

Research paper

# Volcanic risk perception of young people in the urban areas of Vesuvius: Comparisons with other volcanic areas and implications for emergency management

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## Abstract

More than 600 000 people are exposed to volcanic risk in the urban areas near the volcano, Vesuvius, and may need to be evacuated if there is renewed volcanic activity. The success of a future evacuation will strongly depend on the level of risk perception and preparedness of the at-risk communities during the current period of quiescence. The volcanic risk perception and preparedness of young people is of particular importance because hazard education programs in schools have been shown to increase the clarity of risk perception and students often share their knowledge with their parents. In order to evaluate young people's risk perception and preparedness for a volcanic crisis, a multiple choice questionnaire was distributed to 400 high-school students in three municipalities located close to the volcano. The overall results suggest that despite a 60-year period of quiescence at Vesuvius, the interviewed students have an accurate perception of the level of volcanic risk. On the other hand, the respondents demonstrate a clear lack of understanding of volcanic processes and their related hazards. Also, the interviewed students show high levels of fear, poor perceived ability to protect themselves from the effects of a future eruption, and insufficient knowledge of the National Emergency Plan for Vesuvian Area (NEPVA). The latter result suggests that in comparison with volcanic crises in other regions, during a future eruption of Vesuvius, there may not be enough time to educate the large number of people living near the volcano about how to appropriately respond. The inadequate risk education and preparedness of respondents implies that a strong effort is needed to improve communication strategies in order to facilitate successful evacuations. Therefore, it is important to take advantage of the present period of quiescence at Vesuvius to improve the accuracy of risk perception of youth in local communities.

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## 1. Introduction

Vesuvius has a history of explosive eruptions that have proven to be deadly for those living near it. While stories about its most famous eruptions are still prevalent in popular culture, the lack of an eruption since 1944 has led to complacency among residents near the volcano (Dobran, 2006). Almost 600 000 people reside in the Red Zone, an approximately 250-km<sup>2</sup> area around Vesuvius defined by the government's National Emergency Plan for the Vesuvian Area (NEPVA) as likely to

experience the most hazardous effects of pyroclastic flows and lahars in the event of a large subplinian eruption (ISTAT, 1991; Presidenza del Consiglio dei Ministri Dipartimento delle Protezione Civile, 1995, 2001; ISTAT, 2001). According to NEPVA, an additional estimated 1 100 000 people could be affected by heavy ash and lapilli fallout and lahars in the 1800-km<sup>2</sup> Yellow Zone.

Past studies have shown that residents near Vesuvius do not have high levels of perceived volcanic risk (Davis et al., 2005; Barberi et al., 2006, Dobran, 2006). The fundamental equation of volcanic risk is defined as:  $\text{risk} = \text{hazard} \times \text{vulnerability}$ , where hazard refers to the probability of the occurrence of a specific volcanic phenomenon, and vulnerability defines the degree of loss

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to elements exposed to the hazard (e.g. humans, buildings, economic activities) (Blong, 2000). Risk perception is a subjective judgment that people make about the characteristics and severity of a *risk* (Paton et al., 2001).

The low-levels of perceived volcanic risk are significant because if a high intensity event were to occur, such as a volcanic eruption, people might adopt inadequate behaviors due to a lack of risk awareness and perception. This could lead to a serious crisis management problem (De La Cruz-Ryna et al., 2000). Further, the public's perception of risk is frequently found to be biased, with people exaggerating the impact of large spectacular events and underestimating that of pervasive or frequent ones (Slovic, 1987). Volcanic eruptions are generally less common than other natural hazards, therefore in most cases individuals seldom gain personal experience of such events. This can lead to an individual low level of perception of risk (Johnston and Ronan, 2000). Periods of quiescence, which are most common in volcanically active regions, afford the best opportunity to develop mitigation strategies to maintain risk perception at an effective level. Individuals who have an accurate perception of their vulnerability are more inclined to appropriately respond to warnings and undertake protective behaviors (Mileti and Sorensen, 1990; Lindell, 1994).

On and around Vesuvius, the lack of land-use planning, along with volcanic quiescence since 1944, have led to extensive urbanization on the volcano's slopes during the last 40 years (Cosenza, 1997; Dobran, 2006). A lack of adequate preparedness by local communities could render NEPVA's emergency plans ineffective. The large number of people who would have to be evacuated from the Vesuvian area would make evacuating in a timely manner extremely challenging. In contrast, in slightly urbanized areas close to volcanoes (i.e. villages with less than 60000 inhabitants), the success of evacuation does not strictly depend on the pre-disaster risk perception and education of local communities, as was illustrated by the 1995 Soufrière Hills volcanic crisis in Montserrat, West Indies (Buffonge, 1999; Kokelaar, 2002) and the 1991 Pinatubo eruption in the Philippines (Johnston and Ronan, 2000). In both cases residents were not prepared to evacuate before eruptions, but evacuations were carried out effectively.

Some studies have been conducted on the risk perception of residents near Vesuvius, but only few have focused solely on the perception of young people in the region. It is important to focus on young people's risk perception because the more a young person is aware of hazards and the realistic risk associated with them, the more potential there is for adults, particularly parents, to be better educated through the child sharing information with them (Ronan and Johnston, 2001). In addition, they have shown that young people involved in hazard education programs demonstrate appropriate risk perceptions. Appropriate risk perception is considered to be demonstrated through the increased knowledge of protective actions and more realistic risk perceptions, and an increased ability to cope emotionally (Ronan and Johnston, 2001). Taking into account the above considerations, schools play a vital role in natural-hazard education by providing one of the most effective and least expensive methods to maintain appropriate risk perceptions (Johnston and Ronan, 2000).

This study examines 400 questionnaires administered to high-school level students living in three municipalities in the Red Zone near Vesuvius. The questionnaire is designed to estimate their volcanic risk perception and volcanic-hazard education, to highlight the level of preparedness and participation of youth in local communities with respect to volcanic risk. This is fundamental for the success of an evacuation, especially at Vesuvius where a large number of people living around the volcano probably will not become immediately aware of the situation during a crisis. The results of the questionnaire are compared with case studies in different volcanic areas to determine differences and similarities in behavior and perception during potential volcanic crises.

## 2. Vesuvius background

### 2.1. Eruptive history

Vesuvius is located about 10 km south of the large city of Naples, with a population of about 1 000 000 (Fig. 1). Vesuvius is a stratovolcano that reaches a height of 1281 m above sea level. Volcanic activity dates back to at least 400 000 BP (Arnò et al., 1987). The earliest period of volcanic activity was dominated by four plinian eruptions ("Pomici di Base," 18 300 BP; "Pomici Verdoline," 16 000 BP; "Mercato," 8000 BP; and "Avellino," 3780 BP) (Rolandi et al., 1993). Vesuvius' most famous plinian eruption occurred in A.D. 79 and produced pyroclastic flows that killed approximately 2000 people. Volcanism between A.D. 79 and 1631 included at least two *subplinian eruptions* and a series of small, low-energy interplinian eruptions that produced lava flows and scoria deposits on the southern and western flanks of the volcano (Principe et al., 2004). A subplinian eruption occurred in A.D. 1631, after which there was predominantly *open-conduit* activity with eighteen distinguishable *Strombolian* cycles (Arnò et al., 1987). Most recently, effusive and explosive activity occurred in 1944, marking the volcano's transition to a state of *closed-conduit* activity. There has been no evidence of renewed volcanic activity at Vesuvius since the 1944 eruption (De Natale et al., 2001).

### 2.2. Eruption scenarios

While the historical eruptive activity of Vesuvius is well known, there is much debate about the scale and timing of the next eruption (Scandone et al., 1993; Lirer et al., 1997; Palumbo, 1999; Borgia et al., 2004; Santacroce et al., 2005; Mastrolorenzo et al., 2006). Lirer et al. (1997) and Mastrolorenzo et al. (2006) report that the worst-case scenario is possible, which would involve a large plinian eruption similar in scale to the A.D. 79 and 3780 BP eruptions. NEPVA has adopted a different scenario, which is that the next eruption of Vesuvius will be similar in scale to the subplinian A.D. 1631 eruption. Some scientists disagree with this assessment, for example Borgia et al. (2004) who reported that due to spreading processes at Vesuvius, the likelihood of a plinian eruption is reduced, while an effusive eruptive scenario is more likely with associated minor risk.

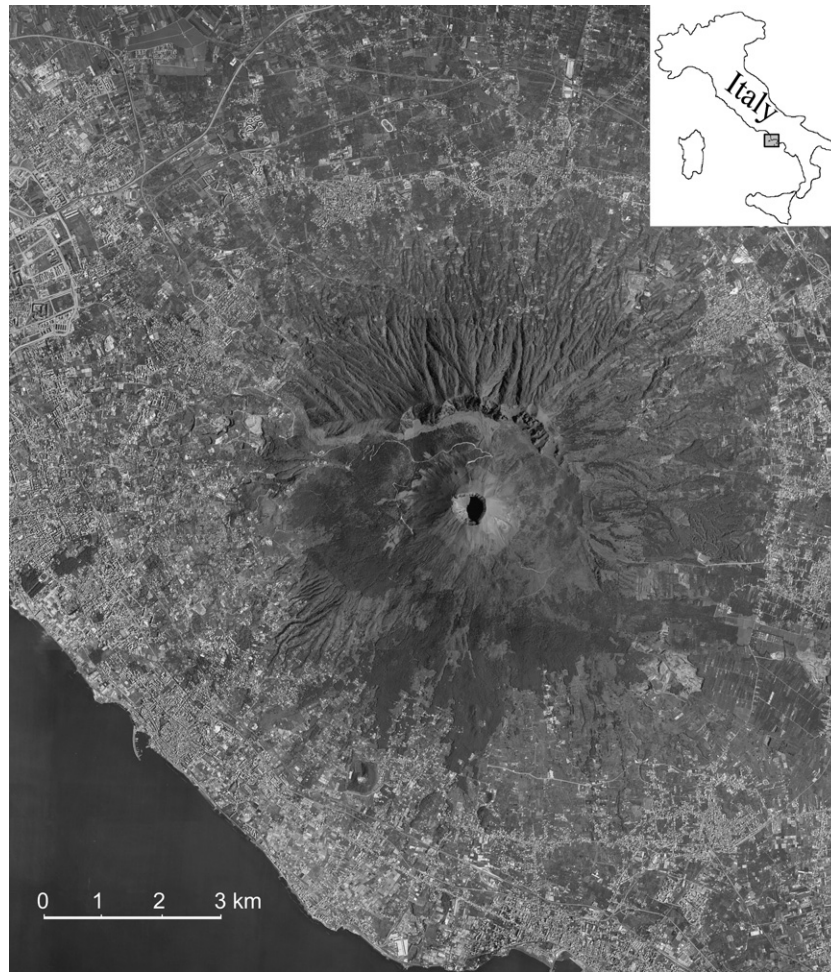


Fig. 1. Airphoto of Vesuvius. The extensive urbanization of the volcano's slopes is evident, particularly on the southwest sector (CGR-Parma, Programma it 2000).

The impact of future eruptive activity on populated areas will differ depending on the type of activity. If the worst-case scenario were to occur, 3 000 000 people living in and around downtown Naples would potentially be exposed to volcanic hazards (Mastrolorenzo et al., 2006). If an eruptive scenario occurred that was similar to that of the A.D. 79 eruption, about 1 200 000 people would be impacted (Lirer et al., 1997). Less dramatic activity that is similar to the A.D. 1631 eruption would impact about 20% (50 km<sup>2</sup>) of the Red Zone with devastating pyroclastic flows and 10–15% (about 270 km<sup>2</sup>) of the Yellow Zone with severe damage (Santacroce et al., 2005). Effusive eruptive activity would impact communities very close to the volcano, but would probably not be life threatening.

Forecasting when Vesuvius' next eruption will occur is even more complex due to the large number of options. Scientific studies are mainly based on statistical and fractal elaboration. The results suggest that a plinian volcanic eruption (VEI=5) may occur around A.D. 3300, while a smaller plinian or vulcanian eruption (VEI=4) may occur in the 21st century (Palumbo, 1999; Luongo and Mazzarella, 2003).

While the exact timing and scale of the next eruption of Vesuvius is not known, scientists (i.e. Sparks, 2003) agree that it would be very difficult to provide an accurate eruption

forecast in days or even weeks. This may prove problematic because NEPVA has based its evacuation plan on the assumption that scientists will provide warnings about an impending eruption at least two weeks in advance. The potentially short warning time, compounded by the large number of people who will need to be evacuated, necessitates the need for communities to be prepared to respond quickly and appropriately to evacuation instructions.

### 2.3. Previous studies about risk perception at Vesuvius

Volcanic risk perception studies are important because they provide information about the level of preparedness of at-risk communities for possible impending eruptions. The majority of studies on the public's volcanic-hazard related risk perception have been conducted in the United States, including at Mount St. Helens (Perry and Green, 1983; Saarinen and Sell, 1985; Perry and Lindell, 1990), Mount Shasta (Perry, 1990), and at Mauna Loa and Hualalai (Gregg et al., 2004). A large number of studies have also been conducted in New Zealand, including at Ruapehu and Egmont (Johnston et al., 1999; Miller et al., 1999; Becker et al., 2001). Fewer studies have been performed about volcanoes on the Caribbean Island of Martinique (D'Ercole

et al., 1995), in Greece (Dominney-Howe and Minos-Minopoulos, 2004) and in Japan (Yoshii, 1992).

Several studies have been conducted on the risk perception of residents living near Vesuvius in recent time (Vesuvius, 2000; Davis et al., 2005; Barberi et al., 2006; Dobran, 2006). These studies provide valuable information that is used as background for this study. In particular Davis et al. (2005), explored the volcanic risk perception of adult residents of the Red Zone and the Yellow Zone around Vesuvius. They found that although there is a high probability of an eruption within the next 5 years that could impact the Yellow Zone, most Yellow Zone residents considered the likelihood very low that their towns would be seriously affected by an eruption because of the distance of their cities from the volcano. Even though residents of the Red Zone are closer to Vesuvius (within 7–8 km), most people considered volcanic risk as a minor problem compared to the ‘everyday’ problems associated with public services, traffic, crowding, crime and unemployment. Further, despite a great deal of publicity about NEPVA’s evacuation plans during the past 10 years, the Red Zone residents expressed little faith in the government’s ability to protect them. Due to the similar perceptions in both zones, this study only focuses on residents in the Red Zone.

A study about volcanic risk perception was conducted by Dobran (2006) that was focused on school children and adults in the Vesuvian area as part of the VESUVIUS 2000 project, which aims to develop volcanic risk reduction guidelines based on interdisciplinary scientific approaches. The study concluded that education about volcanic eruptions and their associated risks can increase the ability of individuals to appropriately prepare for a possible eruption, supplanting feelings of complacency, false security, and reluctance to evacuate. Based on the result of Dobran’s (2006) work, this study focuses in more depth on contrasting the results from students who have and have not participated in volcanic-hazard education programs.

### 3. Method

#### 3.1. Participants and setting

The Vesuvian area is divided into 18 municipalities (Fig. 2) with a population of about 600 000 people living in a 228 km<sup>2</sup> area (ISTAT, 1991, 2001). Ten of the 18 municipalities near Vesuvius were invited to participate in the survey and six accepted the invitation, but only three could facilitate the survey in a timely manner. The survey was conducted in a high school in each of the three municipalities (Fig. 2); one municipality is in the northeast sector in San Giuseppe Vesuviano (24 689 inhabitants), and two are in the southwest sector in Portici (60 068 inhabitants) and Torre del Greco (90 465 inhabitants). Portici and Torre del Greco are the most populated municipalities near Vesuvius, they are in the Red Zone, and both suffered extensive damage during Vesuvius’ last eruptive cycle in 1631–1944 (Principe et al., 2004). While San Giuseppe Vesuviano is also located in the Red Zone, it has been protected from past lava flows and other volcanic activity, due to the morphology of the area. The municipalities have similar demographics, and cultural and ethnic backgrounds. In general, the

Vesuvian area has many low-income families (ISTAT, 2001). In all 18 municipalities, industry, manufacturing, services and commerce employ the majority of the population (73%), followed by public administration and education (21%), and agriculture and fishing (6%). Three percent of the population has a college degree, 17.8% has a secondary school diploma, 31.8% graduated from intermediate schools, 29.6% completed a primary school education, 14% did not complete primary school, and 3.3% are illiterate (ISTAT, 1991).

Questionnaires were submitted to 400 high-school students in three different schools during May 2006. Some of the students had participated in volcanic risk education programs in their high schools. One survey was administered at a school per day, so the entire distribution of the surveys took three days. There were 100 respondents from San Giuseppe Vesuviano (2893 high-school aged residents), 120 respondents from Portici (4367 high-school aged residents), and 180 respondents from Torre del Greco (8444 high-school aged residents). The surveys were administered in similar physical settings at each school; teachers distributed the questionnaires and were present while the students answered them, no assistance was given to the students while they worked on the questionnaires, the students were aware that the questionnaire was about volcanic risk perception and received information about the goal of the survey, and their answers were anonymous. After the students completed the questionnaires, the researchers entered the classroom and retrieved the questionnaires. All of the distributed surveys were returned and they were all complete and usable, representing a 100% response rate. The total time necessary to administer each survey was approximately 35 min. The participants ranged in age from 13–19 (high school in Italy lasts for 5 years, with many students reaching their 19th birthday before graduating), with a mean age of 15.6 years old (sd=0.784). The respondents’ genders were 56.1% female and 43.9% male, while the gender of high-school aged residents of the municipalities was 49.7% female and 50.3% male.

#### 3.2. Survey material

The questionnaire was composed of 25 multiple choice questions. It was adapted in part from a questionnaire developed for studies of volcanic-hazard risk perception in New Zealand. These studies involved high-school level students living in municipalities with low population density near a volcano with a similar eruptive style as Vesuvius (Blong, 2000; Johnston and Ronan, 2000). The questionnaire focuses on four main topics:

*Knowledge of Vesuvius’ eruptive history and volcanic processes*—Questions were asked in order to test the effectiveness of scholastic science programs and specific volcanic risk education programs. This is important because this knowledge is fundamental for the identification of hazards associated with eruptions.

*Perception of the volcanic environment*—This is important because it represents personal experiences which can contribute to maintaining awareness of living in a dangerous area.

*Perception of risk*—Questions were asked about risk perception to explore the perceived personal vulnerability to volcanic hazards, and the anxiety about or fear of the hazard.

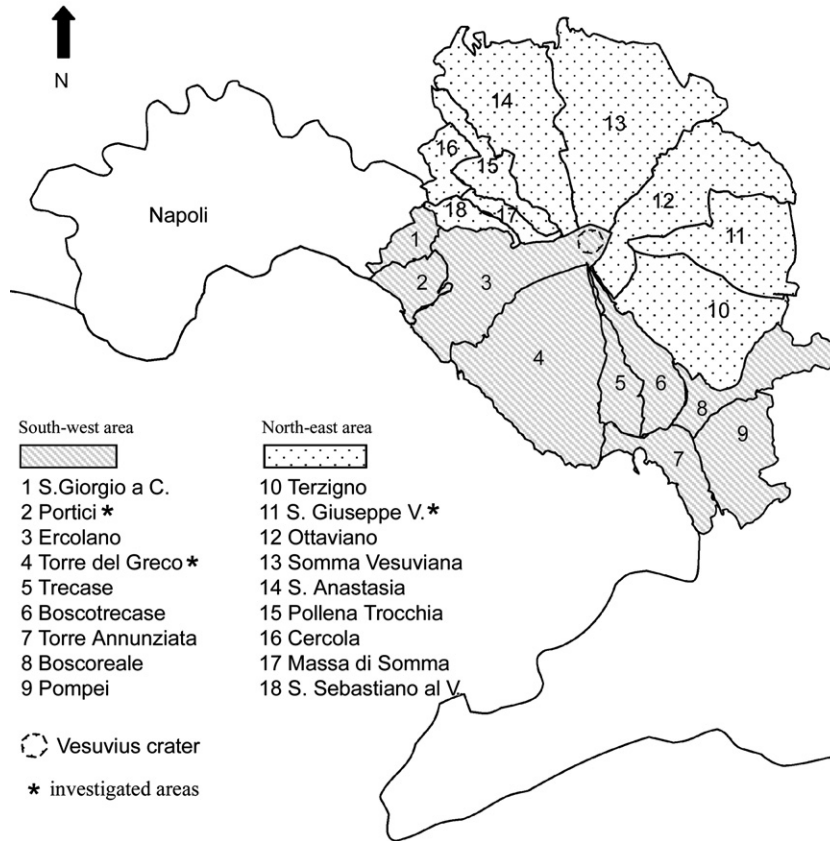


Fig. 2. Sketch of municipalities of the Vesuvian area (modified by Dobran, 2006).

*Knowledge of evacuation planning*—This was asked about in order to evaluate the students’ confidence in the government’s level of preparedness and their ability to provide accurate information about potential eruptions (trust in officials). Further, the knowledge of evacuation planning correlates with local community’s ability to appropriately respond to warnings.

The questions focused on specific issues related to a possible eruption of Vesuvius and did not consider the other problems residents commonly face living in the Vesuvian area, including a high crime rate, delinquency, heavy traffic, low-quality public services, and heavy pollution. These issues cause a low quality of life that local, regional, and national governments have found

difficult to improve. This point is illustrated by a recent study by Davis et al. (2005) that concluded that with respect to the most frequently mentioned community problems of the Vesuvian area, only 7% of residents in the Red Zone ( $n=286$  respondents) and 0% in the Yellow Zone ( $n=80$  respondents) consider the risk of an eruption at Vesuvius a major problem. The majority of those interviewed declared that crime, delinquency, traffic, public services, and pollution were their main problems. The goal of this study is to determine the level of preparedness of students living near Vesuvius, so the questionnaire only focuses on issues related to volcanic risk and not the other problems residents face in the region. Demographic information was also

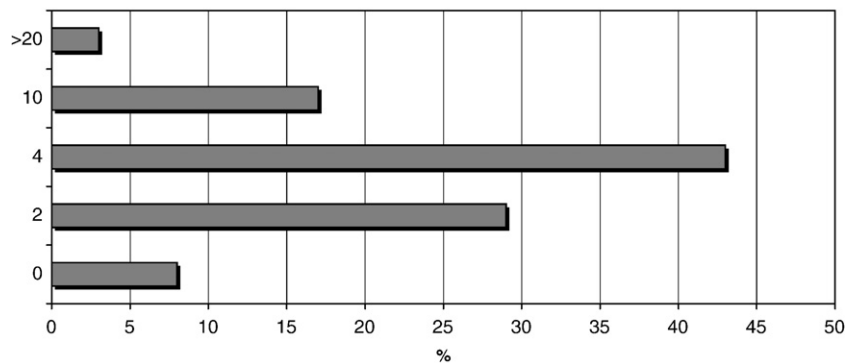


Fig. 3. Response to question: How many plinian eruptions have occurred at Vesuvius during the last 25000 years?

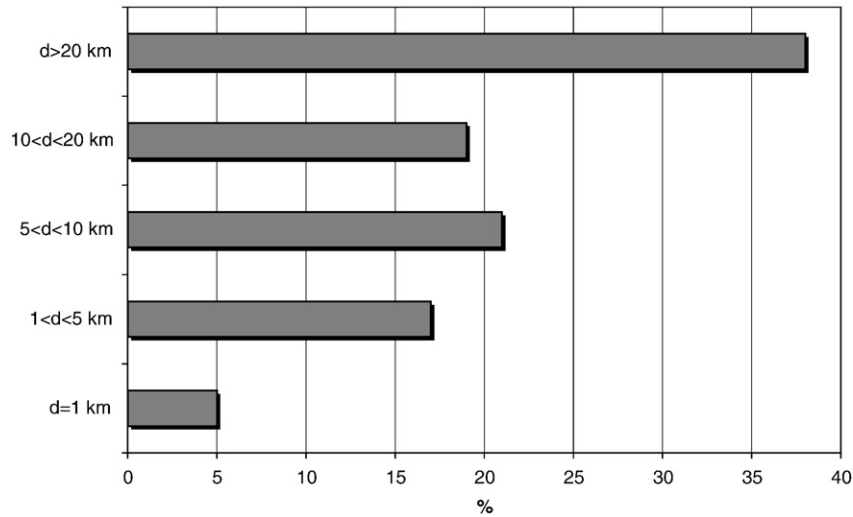


Fig. 4. Response to question: At what distance from the main vent can damage and fatalities be caused by an high-energy eruption (plinian) of Vesuvius?

requested about the students' age, gender, and municipality of residence.

**4. Results**

*4.1. Knowledge of Vesuvius' eruptive history and volcanic processes*

Eighty-eight percent of the respondents' state that they know the eruptive history of Vesuvius and 74% state that they are able to recognize the difference between effusive and explosive eruptions. When asked "How many plinian eruptions has Vesu-

vius experienced?", 43% of respondents correctly chose four plinian eruptions, while the rest mainly are divided into an overestimate of N4 (20%) and an underestimate of b4 (37%) (Fig. 3). A majority of the students (70%) did not know why highly explosive eruptions are named plinian. They were asked to estimate "At what maximum distance from the main vent can a high-energy eruption (plinian) cause damages and fatalities?". The respondents provided appropriate estimates, with 57% stating that the damage can impact distances from at least 10 km to more than 20 km (Fig. 4).

When asked about their knowledge of volcanic processes, the respondents state that the most dangerous processes that would

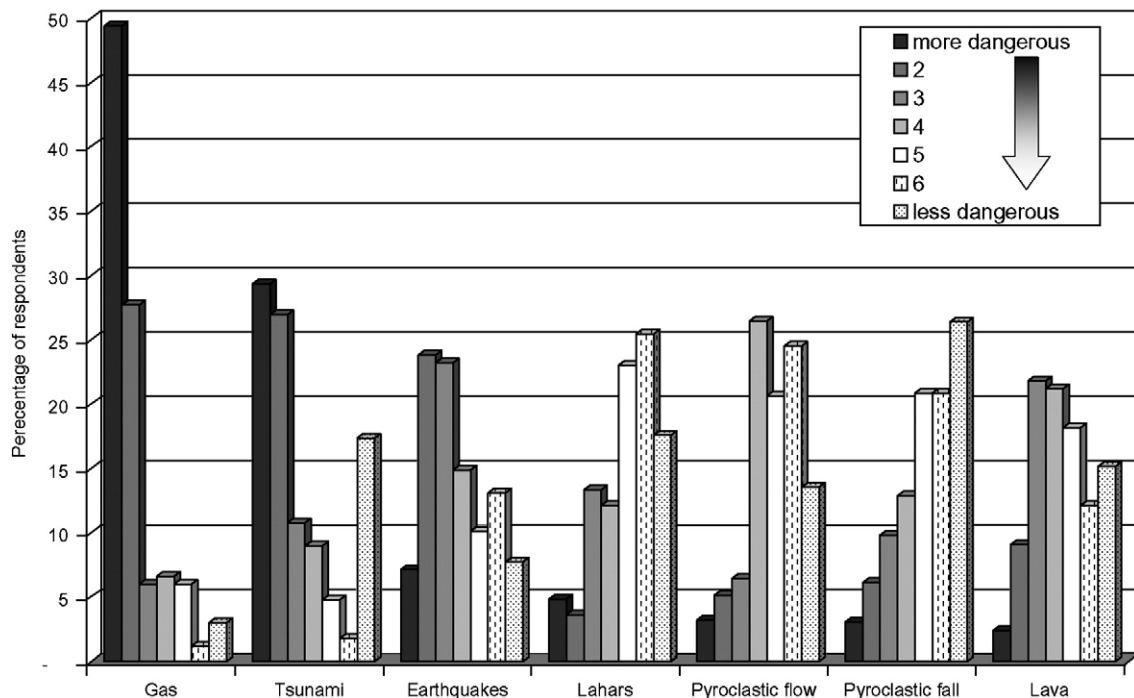


Fig. 5. Histogram showing the response to the question: Put the following processes that could occur during an eruption at Vesuvius in order from most to least dangerous to the people living near the volcano: Lava flow, pyroclastic flow, pyroclastic fall, gas emission, earthquake, tsunami, and lahar.

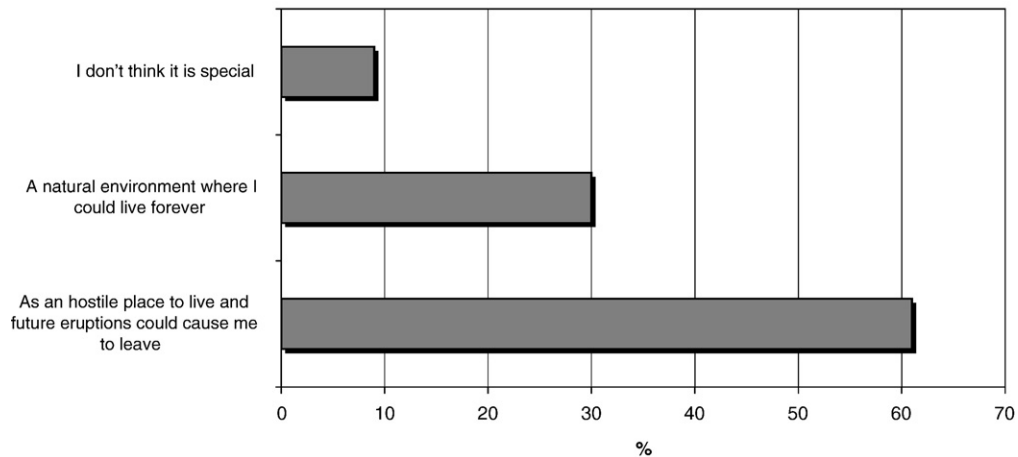


Fig. 6. Response to question: How do you perceive the volcanic environment?

occur should Vesuvius reawaken are gas emissions followed in decreasing order of likelihood by tsunamis, earthquakes, lahars, pyroclastic flows, pyroclastic falls, and lava (Fig. 5).

#### 4.2. Perception of the volcanic environment

In regard to the perception of the volcanic environment, 61% of respondents consider their municipality a “hostile place to live,” while a surprising 30% think that a volcanic environment is a “quite natural environment to live in forever” (Fig. 6).

The main reasons that respondents are aware that they are living in a dangerous volcanic area is the daily reminders of the devastating effects of past eruptions, like recent historical A.D. 1631–1944 lava flows, the ubiquitous presence of volcanic features built atop lava flows, and the numerous ancient Roman ruins (e.g. Pompei, Ercolano, Stabia) in the middle of the modern cities (Fig. 7).

#### 4.3. Perception of risk

Although a high percentage of respondents (97%) are conscious of living in an area classified as having a high volcanic risk, only 55% declare that they know the meaning of volcanic risk. In addition, a majority of students (78%) know that their municipalities have experienced damage and injuries due to previous eruptions.

One question was asked in order to try and understand how the respondents feel about the likelihood of future eruptions. A majority of respondents said they feel panic (42%) when they imagine a future eruption occurring at Vesuvius, while 21% reported feeling an inability to act, 18% felt anxiety, 10% felt fear, and 4% felt indifference (Fig. 8).

When asked “Which category of risk takers are you in?”, 39% of the students responded that they are “concerned and thinking that urgent actions are necessary to reduce the risk in the Vesuvian area”, 27% feel they are fatalist and hope for the best,

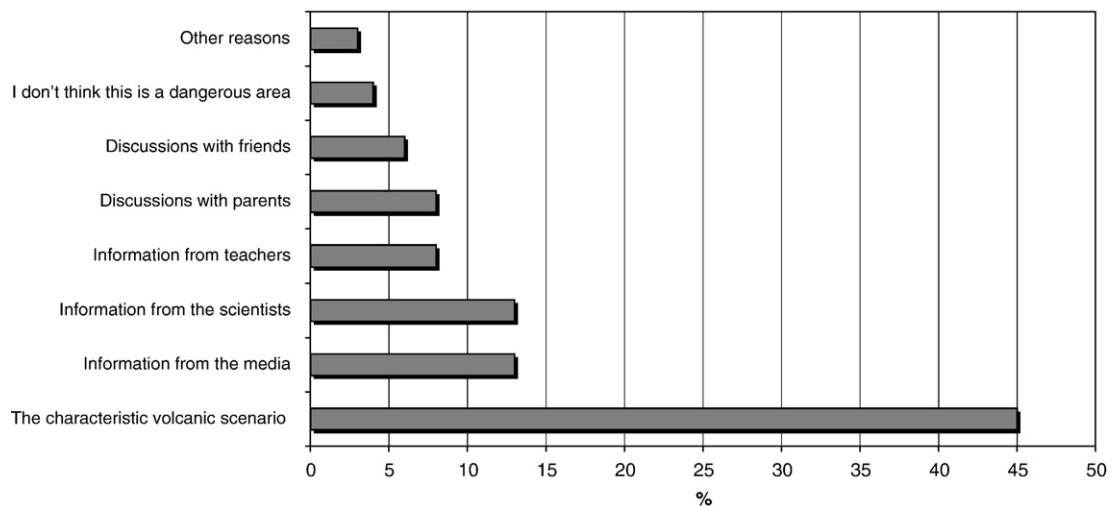


Fig. 7. Response to the question: What makes you the most concerned about Vesuvius?

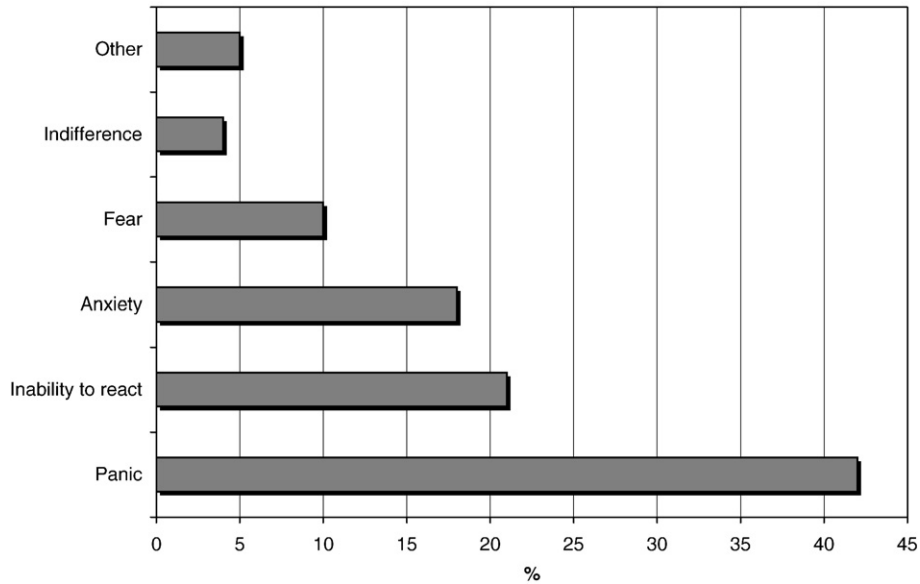


Fig. 8. Response to question: What is your feeling if you imagine the likelihood of future eruptions at Vesuvius?

16% trust in local institutions and think that everything will be OK, while only 6% consider themselves self-sufficient (Fig. 9).

Important results were revealed from questions about the willingness of respondents to move to “safer” areas if they could. Forty-four percent of respondents would move elsewhere, 40% declare that they don’t know, and 16% are not willing to relocate to other areas.

#### 4.4. Knowledge of evacuation planning

When asked about who will provide information in case of an eruption, 30% of participants think that scientific authorities will supply information, while about 34% do not distinguish between the mass media, Civil Protection, or scientific authorities (Fig. 10). Many students seem to trust scientific studies

about the future behavior of Vesuvius. Sixty four percent think scientists will be able to forecast a future eruption of Vesuvius, 27% are not able to judge this issue, while only 8% believe scientists will not be able to forecast an eruption.

Some failings of the volcanic risk education of many students appear to be their apparent lack of knowledge about NEPVA and confusion about how to behave during a volcanic crisis. Thirty-two percent of respondents feel that they don’t have a sufficient level of training to face an emergency (Fig. 11). When asked about NEPVA, 62% of respondents state that they have heard of NEPVA, but 60% know very little about what NEPVA does, and 23% don’t know anything at all about it.

When asked about the percentage of the population that will be able to leave the Red Zone during an eruption, the majority

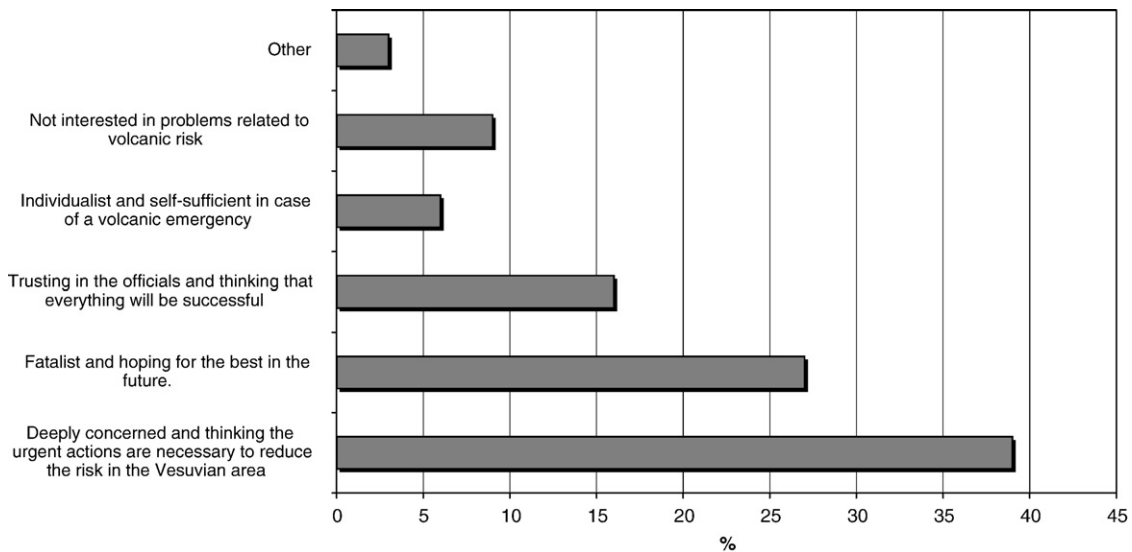


Fig. 9. Response to question: Which category of risk takers are you in?

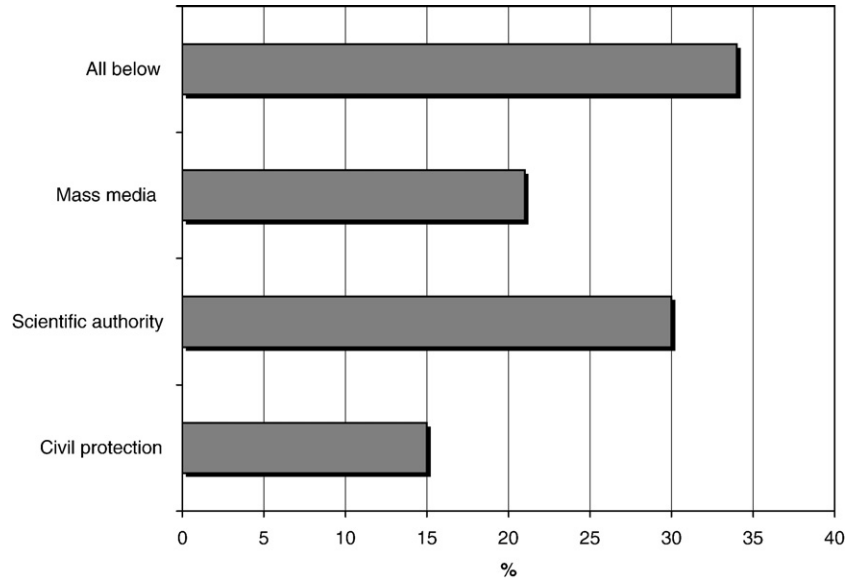


Fig. 10. Response to question: Who will provide information during a volcanic emergency?

of students declare that no more than 50% of the population will be able to evacuate, 14% estimate that less than 10% will succeed, and only 2% of respondents think that everyone will be able to evacuate (Fig. 12). This question was asked because it provides information about the degree of trust the students have in officials to organize the evacuation. It is interesting to note what outcomes the students think will influence the success of an evacuation once a warning is broadcast (Fig. 13). Surprisingly, only 3% of respondents consider the policy of the Central Government as a main contributor. Eight percent favored assistance from friends and parents, 27% level of cooperation between officials, 23% risk education, 22% level of quality of facilities necessary for the evacuation, and 17% assistance provided by other regions and countries. Lastly, many students preferred returning to their

municipality after a hypothetical large eruption (34%), 24% would not return and 42% are undecided (Fig. 14).

## 5. Discussion

### 5.1. Knowledge of Vesuvius' eruptive history and volcanic processes

The questionnaire results reveal that the respondents have a fairly good knowledge of the volcanic history of Vesuvius, but they are not able to provide detailed information about volcanic processes. The majority were able to answer correctly questions about the number of plinian eruptions at Vesuvius and the area that will be impacted by a high-energy eruption. This illustrates the

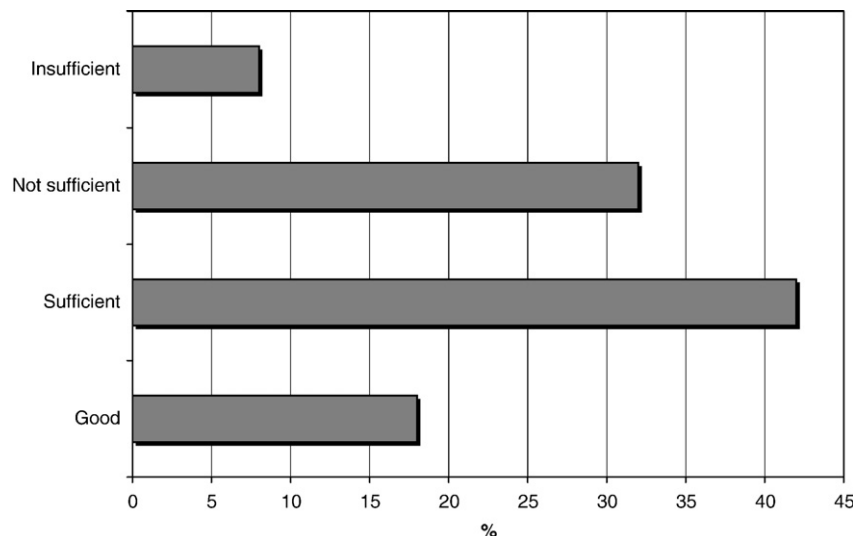


Fig. 11. Response to question: What is your level of training for dealing with an eruption-related emergency?

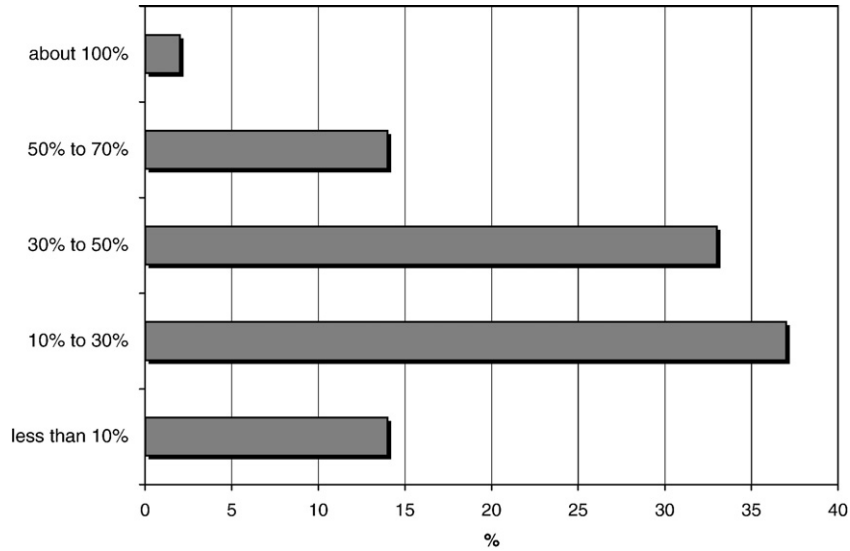


Fig. 12. Response to question: What percentage of the population do you think will be able to evacuate the red zone in case of an eruption?

relatively good knowledge of Vesuvius’ eruptive history (Figs. 3 and 4). The fact that the majority of answers were incorrect to questions about the most dangerous volcanic phenomena, reveals a lack of knowledge about volcanic processes (Fig. 5). It is remarkable that 49% of respondents consider gas emissions the most dangerous phenomena. The students believe volcanic gases, and the associated risk of injuries and fatalities, are dangerous but they seem less aware of the main physical processes (i.e. pyroclastic flows and surges) associated with high-energy gas releases. Despite the fact that during the past 25 000 years Vesuvius has had four major plinian eruptions that have produced devastating pyroclastic flows (Luongo et al., 2003), 26.5% of respondents rated pyroclastic flows as the fourth most dangerous hazard and only 3.2% rated them as the most dangerous.

It is even more surprising that 29% of the students rated tsunamis as the second most dangerous hazard associated with eruptions at Vesuvius, despite the fact that no seriously damaging volcano-related tsunami has been recorded in the Tyrrhenian basin in historical time. The respondents may have stressed the importance of tsunami hazards following heavy exposure to the shocking stories and images provided by the media after the 26 December 2004 tsunami in the Indian Ocean killed over 200 000 people. Their perceptions may also have been affected by recurrent stories in the media arguing that there was a high likelihood of a tsunami occurring in the Tyrrhenian basin in the future. Such information has produced the erroneous idea that similar catastrophic disasters could also occur in Italy as a consequence of eruptions at submarine volcanoes,

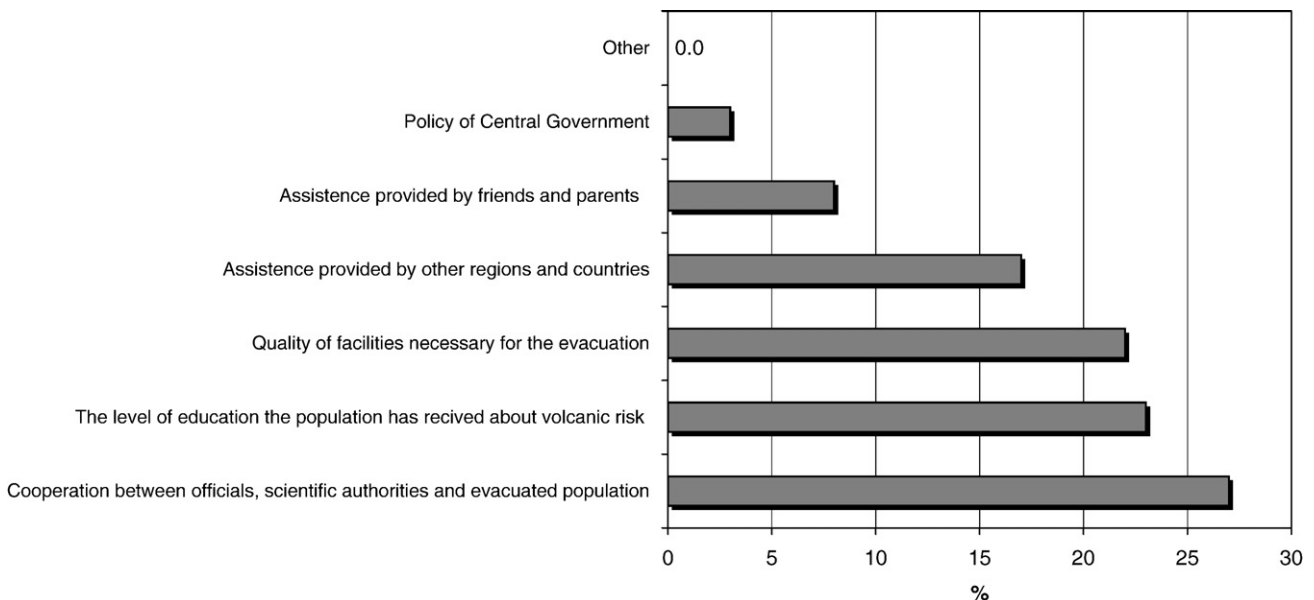


Fig. 13. Response to question: The outcome of an evacuation will depend on which of the following once an eruption warning is broadcasted?

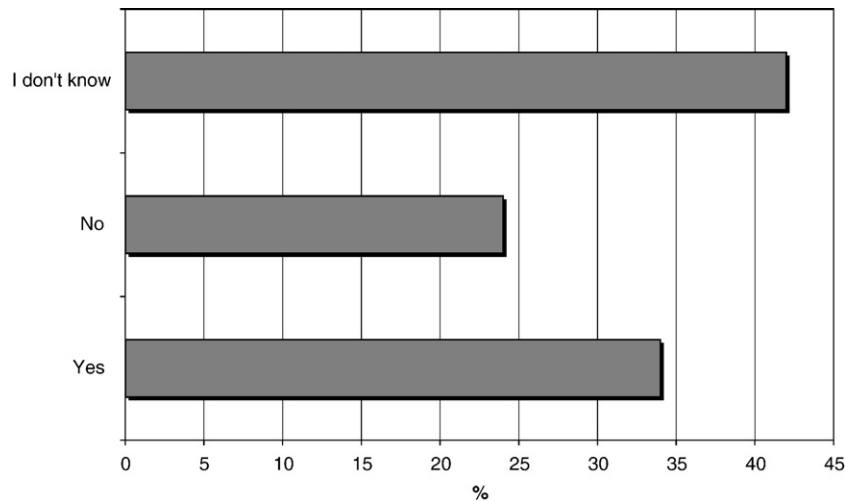


Fig. 14. Response to question: Would you return to your municipality to live after an hypothetical large eruption of Vesuvius?

such as Vavilov and Marsili, or at one of several active volcanic edifices close to the Tyrrhenian cost line.

Students' inaccurate understanding of the danger posed by volcano-related hazards appears to be a consequence of insufficient scientific information about volcanic processes provided in the school programs. Scientific information needs to be enhanced using more appropriate technical expressions to explain different volcanic processes and related hazards. It is also clear that rumors and misinformation may also contribute to the students' inaccurate hazard perceptions. This situation may be exacerbated during an eruption because it is common for incorrect information to be spread during emergencies, in particular the media may provide misinformation to a large number of people if not appropriately supported by scientists (Blong, 1984).

### 5.2. Perception of the volcanic environment

It is surprising that 30% of students think that a volcanic environment is a "quite natural environment to live in forever." This result is possibly due to the lack of knowledge of volcanic morphology, processes, and structures as is illustrated by the large number of respondents who were unable to recognize a lateral vent, despite the fact that it should be easily identifiable from a glance.

Another important observation comes from the question about the respondents' awareness of the dangerousness of the area where they live (Fig. 7). Almost half of respondents (45%) declare that thinking about "the volcanic scenario" makes them realize the dangerous nature of Vesuvius. This finding is interesting because while "social sources," such as information provided by the media and scientists, are potential policy tools, "personal experience," is not (Johnston et al., 1999). Taking these responses into consideration, we would expect that 45% of respondents would have a fairly constant level of risk perception because of the daily view of the volcano they have. Further, the above statements also reveal that respondents are aware of the volcanic landscape, but they are not educated about specific

volcanic structures such as lateral vents, which are evidence of the frequent activity of Vesuvius in the past 400 years.

### 5.3. Perception of risk

Previous studies of volcanic risk perception at volcanoes in Hawaii (USA) have shown that perceived risk is linked to the proximity of individuals to the hazard source and is correlated with the frequency of eruptions (Blong, 1984; Gregg et al., 2004). Even so, in Hawaii, despite the frequent activity of Mauna Loa and generally the high risk perception of the public, about 10% of the population of the town of Kona are unaware that the volcano can erupt again (Gregg et al., 2004). Risk perception studies performed in relation to the Mount St. Helens 18 May 1980 eruption, revealed that although the volcano has had relatively large-scale eruptions, residents near the volcano had a low risk perception because the hazard occurs infrequently, unlike in Hawaii (Blong, 1984). In light of these data, it is not surprising that volcanic risk perception is very weak or absent for populations living close to volcanoes that have long periods of quiescence. The over 60 years of quiescence at Vesuvius has led to a complacent society near the volcano, but various studies have shown that focused education programs can increase individuals' risk perception (Johnston and Ronan, 2000; Perry and Hirose, 1991).

Almost all of the respondents (97%), are aware that they live in an area classified as having a high volcanic risk and 61% of them consider the volcanic environment a "hostile place to live and from which, due to future eruptions, they could also be obliged to leave" (Fig. 6). This response indicates that students' knowledge of the potential volcanic hazard in the region may lead them to reverse the trend observed in the last 60 years of Neapolitans migrating closer to the slopes of Vesuvius. It is important to note that middle-aged people usually have a more accurate perception of risk than younger people (Blong, 1984), so the education the students have received may lead them to have even more accurate risk perceptions as they age.

Forty-six percent of respondents declare that they are involved in volcanic risk education programs; this is an encouraging result if we consider that in Kona, Hawaii, where there is a high frequency of eruptions, about 50% of those interviewed ( $n=462$ ) had been involved in a hazard education program (Gregg et al., 2004).

The way people behave during an eruption strongly affects the efficiency of an evacuation. The more calm people are, the easier it is to evacuate them. Most respondents reported that they feel a sense of panic when they think about a future eruption at Vesuvius (42%). According to Wenger et al. (1975), panic is an extreme agitated behavior that increases the danger toward those at risk and others, and it is often observed during the occurrence of a natural disaster. Conversely, other authors find that panic does not necessarily represent “terror, confusion, and irrational behavior” (Goldenson, 1984; Johnson, 1987). Different types of behavior have been witnessed during natural disasters in Italy. Agitated behavior was observed when an M 6.8 earthquake in 1980 affected the Basilicata and Campania Regions (Alexander, 1990), whereas some calmer responses were described during historical eruptions of Vesuvius. Perret (1924) reported that the behavior of Neapolitans during the 1906 Vesuvius eruption, was admirable: “...greater patience, resignation and *savoir faire* could hardly have been expected of any race.” Similar behavior was observed during the 1944 eruption, when a lava flow destroyed San Sebastiano al Vesuvio and Massa di Somma (Pesce and Rolandi, 2000). During this eruption, instead of behaving in an agitated manner, people calmly invoked the patron saint of the city of Naples (San Gennaro) in the hopes of stopping the lava flow. This attitude of Neapolitans, often observed in the past and reported by numerous chronicles (Dobran, 2006), is typical of people who believe that their lives are controlled externally (i.e. fatalists). This seems to be in part supported by the number of respondents (27%) who describe themselves as “fatalist” when asked what category of risk takers they categorize themselves as.

Despite the strong “sense of place” or “home” that Neapolitans have shown throughout history, a significant percentage of respondents (44%) seem to be willing to move to other areas to guarantee their own security. On the other hand, 40% of respondents declare that they don’t know if they are ready to move. These statements may be linked to different factors (i.e. individual perception of the degree of hazard and attendant risks, individual level of fear, cultural level, economic and social factors, advances toward a more contemporary society) (Bryant, 2005). We think that in the Vesuvius area, the individual choices of the respondents to move or not is strongly related to economic and social factors. Individuals and families are often constrained to their residences by their jobs, the difficulty of finding others residences, and by the high social and economic costs associated with relocating to nearby communities with lower volcanic risk. This should be taken into account by Civil Protection and other officials whose goal will be to facilitate the relocation of people willing to move, and also to reduce the risk of people who do not relocate. The former solution has been adopted by the “VesuVia” program (2003), which intends to reduce the population of the Red Zone by providing economic incentives of 30 000 Euro per family to move to a safer location (Arie, 2003). Unfortunately,

the program has had very limited success due to economic and social circumstances that have prevented people living near Vesuvius from relocating to safer zones (McGuire, 2003). The results from our survey suggest that perhaps the next generation will be more willing to relocate before an eruption, although it must be noted that the students’ risk perception may change as they age and become more invested in their towns and homes.

Residents will also face the decision of whether or not to return to their homes after an eruption. When considering the post-eruptive phase, a significant percentage of respondents (34%) declare that they would return to their municipalities after a large eruption. A recent study shows that people who evacuated from the town of Baños due to an eruption of Tungurahua volcano in Ecuador in 1999, returned to the high risk area with a low level of concern and anxiety about future eruptions (Lane et al., 2004). Although a high percentage of respondents declare fear, panic and anxiety (70%), only 24% of students state that they would not be willing to return after a large eruption at Vesuvius. Historical cases have shown that as more people return to their communities there is an increase in perceived risk due to their earlier eruptive experience (Lane et al., 2004).

#### 5.4. Knowledge of evacuation planning

A reliable information source is of fundamental importance to the success of an emergency plan. Once the critical conditions are defined, the consensus of scientists and a scientific committee in charge must be shared with officials and local communities in a clear and unambiguous manner (De La Cruz-Ryna et al., 2000). The students declared that they would prefer to receive information during a volcanic crisis from: scientific authorities (30%), the mass media (radio and television) (21%), Civil Protection (15%) and most do not have a preference (34%). Comparing these results with those obtained from adults in Hawaii (Gregg et al., 2004), a similar percentage of Kona inhabitants prefer to receive information from scientific authorities (34.5%), while a larger percentage of interviewees (58.4%) prefer the mass media. In a smaller community like Santorini island in Greece, the majority of residents believe that during an eruption the information will be provided by the Mayor (23%), and fewer consider the government (11%) and police (11%) as a potential source, while only a small number of respondents declare the Army (8%) and scientists (3%) as a preferred supplier of information (Dominney-Howes and Minos-Minoupolus, 2004).

The respondents to our survey give the impression of trusting scientists more than the mass media or Civil Protection. A similar situation was observed during the 1995 Soufrière Hills volcanic crisis in Montserrat in the West Indies. In fact, during the early phases of the eruption scientists from the Montserrat Volcano Observatory (MVO) were occasionally interviewed by the media, causing confusion between the information they provided and other information supplied by government officials and Emergency Operations Centre staff. From October 1995 onwards there was a shift in the method of relaying information because the MVO scientists had wider exposure

through Radio Montserrat and Montserrat Community TV. Consequently, many facts related to the volcanic phenomena in general and in particular to the behavior of Soufrière Hills activity were openly explained and discussed with greater participation by the public than prior to October 1995 (Buffonge, 1999; Clay et al., 1999; Aspinall et al., 2002; Kokelaar, 2002). Subsequently, by June 1997 many residents of Montserrat were following the scientists' example rather than the official guidance (Loughlin et al., 2002). The possibility of this type of result must be taken into account by officials when trying to disseminate information during a volcanic crisis.

The lack of understanding or trust between at-risk communities, authorities, and scientists can lead to disasters as was the case with the failed warning that occurred during the 1985 eruption of Nevado del Ruiz in Colombia which devastated the city of Armero. Despite warnings provided by scientists, at the time of the eruption emergency responders did not know how to appropriately disseminate the information to at-risk communities. The lack of a warning system and tested communication between government, scientists, and the local communities, along with community members' fear of government officials were the main reasons for the failure of the warning and evacuation. As a consequence, more than 20 000 people were killed when lahars inundated the city of Armero (Johnston and Ronan, 2000).

The trust that the respondents have in scientists is further confirmed by the statement that 64% of respondents think that scientists will be able to forecast a future eruption of Vesuvius. While trust in scientists is a positive thing, their responses demonstrate that students are not taught about the uncertainties related to volcanic forecasts. They are not aware that one of the main limits of volcanology is the difficulty of precisely forecasting volcanic eruptions. The problem of forecasting when and how Vesuvius will erupt is still a matter of debate, as is demonstrated by the diverging opinions of individual scientists who are trying to forecast Vesuvius' eruptions (Lirer et al., 1997; Palumbo, 1999; Borgia et al., 2004; Santacroce et al., 2005; Mastrolorenzo et al., 2006). For this reason, volcanic risk education needs to take into account the uncertainty of forecasting an eruption and the related likelihood of providing false alarms. This may produce a higher tolerance of Vesuvius' volcanic risk, providing scientists with some extra time to better study the behavior of the volcano and to produce an appropriate eruption forecast. On the contrary, low tolerance of risk may push scientists into quickly issuing inappropriate forecasts, supported by incomplete data, and therefore raising the chance of false alarms (Newhall, 2000). The experiences of the MVO team during the 1995–1997 Soufrière Hills eruption have also shown that the inability of scientists to predict the time and scale of specific volcanic phenomena can frustrate some people, possibly causing them to make, and act upon, their own assessments (Loughlin et al., 2002).

The respondents are aware that a successful evacuation depends on four main elements: cooperation between officials, scientific authorities, and at-risk populations; risk education of at-risk populations; high-quality evacuation facilities; and assistance provided by other regions and countries (Fig. 13).

These outcomes are necessary for the successful evacuation of the more than 600 000 people living on Vesuvius' flanks, in particular volcanic risk education and disaster preparedness of local communities could produce a better response during an emergency (Paton et al., 2001). The eruptions of Pinatubo in 1991 and Soufrière Hills in 1995 are examples of how at-risk communities can prepare for disasters in a very short time (days, months). Thousands of lives were saved during the Pinatubo eruption, despite the long quiescence of the volcano and the lack of emergency preparedness of the people, because scientists were able to provide timely warnings to local communities (Ewert and Newhall, 1991). Similarly, about 10 000 people were gradually evacuated during the volcanic crisis at Soufrière Hills (Kokelaar, 2002). These evacuations were successful, but it is important to note that only tens of thousands of people were involved. At Vesuvius, the population involved in the evacuation will be one or two orders of magnitude greater, which may necessitate the adoption of a different strategy in order to guarantee the safety of local communities in the event of an eruption.

## 6. Conclusions

The results suggest that, despite 60 years of quiescence at Vesuvius, the interviewed students living in three municipalities in the Red Zone have relatively appropriate volcanic risk perception. This may be attributable to the volcanic risk education programs provided to many of the students by their high schools. There were no differences in risk perception among the respondents in the three different municipalities. The respondents seem to have a fairly good understanding of the eruptive history of Vesuvius, while they were less knowledgeable about volcanic processes and knew very little about NEPVA. Further, when comparing the responses from students who had participated in risk education programs (46%) with those who had not, we found that risk education program participants have more awareness of risk and reduced hazard-related fears. The findings of this study strongly support the value of hazard education for young people. This is also supported by previous public education and awareness programs, such as a program implemented by the Taraki Regional Council during 1995–1997 in New Zealand. After this program, the level of awareness about volcanic hazards in the Taraki region increased from 37% to 56% (Johnston and Ronan, 2000).

The observed lack of knowledge about volcanic processes could also lead to low volcanic risk perception. Students need to become more familiar with scientific definitions of volcanic processes in order to better understand the potentially deadly hazards that could be associated with a future eruption of Vesuvius. The trust the respondents have in the scientists' ability to forecast an eruption provides a great opportunity to implement communication between volcanologists and local communities. This is an important issue because risk understanding, risk perception, and consequential behaviors of people during an emergency, are strictly dependent on the quality of the scientific and technical information provided to local communities. The lack of effective communication between officials, scientists, and communities can produce social amplification or

attenuation of risk with potentially dangerous effects on evacuation decisions (Johnston and Ronan, 2000).

The lack of knowledge about NEPVA is a sign of the absence of well-tested communication strategies and effective information dissemination in the study area. This lack of knowledge means there is little interest in participating in risk-reduction activities. This was illustrated during the recent “Major Emergency SIMulation EXercise,” during 17–22 October 2006 at Vesuvius (MESIMEX, 2006). About 2000 people living in the Red Zone took part in the event, with great interest and participation by the scientific community and officials, but only weak participation by local communities. More effective organization and education should be used for future simulations to avoid similar modest participation by at-risk communities in the future.

The present knowledge of the respondents about NEPVA, volcanic risk, eruption forecasts, and methods of disseminating information during an emergency seems to be inadequate for an efficient evacuation. For this reason, the information that NEPVA and risk education programs provide must be shared far enough in advance in order to improve disaster preparedness. In the Vesuvian area, this is a long-term goal considering the complexity of the social organization and the large number of people exposed to volcanic risk. We think that the option of trying to mitigate the impact of an eruption during an ongoing volcanic crisis, as was done during eruptions at Pinatubo and Soufrière Hills, will not work at Vesuvius due to the large number of people who will need to be evacuated. At Vesuvius, residents must begin to prepare for possible evacuations during quiescent periods. In the absence of adequate preparedness measures, an evacuation could become “enforced” or even worse, a “failure.”

Emergency planners have a good opportunity to enhance the risk perception of vulnerable communities while Vesuvius is quiescent and information can be shared in a calm controlled manner. Furthermore, in the Vesuvius area, where a complex social situation exists (i.e. high level of urbanization, high population density, elevated rates of crime and delinquency, pollution, and very different cultural background of local communities), the risk perception must be enhanced using a multi-disciplinary approach. To increase the volcanic risk perception of all members of society new resources and methods of dissemination will be necessary, including permanent and temporary exhibits, regular workshops for educators, public talks, and dissemination of news and printed materials concerning volcanic hazards at Vesuvius. Such goals must involve scientists, researchers, officials, teachers, practitioners, and local communities. In addition, scientists should make an effort to improve the public’s knowledge of Vesuvius’ volcanic hazards in order to enhance the risk awareness of local communities. Educating young people about volcanic risk is of particular importance because they are the next wave of decision makers and what they are taught today may influence the choices they make in the future.

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