DRAFT PROPOSAL

VOLCANO TOURISM SAFETY RECOMMENDATIONS 2023

Recommendations for Additional Visitor Safety in Active Volcanic Environments

Researched & Prepared by:
Patricia J. Erfurt, PhD
Research Scientist GEOTOURISM Australia
Patricia.Erfurt@my.jcu.edu.au

Recommendations for Strategic Planning and Policy-making related to Risk Management and Visitor Safety in Active Volcanic and Hydrothermal Environments

Potential Hazards in Volcanic Environments

Volcano tourism has become a popular outdoor adventure experience involving locations that are generally at a considerable distance from essential emergency and rescue services.

While the same applies to many other non-volcanic areas that also present a range of potential hazards (e.g. hiking accidents, getting lost or being confronted by sudden weather and/or temperature changes, landslides or rockfalls following heavy rain, fog, snow avalanches, altitude sickness, hypothermia), these dangers are compounded by the complexity of hazards typical encountered around active and even at dormant volcanoes.

Adventure seeking volcano tourists embarking on challenging excursions into active volcanic and hydrothermal environments must be properly prepared. This includes familiarising themselves with all potential hazards common in these areas.

A comprehensive overview of the potential risks for tourists in volcanic areas is presented in Table 2, which offers visitors of active volcanic areas the opportunity to evaluate their personal risk perception. This is frequently influenced by the exciting prospect of visiting active volcanic and hydrothermal areas and can lead to a reduction of an individual's alertness and a lack of cautiousness (Erfurt-Cooper 2010; Erfurt-Cooper 2011; Erfurt-Cooper 2014; Erfurt et al 2015; Erfurt 2022).

Safe conduct in active volcanic and hydrothermal areas is essential to avoid accidents and injuries. Quite often volcano adventure tourists overrate their competence to deal with unfavourable situations. The consequence of abandoning common sense and a false sense of security can lead to serious accidents and injuries or even fatalities. It is not uncommon that being unprepared for unexpected situations requires the assistance of rescue services.

This means that every tour operator and tour guide must have access to constantly updated information about the state of the active volcanic and hydrothermal area including any potential hazards that could be encountered by visiting tourists. This information must be provided by the monitoring agencies and local authorities. Volcanic alert levels (VAL) do not always have a clear meaning to visitors of volcanic environments and unless access to a volcano is restricted by introducing exclusion zones, there will not be a sufficient sense of possible danger.

Examination of warning signage in volcanic areas has shown that many signs are only in one or two languages, English is usually included. Relevant information must be available in more than one or two languages to assure the safety of **all** tourists at active volcanic and hydrothermal tourist destinations. In Latin American countries signage is frequently provided in Spanish and English. In Japan volcanic and hydrothermal tourist areas offer safety advice in three to four different languages. China and Indonesia commonly use English translations for important visitor information boards. Iceland usually provides several translations of the most important warning signs.

While up-to-date information is provided by rangers and at visitor centres (where these are available), this is not the case at many less developed volcanic and hydrothermal tourist destinations. Also, some people choose to ignore informative talks by rangers and frequently overestimate their own ability to cope with unexpected emergencies, which could lead to dangerous situations for all involved, including rescue teams.

Guidelines and recommendations for visitor safety

Volcano tourists must be aware that all safety instructions (where available) must be followed for their own benefit. In areas where no such visitor guidelines are available as yet, the **recommendations** below could contribute to the development of strategic safety instructions for visitors of active volcanic environments.

The following revised list (based on earlier publications) consists of various recommendations to increase visitor safety in active volcanic environments. These suggestions provide a foundation for essential safety guidelines and are developed for volcano tourists visiting active environments worldwide. Such guidelines could be modified to suit individual areas and should be in place at all volcanic and hydrothermal tourist destinations.

1) For all **hazardous volcanic and hydrothermal environments** precise information is essential and therefore logistics with **no room for error** are needed.

2) In many countries, relevant authorities including governments, local governing bodies, monitoring agencies and geological surveys, tourism organisations, tour organisers and operators provide **updated** information on their media platforms as well as on-site.

3) However, not every active volcanic/hydrothermal area is monitored as much as necessary or not at all. This may be either due to a lack of access and/or remoteness as well as the danger of an unexpected eruptive event. The absence of monitoring stations can also be due to budgetary restrictions. Due to valid safety concerns such volcanic and hydrothermal areas must be ruled out as tourist attractions.

4) In support of effective risk management, all visitors of **active volcanic and hydrothermal areas** must be encouraged to independently obtain **essential** information **in advance**. Visiting tourists must be informed about **every potential hazard** related to the volcanic environment they intend to visit and must be made aware of any particular dangers they may encounter prior to their visit.

5) In addition to being available through appropriate media outlets, **updated advice** about the current state of volcanic activity should also be provided at the travel destination's hotel receptions, tour booking agencies, vehicle hire companies etc.

6) **Smart phone apps** are already in use at many tourist destinations with local information via QR codes. In the case of volcanic attractions phone apps can include real time status updates for volcano tourists (e.g. Geonet App). **Specially** developed **volcano apps** can be used to provide all **essential information** for a specific volcanic region **including emergency advice** as well as real time communication of warnings of imminent danger. A **translation option** is also required.

7) **Social media networks** like **Facebook** (fb) and **twitter** are increasingly used for local disaster management to give the public access to real time information and updates. These media platforms are already used for some active volcanic and hydrothermal areas with some destinations using fb for information such as weather and state of activity, alert levels (e.g. Mt Unzen, Mt Aso, Japan; Mt Etna, Italy; Mt Merapi, Indonesia; Mt St Helens, USA; Katla Geopark, Iceland; Tongariro, New Zealand). However, the topic of visitor safety is rarely prioritised, commonly lacking detailed information for volcano tourists.

8) Social media platforms such as t**ext messaging** or **WhatsApp** are commonly used to communicate instant information and can be used to continuously update

tourists in active volcanic regions, on the condition that a reliable phone reception is available.

9) To provide an instant, reliable overview of the relevant and updated information it is therefore recommended that all sites should follow a generic template, with a function for translation into different languages.

10) Visitors must be fully aware that a visit of an active volcano is their **personal choice** between an acceptable and an unacceptable risk.

11) Tour operators and tour guides, travel agents, tourist organisations and all information centres must be aware of any **possible risk factors** involved at the volcanic and/or hydrothermal destinations they are promoting and communicate this very clearly to their clients/customers. In some active volcanic areas the focus of park management appears to be more on the danger from encounters with local wildlife than on potential accidents and injuries from thermal burns in hydrothermal areas or toxic gas emissions during unexpected eruptive activity.

12) **Tour guides** in active volcanic and hydrothermal areas must have the **appropriate geophysical knowledge** to be able to **interpret** signs of imminent danger and **rapidly assess** developing crisis situations. Tour guides also must be **suitably trained** for emergency situations.

13) Tour operators and guides must be aware that in the event of an unexpected eruption **tour guides** are almost certainly **equally affected and/or incapacitated.** Therefore it **cannot** be reliably expected that tour guides will be in a position to lead their groups to safety.

14) Guidelines and instructions for visitor safety must be available in **ALL major languages** consistent with known visitor patterns at a destination.

15) In many active volcanic regions **additional signage** is still needed in more languages. Preferably with supplementary images or pictograms for **instant visual recognition**.

16) Suitable **factsheets** (Figure 1) with symbolic signage or pictograms should be handed out to **every visitor** of **ALL** volcanic environments, active and dormant, as well as hydrothermal areas. Factsheets should be straightforward and follow a generic template that can be applied to **ALL** areas and should be available online for every volcanic and hydrothermal region.

17) **Vital information** should include **emergency phone numbers**, a **hazard map** with colour coded danger zones (Figure 1 – example factsheet), recommended **escape routes**, **shelter** locations and **emergency meeting** points.

18) **Factsheets** should be no larger than A5 size, **short, basic and accurate** without information overload, and available in different languages.

19) **Location maps** that are easy to interpret are generally available at visitor centres or handed out at the entrance to volcanic national parks or other protected sites. **Multilingual** editions should include complete interpretations of any warning signage within active volcanic areas. However, location maps may not be available for remote or unmonitored volcanoes.

20) **Escape routes** must be **clearly marked** on printed maps, factsheets and on all signage located in the volcanic area and easy to follow.

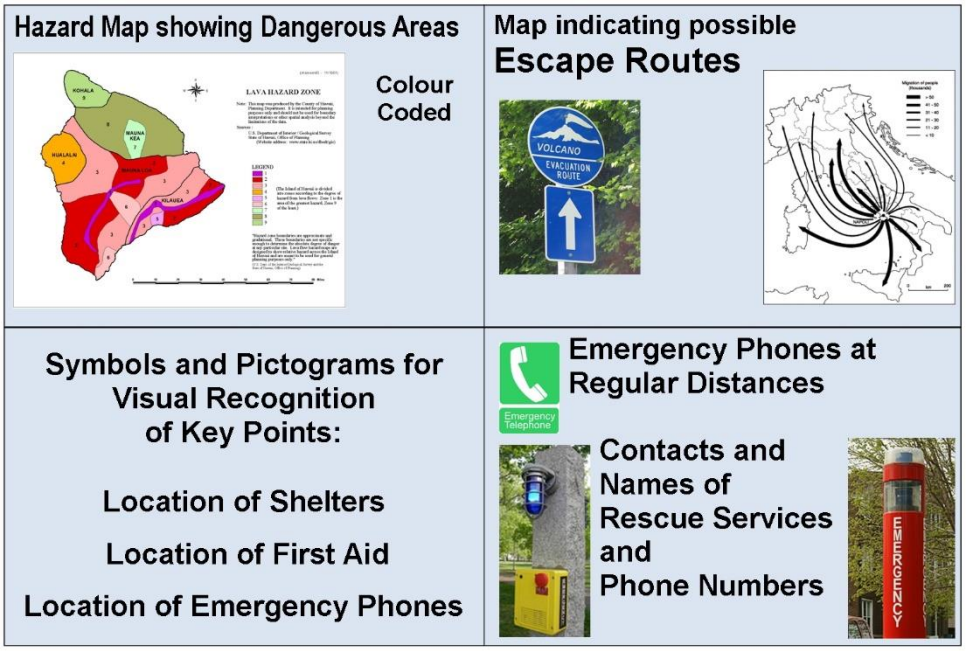

Figure 1: *Example of a factsheet which could be used as a template for every individual volcanic region*

21) **Sign-posts or guide-posts** could be **colour coded** to clearly indicate to the tourists whether they are in a safe (green) zone, or in a dangerous (yellow, orange, red) zone. Tourists must be **aware** of the zone they are in at all times (Figure 2).

22) Rescue efforts also could be made easier if such guide-posts are **numbered** (colour and numbers both should be **reflective** to be useful after dark) and therefore could be used as **markers to identify** individual zones. The lower the number, the closer to the actual danger zone.

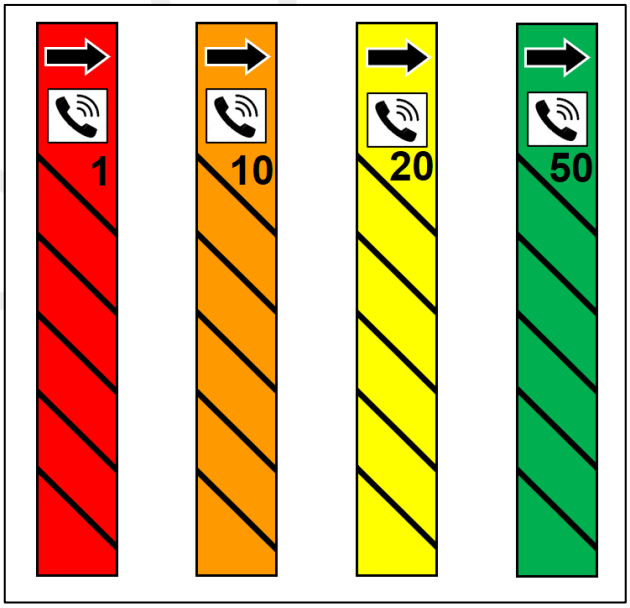

Figure 2: *Colour coded and numbered guideposts indicating different zones around active volcanic and hydrothermal environments. Arrows point in the direction of the nearest emergency phone*

23) In many active volcanic areas **emergency shelters** are still needed. These shelters must be properly constructed of reinforced concrete with thick walls with their size calculated based on known visitor numbers (Figure 3). They must be

easy and quick to access in sudden emergency situations and contain **posters** with visual interpretation of **signs indicating imminent danger**.

Figure 3: *Concrete shelters used in Japan next to an active crater. These shelters are built from reinforced concrete and can hold around 50 people*

24) In particularly dangerous active areas **emergency phones** and **CCTV/ webcam** surveillance must be installed at the emergency shelters and connected to a local monitoring station / volcano observatory and linked to local emergency & rescue services.

25) **First aid** kits should be available at emergency shelters as well with multilingual instructions for their use. In case of organised tours the tour guide(s) should be experienced/competent in providing first aid in case of injuries, especially thermal burns. First aid kits must be fitted with a content suitable for injuries to be expected in active volcanic and hydrothermal areas.

26) **Communication services** such as local/regional telecom companies must be in a position to provide reliable mobile phone reception in **all remote areas** that are frequented by (large numbers of) tourists. Visitors worldwide rely on their mobile phones and must be able to contact emergency services without delay if no emergency phones are accessible.

27) **Emergency phones** must be installed at **certain distance intervals** with **visual explanation** of how to use them in a crisis situation. **Arrows on colour coded guide-posts** could indicate in which direction the closest phone is located (Figure 2). These phones must be reliably connected to the nearest emergency services, who should be on standby.

28) That is why emergency and rescue services **must work closely** with monitoring agencies/volcano observatories to be **informed at all times** of any potential and/or imminent volcanic event. Rescue personnel must be fully trained to treat severe injuries sustained during a volcanic or hydrothermal eruption.

29) In the interest of public health and safety, monitoring agencies and/or volcano observatories must be in a position to communicate explicit warnings and caution tourism businesses that it is not advisable to conduct tours where people are led inro the vicinity of an active crater.

30) Helicopter **rescue services** should be available in every country for every volcano that is regularly visited by tourists. The cost factor should be of little relevance as most countries maintain extensive defence forces (taxpayer funded), who are frequently called upon to assist with emergency rescue situations and during disasters. Defence forces are also highly trained and able to assist with the **logistics of communication** and **transport** in a crisis situation. As part of **disaster management and prevention** it is important to enlist the help of **all organisations** that are trained for challenging scenarios.

31) **Access** to active volcanic environments should be **graded** not only by using a volcanic alert level system (VALS), but also according to all potential **hazards** and **risk factors** that could be encountered when visiting an active volcano. This should be based on regular up-to-date advice from **qualified volcano scientists** (e.g. volcano observatories, geological surveys), who are monitoring the area 24/7.

32) **Prior to** embarking on expeditions (not just a sightseeing daytrip) in **remote** and **challenging** volcanic areas, **all** participants must be required to undergo appropriate **training** for emergencies to be prepared for unexpected situations. Relying solely on the leading tour guide is **not sufficient**, especially in the case of an emergency. Guides will be equally affected in case of an eruptive event and could be too incapacitated to render any assistance to their tour group.

33) **Insurance companies** should provide updated and reliable information for travellers, whether visiting **risk prone areas**, such as active volcanic environments that are part of a **general sightseeing itinerary**, is covered in the event of injury or death. Policy holders should be encouraged to seek detailed information about any potential risk **before they travel** and whether they require **extra cover** in the event of a volcanic accident or disaster, especially if they incur **costly rescue** missions and/or medical treatment.

34) While there should be an obligation for relevant authorities such as monitoring agencies to provide detailed up-to-date information, it is the **responsibility** of individual tourists to **follow all safety advice**. To encourage this, any rescue service expenses should be recovered from those individuals, whose **irresponsible and reckless actions** are causing rescue personnel to **risk their lives** to save them. This may encourage a more responsible behaviour.

35) In the same way, tour operators and guides who lead tourist groups into active environments should be **held responsible** for damages occurred due to insufficient safety standards. This may **encourage a stronger focus on safety** instead of economic gains.

36) To **minimise** the overall risk, **only vehicles suitable** for access to volcanic environments should be permitted for use. They need to contain **first aid kits** and necessary (satellite based) **communication equipment** in case of an emergency. Strict policing is required.

37) In dangerous environments visitors need to wear **personal protective equipment (PPE),** including **safe footwear** (closed sturdy shoes), **hard hats** (helmets) (Figure 4) and carry a **gas mask** with filters that are effective in the protection from toxic volcanic gases. However, in the case of an eruption and in the absence of protective concrete shelters this basic PPE will not provide sufficient protection.

Figure 4: *Protective hard hats*

38) When visiting volcanic or hydrothermal areas with the potential for eruptive activity it is important to **wear several layers** of clothing made **from natural fibres** (cotton, linen), which may provide some protection from thermal burns. To prevent injuries from (small) hot airborne pyroclasts, **aluminised protective clothing** could be worn over normal clothing to minimise the impact/injuries from extreme heat (Figure 5). This advice is for minor eruptive activity only and in conjunction with quick access to protective shelters. It is **not** an encouragement to visit hazardous areas.

Figure 5: *Aluminised protective clothing*

39) **Tourist organisations** of countries with active volcanic and hydrothermal environments must insist on **internationally applicable safety guidelines** to be able to pass these on to their clients.

40) To avoid unnecessary problems it is paramount to know at any given time **how many people** are inside an active volcanic area and approximately where. While this may sound like a challenging task, it **can save lives**. Given the state of today's digital technology this is possible by **wearing a special tracking bracelet**, which is **returned after leaving** the active environment.

41) A mandatory check-in at volcanic tourist sites using a QR code is another option to keep track of visitor numbers in combination with tracking the exact location of individual tourists.

42) If an active area **does not have access** for emergency services to enable a fast evacuation, either by road or by air, this area should be declared an **exclusion zone**, and nobody should be allowed to go there.

43) If an active volcanic area cannot be **reached safely and in time** by emergency services, and without **unreasonable risk for rescuers**, this area should not be accessible to visiting tourists.

44) If an active volcanic environment **cannot be clearly and reliably determined as 'safe to visit'** by volcano scientists who are closely monitoring an area, it should be **'out of bounds'** for tourism.

45) **Unmonitored** volcanoes should **not** be used as tourist destinations.

46) Strict adherence to safety regulations must be mandatory for every person entering active volcanic and hydrothermal areas. At a minimum, these regulations should mirror the safety protocols volcano scientists have to follow while carrying out work in active environments.

With the growing interest in **geotourism,** volcanoes and hydrothermal areas are even more in the spotlight as interesting and adventurous destinations. To make volcano tourism **as safe as possible is the number one priority** to which the suggested recommendations for the improvement of visitor safety in active volcanic and hydrothermal environments could present a significant contribution.

The proposed recommendations are also suggested as potential additions for volcanic tourist destinations that have already developed planning strategies for emergency events but need to include temporary visitors as well, as hazard assessment and risk mitigation strategies are mainly developed for local residents. This is of particular importance, as visitors may not be familiar with proposed emergency escape routes in case of a necessary evacuation following an eruption.

The following table lists the most common hazards and risk factors related directly to active volcanic environments.

Volcanic Hazard	Description	Potential Impacts/Effects
Acid Rain	created when rain passes through clouds containing released volcanic gas such as sulphur dioxide or acid particle emissions – this can cause the formation of acid rain	impact on human health includes irritation of eyes and skin – negatively affects water quality and vegetation
Air Fall Deposits Block-and-Ash Flow Deposits (BAF)	generated during eruptions when blocks, bombs or lapilli are ejected from an eruption column – contain volcanic ash (tephra) – also known as pyroclastic fall deposits or block-and-ash flow deposits	a significant hazard in the proximity of the volcano due to the various sizes of glowing pyroclasts – can be spread over vast distances – **extremely dangerous**
Hydrothermal Eruptions	known to occur in hydrothermal areas – difficult to predict – may be caused by human activities such as hydraulic fracturing, excessive drawdown of deep reservoir fluids and changes in reservoir pressure	consist of the ejection of boiling water, hot mud, steam, and rock fragments – can affect small areas around hydrothermal vents but can extend to several kilometres in diameter – risk to tourism in geothermal areas across the world
Jökulhlaup	Icelandic name for a 'glacier burst' following a volcanic eruption underneath a glacier or ice cap – unique flooding event found in Alaska and Iceland – not always volcanogenic but can be caused by heat from underlying geothermal systems	can cause the sudden release of vast volumes of melt water and result in severe and widespread flooding – **extremely dangerous**
Lahars	debris flows that are generated by the mobilisation of pyroclastic material with the consistency of wet cement – can be caused by an eruption (hot primary lahar) or triggered through heavy rainfall,	can carry large boulders and are known to destroy the foundations of buildings and bridges – can travel many tens of kilometres from a volcano at considerable speed and momentum – lahars are a threat to

	snow melt or rim failure of crater lakes long after a volcanic eruption (cold secondary lahar) – lahars are gravity controlled and follow either valleys or riverbeds	people and infrastructure well beyond the immediate surrounds of a volcano – **extremely dangerous**
Landslides (volcanic) Debris Avalanches	the collapse of parts of steep sided volcanoes or eroded and unstable tephra layers – can be triggered by volcanic unrest but can also occur in the absence of an eruption – landslides have the potential to transform into lahars after heavy rainfalls	if a landslide is triggered by an earthquake or eruption in a submarine environment it can generate a tsunami – all landslides pose a significant hazard even in a dormant volcanic environment – can have devastating effects on surrounding human settlements and all natural habitats
Lava	molten or semi-fluid rock emerging from the earth at temperatures above 1000°C – lava can erupt as fire fountains or lava flows at varying viscosity – while underground lava is termed magma	causes severe thermal burns and/or death when the human body is exposed to hot lava to an extent that can be fatal
Lava Flows	a common volcanic hazard caused by effusive eruptions, also known as Hawaiian eruptions – they consist of red-hot molten rock and usually follow the topography – temperatures can be around 1,200°C	hiking across fresh lava fields can cause severe thermal burns as well as cuts from sharp edged lava crust – lava flows can destroy infrastructure (e.g. buildings, roads) and bury everything in their flow path – slow lava flows usually allow for evacuation
Lava Haze (LAZE)	a gas cloud that consists of hydrochloric acid (HCl) and forms when lava flows enter the ocean and come in contact with seawater	LAZE gas clouds or mist affect the respiratory system, irritate eyes and skin and can be fatal depending on the concentration and time of exposure – **extremely dangerous**
Phreatomagmatic or Hydrovolcanic Explosion/Eruption	caused by the interaction of water with hot rock or magma and creates what is also known as ultra-vulcanian eruption or steam-blast eruption	phreatic explosions consist of steam, water, ash, rock, and volcanic bombs and are **extremely dangerous**
Pyroclastic Density Currents (PDCs)	generic term that refers to a diverse range of gravity currents and includes all pyroclastic flows, surges, and ash flows – PDCs are composed of a mixture of gas and fragmented magma and can reach temperatures of up to and above 800°C and travel at speeds of several hundred km per hour	PDCs generally travel down volcano slopes but can jump over ridges or travel uphill and bury the landscape in layers of volcanic debris – considered as the most hazardous and life-threatening volcanic phenomenon – due to the velocity of PDCs escape is **not** an option – **extremely dangerous**
Tephra Volcanic Ash	a common and hazardous fallout from eruptions containing airborne fragments of rock and minerals from <2mm in diameter to larger fragments – of all eruptive hazards, tephra falls can have the widest reaching effect as the fine	tephra particles can affect respiratory and cardiovascular systems as well as irritating eyes and skin – during large eruptions the particles (commonly known as volcanic ash) pose a considerable danger to aircraft and can also have

	particles are transported by the wind for thousands of kilometres	severe impacts on climate and weather
Tsunami	also known as 'sea wave' or 'harbour wave' – usually a series of ocean waves – caused by the displacement of water offshore either by an earthquake or by a submarine volcanic eruption – can reach heights of over 30 metres and travel at speeds of >800 km/h in deep water	can cause widespread erosion of shorelines, roads, buildings, and other infrastructure – can travel hundreds of metres inland – large tsunami can cause the loss of thousands of lives (>227,000 in Indonesia, 2004; >18,000 in Japan, 2011) – **extremely dangerous and destructive**
Volcanic Bombs	volcanic bombs and blocks are ejected during explosive eruptions and can travel considerable distances – they vary in size but are larger than 64 mm in diameter up to several metres in diameter	can cause serious injuries including death from impact and burns
Volcanic Earthquakes Volcano-tectonic Earthquakes	seismic activity can be the sign of a restless volcano and caused by the movement of magma or fluids underground – volcanic earthquakes can occur at any time and do not necessarily indicate an impending eruption – explosion quakes are associated with explosive eruptions	can cause the ground to crack and ground deformation as well as damage to manmade structures through land subsidence
Volcanic Tremors Long Period Earthquakes	continuous seismic signals that indicate a volcanic eruption may be imminent	a warning for people to plan their evacuation if they reside near an active volcano or are visiting the area
Volcanic Gas Emissions	by-products of volcanic activity include gases such as SO_2, CO_2, H_2S, H_2, CO – a serious hazard close to active volcanoes or near hydrothermal steam vents – the majority of volcanic gas emissions (including water vapour (H_2O)), are invisible and cannot be detected by humans until they cause a reaction	apart from water vapour, volcanic gases can range from merely irritating to causing breathing problems – toxic volcanic gases at higher concentration can cause fatalities in a very short time and without warning – **extremely dangerous** – over extended time periods volcanic gases can negatively affect the climate – can cause chronic health conditions
Volcanic Smog (VOG)	a visible haze generated from volcanic gas emissions mainly consisting of H_2O, SO_2, CO_2 – depending on the weather a reaction of volcanic gases with moisture and oxygen creates a form of air pollution common in areas surrounding active volcanoes – reduces visibility for traffic	can cause irritation of the respiratory system and can aggravate pre-existing medical conditions – VOG can irritate the skin and the tissues and mucous membranes of eyes, nose, and throat – can produce serious respiratory distress in individuals suffering from asthma

Compiled from various sources including: Aspinall and Blong 2015; Brown and Andrews 2015; Chester et al 2001; Dufek et al 2015; Erediato and Luongo, 1997; Francis and Oppenheimer 2004; Geoscience Australia 2020; Government of Canada 2020; Gudmundsson 2015; Hansell et al 2006; Heggie et al 2010; Lockwood and Hazlett 2010; McNutt and Roman 2015; Riley 2020; Schmincke 2006; Siebert et al 2015; Tilling 2005; USGS 2020a; USGS 2020b; Vallance and Iverson 2015; Van Wyk de Vries and Davies 2015; Zobin 2003.

The volcanic hazards mentioned in the above table are directly related to the state of activity of a volcano and carry the potential to cause severe injuries and/or loss of life for visiting tourists. Even though volcano tour operators, visitors and their guides can prepare for some of these risks, serious consideration must be given to embarking into an area where help may not be available without delay, or even not at all.

In the event of an eruption visiting tourists should never rely entirely on their guides to lead them to safety, because everybody in a tour group will be equally affected by the impact of a violent eruption. The certain panic and confusion in such a situation necessitate safety procedures that are practical and permanently in place, although the best approach always should be the avoidance of entering hazardous volcanic or hydrothermal areas altogether.

References

Aspinall W, Blong R (2015) Volcanic Risk Assessment. In: Sigurdsson H et al (eds) Encyclopedia of Volcanoes, 2nd edn. Elsevier – Academic Press: London, pp 1215-1231

Brown RJ, Andrews GDM (2015) Deposits of Pyroclastic Density Currents. In: Sigurdsson H et al (eds) Encyclopedia of Volcanoes, 2nd edn. Elsevier – Academic Press, London, pp 631-648

Chester DK, Degg M, Duncan AM, Guest JE (2001) The increasing exposure of cities to the effects of volcanic eruptions: A global survey. Environmental Hazards 2(3):89–103. https://doi.org/10.1016/S1464-2867(01)00004-3

Dufek J, Esposti Ongaro T, Roche O (2015) Pyroclastic Density Currents: Processes and Models. In: Sigurdsson H et al (eds) Encyclopedia of Volcanoes, 2nd edn. Elsevier – Academic Press, London, pp 617-629

Eredidato D, Luongo G (1997) Explosion quakes at Stromboli (Italy). Journal of Volcanology and Geothermal Research 79(3–4), 265-276. https://doi.org/10.1016/S0377-0273(97)00033-4

Erfurt-Cooper P, Cooper M (2010) Volcano and Geothermal Tourism: Sustainable Geo-Resources for Leisure and Recreation. Earthscan, London

Erfurt-Cooper P (2011) Geotourism in Volcanic and Geothermal Environments: Playing with Fire? Geoheritage 3(3): 187–193. https://doi.org/10.1007/s12371-010-0025-6

Erfurt-Cooper P (ed) (2014) Volcanic Tourist Destinations. Geoheritage, Geoparks and Geotourism Series. Springer, Berlin

Erfurt-Cooper P, Sigurdsson H, Lopes R (2015) Volcanoes and tourism. In Sigurdsson H et al (eds) The Encyclopedia of Volcanoes, 2nd edn. Elsevier – Academic Press, London, pp 851-864

Erfurt P (2022) Volcano Tourism and Visitor Safety: Still Playing with Fire? A 10-Year Update. Geoheritage 14: Article number 56. https://doi.org/10.1007/s12371-022-00691-y

Francis P, Oppenheimer C (2004) Volcanoes. 2nd edn. Oxford University Press, Oxford

Geoscience Australia (2020) What is a tsunami? https://www.ga.gov.au/scientific-topics/community-safety/tsunami. Accessed 25 July 2023

Government of Canada (2020) What are the hazards from volcanoes? https://chis.nrcan.gc.ca/volcano-volcan/hazard-risque-en.php. Accessed 25 July 2023

Gudmundsson MT (2015) Hazards from Lahars and Jökulhlaups. In: Sigurdsson H et al (eds) Encyclopedia of Volcanoes, 2nd edn. Elsevier – Academic Press, London, pp 971-984

Hansell AL, Horwell CJ, Oppenheimer C (2006) The health hazards of volcanoes and geothermal areas. Occupational Environmental Medicine 63(2), 149–156. DOI: 10.1136/oem.2005.022459

Heggie TW, Heggie TM, Heggie TJ (2010) Death by volcanic laze. In: Erfurt-Cooper P, Cooper M (eds) Volcano and Geothermal Tourism: Sustainable Geo-Resources for Leisure and Recreation. Earthscan, London, pp 118–119

Lockwood JP, Hazlett RW (2010) Volcanoes: Global perspectives. Wiley-Blackwell, Chicester

McNutt SR, Roman DC (2015) Volcanic Seismicity. In: Sigurdsson H et al (eds) Encyclopedia of Volcanoes, 2nd edn. Elsevier – Academic Press, London, pp 1011–1034

Riley CM (2020) Volcanic Earthquakes. http://www.geo.mtu.edu/volcanoes/hazards/primer/eq.html. Accessed 25 July 2023

Schmincke HU (2006) Vulkanism. Springer Verlag, Berlin

Siebert L, Cottrell E, Venzke E, Andrews B (2015) Earth's Volcanoes and Their Eruptions: An Overview. In: Sigurdsson H et al (eds) Encyclopedia of Volcanoes, 2nd edn. Elsevier – Academic Press, London, pp 239–255

Tilling RI (2005) Volcano hazards. In: Marti J, Ernst GGJ (eds) Volcanoes and the environment. Cambridge University Press, Cambridge, pp 55–89

USGS (2020a) Volcano Hazards Program - Volcanic gases can be harmful to health, vegetation and infrastructure. https://www.usgs.gov/natural-hazards/volcano-hazards/volcanic-gases. Accessed 25 July 2023

USGS (2020b) Natural Hazards - What health hazards are posed by vog (volcanic smog)? https://tinyurl.com/2tpwvnxa. Accessed 25 July 2023

Vallance JW, Iverson RM (2015) Lahars and Their Deposits. In: Sigurdsson H et al (eds), Encyclopedia of Volcanoes, 2nd edn. Elsevier – Academic Press, London, pp 649–664

Van Wyk de Vries B, Davies T (2015) Landslides, Debris Avalanches, and Volcanic Gravitational Deformation. In: Sigurdsson H et al (eds) Encyclopedia of Volcanoes, 2nd edn. Elsevier – Academic Press, London, pp 665–685

Zobin VM (2003) Introduction to Volcanic Seismology. Chapter 13–Explosion earthquakes. Elsevier Science, pp 227–250