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Exploring the best communication channels to inform a local population about volcanic risk: comparing information approaches at El Misti, Arequipa, Peru

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ABSTRACT

Which communication channels should be prioritized to make populations aware of local volcanic risks? In the internet age, is it still necessary to privilege the classic channels (radio, television, posters), or are the new communication channels (websites, social media) sufficient? Using an interview-based survey of a population in Peru ($n = 76$) who have been the object of several volcanic risk communication campaigns using posters, websites, social media and traditional media, we compare the recall (*memorization*) and perception of these previous campaigns. Two main empirical results emerge from the interviews: 1) Websites are proving to be particularly effective communication channels in this context, in stark contrast to the low impact of the printed press; 2) We find that the same communication campaigns are perceived differently by residents depending on the neighborhood in which they live. This second empirical result advocates for a much more territory-based and localized strategy, where the district by district socio-cultural and geological environment form the foundations for communication strategies.

RÉSUMÉ

Quels sont les canaux de communication à choisir en priorité pour sensibiliser à un risque volcanique local? À l'ère d'internet, est-il encore nécessaire de privilégier les canaux classiques (radio, télévision, affiches), ou les nouveaux canaux de communication (sites web, médias sociaux) sont-ils suffisants? Sur la base d'une enquête par entretiens auprès d'une population du Pérou ($n = 76$) ciblée par plusieurs campagnes de communication sur le risque volcanique utilisant des affiches, des sites web, des médias sociaux et des médias traditionnels, nous étudions de manière comparative le souvenir et la perception de ces précédentes campagnes. Parmi les données obtenues lors des entretiens avec ces 76 répondants, deux principaux résultats empiriques émergent de cette enquête 1) Les sites web s'avèrent être des canaux de communication particulièrement efficaces dans notre contexte, notamment par rapport au faible impact des médias imprimés. 2) Les mêmes campagnes de communication sont perçues différemment par les habitants selon le quartier dans lequel ils vivent. Ce deuxième résultat empirique plaide pour une stratégie beaucoup plus territoriale et locale, où l'environnement socioculturel et géologique local est la base de la communication.

KEYWORDS: Communication campaigns; Reception study; Communication channels; Risk perception; Volcanic risk communication.

1 INTRODUCTION

Effective communication is important in risk management. In a volcanic eruption, the material damage and the number of victims may be higher in the areas where inhabitants are the least informed and least prepared [Rakow et al. 2015]. This economic, social, cultural, and institutional vulnerability [Thouret 2002] is accentuated by the lack of awareness of any implemented risk reduction campaign. The risk of human mortality and material damage is not only linked to the on-site presence of humans and infrastructure; it also depends on “the way in which a society is organized and organizes a territory” [d’Ercole and Pigeon 1999, p. 344].

A successful communication campaign is not only founded on the quality of messages disseminated. It also depends on the relevance of the communication channels chosen [Sarboni 2012]. This requires knowing beforehand what the main

sources of information for the population are when they seek information on volcanic risk [Handmer 2000].

In the internet age, we should consider if websites and social media are sufficient to communicate risk information to an exposed population. With the increasing number of people connected to the internet, the question arises if traditional communication channels, such as posters and leaflets, but also television and radio broadcasts, are becoming secondary? For volcano monitoring organizations in particular, is it a judicious choice to rely more and more, or even exclusively, on their institutional websites, Twitter accounts, or the publication of videos on Instagram?

Targeted studies conducted on information practices are important from a theoretical and a practical point of view, in order to describe and analyze how the inhabitants close to volcanoes search for and understand information about the volcanic hazards that concern them. This type of work aims to understand the barriers and levers that influence the search for information [Montagni et al. 2018] on volcanic risk.

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In this study we explore the volcanic risk perception and knowledge of local people living in two districts of the city of Arequipa, Peru, on the flanks of El Misti volcano, particularly in light of recent awareness campaigns undertaken by the volcano observatories and their partners. In view of these campaigns, we investigate how the interviewed residents perceive volcanic risk. We compare their perception with respect to where they live in relation to hazards. In addition, we explore the different communication channels used by participants to access volcanic risk information. We investigate which communication channels should be prioritized so to best make a population aware of a local volcanic risk. We also study if, in the internet age, it is still necessary to prioritize traditional channels (radio, television, posters), or are the new communication channels (websites, social media) sufficient?

2 METHODS

Our study uses information and communication sciences in a comparative approach. With such a comparative methodology, it is possible to examine the differences and similarities of a research object between at least two cases, for example between two countries or two areas [Cossette 2016]. In this work, the comparative approach addresses two distinct districts of Arequipa. Two research objectives are considered:

1. The first objective is to compare the communication channels used by inhabitants. Through this, we check which communication channels are key for information to be disseminated clearly and effectively. This objective is studied in a comparative way by considering the information consumption habits of the inhabitants. We study the differences in the impact of awareness campaigns on volcanic risk conducted through media such as posters, websites, social media, and evacuation simulation exercises.

2. The second objective is to investigate how the information given in these communication campaigns is perceived and used by these inhabitants. The comparative method is used to see whether the importance given by the inhabitants to this information differs between the two different districts of the city. Do the inhabitants of the districts most exposed to the volcanic risk take more account of this information?

Thus, the aims of this comparative approach are, on the one hand, to highlight contrasts in the use of communication channels and, on the other, to distinguish contrasts in different population categories and geographic areas.

Below we explain ethics requirements and the methodology behind the choice of location, data collection, and data analysis protocols.

2.1 Ethics

Our El Misti communication project was designed with the ethics of engaging in developing countries as a foundation, and also designed to work on an even footing with local colleagues, respecting local conditions and customs. The project was initiated by French university researchers in communication science and in volcanology. One of these (van Wyk de Vries) has had a 20-year relationship with the Peruvian volcanology

community, and thus proposed the project after consultation with local practitioners (co-author L. Macedo Franco). The study was co-constructed to be adapted to meet the needs and wishes of the local observatories, while also providing an opportunity for the French researchers to engage in a new field.

In Arequipa, the French team worked as visitors within the OVS IGP structure (*Observatorio Vulcanológico del Sur of the Instituto Geofísico del Perú*, henceforth referred to as IGP). All parties discussed the proposed work and together formed a theoretical and operational plan. The work was apportioned depending on expertise and on practical and time constraints. For example, the Peruvian IGP professionals took charge of the survey's organization and face-to-face work with the population (this is described below), while the French communication researchers undertook the post-survey analysis (S. Rouquette and L. Jaquez). The French researchers made a first draft of the paper, which was then reviewed and discussed by all parties. A Spanish version of the paper was also produced, to make its findings easily available. This version will be presented to the Peruvian community at large, and particularly those who were surveyed.

The survey was conducted in Peru and complied with local ethics rules, though there are no specific regulations dealing with such surveys. The IGP, however, follows protocols when interacting with locals and communities, based on respect for the individual and for the community, and also respect for individual and community rights*. We met and discussed the project with the two mayors of the districts surveyed (Sachaca and Alto Selva Alegre) and their teams. They gave permission for the work to be undertaken in their districts (with Samuel Tarqui on 31/01/2020 for Selva Alegre and with Emilio Diaz Pinto on 30/01/2020 for Sachaca).

The survey data was thus collected by local Peruvians according to their regular practices and analyzed by French researchers in a way that met French university ethics guidelines. French researchers are expected to abide by all personal and privacy laws. Thus, we ensured that the privacy of the Peruvian people surveyed was fully respected (all survey data are anonymous) and guaranteed by the IGP and the French researchers, meeting ethical practices in both Peru and France.

2.2 Choice of survey location

An important condition of our study was to choose a place in which awareness campaigns on volcanic risk are regularly conducted on the local population concerned by this danger. We chose Arequipa, a large Peruvian city located near an active volcano called El Misti. The local authorities and volcano monitoring organizations have been delivering local risk reduction campaigns for more than ten years. The latest survey was carried out in the year prior to this survey, which allows us to specifically study the recall of this campaign.

The first awareness program on hazards related to volcanic activity was launched in 2006 in Arequipa by the geological survey and volcano monitoring organization OVI-INGEMMET (*Observatorio Vulcanológico del Instituto Ge-*

*<https://www.igp.gob.pe/informacion-institucional/sistema-gestion-seguridad/politica>

ológico Minero y Metalúrgico, henceforth referred to as INGEMMET). Since then, multiple communication channels have been used such as posters, brochures, television and radio programs, websites, Twitter accounts, and Facebook pages. This provides an opportunity to assess the effectiveness of each of these channels to reach the target populations. The two volcano monitoring organizations, INGEMMET and IGP, have also conducted or participated in evacuation drills (in 2010 and 2018 respectively), and they have directly raised awareness through these drills involving several hundred people*. This context makes it possible to conduct a diversified, thematic, and in-depth survey on how these communication campaigns are received by the target population.

Arequipa is of particular interest to us, as a previous survey showed that in 2008 awareness of the risk was low [Martelli 2011] despite El Misti being considered an active volcano, with the last small fumarolic event in 1985 [Thouret et al. 2001; Global Volcanism Program 2013]. El Misti is constantly monitored by IGP [Machacca Puma et al. 2021], and INGEMMET [Aguilar Contreras et al. 2021]. The surrounding area is exposed to different volcanic hazards [Thouret et al. 2001; Aguilar Contreras et al. 2021; Machacca Puma et al. 2021]. The principle hazards are:

1. Lahars. These occur every year in the rainy season, when loose deposits are mobilized in the many valleys (*quebradas*) extending from the volcano, and many are channeled into urban areas. Many *quebradas* have been built up with housing, greatly increasing the risk. Lahar hazard would be high with even a small eruption, which would increase the amount of material to be remobilized [Martelli et al. 2008].

2. Tephra. Even a small tephra-producing eruption can be hazardous, due to the proximity of the crater of El Misti to the city. For example, two nearby volcanoes, Ubinas and Sabancaya, have caused significant disruption with recent small eruptions [Aguilar Contreras et al. 2021; Machacca Puma et al. 2021]. Larger eruptions, like the 2000 BP Plinian eruption (VEI 4) or the 15th century eruptions (VEI 2) would have major impacts on modern urban infrastructure, agriculture and day-to-day life in and around Arequipa [Thouret et al. 2001].

3. Pyroclastic flows (or pyroclastic density currents). These can accompany large eruptions like the 2000 BP event, and would be channeled into the *quebradas* that enter the city, causing significant destruction. Pyroclastic flows have occurred at least 10 times every 10,000 years, according to Thouret et al. [2001], and deposits are found under many of the city's districts.

The INGEMMET hazard maps show the possible extent of pyroclastic flows, as well as lahars and tephra fall [see description in Aguilar Contreras et al. 2021]. These maps show that the risk is high, especially for the districts of the city located on the slopes of the volcano. Considering the three principle hazards that pose a risk to the city of Arequipa, we feel that the importance of efficient communication is particularly high.

* <https://www.gob.pe/institucion/igp>

2.3 Panelists

An interview-based survey was conducted with a specific group of individuals ($n = 76$) which we call *the panel of inhabitants* (or panelists). An important methodological condition is to ensure that the recruitment of the panelists was not biased. Because the comparative method followed here was based in part on a comparison between different parts of the population, the panel was assembled using a non-proportional stratified sampling method [Cossette 2016]. The sample was made up of different categories of the population in order to balance the subsets of the sample. This is the first time that research of this type has been carried out in this locality, thus it has an exploratory dimension. Several recruitment criteria were considered in order to ensure the diversity and the quality of the responses obtained; in particular, residential area, gender, age, and socio-professional categories.

2.3.1 Age and gender

Some studies have shown that age and gender have an influence on risk perception [e.g. Ngo 2001], suggesting older people are more likely to have additional vulnerabilities, such as health, which make them more susceptible to natural hazards, while others suggest that these factors have little or no influence. For example, Burningham et al. [2007] found that for flooding risk, local residents were not very concerned regardless of the age of the inhabitants. Further, only 52 % of residents over 65 years of age were aware that their property was in a flood risk area despite the fact that all the research sites had been impacted by severe events in the past, and they did not seriously consider the possibility of being personally affected. This suggests that in this case experience and age do not play a particular role in risk awareness [Burningham et al. 2007; Wachinger et al. 2013]. In contrast, young inhabitants of the city are likely to be more familiar with information and communication technologies than older inhabitants. So, in order not to bias the results of this study, it was important to select a panel of people of different ages.

In the same flood study [Burningham et al. 2007], only 49 % of the women and 52 % of the men surveyed were aware that their property was in a flood zone. For our survey, in order to take into account the potential effects of gender, 39 of the respondents were women and 37 were men.

The mixed age and gender composition of the panel allows us to evaluate these potential influences on volcanic risk communication reception.

2.3.2 Socio-professional status

The panel was constructed with a wide range of socio-professional respondents, so as not to introduce bias by an uncontrolled social dimension [Haynes et al. 2008b]. Thus, the panel of 76 people from Arequipa includes many housewives (14); 'blue-collar' workers (i.e. manual workers; 11, including, for example, 2 bricklayers); farmers, employees, and technicians (5); craftsmen and shopkeepers (10); intermediate professions and middle managers (for example a communicator and two tourist guides); liberal professions; and senior managers (for example, 7 engineers).

The categories of workers, employees, and intermediate professions used here are based on the *Institut national de la statistique et des études économiques* (INSEE, National Institute of Statistics and Economic Studies) typology of social and professional categories.

2.3.3 Parenting status

Parenting status (being a parent or not) was also considered, to take into account the potential influence of children on the adults' sensitivity to volcanic risk. Risk awareness campaigns targeting children in Arequipa were conducted by INGEMMET*, with the idea that the children would relay these instructions to their parents, or grow into informed adults themselves. Other studies in Latin America have found that after an evacuation, parents with children were less likely to return to higher-risk areas than adults without children as they wished to protect their offspring [Lane et al. 2003]. Thus, the fact of having or not having children potentially influences the perception of risk, which is taken into account in this panel by including several questions on parent/child aspects.

2.3.4 Location

Special emphasis was placed on the district where the respondents live. Two districts with very different levels of hazard were chosen to measure the effect of location on communication campaigns.

Spatial differences have been known to be important for the perception of certain natural hazards, with people living in areas at risk of flooding, for example, being more sensitive than others [Ruin et al. 2007]. Two studies in France showed that people's own experience of flooding was the most important factor for risk perception. [Ruin et al. 2007; Wachinger et al. 2013]. Does this factor feature in Arequipa? Do people living on the slopes of the volcano feel less secure than those living on the plain? If so, should communication be varied according to residential/volcanic risk areas? To take this parameter into account, two different districts were chosen to be surveyed. The first, Sachaca, is a low hazard district located on the southern plain of Arequipa on the far side of the city to El Misti. The second is Alto Selva Alegre, which is the closest city district to the volcano and is affected by lahars as well as potential ash fall and pyroclastic flow hazards (Figure 1).

As shown in Figure 1, the district of Alto Selva Alegre is in a high hazard area (red area), while the district of Sachaca is in a less hazardous area (gray area). Of the 76 respondents, 35 live in the district of Sachaca and 41 in the district of Alto Selva Alegre. For more detail on the demographics of our panelists please see Table 1.

2.4 Interview survey design

The selected panel of 76 respondents were interviewed for between twenty minutes and one hour. All the inhabitants were interviewed between January and June 2020, mostly in their homes.

The panel size allowed for in-depth qualitative interviews. In this study, we used open-ended questions. While answers based on closed-ended questions (for example: which media

Table 1: Demographics of the interviewees.

Characteristic		District		Total
		Sachaca	Alto Selva Alegre	
Gender	Men	18	19	76
	Women	17	22	
Age	<45	18	30	76
	>45	17	11	
Parent	Yes	25	25	76
	No	10	16	

do you use?) are used in a psychometric approach to risk perception [Verlynde 2018] and have the advantage of being able to cover large numbers of respondents, qualitative approaches are necessary when it comes to analyzing the multiplicity and complexity of factors, expectations, and perceptions that come into play in interpreting the disseminated messages. In particular, open-ended interview questions allow for topics to arise that were not initially expected but are ultimately of central importance to respondents. This is both the challenge and the interest of analyzing how the communication campaigns were received by the population which, as Douglas [1966] stated, gives a central place to the social and environmental framework of the receivers in understanding the mechanisms of interpretation of natural risk prevention campaigns. Open-ended questions that fall under qualitative analyses are favored in order to, "root the theory in the reality experienced by the actors" [Luckerhoff and Guillemette 2014].

After a series of questions about their perception of their local environment and the volcanic risk (Appendix A: questions from the section, 'Perception of the neighborhood, the volcanic risk and knowledge of risk management instructions'), the interview questions aimed to identify the most appropriate communication channels for the intended targets (Appendix A: questions from the section, 'Their sources of information about volcanic risk').

In general, the questions aimed to take into account the range of parameters that impact communication campaigns on volcanic risk locally.

2.5 Survey strategy

In our experience, we have found that when working with communities in Peru, where there are often social and cultural issues that can cause conflict and mistrust, a first step is to choose an interviewer who is close—linguistically, socially, and culturally—to those being engaged with.

It is known that in the case of interview-based surveys the answers can be altered "by everything that respondent knows about his interlocutor, his status and activities within the institution, by the expectations or designs that he lends to him" [Papi 2016, p. 257]. Therefore, as well as following the usual rules of engagement of the IGP, we used local Peruvian interviewers (local university students) who know the area and have a perfect command of local culture, language, and expressions.

* <http://ovi.ingemmet.gob.pe>

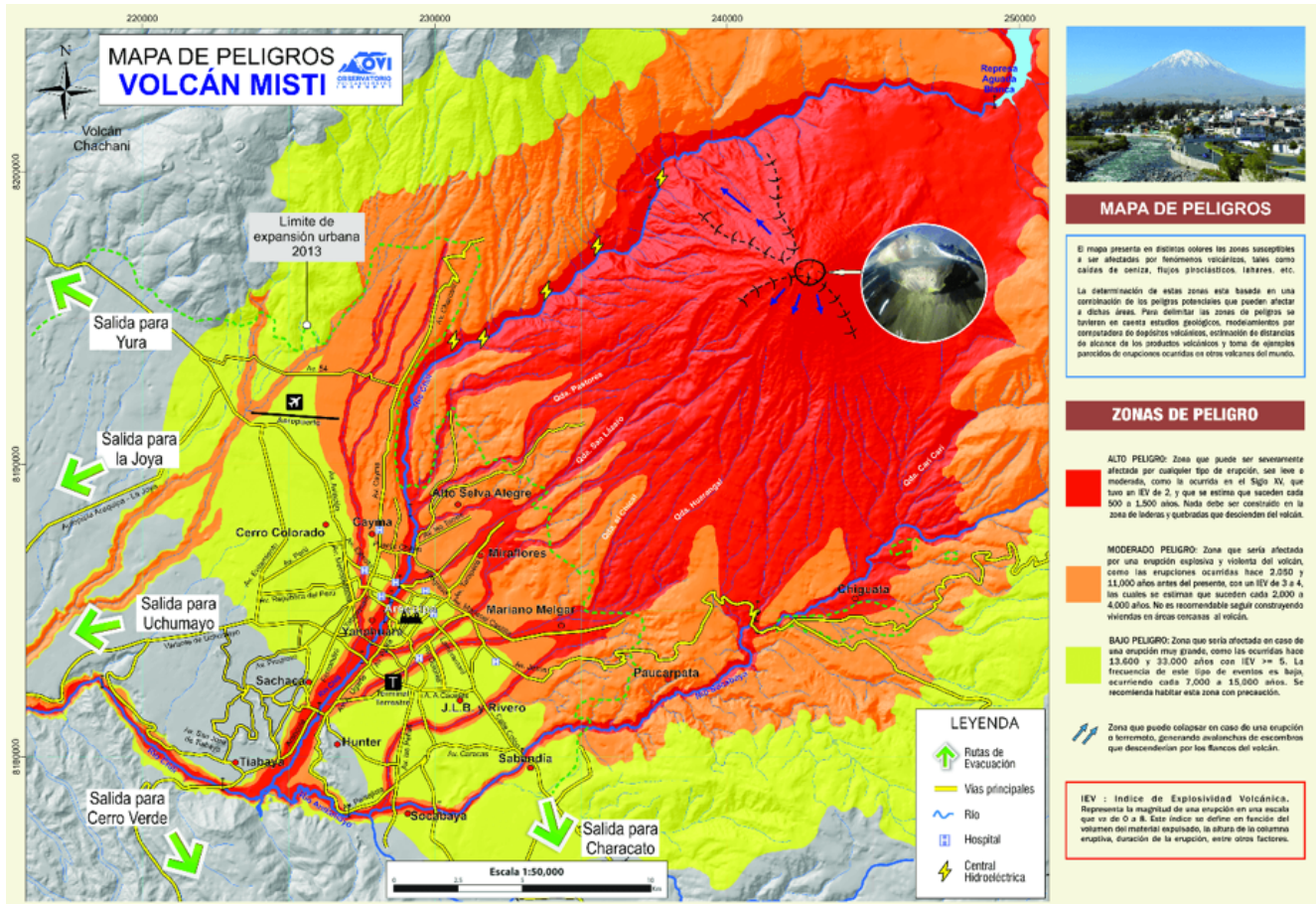


Figure 1: Multi-hazard map of the proximal zone of Misti volcano.

Source: INGEMMET: http://ovi.ingemmet.gob.pe/?page_id=128.

Considering the number and type of interviews scheduled, it was necessary to recruit several of these local interviewers and then train them in interviewing techniques. Four interviewers, in their final year of their five-year '*Licenciatura*' undergraduate degrees from the Universidad Tecnológica del Perú in Arequipa were recruited through the IGP by co-author, L. Macedo Franco. The interviewers were trained in sociological interview-based surveying in January 2020 and supervised both on site with L. Macedo Franco and remotely during several videoconference meetings with L. Jacquez and S. Rouquette. Their work was supported by an internship stipend paid by Université Clermont Auvergne.

Interviewees were recruited by going door-to-door in the two selected districts because it was important not to conduct a survey exclusively via the internet, so as not to exclude people who have no internet access. The interviews were recorded using a dictaphone and then transcribed.

The public health context (COVID-19) added a constraint on the final stage: one third of the interviews had to be conducted remotely because the interviewers were not allowed to visit the inhabitants from February 2020; a constraint that did not have much impact on the answers except for the questions related to the recall and recognition of the posters disseminated the previous year concerning volcanic risk. However, the number of interviews conducted among the inhab-

itants before the lockdown (approximately 50) was sufficient to obtain a large enough number for redundancy, assuring the quality of answers on this question.

3 RESULTS

The full content of the survey responses of the 76 interviewees forms a very large corpus (or database) and is available in [Supplementary Material 1](#). In order to structure the large number of results, we provide a progressive presentation of separate findings, each with an analysis, and progressive conclusions. We find this is the most efficient way of dealing with the survey, and this progressive method is standard in sociological research. The results are presented in five different parts:

- Section 3.1: Perception of the neighborhood, the volcanic risk and knowledge of risk management instructions;
- Section 3.2: Territory-based communication;
- Section 3.3: The comparison of audiovisual and print media;
- Section 3.4: The internet as a source of information on volcanic risk;
- Section 3.5: The importance of family dynamics in communication.

Table 2: Main hazards related to the volcano cited by the respondents.

Hazard	Number of responses mentioning hazard*
Ash fallout	24
Lava flows	21
Gas emissions into the atmosphere	15
Eruption	10
Earthquakes	10
Lahars	3
Pyroclastic flows	3
Projections of volcanic bombs	1
Total (from 76 respondents)	87

* A respondent can give several answers.

3.1 Perception of the neighborhood, the volcanic risk and knowledge of risk management instructions

This section deals with the respondents’ awareness of volcanic risk and is called, ‘Perception of the neighborhood, the volcanic risk and knowledge of risk management instructions’ (Appendix A). A companion work on the survey has shown that volcanic risk is largely unknown to the inhabitants of Arequipa. These results are summarized in Table 2.

Any eruption of El Misti would produce gas and ash, but these hazards were only mentioned by 15 and 24 respondents, respectively, when asked about hazards associated with the volcano. Further, few of them give details when asked to qualify the volcanic hazards, even when they specifically mentioned these hazards.

Seven people included somewhat vague responses, simply mentioning “eruptions” as being the main hazard associated with the volcano, but without explaining in more detail what hazards the eruption would produce and what consequences there might be. The people thus mention the hazard but not their own vulnerability and that of their territory. However, clear perception of a risk is not only to be aware of the hazard but also to understand the type of damage it could cause.

Some of the main volcanic hazards were not generally described as risks that concern the city (pyroclastic flows, lahars, etc.). The lack of mention of lahars is surprising as Arequipa is a city that is very regularly exposed to intense rain that causes damage such as overflowing rivers, floods, seepage in houses, landslides (“avalanchas”), and lahars (“huaycos”). The inhabitants are very concerned and aware of the risks related to heavy rain and the overflowing of storm drains, “torreteras,” but they do not make any link with the volcano.

Many respondents say they are insufficiently informed of what protective actions to take. Of the 76 residents interviewed, 26 said they did not know what to do in case of a volcanic eruption. Only 12 said that they were aware of the instructions given by the authorities and only 5 respondents had the recommended emergency kit (lamp, radio, battery, and food in reserve at home). For example:

Q: “Do you know what to do in case of a volcanic eruption?”

A: “No, the truth is I’m not prepared, I might have to leave, but I wouldn’t know where, I don’t have a lot of information about that, more about earthquakes, but not in the case of volcanoes”
(man, 23 years old, production operator, Sachaca).

This lack of knowledge is despite the fact that the IGP and IN-GEMMET have set up numerous communication operations (Twitter account, recruitment of communicators, awareness conferences, etc.).

3.2 Territory-based communication

The second part explores if volcanic risk awareness and feeling of exposure to risk varies depending on the district inhabited (Alto Selva Alegre and Sachaca).

The volcanic risk varies according to the districts in which the respondents live: it is higher in Alto Selva Alegre, which is closer to the volcano. Table 3 shows that the sense of safety is lower among the residents of Alto Selva Alegre than among those of Sachaca.

Table 3: The territorial perception of risk.

Response*	District			
	Sachaca		Alto Selva Alegre	
Yes	17	48 %	13	32 %
No	5	14 %	16	39 %
Neither yes nor no	4	12 %	2	5 %
No answer	9	26 %	10	24 %
Total number of people interviewed	35	100 %	41	100 %

* Response to the question, “Do you feel safe in the location of your home in relation to El Misti volcano?”

For the inhabitants of Sachaca, 48 % said that they felt protected from volcanic risk because of the geographical distance and 14 % said they did not (Table 3). Several of them mentioned the other districts built on the slopes of the volcano as being at greater risk. For example:

Q: “Do you feel safe in the location of your home in relation to the Misti volcano?”

A: “In the district of Paucarpata, they were more affected when they lost their house”
(man, inhabitant of Sachaca, 30 years old)

A: “I consider that the area [Sachaca] is not risky because it is far away compared to the areas near Misti. Likewise, in case of earthquakes it is not perceived with great intensity because the area is rocky. I feel safe because of the distance from the volcano”
(man, inhabitant of Sachaca, 47 years old)

A: “Above all, the most affected would be those who live in Alto Misti. I have family in that district and

that is what worries me the most”
(*woman, farmer, Sachaca, 58 years old*)

Q: “How do you perceive your district?”

A: “It’s a district with rocks and dirt, but it’s a good place, because it has a nice view where you can see the green areas and we are far from El Misti volcano, that’s how I perceive it”
(*man, 55 years old, worker, homeowner, Sachaca*)

In Alto Salva Alegre, the perception of risk is different. 39 % of respondents said they believe that they live under the threat of the volcano (Table 3). For example:

Q: “Do you feel safe in the location of your home in relation to the Misti volcano?”

A: “the truth is that I don’t feel safe” (*woman, 42 years old, housewife, Alto Salva Alegre*).

As Table 3 shows, this does not mean that these concerned residents have a precise or clear knowledge of the volcanic risks associated with El Misti volcano (e.g. only 24 % of the residents surveyed mentioned the risk of ash), they just felt vaguely at risk.

The different feedback by district is particularly interesting because it encourages us to examine the relevance of a communication strategy modified by district and, consequently, the interest of communication tools adapted for territory-based communication. These results also allow us to stress the importance of reinforcing awareness of volcanic risk in Arequipa, and explore aspects of territorial differences below.

3.2.1 What are the implications of territorial differences?

Questioning the perception of risk according to the exposure in different districts offers the possibility exploring if it is beneficial to communicate differently depending on the district.

One trend emerging from the analysis is that this perception does indeed vary depending on the district (Table 3). Some inhabitants surveyed indicated they are looking for different explanations; or more precisely, explanations adapted to their specific situation—in particular territorial situations, for example:

Q: “Do you feel safe about the location of your house in relation to El Misti volcano?”

A: “I consider that yes, but I have doubts, because according to the information that I have found about volcanic eruptions, because near my house there is a torrent, it is about 5 km away, I consider that it could flow there, but I have doubts and I would like to have more information about it. I looked and there was no plan for Cerro Colorado, they only talked about a part of the district for evacuation which was towards Yura and Majes, but the area where I live was not taken into account” (*woman, 22 years old, owner, engineering studies, Alto Salva Alegre*)

Q: “If you need information, what are your sources?”

A: “The municipality has an evacuation plan in case of a volcanic eruption. I know it exists, but I don’t know it and I think the municipality has left it out”
(*woman, 27 years old, owner, accountant, Alto Salva Alegre*)

The part of the survey asking residents if they feel safe where their home is in relation to El Misti volcano (Table 3) is indicative of the importance residents place on targeted information specific to their district. The appeal of this targeted information can be explained because the value of information is relative. We can speak here of *use value*: the more a resident feels territorially concerned by a risk, the more they will find the risk reduction campaign relevant or useful for them, and relevant to their problems. This expectation of territory-based information can be expressed in many ways, as the expectations of the inhabitants are multiple in this area. For example, a respondent who wants more detail in the event of an evacuation for the disabled:

Q: “Do you have any questions you want to ask me or that I should ask you?”

A: “I would like you to consider the situation of each family, for example, each family is different, I can plan actions to take into account the vulnerabilities of my family, for example, if I had a person with a disability or a disease, what actions would I take about it? Some do not have the knowledge of the volcanic risks, maybe because of the lack of communication and support to the families that have these problems. I would like to see a question about if the family has vulnerable people that can be affected in these events, such as people with disabilities or Alzheimer’s disease, etc. It would be good to consider that part, because families are not going to leave their family members out of the picture”

(*woman, 22 years old, engineering studies, owner, Alto Salva Alegre*)

The local interest comes from the fact that individuals feel more concerned by a risk when they know that this risk directly concerns them. As encapsulated by Verlynde [2018, p. 148]: “This can be analyzed at the spatial level, for example in the fact of being included or not in risk areas”. Hazard and risk maps can be used as a tool to communicate the territorial dimension of volcanic hazard and risk. By communicating to the inhabitants specific details of the streets, neighborhoods, and areas most affected by lahars, this strategy “can prevent the risk from being overestimated or underestimated” [Verlynde 2018, p. 377]. “Fostering the development of this knowledge of risk among inhabitants can thus strengthen their sense of security as well as the bonds of trust with public authorities” [Verlynde 2018, p. 377]. However, this depends on these risk maps being written in a simplified manner suitable for the general public [Haynes et al. 2007, p. 628].

The idea behind this strategy is that the inhabitants of neighborhoods visually marked as being at greater risk would feel more involved and so they would take more action. Communicating primarily about lahars in some neighborhoods and

more about the consequences of ash fall in others, depending on their respective levels of hazard and risk*, would be another way of territory-based communication. This strategy is based on the idea that people can live in higher-risk areas if they are clearly aware of it, accept that risk, and are prepared to plan and take actions in case of a hazard escalation [Lavigne et al. 2017].

It is also important to emphasize here that this territory-based communication partially exists in Arequipa, as hazard maps already exist (notably on the INGEMMET website[†]). This research has the advantage of revealing that communication by residential area using existing hazard maps could be very useful. Such a strategy can be put into practice in many ways such as:

1. more communication on evacuation locations;
2. adapting messages to the different neighborhoods;
3. favoring territory-based communication media (posters, neighborhood presentations), highlighting hazard and risk maps.

Such an approach has the advantage of potentially reducing behavior that is unsuited to the area and the local situation: inhabitants who do not know that they live in particularly exposed neighborhoods for lahars may flee into hazardous zones [d'Ercole 1994, p. 124–125].

Local posters could be a way of targeted territory-based communication. Though posters are not a source of information mentioned by the inhabitants interviewed (none of them mention posters), poster communication makes it possible to differentiate the communication according to the level of risk in each of the districts.

Posters can reach inhabitants who do not automatically think to inform themselves on the subject. Those who have noticed volcanic risk communication posters remember having seen them in places where they often go, as if repetition were one of the main factors in memorizing the message. Whether it is a shopping center, a health center, a bus shelter, or a restaurant, they are all places where people live or use public transport on a daily basis:

Q: “Have you seen this poster and brochure that we showed you during the interview anywhere?”

A.: “Yes, I saw one in a shopping center and I found it very alarming”
(woman, 50 years old, housewife, owner, Alto Selva Alegre)

A.: “Some time ago I saw posters at the health centre in my district.”
(woman, 21 years old, owner, student, Alto Selva Alegre)

Q: “Have you seen posters that talk about volcanic risk?”

A.: “I haven’t seen any signs so far, but I think they should be posted or displayed on public transport, at

bus stops and in restaurants”
(woman, 26 years old, owner, student, Alto Selva Alegre)

In theory, to be effective, posters need to be placed in areas where the target audience can easily see them: busy streets, public transport (buses), major crossroads, or buildings located in areas where the target population circulates.

Another constraint is the amount of time passers-by spend reading the posters. Crépet [2016] showed that the average reading time of posters does not exceed two seconds. Therefore, they must be both legible and adapted to the place and context of dissemination: “the content of the message must be related to the activity of the receiver; the message is not exhaustive; the message is easy to identify” Crépet [2016, p. 319]. Even in the case of risk communication, the most important question regarding poster placement is to determine the locations most frequented by the target audience. During the interviews, interviewees themselves suggested both traditional (shopping mall) and more surprising (bus shelter) locations. In fact, a large number of Arequipa’s inhabitants travel by public transport, as the strong demographic growth and the urban expansion that is taking place further and further from the center of Arequipa have led to a strong demand for public transport services on the part of the population [Ramirez-Gaston 1983].

A visit to the neighborhood of Alto Selva Alegre shows that the local authorities and monitoring bodies are well aware of the value of these territorially targeted campaigns, as a few painted posters still adorn the walls of the neighborhood (Figure 2). In addition to posters, this territory-based communication can take various forms, with drawings or panels placed in front of the most at-risk areas [e.g. the *quebradas* for the lahars: Morin 2012, p. 303], the advantage of *in situ* information being that people can visually conceptualize the risk [Morin 2012].

Field observations also showed that the few posters on volcanic risk posted in the Alto Selva Alegre neighborhood were in bad condition. This is shown by the poster found at the top of the district in 2020 which had partially disappeared when we returned in 2021 (Figure 2). By this time, the paint had faded and the risk reduction message has visually lost its luster. The few remaining danger or evacuation signs in this area are in a degraded state.

These observations also illustrate, as for the Ecuadorian city of Baños [Lane et al. 2003], the difficulty of long-term implementation of this option. However essential they may be for implementing a territorially differentiated risk-reduction campaign, these poster communications require regular maintenance, otherwise there is a risk of giving a message that is the opposite of the initial objective (a faded, outdated campaign and therefore risk reduction behaviors that are no longer useful).

3.3 The comparison of audiovisual and print media

The survey was designed to check the effectiveness of communication channels in disseminating volcanic risk information and to determine whether websites and social media are now consulted more than those messages broadcast on tradi-

* http://ovi.ingemmet.gob.pe/?page_id=128

† http://ovi.ingemmet.gob.pe/?page_id=128





Figure 2: “Mr. Misti” taken down on the heights of Alto Selva Alegre, January 2020, photo credit: S. Rouquette.

tional channels of communication. These results may influence whether it is necessary to adapt volcanic risk communication methods to local populations.

It does not matter how good a risk reduction campaign is if the message does not reach the target population. In a communication campaign, the relevance of the dissemination channels chosen is as important as the relevance of the messages [Sarboni 2012]. Channels are amplifiers of the campaigns and sometimes can even be the first source of information for the target populations, in particular for inhabitants who do not have direct experience of the risk considered [Wachinger et al. 2013]. According to Seydlitz et al. [1994], the frequency of media coverage is more important than the tone of the media, particularly for audiences with no direct or recent experience of the hazard. Thus, the potential role of the media in raising awareness of volcanic risk is greater the more the media make hazards and risk a recurrent news item [Slovic 1987, p. 280], especially those that generate catastrophic and visually spectacular consequences.

For all these reasons, it is necessary to determine which communication channels prove to be the most effective; bearing in mind that each media and communication support has its specific advantages. For example, the audience reached,

control of information by officials, or the speed of information dissemination during an eruption vary with each platform.

3.3.1 Results: the strong influence of audiovisual media

We explore which are the main sources of information for the residents about volcanic risk. Results (Table 4) show that around El Misti the internet has become a central source of information, whether it be through institutional websites (11 out of 76 respondents), social media (4), or the internet without additional specifics (16). Conversely, the written press (0), schools (2), downloadable smartphone applications (1), and public conferences (2) reach a limited audience. However, audiovisual media still have a significant place in the ratings (radio 18 and television 21). The preference for radio and television over printed media is explored further.

3.3.2 Audiovisual vs. print

A first element explored is the influence of the more spectacular nature of television images. It has been found that the spectacular character of an image makes it easier to remember [Schwarz et al. 2016], but here all all media—radio, print, and television—give great importance to spectacular news related to natural hazards. The news is often highly emotionally charged, despite the media then prioritizing “... physical in-

Table 4: Main sources of information on volcanic risk of respondents living in Arequipa.

Source	Number of respondents
Internet (without additional specifics)	16
Social media (Facebook, Twitter)	4
Internet, institutional websites	11
TV	21
Radio	18
Print media	0
Mobile apps	1
Conferences	2
None	0
School	2
No reply	1
Total	76

formation about the events and the first consequences rather than the protective advice that the population would ‘need’ [d’Ercole 1994, p. 120]. To illustrate this we provide a criticism made by this respondent:

Q: “Did you hear about the lahar descent alarm on March 13? Where did you see the news?”

A: Yes, I heard it on the radio, but the truth is that I did not take it seriously because the press often exaggerates, at least I think that.
(woman, 50 years old, housewife, Alto Selva Alegre)

Thus, the perception that coverage is exaggerated due to a focus on danger and spectacle is a feature of all media, not just television.

A second element explored is the that access to the different types of media likely affects the choice of media for receiving hazard and risk information. In Peru, 86.7 % and 75.5 % of urban households had access to television and radio respectively, in 2020*. Fewer households had access to the internet (60 %[†]). It is estimated that 40 % of the population of Arequipa reads written press[‡]. Under these conditions, programs broadcast on the television and radio have a wider audience among the local population than articles published in the written press.

Newspaper consultation is low (zero in our panel). Why should newspapers not be consulted for information on volcanic risk? It may be because the press does not often write about volcanic risk, especially with the current low level of volcanic activity at El Misti. A keyword search of the newspaper database for *El Comercio* revealed that between 2018 and 2020, the newspaper only reported on the implementa-

tion of simulations and the development of the risk map by INGEMMET. Poor coverage was noted by this resident:

Q: “If you need to find out information about volcanic hazards, what are your sources?”

A: “The internet, because you never hear about it in the news or in the written or spoken press”
(man, 43 years old, Sachaca, owner)

An additional element that may explain the limited importance given to the written press is the credibility given locally to this media. Credibility is generally weak in the eyes of the population. For example, when asked about this by the Ipsos Institute (an international opinion polling company) in 2008, 43 % of Peruvians considered the written press to be credible, a much lower percentage than for radio (67 %) and television (55 %) [Requena 2014]. This lower credibility of the printed media is due to the strong politicization of the printed media [Requena 2014]. The selection of columnists who appear in these pages is an example of this politicization, which is significant in a country where distrust of political speech is high; only 10 % of Peruvians interviewed by Requena [2014] consider political speech to be credible, especially following the revelation of various cases of corruption [Montoya 2007].

Volcano hazard prevention and monitoring are not directly political issues, even though volcano monitoring institutes are under the responsibility of government ministries (e.g. the Ministry of the Environment for the IGP). Since volcano monitoring is not a regular topic in political battles, the impact of public distrust of an overly partisan printed media is limited. However, as the level of credibility of the printed media is low, it indirectly impacts any press articles that deal with the public management of natural hazards, and it must be taken into account in an analysis of the impact of the different communication channels.

3.4 The internet as a source of information on volcanic risk

3.4.1 Internet use

Table 4 shows that the internet has become a common channel for accessing volcanic risk information, whether on websites (11 of 76 respondents), social media (4), or the internet in general (unspecified: 16).

Q: “If you need information, what are your sources?”

A: “Internet pages, including the pages of the municipality, also the page of the Instituto Geofísico”
(man, 22 years old, tenant, student, Alto Selva Alegre)

A: “I would use the pages and applications of the IGP, the one of the volcanological centers where they give notifications, where they inform us. I consider it good, I even recently signed up for the IGP’s Twitter and the seismic application, where they report on earthquakes. I have noticed that the IGP application arrives faster than Twitter”
(man, 28 years old, owner, student, Alto Selva Alegre)

* <https://www.inei.gob.pe/media/MenuRecursivo/boletines/boletintics.pdf>

[†] <https://www.inei.gob.pe/media/MenuRecursivo/boletines/boletintics.pdf>, p. 9

[‡] https://cpi.pe/images/upload/paginaweb/archivo/23/LectoriaDiarios_2016.pdf

A.: “Last year around November, I searched about volcanic activities, the volcanoes that erupted, the types of minerals found in volcanic eruptions, I searched the internet”
(*man, 23 years old, tenant, student, Alto Selva Alegre*)

A.: “If I needed information I would go to the internet, I would look for information about this through the internet”
(*woman, 50 years old, housewife, owner, Alto Selva Alegre*)

Of the 76 survey respondents, 11 indicated that they use institutional websites as a source of volcanic risk information. For example:

Q.: “If you need to find information about volcanic hazards, what are your sources?”

A.: “I would check by going to the civil defense website”
(*woman, 49 years old, cook, owner, Alto Selva Alegre*)

A.: “I always get information through the IGP website or the civil defense”
(*man, 58 years old, university professor, owner, Alto Selva Alegre*)

A.: “I would investigate more on the internet, on the pages of the municipality, also the page of the Geophysical Institute of Peru, in the applications, also the television, the radio and the news”
(*man, 23 years old, tenant, student, Alto Selva Alegre*)

A.: “Official web pages or web pages of institutions via the internet”
(*man, 30 years old, owner, single, tour guide, Alto Selva Alegre*)

Social media offers a digital solution that complements websites. It can be used in upstream volcano risk awareness campaigns, when the volcano is quiet, as well as communication campaigns conducted during a crisis. During an eruption, the speed of social media is an advantage as explanations on how to behave can be relayed by friends, contacts, and family, and messages can be disseminated quickly in case of an alert.

Firstly, in the event of a crisis, the inhabitants think they will get as much information from social media as from television. For example following a questionnaire-based survey conducted online involving 4459 Peruvians, 1752 respondents (39 %) answered that in the event of an eruption they partially agreed with the idea of preferentially receiving information via social media, while 1194 (27 %) totally agreed with this idea.

In the case of our survey, the number of respondents that used social media as a source of information about volcanic risk is still lower than that of traditional and other communication channels (Table 4). This demonstrates that social media should not currently be the dominant channel for volcanic risk communication, though it can be included within a wider communication strategy.

3.4.2 The advantage of the internet

Several features of the internet contribute to its value as a source of information on volcanic risk.

The sources of online information on volcanic hazards are numerous and varied. Depending on their level of knowledge

or interest, internet users can visit specialist and general sites. The variety of means of connection (smartphone, computer, tablet), connection times (available to access at any time), and type of information available are all major advantages of the internet as a source of information [Rouquette 2009]. This permanent connectivity also has the effect of broadening the keyword requests and topic searches from internet users [Rouquette 2009]. Interest in news about volcanoes can be influenced by the activity at that moment [Rouquette 2010], conversations with friends or family (especially children), or listening to a television report.

The internet is a free source of information in the sense that consulting several websites does not cost more than limiting oneself to one. The hypertextual* nature of the internet and the tendency of internet users to serendipitously browse (that is, browsing from link to link, at random, which leads to unexpected and fruitful search results), offers the possibility of letting their curiosity carry them along, clicking from link to link and finally landing on information that they would not have been consulted otherwise. All these elements make the internet a convenient source of information. When asked “How much time per week do you usually spend on consulting the news?”, one survey respondent replied “I use the Internet almost all day” (42-year-old woman, owner, housewife, Sachaca).

Some (4 out of 76) also remember seeing the IGP-produced posters on volcanic risk on the internet and not in the street. These posters show the ash escaping from the volcano and have instructions on how to behave in the event of an eruption. It is clear from our study that respondents think that the internet also offers the advantage of broadening the distribution of communication products initially designed for other media. For example:

Q.: “What is the last risk communication campaign that you can remember?”

A.: “In 2018 approximately, I searched about what was happening in Misti and the ashes, mostly for the areas near Misti, it was through the internet, but lately you don’t remember any campaign in these more current years”
(*man, 31 years old, communicant, owner, Alto Selva Alegre*)

A.: “Actually, I have read articles, but all via the [inter]net, also I saw a poster about evacuation or drills for volcanic hazards, about a few months ago, saw it on social media on a news page”
(*man, 28 years old, owner, self-employed, Alto Selva Alegre*)

The feedback is important to note for several reasons. Firstly, it shows how the technical features of the internet offer a communication advantage that is actually useful to volcano monitoring organizations. Digital communication offers several advantages. Unlike the printing of posters, enriching a website with video content or existing images costs nothing in terms of printing and distribution, as everything is online.

*The internet as a hypertext is a network of information that allows a user to go from one source of information to another through a system of references called links.

In addition, a website or a Facebook page is not constrained by limited distribution space, unlike communication by posters, brochures, or leaflets. Digital communication is also not limited by a number of words, pages, or even an imposed regularity of distribution (daily or weekly): a magazine published every week on newsstands can be updated every day online. Television websites can publish written articles while newspaper websites can broadcast videos. The convergence of temporalities of online content of different communication media [Rouquette 2010] undoubtedly offers an advantage here. Thus, communicators responsible for volcanic risk reduction campaigns should have an interest in disseminating audiovisual productions or posters on the internet because it is cheap and technically and temporally not very constraining. The internet constitutes a second market for the dissemination of communication content produced in other contexts, offering these products an additional chance of being seen.

The websites and digital social networks broaden the means of dissemination of risk reduction campaigns, with 60 % of Peruvians having an internet connection*. However, the internet is more suitable for reaching a young population (only 27 % of those over 60 are connected), households with children (four-person households are three times more connected than two-person households), and educated inhabitants (95 % of those with a university degree are connected) compared with those with a primary education (25 %[†]). Importantly, the inhabitants of the disadvantaged and high-volcanic risk areas of the Alto Selva Alegre are priority audiences for volcanic risk communication campaigns (21 % of inhabitants of Alto Selva Alegre are considered to be living in poverty[‡]). That said, the rapidly increasing connection rate (+6 percent in one year[§]) is gradually diversifying the profile of Peruvian internet users.

3.4.3 The contribution of websites to the dissemination of the risk-reduction campaign

There is a danger that people living in a hazard zone will come across publications containing recommendations that differ from the official ones, and that may reduce their impact [Haynes et al. 2008a]. This danger may be even higher online, as it is easy to move from one site to another and not all internet users verify the sources of the information and claims they find there. According to the literature on digital communication [Gayet and Marie 2019], the address of the official website should be communicated consistently in risk communication products, a point made by this respondent, who was surprised not to find the URL[¶] of the volcano monitoring organization on the proposed poster:

Q.: “What communication tool did you use?”

A.: “First of all, on the website, on the INGEMMET website and the Geophysical Institute of Peru, but for example in this poster, I don’t see a phone number where you can call, nor an address, it just tells you about the problem, but it doesn’t say where to go to look for information”

(male, 38 years old, teacher, owner, Sachaca)

The current referencing of the sites of the two volcano monitoring organizations is satisfactory, as shown by the test carried out in Spanish in February 2021 from a Mexican IP address. When “*la actividad histórica del volcán Misti*” was searched, the first two links offered were to videos of local TV reports in which IGP experts are interviewed. This is an important result given the number of respondents who said that they would prefer institutional sites if they had to find out about El Misti and how to behave. Search engine optimization (i.e. the place of the URL of the site in the answers given by the search engines, without paying to improve the reference rating of the site, for example by buying keywords) would increase the likelihood of people accessing institutional webpages when searching for volcanic risk information.

For the institutional sites to be better referenced, several recommendations can be followed. This does not only imply having consistent and updated content, but above all content that meets the expectations of internet users, since “a good website is first and foremost a site that answers the main questions asked by its main targets” [Rouquette and Chauzal-Laguier 2023]. In other words, they must very clearly answer questions such as: What should I do in case of a hazard? Am I in a high-risk area? How can I protect and prepare myself?

Any website that focuses on the expectations of its users increases its chances of meeting the objective of raising public awareness of volcanic risk. In contrast, focusing foremost on the history, background, and structure of the institution and the news of the monitoring organization reduces the chances. Online, it is the internet users who look for the information and not the organization that looks for the internet users. In a poster campaign, the organization can impart its message to passers-by simply by being on display. In a radio or television campaign, it interrupts a program listened to by listeners and viewers. Online this works in reverse—the volcano monitoring organizations offer content, but it is up to the inhabitants to go and find it. It is therefore particularly relevant to apply a communication strategy focused on the expectations of the targeted users [Rouquette 2017].

However, many of the interviewed inhabitants do not, on their own initiative, request or look for information about volcanic risk. To the question “When did you last inquire about volcanic risk?” 43 of the 76 respondents answered “no, they don’t inquire about volcanic hazards”. This lack of interest about a natural hazard which may impact them directly was also noted in other fields. In the case of the risk of flooding, for example, Verlynde has shown that:

“by comparing the answers on the fact of being informed and those on the fact of feeling sufficiently informed by the public authorities, correlations appear.

*https://www.inei.gob.pe/media/MenuRecursivo/boletines/boletines_tics.pdf

[†]See footnote above*

[‡]http://munialtoselvaalegre.gob.pe/transparencia/infor_presupuestal/memoria_anual_2017.pdf

[§]See footnote above*

[¶]Uniform Resource Locator, also known as a web address.



The inhabitants who feel informed are [...] more likely to have been informed independently (more than half, 51%). In contrast, those who do not feel sufficiently informed are less likely to have taken this step (3 out of 10 people, 30%) [Verlynde 2018, p. 294].

For this reason, it is not possible to base a risk communication strategy solely on communication channels such as websites, whose effectiveness relies on the curiosity of inhabitants/internet users—the curiosity has to be created and maintained. Other direct and targeted media must be used.

3.4.4 *The contribution of social media to the dissemination of the risk-reduction campaign*

The value of being able to continuously update information about volcanic hazards through social media is also observed, in a different vein, by the investigation of Sennert et al. [2015]. Their work focuses on user requests for volcano observatory accounts. They make the following observation: internet users are waiting for “information, images and official data about recent or ongoing eruptions,” for example images of an eruption given by webcams. To interest a web user, they advise a simple method: provide recent images by indicating their time and date. The downside to focusing on recent images is that it reduces the appeal and visibility of older images of volcanoes [Sennert et al. 2015].

Many of our survey respondents indicate that they use social media and explain that they do so because social media is commonly accessed by a mobile phone, which is convenient as they can be carried and consulted anywhere and at any time, which is not always the case with traditional media. For example:

Q: “If you need to get information, what are your sources?”

A: “Well, in the past there was radio and television, but now there are social media and WhatsApp social groups, there are many channels of information, in this case WhatsApp that everyone uses because the information is useful at any time, any place and within reach of your pocket, which did not happen before with the cell phone or the radio”

(*man, 38 years old, teacher, owner, Sachaca*)

A social network such as WhatsApp can be used as a communication relay between inhabitants anxious to share information on the news of a danger linked to the inhalation of volcanic ash (as was the case in Indonesia between inhabitants of the village close to the Merapi volcano [Schwartz-Marin et al. 2020]). However, social media also offers the possibility of reaching inhabitants who are connected but not very concerned by the volcanic activity in their area. In this way, an inhabitant of Arequipa could consult a video talking about El Misti volcano because one of their Facebook contacts suggested listening to it on Facebook and not because they are subscribers to the Facebook page of the IGP or INGEMMET. There is also value in the capacity of the social media accounts of risk-management organizations to reach a public that does not want to miss anything in the news. As explained by Veil et

al.: “social media allows for human interaction and emotional support and has been shown to be important to stakeholders dealing with crises” [Veil et al. 2011, p. 120].

Overall, websites and social media offer an effective complementary communication medium to the audiovisual media. While the former offers the possibility of presenting a structured official risk-reduction campaign online and of disseminating content initially produced for other media (posters, videos), the latter allow the provider to inform curious inhabitants about volcanic news. Both channels benefit from the advantages of the internet: permanent access in all places, flexibility of dissemination (at any time and with a wide range of content: images, texts, videos), dissemination facilitated by freely accessible content, and also by chance access.

In addition to the traditional media and the internet, volcano monitoring organizations have other communication channels at their disposal: in particular, urban posters (posters in the subway and on bus shelters) for territory-based communication, schools for a communication based on family discussions, and simulation exercises.

3.5 *The importance of family dynamics in communication.*

In the survey, intra-family communication stands out as an important communication source. When 51 survey respondents were specifically asked, “Do you talk about volcanic risk with your family?” 38 responded positively (from time to time or often). For these inhabitants, their family, children, and relatives are both a source of information and a motivation to be interested in the subject. This result suggests an unusual strategy for Arequipa: to use family conversations as one channel of communication. The following examples illustrate this:

Q: “Do you know people who have been impacted?”

A: “Yes, my distant uncles once told me that they had a volcanic experience many years ago”
(*man, 32 years old, taxi, owner, Alto Selva Alegre*)

Q: “Do you talk about volcanic risk with your family, friends, neighbors, etc. at any time?”

A: “Yes, everything I learn at university about risk I pass on to my family”
(*woman, 26 years old, owner, student, Alto Selva Alegre*)

It would be a mistake to see this phenomenon only as a topic of conversation between people who share an environment or daily considerations. Only 2 of the 51 respondents who were also asked whether they talked about this topic with their neighbors responded that they did. Thus, family communication is important, and far more than for neighbors. This is likely due to a number of factors. Arequipa is a city that has had a large influx of migrants from other regions in Peru, so districts, especially the new ones, that are particularly at risk, do not necessarily have a long history of family residence. Importantly, it is usual for many parents to pass on their knowledge to their children in all areas of life, from the most everyday things to the less ordinary. This is demonstrated by this respondent:

Q: “Do you talk about volcanic risk with your family, friends, neighbors, etc. at any time?”

A: “Above all, with my younger children, because they ask me about the volcano, and I tell them that if it erupts, Arequipa would disappear, so we have to be prepared”

(*woman, 58 years old, farmer, Sachaca*)

A: “Yes with my children, one of them told me that they had seen on social media that we are in a red zone on the risk map of El Misti”

(*woman, 40 years old, housewife, Alto Selva Alegre*)

This family communication works both ways, as children do not hesitate to relay to parents what they have learned at school.

Another phenomenon can come into play: the parental concern to protect their children or to teach them the actions necessary for their safety. Flanquart [2016] observed a similar phenomenon for local industrial risks, and concluded that this behavior reveals the concern of parents to ensure the safety and good health of their offspring [Flanquart 2016]. When life is given, Cordié [2002, p. 75] explains, it is in a more or less instinctive concern to, “thumb our noses at death,” it is to create a being that will survive us, “who takes after us,” and “who cares about us”. There is nothing illogical in considering that this concern and advice, which primarily concerns everyday life (how to cross a road, etc.), extends to recommendations on volcanic risk matters. Moreover, the stories of the disasters tell us how the people affected by these disasters first try to get in touch with their family and friends, by all possible means [Ferrer et al. 2021].

The increased importance given by residents to messages when it comes to their family is not only about the importance they attach to these messages. It is also about the value placed on family members as reliable sources of information in general, and in particular in the field of volcanic risk information. Research on the island of Montserrat found that local people put more trust in information from friends and family than in information from scientists [Haynes et al. 2008a]. Even if it has to be examined as much in terms of social fiction, Bourdieu does explain that the family institution is socially constructed as “the locus of *trusting* and *giving* – as opposed to the market and the give-and-take” [Bourdieu 1993, p. 33].

Family relationships must themselves be assessed in terms of this socially shared concept of the family institution. In the absence of direct experience, the representations of risk that inhabitants have are fed by the indirect experience of family members. Family members with whom they tend to speak in confidence about all subjects that concern them, in particular with their closest relatives (parents/children), include subjects relating to personal safety. This is noted by Weinstein [1989] where risk perception is, among other things, correlated with an indirect experience of one’s family circle.

The results of this research open up two opportunities. The first consists of raising awareness among children during introductory sessions on volcanic risk in the city’s schools, counting on the fact that—as is the case with these

inhabitants—the children will in turn raise awareness among their parents:

Q: “Did last year’s IGP poster and brochure communication campaign that we showed you during the interview convince you to take action based on this information?”

A: “The communication campaign convinced me, I would participate if I were free” (*man, 53 years old, civil construction, owner, Sachaca*)

A: “I think they should provide more information about where to evacuate, how to evacuate, what food sometimes should be eaten, and I also think they should provide information for young children who are the most interested in this type of issue and insist on their parents participation; they could also train them and the publicity could also be in Quechua, maybe in a small space on the poster so that adults or older people who understand this language can also participate” (*man, 58 years old, owner, university professor, Alto Selva Alegre*)

It should be noted that this form of communication has already been implemented by the IGP, which reports that four training sessions have been conducted in high schools since 2012*. A set of children’s books has also been initiated, dealing with tales of eruptions [Tavera 2014].

Although these training sessions have the advantage of reaching a captive audience, they are also costly and complex to implement. Each of these interventions in a school mobilizes staff who do not have the time or the means to multiply these operations throughout all of the city’s schools. Furthermore, all awareness-raising campaigns conducted in a school setting come up against similar difficulties: their implementation is unevenly distributed according to territories and neighborhoods and—even at the school level—according to the differing sensitivity of school management staff to these issues [Chartrain 2013]. These are all limitations that must be taken into account.

A second opportunity may be capitalized on in relation to family communication: that of a mass communication campaign that uses family arguments or motivations more directly to encourage action. This is a strategy which can resonate with the population in many ways, for example by visuals representing parents and children, by the choice of connotative words (“your loved ones,” “your family”), or by the deployment of messages integrating an emotional dimension relating to the protection of children and their entourage; a common situation in public communication strategies using images of children [Rouquette 2017]. Lessons learned from other cultural locations where the family and collective neighborhood action are strong, such as the Philippines, could be incorporated [e.g. Morillo et al. 2013; Ferrer et al. 2021].

4 CONCLUSIONS

We have presented a survey conducted on 76 inhabitants of two separate districts of the city of Arequipa, one at greater

*<https://www.gob.pe/institucion/igp/noticias>

risk than the other to the possible hazards of El Misti volcano. The survey was conducted by in-depth interviews of a balanced selection of the population, using the appropriate ethical constraints in force in Peru and in accordance with French social science ethical rules. The study was also enacted in a way to co-construct the research with the local personnel, to work with their needs as well as the European academic ones. The study was based on a comparative approach and used previous information campaigns of our partners disseminated in the city as a key information source. The survey was directly carried out by local university students trained by the group in survey techniques and the work was overseen by both Peruvian and French scientists.

The survey has provided useful information on how to improve the current volcanic hazard/risk communication campaigns. We have divided the results into five sections that deal with: 1, the actual perception of risk; 2, the spatial perception of risk; 3, the comparison of audiovisual and printed media; 4, internet-based communication; and 5, family-based communication.

1. Regarding risk perception, the results highlight the difficulty of sensitizing a local population to the volcanic risk. In spite of the numerous communication operations carried out over many years, the majority of the inhabitants questioned still have difficulty evaluating their volcanic risk. For example, an eruption of El Misti would produce gas and ash, and only 24 respondents mention ash and 15 mention gas as hazards associated with El Misti volcano. In addition, the vast majority of respondents were not aware of any preventative measures. Of the 76 residents interviewed, 26 said they did not know what to do in the event of a volcanic eruption.

This result leads us to ask how can the impact of volcanic risk communication campaigns be improved? The second subject leads to a partial answer, that of using a territory-based approach.

2. The survey compares two districts of the city, one in which El Misti poses a high risk, the other in which the risk is negligible. In this territorial context, 48 % of the inhabitants of the low-risk Sachaca feel protected from the volcanic risk, while only 39 % of the high-risk district of Alto Selva Alegre. Thus, we suggest that a communication strategy based on the specifics of a location, using local context (i.e. a territory-based approach), would be more effective.

3. The third part dealt with audiovisual and printed media, and the main sources of information for the residents about volcanic risk. This comparison showed that, of the traditional media, television remains the one that reaches the most people, especially in comparison to the printed media.

4. The fourth result deals with the internet and concerns the comparative interest of institutional websites and social networks. The proportion of respondents who consult institutional websites is higher than the proportion who get information online via social networks. For this reason institutional websites have a very high importance in communication. However, as exposure relies on residents actively visiting websites, other media sources need to introduce and invite

people to use websites, which also need to be prominent in searches.

5. The final result is about family communication. The survey reveals the importance that the inhabitants give to intra-family exchanges for advice on risks and personal safety. When 51 survey respondents were specifically asked, “Do you talk about volcanic risk with your family?” 38 responded positively (from time to time or often). In contrast, respondents did not tend to communicate with neighbors on this topic.

In general, we have seen clearly the advantage of territory-based communication. As the inhabitants are sensitive to information and risks that are specific to their neighborhood, a differentiated communication strategy based on risk levels and neighborhoods has many advantages. Urban advertising offers the possibility of targeting a local audience.

The comparative analysis of the use of different communication channels reveals, secondly, that certain communication channels should be prioritized. It is necessary to take into account the media access and habits of the local population. Urban households had high access to television and radio in 2020, so these remain very important; internet coverage is increasing, and will become more important. We have seen that it is valuable to continue investing in institutional websites. Even if the construction of a website involves a heavy initial investment, its rapid updating allows the content of the site to evolve rapidly. Sites allow structured communication, perfectly adapted to the objectives of a risk reduction campaign conducted by official bodies and based on scientific knowledge. For reliable and quality educational information, an institutional website is a real asset, provided that it effectively meets the expectations of internet users.

A consideration of family matters shows that campaigns that more directly exploit internal family communication may have greater impact.

Finally, it should be noted that the conclusions of this work are valid for the Peruvian area studied here. They would require further investigation to verify their relevance in other areas and contexts. However, the general outcomes may have universal application which can be tailored to other sites. This work emphasizes the complexities of communicating risk, and shows that a great deal of forethought and continual assessment is required.

AUTHOR CONTRIBUTIONS

Conceptualization of the research: Lise Jacquez and Sébastien Rouquette; methodology: Lise Jacquez and Sébastien Rouquette; training of interviewers in sociological interviewing methods: Sébastien Rouquette; Peru survey organization, strategy, recruitment, institutional contacts: Luisa Macedo Franco; data analysis and interview analysis: Lise Jacquez and Sébastien Rouquette; creation of tables: Lise Jacquez and Sébastien Rouquette; drafting of the manuscript: Lise Jacquez and Sébastien Rouquette; reviewing: Lise Jacquez, Sébastien Rouquette and Benjamin van Wyk de Vries; Funding acquisition: Lise Jacquez, Sébastien Rouquette, Benjamin van Wyk de Vries; Spanish translation: Jorge Concha and Luisa Macedo

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DATA AVAILABILITY

Interview responses are available as [Supplementary Material](#) alongside the online version of this article.

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APPENDIX A

Questions asked during the interviews

The interviews conducted focused on two main themes. Here is a summary of the questions asked in each of these areas

Perception of the neighborhood, the volcanic risk and knowledge of risk management instructions

Where do they live?

- How long have they lived in the neighborhood?
- Why do they live there? Did they choose this neighborhood?

- How do they perceive their territory?

- What risks are they most concerned about: natural risks or other risks (safety, pollution, natural hazards etc.)?

- The Misti volcano: what words do they associate with the volcano?

- Do they have any memories of the volcanic activity (year, what happened)?

- Qualify the volcanic risk: what is for them the risk linked to the volcano (mud, gas emanations?)?

- Their sensitivity to the risk with a scale of involvement: "for me, the communication on the volcanic risk is: Important /Boring/ Useful/ Exciting /Insignificant/ worthless/."

- What should be done in the event of a volcanic risk?

Their sources of information about volcanic risk

- If you need to find out, what are your sources:

- The last two times you asked about the volcano, what were your sources (Facebook? Radio? The press? Television? Will they quote children, neighbors? The town hall? other)

- What was the last risk communication campaign you remember (possible to describe: which ones, when? where?)