels of radon and carbon dioxide than recommended in schools in the districts of Porto and Bragança, both in northern Portugal. The news articles also mentioned situations where school administrations or local authorities claimed to be unaware of and not having authorized the study, although the researcher pointed out that "the institutions showed concern in rectifying the situations". Despite the alert, the articles tend to focus more on the concentration of carbon dioxide and fine particles, and the condition of developing asthma in children attending

these environments. Thus, radon is only mentioned as a carcinogenic gas, without further explanations about its origin or prevention methods. The details of Category 3 are presented in the (Table 5) below:

Table 5. Category 3.

Category 3: Gas in Schools	11 News Articles
Is the risk caused by humans?	Present*
Can it cause illness or some type of medical condition?	Present*
Is the risk localized in a specific geographic area?	Present
Is it a source of disagreement among experts?	Absent
Is it difficult to detect?	Absent
Is it beyond people's control?	Present
Are there statistical data on the risk?	Absent

Considering the emphasized risk in the articles, regarding carbon dioxide and fine particles, it is understood to be caused by humans, as simple cleaning and ventilation of the premises could solve the problem. Radon is mentioned as "natural", without further explanations.

The main medical condition mentioned in the texts is the development of asthma. Radon is only referred to as carcinogenic.

The study is limited to schools and daycare centers in the districts of Porto and Bragança.

The articles are based solely on the study conducted by Sofia Sousa, a professor and researcher at the Faculty of Engineering of the University of Porto (FEUP), without discussion with other experts.

Although it is explained that a scientific study was necessary to detect these gases, there is no explanation of how this detection is performed and the need for a researcher for this purpose.

Ventilation of the rooms, especially after cleaning, is recommended in all the articles.

The statistical data presented are related to the number of schools and daycare centers analyzed, indicating that over 50% have carbon dioxide concentrations above the legally prescribed thresholds in Portugal. However, there are no statistics provided regarding the risks of this exposure.

(4) Lack of mandatory audits:

This category consists of five news articles, with four of them from November 28 2017. These articles focus on the loss of rigor in legislation. Due to this loss, gyms, schools, shopping centers, and hospitals had gone 4 years without mandatory audits for air quality. Interestingly, the only news article in this category that does not refer to these events is from 2004, and it specifically focuses on the lack of a plan for verifying indoor air quality.

Radon is mentioned in the texts as a metric to be evaluated, but it falls under the concept of "pollutants", without delving into any health issues or risks associated with the gas. The details of Category 4 are presented in the (Table 6) below:

Table 6. Category 4.

Category 4: Lack of Mandatory Audits	5 News Articles
Is the risk caused by humans?	Present
Can it cause illness or some type of medical condition?	Absent
Is the risk localized in a specific geographic area?	Absent
Is it a source of disagreement among experts?	Absent
Is it difficult to detect?	Absent
Is it beyond people's control?	Present
Are there statistical data on the risk?	Absent

The risk that the news articles are based on is precisely the lack of mandatory audits, something that, according to the texts, should be addressed through stricter legislation.

Although the articles mention that air quality inspections found "pollutants such as radon" in addition to legionella, they do not go beyond this statement to explore the diseases they could cause.

Since the texts focus on legislation, it is understood that the risk applies throughout the country, but it is limited to indoor environments. There is no further explanation regarding the geographic location of this risk.

Only Nuno Roque, Secretary-General of the Portuguese Association of Companies in the Thermal, Energy, Electronic, and Environmental Sectors, is consulted as a source.

The difficulty of detection is not addressed, so it is implied that only a specialized technician would be able to detect the presence of these gases, although the articles do not elaborate on the qualities of the pollutants.

It is suggested that the only way to control the risks posed by pollutants is through more robust legislation, with periodic technical visits to establishments for measurement.

No statistical data are presented as a means of comparison or supporting information.

(5) Others (unrelated):

This category includes eight news articles that, although containing the word "radon" in their body text, do not make any reference to the subject being studied. The articles can have a promotional tone, such as ID18 and ID33, an opinion article about homeopathy like ID19, or even discuss a technological advancement with high sensitivity that can ignore radon present in the soil, like ID28.

Because of this, most of the news articles in this category are not considered risk communication, despite the term "radon" appearing in all of them. This condition excludes the applicability of the framework developed for this category.

(6) Others (marginally related):

With 12 news articles, category 6 can be considered the one with the most recent texts, covering the period from 2017 to 2022, with only ID47 from 2010. The dominant theme in this category is lung cancer, with pollution, radon, and smoking appearing as catalysts for this condition.

Even the global emergence of COVID-19 is included in this category, in ID82 and ID83, indicating that ventilation of indoor spaces was beneficial not only for COVID-19 but also for reducing radon accumulation, although it fails to explain the reason for this analogy. The details of Category 6 are presented in the (Table 7) below:

Table 7. Category 6.

Category 6: Others (Marginally Related)	12 News Articles
Is the risk caused by humans?	Present
Can it cause a disease or medical condition?	Present
Is the risk localized to a specific geographic area?	Absent
Is there disagreement among experts?	Absent
Is it difficult to detect?	Absent
Is it beyond people's control?	Present*
Are there statistical data about the risk?	Present

Most of the texts are based on a document from the European Environment Agency, which highlights pollution, smoking, and certain cleaning products as the main carcinogens. Following the recommendations in this document, the authors state they can reduce the levels to negligible levels.

The main focus of the texts is the medical condition that can be caused, along with the agents that can contribute to this condition.

It is not specific to a geographic area, but rather provides general indications for the European continent.

A single document is used as a source in most of the news articles, although it is acknowledged that the composition of this document has been the subject of much debate among experts; these discussions are not addressed in the articles in question.

With the exception of ID35, which focuses on early detection and symptoms of lung cancer, the other articles do not share the same emphasis and instead highlight pollution.

The articles imply that adopting the measures proposed in the document can reduce the cases of lung cancer on the continent, but they do not provide specific examples of these measures.

Various statistical data on the incidence of cancer in the continent and the main catalysts are presented.

(7) Risk perception amplifier (localized):

The 10 news articles in category 7, "Risk Perception Amplifier (Localized)", mainly focus on the northern region of the country, including Vila Real, Porto, Viseu, and Guarda. They primarily discuss studies conducted by researchers during their doctoral programs at universities. The articles emphasize the scientific aspects of the studies, which reveal radon concentrations higher than the limits set by the European Union. However, they fail to provide detailed explanations of the origin of the gas, stating only that it comes from uranium in the subsoil. They also do not thoroughly explain how it harms human health. Additionally, prevention measures are rarely emphasized in the texts, with only brief mentions of ventilation systems in basement areas and requalification works.

The risk awareness regarding the gas is also not strongly reinforced, as the articles tend to present the situation as "not very concerning" or "no cause for alarm". In fact, news article ID49 specifically discusses the lack of concern among residents of Amarante regarding the discovery, stating that their habits were not changed. The details of Category 7 are presented in the (Table 8) below:

Table 8. Category 7.

Category 7: Risk Perception Amplifier (Localized)	10 News Articles
Is the risk caused by humans?	Present
Can it cause a disease or medical condition?	Present*
Is the risk localized to a specific geographic area?	Present*
Is there disagreement among experts?	Not present
Is it difficult to detect?	Present*
Is it beyond people's control?	Present*
Are there statistical data about the risk?	Absent

All the articles highlight the natural presence of the gas, making it clear that the risk is of natural origin. However, they do not generalize this risk to the entire region, focusing only on the central areas of the affected cities where the studies were conducted.

The same level of emphasis is not given to the discussion of diseases. Some texts mention that the gas could cause lung neoplasms, but they do not provide examples of how this could happen. The process by which the gas acts as a catalyst for lung cancer is not mentioned.

The risk is presented as specific to a geographic area, such as the central areas of Amarante or the historic zone of Guarda. However, a 2020 study by the Portuguese Environment Agency (APA) found that a large portion of the soil in northern Portugal is contaminated, not just the areas mentioned in the texts.

The news articles were based on studies conducted by experts, and no contradictory opinions or other sources were presented. Since the last news article in this category is from 2017, there were likely no additional studies available at that time to support the data presented in the Portuguese context.

Regarding the detection of the gas, the texts clearly state its odorless and tasteless properties, making it difficult to detect. They emphasize the need for scientific equipment

and technical expertise to measure the gas, mentioning that the installed detectors were sealed in metal to avoid material loss and sent to the study's laboratories.

The actions people could take to control the situation, such as forced ventilation of basements and requalification works, were only briefly mentioned. Simple ventilation of indoor spaces was also mentioned but was not the primary focus of the news articles.

No statistical data were provided to support the risk of gas concentration in households or its incidence in the country or region.

From the perspective of risk communication, these news articles have little value in amplifying the perception of the problem. They do not properly fulfill the basic criteria for risk assessment, generating little or no impact on people's behavior, even for those located in the reported regions. The study by Petts et al. (2001) also highlights the need for humanization, showcasing cases of people who have suffered from the consequences of these risks and providing statistics that support the need for action. None of the news articles in this category provided any related information in this regard.

(8) Risk perception amplification:

Category 8: Risk perception amplification consists of six news articles published in 1998 (the oldest news article in the study) 2000, 2004, 2011, and 2020 (during the study period conducted by the Portuguese Environmental Agency). The last two articles, both from this year, relate to the beginning of the APA study. The time gap between the articles raises concerns regarding risk communication, as stated by Beck (2014) and Petts et al. (2001). To effectively inform the population about a risk, the media should adopt a narrative format, which was not observed in the analyzed articles. Despite the extensive time period covered, there was a scarcity of news on the subject.

Applying the same concepts of risk evaluation tools provided by the media, the following Table 9 was developed:

Table 9. Category 8.

Category 8: Risk Perception Amplification (Localized)	6 News Articles
Is the risk caused by humans?	Present
Can it cause illness or medical conditions?	Present
Is the risk specific to a geographical area?	Present*
Is there disagreement among experts?	Absent
Is it difficult to detect?	Present
Is it beyond people's control?	Present
Are there statistical data on the risk?	Present*

The texts explore the nature of the risk, explaining in an accessible way its natural presence in granite soils and how it is accentuated in fragmented soils.

Category 8 was much more emphatic in associating the presence of the gas with lung cancer, and took greater care to elucidate how this process takes place.

In the case of national newspapers, the articles explain which parts of the country are most exposed. However, after drawing up the APA map presented above, we have confirmation that more areas than those explained in the selected news stories are affected, even though they mention that the country's geological differences could provide different results for different areas, the news stories seemed to focus on only part of the affected areas.

In all cases, the news stories either dealt with a study that had already been carried out, such as the 1998 Público story on a British study, or with studies that were yet to be carried out, as in the case of the 2020 news stories. The very scarcity of scientific studies means that there is not necessarily a clash of contradictory ideas, although the need for discussion is not even questioned, since there is a certain precision in the measurements made.

The properties of the gas are measured in all the texts, which implies that it is difficult to detect; three (ID25, ID37 and ID65) of the six texts selected still provided data, so that a test could be ordered for the home.

Ventilation is identified as a form of control, as well as building shapes and materials that prevent radon from accumulating. Another point raised about control is that it accumulates more in the winter months, when there is less tendency for natural ventilation.

Some statistical data on the health risks were exemplified, such as the increased rate of lung cancer among people who lived with the gas. Another statistic provided was the incidence of the problem in Europe, making it the second biggest cause of lung cancer, behind smoking. Statistics on the presence of the gas in the country would also contribute to increasing the perception of risk, but were not noted.

From a risk communication perspective, these articles have some value in amplifying awareness of the issue, even if they do not strictly meet the basic criteria for risk assessment. However, their impact on people's behavior is minimal. The selected news articles also lacked a humanization aspect, as no examples or testimonials highlighting the magnitude of the problem were featured.

To gain a thorough understanding of how radon is portrayed and emphasized across Portugal's major news portals, we undertook a quantitative analysis. This method involved meticulously comparing the volume of publications identified through specific search queries using the terms detailed in Table 10 below:

Table 10. Term quantities in comparison.

Term Quantities	Jornal de Notícias[2]	Correio da Manhã	Público	Diário de Notícias	Expresso	Total
Radon	21	8	29	20	40	118[3]
Pollution	100	1757	100	100	1890	3947
Global warming	100	891	100	100	1637	2828
Carbon dioxide	100	588	100	100	1228	2116
COVID-19	100	29,250	100	100	35,618	65,168

The data reveal a clear underrepresentation of radon gas as a problem in the country's major digital news outlets compared to any of the other searched terms. When considering only the data from Correio da Manhã and Expresso, which do not limit the number of search results, the issue of radon gas was reported at a mere 0.027% and 0.112%, respectively, compared to COVID-19. In comparison to the term "pollution", the representation is 0.45% and 2.11%; for "global warming", it is 0.89% and 2.44%; and for "carbon dioxide", it is 1.36% and 3.25%.

In all cases, the representation of the term "radon" in the newspaper coverage is close to null, and the lack of repetition is certainly one of the factors contributing to the general unawareness of the danger. It was only minimally reinforced in 16 articles where radon was the main subject (considering categories 7 and 8), spread over a period of 24 years.

4. Discussion and Conclusions

Below considers the two hypotheses proposed by the study:

Hypothesis 1 (H1). *The media does not use risk communication strategies to report on events related to radon.*

Hypothesis 2 (H2). *The danger of radon is underrepresented by digital media in the country.*

Hypothesis 1 was partially supported; while some texts employed risk communication strategies, the inconsistency and limited prominence of the subject suggest that the risk of radon exposure lacks substantial amplification in the perception of the population through Portugal's major digital media outlets. Hypothesis 2 was confirmed.

The comprehensive nature of this study, encompassing all relevant news from the major digital newspapers in Portugal, inherently reveals the issue's underrepresentation in

the country. The relatively low number of news articles addressing radon, a longstanding issue first reported by Público newspaper in 1998, indicates a lack of public traction, as highlighted by Jornal de Notícias in 2011 (ID49). The subsequent 12 years following this noted indifference, shown by little change in this scenario, underscored by a national study in 2020 that resulted in only two news articles (ID25 and ID37). This national study aimed to create communication pieces for awareness, but it failed to reach the public, at least from the perspective of the country's major digital newspapers. Coordination between research institutions and newspapers could generate better results in this regard.

Mass media tends to anchor new risk communication articles to existing fears and anxieties deeply rooted in popular culture (Petts et al. 2001). This tendency was also evident in the case of COVID-19, where examples of older epidemics or pandemics such as MERS, SARS, and the Spanish flu were extensively used to illustrate the potential dangers of the new disease.

Without a direct precedent for radon, the news articles were more associated with the presence of dangerous gases and elements in mines or with catastrophes such as earthquakes, which accounted for a significant portion of the articles (33 instances or 38.8% of the news about radon). The perception of risk in mines and excavations is already ingrained in the popular imagination. Due to the lack of such precedents, it is common for news about radon to only gain prominence based on the news value of novelty when someone reveals a study in a specific area, without being anchored to a previous problem.

The use of such anchoring is detrimental to the perception of a risk that is quite present in a large part of the country, as it associates it with an exotic and distant event that is far removed from the majority of the population, whereas the danger is not. The underrepresentation is also strongly evident when comparing search terms; hardly anyone who has not studied or has a specific interest in the field would even know what radon is or what damage it can cause.

To effectively prompt individuals to take proactive measures against this pervasive threat that impacts more than 50% of Portugal's territory, it is recommended that there is coordination of media efforts to raise awareness of this risk. Experts in risk communication should strategically harness mass media platforms. Although not within the scope of this study, there is potential in leveraging tabloids and local newspapers to narrate human-interest stories, complemented by national newspapers that provide scientific and statistical insights into the issue. This integrated approach could prove potent, particularly when supplemented with compelling visuals and symbols that resonate with the audience, as highlighted by Petts et al. (2001).

The current journalistic crisis, with staff and budget cuts, may also explain the lack of interest in reporting on a serious yet non-acute problem. It is important to highlight that the media are not official conveyors of risk information, but rather potent tools for amplifying perception. They actively interpret and mediate, aiming to resonate with social preferences and concerns, thereby maintaining their position. Thus, they become entrepreneurs of meaning, transforming raw information and official events into products that bear their presentation style and market brand. Consequently, the safe bet is often chosen over what would be most beneficial for the consuming population.

Enhancing the communication and dissemination of information regarding radon is crucial, given its widespread presence and potential risks. This can be achieved through a coordinated effort involving researchers, risk communication experts, and media outlets to ensure that the public receives accurate and accessible information about radon and its potential consequences.

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Notes

1 Radon Susceptibility Index by Parish, available at: https://apambiente.pt/sites/default/files/_Prevencao_gestao_riscos/Protecao_radiologica/DPA_Rad%C3%A3o/SuscetibilidadeRadao_Freguesia.pdf, accessed on 20 May 2024.

2 The Jornal de Notícias, Público, and Diário de Notícias limit the search results to a maximum of 100.

3 These results include texts with the words "rada" and "rádio", which is why the count is higher than the sample selected for the study on radon.

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