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Guidelines for Managing Radon Hazards in Tourist Volcanic Caves in Spain

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Abstract Tourist volcanic caves are in high demand for ecotourism and geotourism lovers, as well as by sun and beach tourists as a complementary activity during their holidays. There are six tourist volcanic caves in the Canary Islands, all of them managed by the local administration of the island. The managers of these caves must ensure the safety of visitors and workers, who are exposed to natural hazards, such as radon, inherent to the environment in which the activity takes place. The methodology for analyzing natural radon radiation is based on the latest studies published by experts in this field and on previous experiences in tourist caves. This article proposes a protocol for the correct management of radon in tourist caves in the Canary Islands, adapted to current regulations, to mitigate effects on the health of visitors and workers.

Plain Language Summary In our study, we explored the popular volcanic caves in the Canary Islands, a hit among those who love ecotourism and geotourism, and also among beachgoers looking for something different to do on their vacation. These six caves, all managed by the island's local authorities, offer a unique adventure but come with their own set of risks, like exposure to radon gas-a natural hazard in such environments. To keep everyone safe, we delved into the best ways to monitor and manage radon levels, drawing on the latest research and what's been learned from other tourist caves. Our work led to the development of a new plan that fits within current health and safety laws, aimed at reducing any health risks to visitors and staff. This plan is a step forward in making sure that exploring these magnificent caves is not only an unforgettable experience but also a safe one for everyone involved.

Key Points:

- Tourist caves, especially volcanic ones in the Canary Islands, attract many visitors, offering geological and commercial opportunities
- Radon hazards is a major health concern that needs to be considered in the management of underground spaces such as tourist caves
- Sustainable tourism management requires environmental and cultural responsibility, ensuring the preservation of caves

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1. Introduction

The term tourist cave refers to an underground cavity, artificial or natural, exploited for tourist purposes, which may have been prepared for visits, has staff to guide the visit and may require payment in advance for the service provided (Šebela et al., 2013). In this sense, volcanic caves are an important tourist resource for the Canary Islands and receive a large number of tourists each year who visit them, confident that the managers and those responsible for them have adopted the necessary safety protocols (Sanmiquel et al., 2018). There is also an important group of workers who carry out their work inside the caves, such as guides and maintenance personnel. All these people are exposed to natural hazards, such as radon gas, that must be considered in the management of tourist caves (Sainz et al., 2007).

In Spain, karst cavities dominate massively, being found on the Iberian Peninsula and in the Balearic Islands (Ballesteros et al., 2015). They are followed, to a lesser extent, by volcanic caves. The exploitation of volcanic caves as tourist facilities is restricted exclusively to the Canary Islands, an archipelago of volcanic origin. Tourist development of these cavities has not been restricted to guided visits through the underground galleries, in order to contemplate the geological structures or the biodiversity they house. Rather, in some of the most spacious caves, spaces have been arranged for artistic representations, rooms of exhibitions, wineries or restaurants (Júnior & Lobo, 2012).

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Numerous volcanic cavities or volcanic tubes have been identified in the Canary Islands, as a result of the intense volcanic activity of the islands since their formation 20 million years ago (Socorro, 2009). Of these, only the following are currently being exploited as tourist caves: *Cueva del Llano* (island of Fuerteventura), *Cueva del Viento* (island of Tenerife), *Cueva de Los Verdes* (island of Lanzarote), *Jameos del Agua* (island of Lanzarote), *Tubo Volcánico de Guinea* (island of El Hierro), and *Cavidades Volcánicas "Caños de Fuego"* (island of La Palma) (Figure 1).

The tourist management of these caves entails certain peculiarities that are not dealt with in other types of tourist establishments. Being natural underground resources, this activity is exposed to certain natural hazards, which is important to recognize, evaluate and, where necessary, adopt the necessary measures to guarantee the safety of visitors and workers (Bucci et al., 2011). Therefore, managers of this sustainable tourism product are often faced with the unique problems of a natural underground facility. Responsible management of a tourist cave must ensure the safety of workers and visitors, the enjoyment of the tourist resource, and sustainable management to maintain the environmental and natural balance of the cave (Cigna, 1993). Radon exposure of tourists and workers is a major natural hazard faced by tourist cave managers and many studies have been conducted in these caves around the world (Anderson et al., 2021; Grygier et al., 2022; le Roux et al., 2023; Sanmiquel et al., 2018; Solomon et al., 1996). Safety and environmental and natural balance are compromised by the natural hazards that can affect underground caves.

In the Canary Islands, underground water galleries, which can be considered hydrogeological mines, are used to transport water from the aquifer to the surface (Santamarta & Lario-Bascones, 2015). Measurements have been taken in this type of installation and, in practically all cases, radon values exceeded the limits recommended by current regulations (Santamarta, Hernández-Gutiérrez, Rodríguez-Martín, Lario-Bascones, et al., 2020; Santamarta, Hernández-Gutiérrez, Rodríguez-Martín, Marrero Díaz, et al., 2020). Due to the propensity of the Canary Islands to have high levels of radon gas in underground facilities, a specific technical guide has been developed on good practices against exposure to radon gas in underground hydraulic installations in this region (Santamarta, Hernández-Gutiérrez, Rodríguez-Martín, Lario-Bascones, et al., 2020; Santamarta, Hernández-Gutiérrez, Rodríguez-Martín, Marrero Díaz, et al., 2020).

This article proposes a methodology to analyze one of the main natural hazards affecting tourist volcanic caves in volcanic tubes in the Canary Islands, which is natural radiation by radon gas, and to establish protocols for the efficient ecotourism management of these facilities, mainly attending to the safety of workers and visitors.

1.1. Radon Gas in Tourist Caves in the Canary Islands

Radon is a radioactive gas from rocks and soils that tends to accumulate in the air of underground cavities and, in certain quantities, is very dangerous to human health (Robertson et al., 2013). It should therefore be considered as one of the main occupational health problems in volcanic tourist caves (Torres-González et al., 2019).

Radon damages people's health by inhalation. Radon atoms settle in our respiratory tract and, when they disintegrate after their short lifetime (3–4 days), they emit radiation that damages the deoxyribonucleic acid (DNA) of our cells, making them carcinogenic (Denton & Namazi, 2013). Exposure over short periods of time is not dangerous; hence, it is not a major risk for visitors to tourist caves, but it is a risk for cave workers, who remain in the underground facility for many hours during their working day (Santos et al., 2014).

In this regard, volcanic territories are potentially dangerous geological environments, as they have the capacity to emit large quantities of radon gas into enclosed spaces (CSN, 2012). On the other hand, tourist volcanic caves are formed inside pahoehoe lavas of basaltic composition. Volcanic rocks are potential radon producers, but not all volcanic rocks emit the same amount of radon; based on their chemical composition, it is the acidic or salic rocks that contain higher amounts of uranium and thorium (Hernández et al., 2012; Rodríguez-Losada et al., 2022). In the case of the Canary Islands, as the recent volcanic units are very permeable, by cracking during cooling-induced contraction of lava, the radon exhaled by the salic rocks can rise by convection through the joints, to settle in the cavities of the basic units and increase the concentration of radon. For this reason, there are many studies here that have measured radon concentrations that widely exceed the threshold limits established by international recommendations and Spanish regulations (Eff-Darwich et al., 2002; Padilla et al., 2013; Santamarta, Hernández-Gutiérrez, Rodríguez-Martín, Lario-Bascones, et al., 2020; Santamarta, Hernández-Gutiérrez, Rodríguez-Martín, Marrero Díaz, et al., 2020). It is therefore necessary for those who manage volcanic tourist

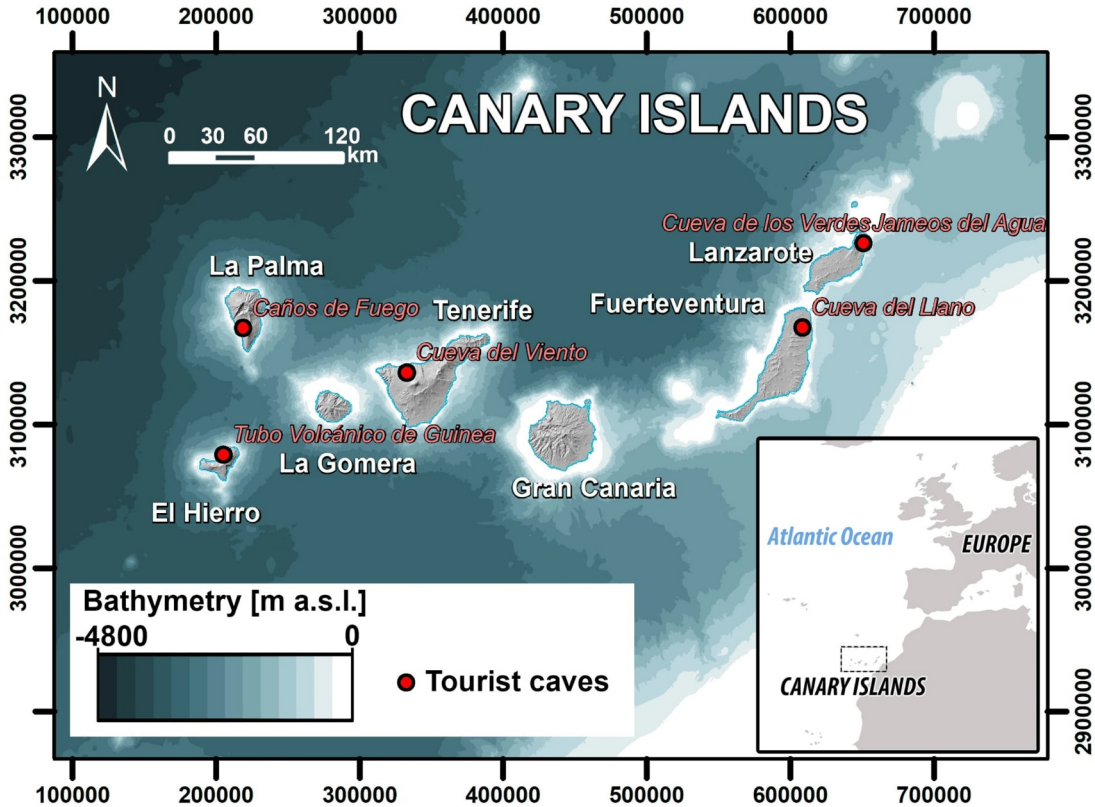

Figure 1. Tourist caves in the Canary Islands, Spain.

caves to develop the relevant studies and controls on radon gas concentration in the air, and to have measurement and mitigation protocols in place to comply with the regulations that safeguard the health of workers and visitors (Santamarta et al., 2021).

Although the Spanish legal system does not include specific legislation for the management of tourist caves, there are regulations that refer to these installations in terms of safety, in the field of ionizing radiation from radon, which must be considered by the managers of the tourist resource. The Council Directive 2013/59/EURATOM of 5 December 2013 (European Commission, 2014) is mandatory for all European Union member states and establishes "*uniform basic safety standards applicable to the protection of the health of persons subjected to occupational, medical and public exposure against the dangers arising from ionizing radiation*." The standard specifies that "*the reference level for the annual average radon concentration in air shall not exceed 300 Bq/m^3 unless justified by national circumstances*." The Spanish Regulation on Sanitary Protection against Ionizing Radiation (SRSPIR) establishes that it is the responsibility of the owners of tourist caves to carry out the pertinent studies to determine whether workers and visitors are exposed to significant concentrations of radon gas (Ministerio de la Presidencia, 2022).

2. Materials and Methods

2.1. Procedures for Studying Indoor Radon Concentration in Caves

The questions that should occupy and concern managers responsible for compliance with the regulations on radon in tourist caves are: who may carry out the mandatory studies; what content they must have; how often they must be presented to the administration; where they must present them; what type of controls and radon measurements must be done and with what periodicity.

The Nuclear Safety Council of Spain (CSN) outlines the procedure to carry out the mandatory studies required by Spanish regulations. The purpose of these studies is to determine if the average annual concentration of radon to

Figure 2. Traffic light for assessment of radon concentration results (Hernández Gutiérrez et al., 2019).

which workers or the public are exposed exceeds the established reference level (CSN, 2012). Accordingly, these studies must be structured in the following four phases:

(1) Planning
In this phase, the following aspects must be defined: homogeneous areas of radon concentration, types of detectors, their location and exposure times. In order to design an effective measurement campaign, it is first advisable to carry out measurements along the cavity with an active continuous measurement detector. This makes it possible to estimate what concentration levels will be obtained in long measurement periods, which points in the cavity are expected to have higher radon concentrations, and to define areas or sections with similar radon concentrations (homogeneous areas) where the passive trace nuclear detectors (DTPA) will be subsequently placed.

(2) Exposure and analysis of the measurement devices
DTPA are the detectors to be used for long exposure times. For underground workplaces, it is recommended that the exposure period of the detectors be 1 year. The CSN recommends that DTPA devices be exposed in four consecutive periods of 3 months each. These detectors should be analyzed by an accredited laboratory according to the ISO/IEC 17025 Standard.

(3) Expression of results and decision making
The 4-color traffic light system (green, blue, orange and red), shown in Figure 2, is used to evaluate the results of radon concentration measurements. Each color corresponds to different reference levels of mean radon concentration (CRn), expressed in Bq/m^3, measured in an indoor workplace over a period of 3 months (Hernández Gutiérrez et al., 2019). These levels are based on the following premises, obtained from recommendations of different public health institutions:

Green (CRn < 100 Bq/m^3): the epidemiological studies referred to by the World Health Organization (WHO, 2009) have shown that there is a statistically significant greater risk of suffering from lung cancer at this concentration.

Blue (100 ≤ CRn ≤ 200 Bq/m^3): the government of the United Kingdom recommends that, if the indoor values in homes exceed 200 Bq/m^3, preventive measures should be taken against radon.

Orange (200 ≤ CRn ≤ 300 Bq/m^3): the upper limit established by the CSN (CSN, 2023) to consider it a priority action area against radon is 300 Bq/m^3.

Red (CRn ≥ 300 Bq/m^3): the reference level established by the European Union, through Directive 2013/59/EURATOM (European Commission, 2014), which says that the reference level for the annual average concentration of activity in the air in member states will not exceed 300 Bq/m^3.

(4) Design and implementation of measures to reduce radon exposure
Ecotourism managers should endeavor to keep exposure for workers and visitors as low as is reasonably achievable, always taking labor, technical, social, and economic factors into account. Remediation solutions can be of two types: (a) constructive solutions consisting of the implementation of air extraction systems; (b) organizational solutions to control the permanence times or to restrict access in critical areas. For esthetic reasons and because of loss of authenticity of the natural tourist resource, type-a solutions are difficult to implement.

(5) Declaration of studies on radon to the competent administration
The Regulation on Sanitary Protection against Ionizing Radiations published in the Spanish Official State, establishes that the managers of tourist caves must declare activities to the competent administration, in matters of the industry of regional governments. In the case of the Canary Islands, this body is the Regional Ministry of Tourism, Industry and Energy of the Government of the Canary Islands.

2.2. Opinion of the Stakeholder

In order to ascertain the opinions, concerns and needs of the managers and those responsible for volcanic tourist caves currently operating in the Canary Islands, interviews were conducted with a selection of people involved in the management of these caves. The questions posed to the interviewees were: (a) What are the most frequent management problems encountered by those responsible for tourist caves? (b) What are the management

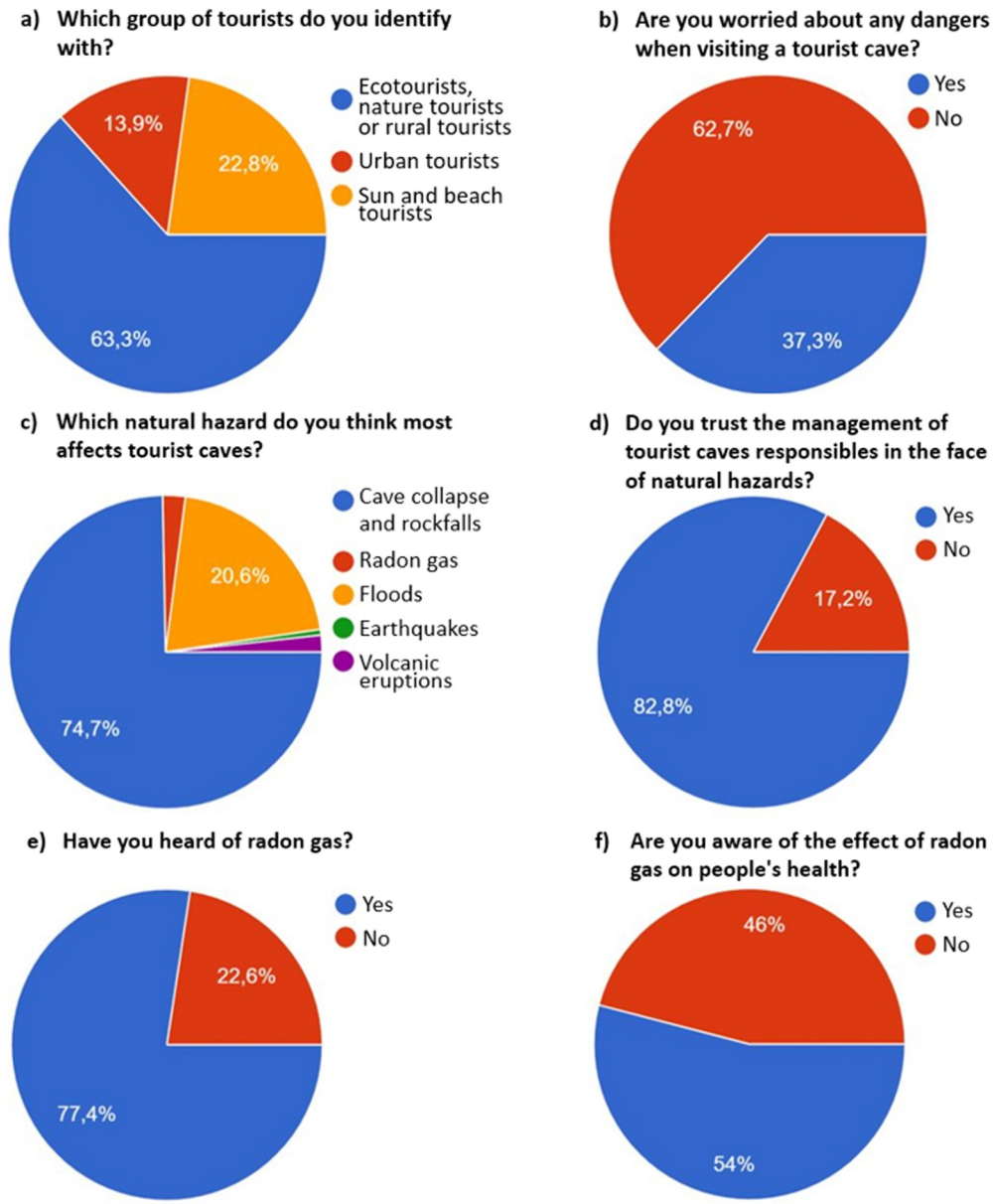

Figure 3. Opinion results of potential visitors to tourist caves.

problems that most concern those responsible for tourist caves? (c) In your opinion, what natural hazards affect tourist caves? (d) In the management of tourist caves, is there any program or protocol for the monitoring or control of the natural hazards that affect these facilities? (e) What protocols, if any, are in place for the monitoring or control of the natural hazards that affect these facilities? (f) What protocols, which you do not have, would you like to have in place for the monitoring or control of natural hazards affecting these facilities?

The opinions of potential visitors to tourist caves, regarding their perception of exposure to natural hazards, were obtained through an online survey of a sample of 346 respondents (Figure 3). The questions were: (a) Age; (b) When it comes to tourism, which of the following groups do you identify with? (c) Do you practice or have you ever practiced nature tourism, geotourism or rural tourism? (d) Would you be interested in visiting a volcanic cave or volcanic tube? (e) When or if you visit a tourist cave, do you have the feeling of being exposed to any kind of danger or is there any kind of danger that worries you? (f) What natural danger, if any, do you feel you are exposed to? (g) Which of the following natural hazards do you think most affect the safety of tourist caves? (h) Do you

have confidence in the management of those responsible for tourist caves in the face of natural hazards that may affect them? (i) Have you heard of radon gas? and (j) Do you know the effects of radon gas on people's health?

3. Results and Discussion

3.1. Stakeholder Interviews and Survey Results

The results of the interviews carried out with the managers of tourist caves affirmed that they agree when it comes to identifying the most frequent management problems they encounter. In order of importance, they are the following:

(1) Safety of visitors and workers: natural hazards prevention
(2) Economic profitability of the ecotourism resource
(3) Human resources: search for qualified personnel, training of personnel who work in the facilities (tourist guides)
(4) Demand management: customer acquisition, advertising, marketing
(5) Control of environmental conditions: temperature, humidity, CO_2, radon gas
(6) Cavity maintenance: cleaning, lighting
(7) Bureaucracy

Regarding the managers' opinions on which natural hazards affect tourist caves, the majority agreed on the following: (a) radon gas level, (b) structural stability, (c) floods, (d) earthquakes, and (e) volcanic eruptions. Of these problems, it is understood that those posing a real danger to workers and visitors are structural stability, radon gas level and earthquakes. This is due to the fact that, when adverse meteorological phenomena that cause floods occur or when volcanic eruptions take place, the installation remains closed to the public.

When asked about protocols the managers currently do not have, and what they would like to have in place for monitoring or control of natural hazards affecting these facilities, they generally agree that it is protocols concerning radon gas control they most need at present.

With regard to the public opinion surveys, it was found that almost half (55.7%) of the people surveyed are between 46 and 60 years old, 20% are between 31 and 45 years old, 13% are over 60 years old, and 11.3% are between 18 and 30 years old. This indicates that most of the respondents are middle-aged people, who are assumed to have enough resources to practice the type of tourism they really like.

When asked which groups of tourists they identify with when it comes to tourism, the majority (63.3%) said they identify with ecotourists, nature tourists or rural tourists; 22.8% identified with urban tourists; and 13.9% identified with sun and beach tourists (Figure 3a). Therefore, the majority of tourists would be predisposed to geotourism in volcanic caves.

The answers regarding whether they practise or have ever practised nature tourism, geotourism or rural tourism were very conclusive: 92.8% responded yes and 7.2% responded no. Therefore, the vast majority have practised ecotourism.

As to whether they would be interested in visiting a volcanic cave or volcanic tube, almost all of them said yes (98%), compared to only a few who said no (2%). This corroborates the notion that tourist caves are very attractive for all types of tourists, both ecotourists and sun and beach tourists (Robledo & Durán Valsero, 2011).

When asked whether they have the feeling of being exposed to any kind of danger or if there is any kind of danger that worries them when/if they visit a tourist cave, 62.7% do not have any concern in this regard but 37.3% do have concerns (Figure 3b). For people who have practised ecotourism and who are interested in visiting a volcanic cave, the percentage of those who feel exposed to danger is high, but it is to some extent understandable. In the underground environment, we feel more vulnerable because the perception of risk is higher (Kortanje, 2009).

In relation to the question regarding which natural hazards they believe most affect the safety of tourist caves, the percentages obtained for each hazard were as follows: (a) cave collapse 74.7%, (b) radon gas 20.6%, (c) floods 2.3%, (d) earthquakes 1.7%, and (e) volcanic eruptions 0.6% (Figure 3c).

When asked if they trust the management of those responsible for tourist caves in the face of natural hazards that may affect them, the majority, 82.8%, do trust the management, while 17.2% do not trust the management (Figure 3d).

As to whether they have heard of radon gas, 77.4% of respondents said yes, compared to 22.6% who declared they have not heard of radon (Figure 3e). However, when asked whether they are aware of the effects of radon gas on people's health, the percentage of people who are not aware of the effects of radon increases to 46%, while the percentage of those who are aware of the effects of radon is 54% (Figure 3f). Therefore, it can be said that almost half the respondents are not aware of the harmful health effects of radon, and there is still a lot of work to be done to raise awareness on this issue. The managers of tourist caves can play a very important role in this respect.

3.2. Protocol for Managing Natural Hazards Due To Radon Exposure

Based on the CSN scheme for studying indoor radon concentration in caves, the action protocol was developed, applying the experience and practice of radon gas control developed in different tourist caves in the Canary Islands and mainland Spain.

Once the radon concentration studies have been carried out, the activities must be declared to the competent administration body. The declaration must include at least the following information:

1. Identification of the owner and, if applicable, company name, and indication of its purpose and location. A brief description of the cavity should be added.
2. Type and known characteristics of the sources of natural radiation present. A theoretical study of cavities, as natural sources of radon gas may be incorporated in connection with this section.
3. Radon concentration measurements. Radon detectors should be exposed for a full year. If DTPA are used, they shall be exposed for four consecutive periods of 3 months duration each. The distribution of detectors shall not be less than one detector per 150 m^2 and, in any case, even if this surface area is not exceeded, a detector shall be located in those areas where human presence is common, rooms or chambers where galleries meet and new bifurcations. Each of these distinct areas shall be referred to as a "homogeneous area." For the expression of radon concentration results, the "Radon concentration measurement result sheet in a homogeneous zone of a tourist cave" is proposed (Figure 4). For a quick assessment of radon concentration, this sheet includes the four-color traffic light system shown in Figure 2.
4. Indication, where appropriate, of processes that may lead to the concentration of radioactive substances or workplaces where radon accumulation may occur. This refers to the study of the spatio-temporal variability of radon content. It is important to gather information on the existence of historical records relating to various environmental variables and to complete the microclimatic information with data that may be provided by the use or temporary installation of a data logger. Normally, if we use active-type radon measurement systems, these incorporate sensors that allow simultaneous recording of temperature and relative humidity (or just one of these variables). It is convenient to carry out this recording of environmental parameters inside and outside the cave, in order to establish a pattern of behavior between radon concentration and seasonality.
5. Number of workers in the different potentially affected sectors of the installation. A list of the number of permanent and temporary workers should be included, together with an estimate of the doses received by them, as a function of the time of permanence and of the radon concentrations in the air measured over several years. It is very practical to draw up a spatio-temporal map of radon concentration in the cavity. If concentrations higher than those established by the regulations in force (>300 Bq/m^3) are recorded, it is advisable to control the dosimetry of the workers. In this case, the resulting doses must be defined for each workstation and for each exposure scenario (CSN, 2012).
6. Where appropriate, protective measures that have been implemented to minimize the risk of worker exposure. Control proposals to minimize the risk of exposure for workers can be presented here, according to the radon gas concentration values recorded. With the information obtained from the measurements of radon concentration in the cavity and the dosimetry of the workers, a planning of schedules and shifts of workers and work areas is carried out, differentiated between "monitored areas" and "controlled areas" (Álvarez-Gallego et al., 2015). A monitored area establishes the possibility of being exposed to an effective dose of less than 6 mSv per year. It is recommended to calculate an area dose to assess radiation exposure. A controlled area implies the possibility of being exposed to an effective dose between 6 and 20 mSv per year. Exposure in 1 year to a total dose of 50 mSv is allowed. Periodic health examinations are mandatory.

Figure 4. Proposed sheet to show the results of radon gas measurement in the caves.

With these considerations in mind, it may be appropriate to organize different guided tours, according to seasonality, of a fixed duration.

These surveys should be repeated every 5 years, unless high radon concentrations are recorded inside the cavity that far exceed the limits set by the current regulations, in which case, the surveys should be repeated at a higher frequency (annually or semi-annually).

3.3. Responsible Tourism Management

Responsible tourism cannot be separated from sustainable tourism, if we stick to the definition of sustainability of the Brundtland Report (Brundtland, 1987): "*Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs*." The preservation and conservation of volcanic caves is based on responsibility for sustainability, environmental, social and cultural factors. Ecotourism managers must assume this responsibility, which is closely linked to proper management of the natural hazards described in this work. Therefore, in the management of this ecotourism product, we can talk about three types of responsibility:

(a) Environmental responsibility. Volcanic tourist caves are a part of the natural heritage of the Canary Islands. Managers, tourists and the local population are responsible for ensuring that it continues to be so, making responsible use of the tourist resource through appropriate behavior and respect for the natural environment, while striving for its conservation.

(b) Social responsibility. The local community that houses a tourist volcanic cave in its territory depends on the continuity of this resource to improve its economy and maintain its social well-being.

(c) Cultural responsibility. Volcanic tourist caves are, in addition to natural heritage, tangible and intangible cultural heritage. Many of them housed the primitive inhabitants of the islands in the past and are part of the idiosyncrasy of the Canaries, and their various uses continue to the present day. The proper management of tourist caves in the face of natural hazards (structural stability and natural radiation) implies a great responsibility for the culture and customs of the Canaries. Due to their media impact, they are an example and reference for other types of uses and exploitations in the Canary Islands that occur because of volcanic cavities (residential, restaurants, leisure, commerce, industry, museums). If the volcanic tourist caves, which are highly visible in Canarian society, fail due to poor management of natural hazards, this will have repercussions for their other uses, as it could stigmatize them.

The responsibility of managers, tourists and the local population was highlighted at the International Union for Conservation of Nature (IUCN) congress held in Sydney (Australia) in 2014. It was said there that it is not possible for governments to assume all the expenses for protecting the environment, so it is essential that the stakeholders also assume responsibility for geoconservation (Hart Robertson, 2014).

4. Conclusions

Spain's tourist volcanic caves are located in the Canary Islands and are an ecotourism product that generates great interest among ecotourists and also among other types of tourists, such as sun and beach tourists. The caves generate significant benefits for the local community. For this reason, their conservation and maintenance must be ensured, while the safety of visitors and workers must be guaranteed.

The need to take radon gas into account as a real threat and a very important danger in tourist volcanic caves is supported by two indisputable pieces of evidence: (a) volcanic soils are potential emitters of radon gas and, in accordance with current regulations, there is an obligation to carry out the pertinent studies to determine that its concentration indoors does not exceed the established thresholds (300 Bq/m^3); (b) any underground installation is

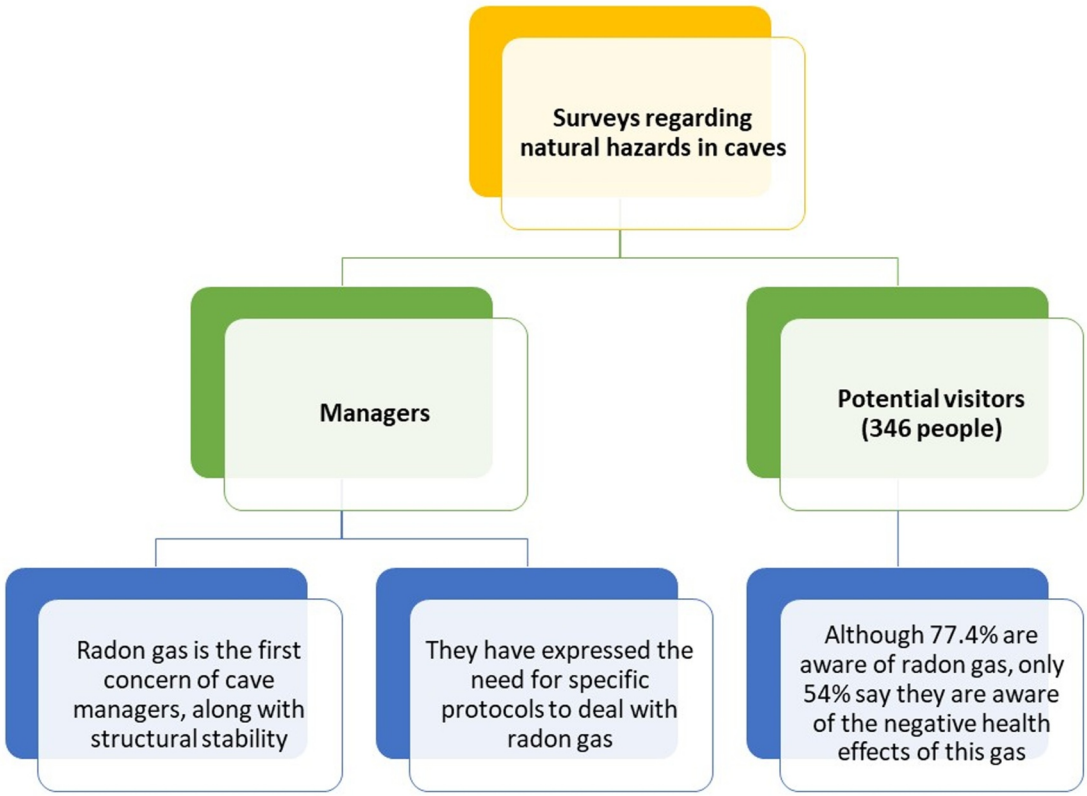

Figure 5. Compilation of opinions on radon gas, drawn from the survey responses of the cave managers visited and 346 potential visitors.

also required by regulation to be studied to determine what concentration of radon it is capable of harboring, regardless of the geological nature of the ground, due to lack of ventilation and by direct contact with the material which radon emanates, the rocks of the earth's crust. This obligation falls directly on the owners of the tourist caves, as specified in current regulations, and is therefore the direct responsibility of the ecotourism managers.

It has become clear from the personal interviews conducted in this study that natural hazards are of great concern to the managers of volcanic tourist caves in the Canary Islands, and that radon gas in particular is of great concern to them (Figure 5). The managers are not always experts in geology or natural radiation, and it became clear in the interviews that they need to be provided with protocols that will enable them to deal with this problem with guarantees.

The control and monitoring of the environmental conditions of the cave are developed as preventive measures against natural hazards, but they also facilitate the regulation of sustainable tourist use of the cave. They allow the establishment of the carrying capacity of the facility, itineraries, schedules, and protection of biodiversity and geodiversity, which guarantees the continuation of tourist exploitation and its contribution to the local economy.

There is a clear responsibility that concerns both the managers of tourist caves and ecotourists, geotourists and tourists in general. Managers have a double responsibility—conserving and protecting the natural resource, and taking care of the dangers that affect it, as well as raising awareness among the local community and tourists regarding their own responsibility in three specific areas: environmental, social and cultural responsibilities. Managers can do this through the use of dissemination tools, training and interpretation of natural resources and natural hazards. Tourists are responsible for the proper use of the natural resources, acting responsibly and respecting the safety rules established by the managers, as well as for participating in training activities and contributing to the dissemination of these values in society.

Radon studies in tourist volcanic cavities can help raise awareness in society about the importance of keeping this gas under control, in order to avoid long-term health problems. In this sense, tourism managers have the responsibility to not only carry out the studies but also to publicize them among visitors.

There is, therefore, a great responsibility toward society in the informative work of managers in relation to the natural hazards that affect volcanic tourist caves. A society informed about natural hazards is a more resilient society that can face and mitigate these hazards.

Conflict of Interest

The authors declare no conflicts of interest relevant to this study.

Data Availability Statement

Data sets for this research are included in Santamarta et al. (2021).

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