REVIEW ARTICLE

Health, wellness, and quality of life in volcanic communities: A comprehensive review of risks and protective strategies

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ABSTRACT

Living in volcanic regions presents unique health challenges that require comprehensive wellness approaches. Mental health, quality of life, and community resilience maybe encounter extremely dangerous situations during a volcanic crisis. It is needed to promote health and wellness alongside risk management. Volcanic eruptions bring us a series of health and environmental problems, which is determined by the different types of the volcanoes and their eruptions. The diseases caused by volcanoes and explosive eruptions can be classified into 5 categories: disease of the respiratory and digestive systems, trauma infection, abnormal cell growth and problems caused by environmental pollution after eruption. Among them, the diseases and injuries caused by volcanic ash mainly include silicosis, pulmonary inflammation, inflammatory body and cytokine diseases, changes in cell morphology, decreased cell density, obvious vacuolation of peritoneal macrophages, thyroid cancer, lung cancer, increased vulnerability to coronaviruses and other respiratory system diseases, as well as acute gastroenteritis, heavy metal poisoning, fluoride poisoning, chemical irritation, and peptic ulcers severe digestive system diseases. During extraordinary times (such as the period of the Coronavirus Disease 2019 [COVID- 19] pandemic), the disaster-causing effect of volcanic ash is more pronounced on susceptible populations, such as asthma patients, infants and the elderly. The widespread pathogenic and harmful factors are volcanic ash and toxic volcanic gases, even during the quiet period of volcanic activity. Volcanoes and volcanic eruptions bring us both wealth and disasters at the same time, which requires us to be able to coexist peacefully with volcanoes. It is of great significance for everyone to carry out popular science education on the background knowledge of volcanoes and understand the volcanoes on which we live. Volcanologists can play a greater role in volcanic education.

Key words: volcanic eruption, ash and gases, quiet release, respiratory disease, digestive problems, health and wellness

VOLCANO AND MAN

Volcanoes and their eruptions are among the most aweinspiring expressions of the natural world and have played a special role in the evolution of the Earth. A volcano is an accumulation of explosively or effusively erupted materials originating from single or multiple vents or fissures at the surface of the Earth or other planets. Volcanic eruption is a process of the explosive ejection of fragmented new magma or older solidified material among with gases and/or the effusion of liquid lava (Rose & Chesner, 1990; Siebert *et al.*, 2010; Stix, 2015). At least 20 volcanoes will probably be erupting as any moment; roughly 70 erupt each year; 575 have had historically documented eruptions; at least 1250 have erupted in the Holocene (past 10, 000 years); an estimates of young seafloor volcanoes exceed a million (Sigurdsson *et al.*, 2015). A supervolcano is a large (> 25 km diameter), often resurgent, caldera volcano from which at least one supereruption (> 500 km^3 of magma

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or 1000 km^3 of material) erupted. The erupted material often has a close relationship to the human life and health.

Over 500 million people, or 10% of the world's population, are living in areas of active volcanism (Small & Naumann, 2001). About 800 million people live within 100 km of an active volcano in 86 countries worldwide. More than 200 million live within a 30 km radius. And about 58 million people reside within a 10 km radius of Holocene volcanoes. Since 1700 principal volcanic disasters have taken a total of about 260, 000 lives. In our experience, we have the eruption of the type that occurs once in 100 years (such as Krakatau in 1883) or the eruption that occurs once in 1000 years (Tambora in 1815). What about the eruption that occurs once in 10 , 000 or 100, 000 or every million years? The supereruption at Toba on Sumatra about 75, 000 years ago and the Yellowstone, 3 times in the last 2100000 years, are probably the best examples on the Earth (Oppenheimer, 2003; Self & Blake, 2008). To strengthen a connection between volcanic eruption and the human health and life, some of the main features of volcanic eruptions and the related health problems are discussed here.

Among the disaster survivors within a volcanic community there exist usually a post-traumatic stress disorder (PTSD) for a prolong time after the eruption. So a long-term psychological adaptation and resilience building is needed for the community citizen. A mental health support systems can properly help improve the quality of life assessments in a volcanic regions.

The fertile soil formed after the volcanic ash eruption attracted people to quickly gather around the volcano again. The residents of the volcanic community spontaneously developed their ability of resilience and adaptive capacity. But a "post-traumatic growth" in disaster-affected populations is also a common sense in a volcanic communication. So we need the community to be cohesion and setting up social support networks enhancing health wellness.

TYPE OF ERUPTION—FEATURE AND EFFECT

Volcanism difference, producing different environmental and human health effects, depends mainly on type and duration of the eruption, among them most hazardous ignimbrite deposits (Fisher, 1979; Sparks, 1976; Siebert *et al.*, 2015; Tilling & Lipman, 1993). Type of volcanic eruption vary widely in both magnitude and duration and display a broad spectrum of eruptive styles and processes. Volcanologists generally describe eruptions in terms of activity type characteristics of particular volcanoes or volcanic regions and group them into explosive and effusive eruption. Hawaiian, Strombolian, Vulcanian, Pelean, and Plinian eruptions are classified in accordance with an increased degree of fragmentation and dispersion of the erupted fragments (Cas & Wright, 1987; Walker, 1973; Walker, 1981). Surtseyan and phreatoplinian eruptions are featured by a major interaction between magma and external water (Fisher & Schmincke, 1984).

Besides the explosive eruptions mainly mentioned above , the effusive eruptions are the other part of the volcanism type on the Earth. Effusive eruptions are named after two volcano-rich regions, Hawaii and Iceland. Hawaiian eruptions can produce long-term activity feeding summit crater lava lakes and the effusion of fluid, low-viscosity lava flows fed by sustained lava fountains along radial fissures, cumulatively building massive shield volcanoes. Icelandic eruptions display similar activity, but mostly originate from a regional fissures such as those that produced the voluminous lava flows of the 1783 “Laki fires” eruption. Icelandic-style shield volcanoes are typically much smaller than their Hawaiian counterparts.

Duration of current volcanic eruptions can last for a very long time, from decades to centuries, other eruptions end swiftly: 10% of those lasted no longer than a single day, most end in less than 3 months, and few last longer than 3 years. The median duration is about 7 weeks (Siebert *et al.*, 2015).

Volcanic explosivity index (VEI) is a widely used metric to describe the size of explosive volcanic eruptions, based primarily on the erupted volume of the deposit or the peak eruption column height (Newhall & Self, 1982). Another two principal quantities that are widely used to define the scale of an eruption are magnitude, the mass of material erupted and intensity, the mass eruption rate (Bryan *et al.*, 2010; Carey & Sigurdsson, 1989).

Quiescent continuous volcanic emissions also add some volcanic gases to the surface, sulfates to the troposphere for instance, but their lifetimes there are much shorter, although longer than anthropogenic sulfates. A local pollution produced by the emission of the Kilauea crater on the Big Island of Hawaii is called “vog”. Global sulfur emission of volcanoes to the troposphere is about 15% of the total natural and anthropogenic emission, producing cooling at the surface (Deckers & Steinnes, 2004; Thordarson & Self, 1996; Wignall, 2001).

It seems that is there any contact with volcanic ash is important for the susceptible people's respiratory disease at different volcanoes such as Soufriere Hills, Mt Sakurajima, St Helens and Island of Hawaii. In the cities and communities surrounding Sakurajima volcano, Respondents identified a range of symptoms perceived to be associated with ash exposure, with 67% experiencing at least one symptom. Protection was particularly important to older people and those with existing respiratory disease, who were more likely to take ash as harmful or associate symptoms with exposures. The pulmonary function and athletic capability on the health in school children varies unclearly. In the entire study including both the exposed asthma-like disease and control groups, the proportion of children with was 6 % and 3 % in boys and girls, respectively. A longitudinal study to characterize Hawaii's volcanic aerosol and investigate its potential effects on asthmatic children found a positive outcome. At Soufriere Hills, the fine ash and particulates brought a serious lung and respiratory system problem to the susceptible populations, including patients, infants, and elderly.

There should be specific wellness strategies for different age groups as well as different genders. The socioeconomic factors and cultural or ethnic disparities also affect health impacts and outcomes. During a long lived explosive activity, such as Soufriere Hills and Sakurajima, volcanic ash exposure affects health across the lifespan of the citizen in communication. A recovery and rehabilitation perspective for chronic disease should be considered in the volcanic environment.

FOCUS ON SOME MAIN VOLCANO DEDUCED HUMAN HEALTH DISASTERS

Injury agents

We can categorize injury agents as various forms of energy that may inflict harm in volcanic eruptions (Office of the United Nations Disaster Relief Co-ordinator, 1977). These agents are grouped into mechanical (mud flow and rock/debris avalanches, ballistic ejecta, and tephra falls), thermal (pyroclastic flows), chemical (gases and aerosols), electrical (lightening), and ionizing radiation (radon gas) or just asphyxia by volcanic gases (carbon dioxide, hydrogen sulfide or methane). Volcanoes can also present hazards in repose periods, for instance, people living on the flanks of volcanoes can be subjected to soil gas emissions. Volcanic ash and dust, such as the crystalline silicon, caused diseases on human health (Baxter *et al.*, 1999), which include mainly: touched acid rain in an open air; eye and skin burn infection and tympanic membrane; gas gangrene (clostridium welchii); necrotizing fasciitis, traumatic asphyxia; and fluorosis that often occurring in regions where drinking water has a raised fluoride level.

Witham (2005) reported that 91, 724 people died as a result of volcanic eruptions in the twentieth century, with most loss of life occurring in two major events, the eruption at Mont Pele´e, Martinique and Nevado del Ruiz, Colombia, disasters of hot ash flow and mud flow.

Ash caused respiratory disease and other hazards

Volcanic ash and gas hazards include mainly respiratory health problems, digestive health issues, eye and skin burns and infections, Deoxyribonucleic Acid (DNA) damage and genetic instability, lung cancer cells, water pollution problem and environmental problems such as aviation aspects that have been discussed in detail (Baxter *et al.*, 1981; Baxter, 1990; Ghosh *et al.*, 2010; Lin *et al.*, 2006; Prata & Tupper, 2009; Shinozaki *et al.*, 2013; Trouiller *et al.*, 2009; Witham *et al.*, 2012; Yano *et al.*, 1985).

Volcanic ash is one of the most common hazards (Camarinho *et al.*, 2013; Gao *et al.*, 2008; Green *et al.*, 1981; Lee & Richards, 2004; Rodrigues *et al.*, 2012). There are different health problems resulted from explosive eruption during the 2010 Eyjafjallajo¨kull eruption in Island, as well as the aviation caused traffic, air pollution and economic problems. Acid gases and toxic metals may adsorb onto the surfaces of fine ash and dust. Volcanic gases adhere to ash, forming salts and sublimates at high temperatures as the ash erupted; at lower temperatures in the plume, acids adhere directly to volcanic glass surfaces and form aerosol or fluid droplets (Thomas & Prata, 2011). Because of the vast surface areas presented by these particle and aerosol surfaces in the erupting plume, the amounts may be enough to cause toxic hazards to animals grazing on ash-coated grass and drinking from surface waters contaminated by deposits of ash (Wilson *et al.*, 2000). 1980 St Helens eruption shows, in 18 of 23 autopsy report, asphyxiation from ash inhalation; ash-related eye complaints in some areas; admissions for asthma and bronchitis; respirable portion contained 3% to 7% of crystalline free silica, a potential pneumoconiosis hazard (Baxter *et al.*, 1981; Fruchter *et al.*, 1980; Green *et al.*, 1981; Heppleston, 1991; Taves, 1980); a variety of hazards including blast, ashfalls flooding, damage to public utilities and possible psychosocial effects.

Volcanic ash fallout is widely hazardous, such as eye irritation and abrasion, foreign bodies, and conjunctivitis ; car accidents; falls from roofs during ash cleanup; chlorinated sewage; electric power lines conductivity of moist ash, and even a social psychological disorders could be induced from it (Baxter *et al.*, 1981; Yano *et al.*, 1985; Hansell *et al.*, 2006). Respiratory health problem is another important hazard type, including cough, asthma or wheezing, acute bronchitis, chronic obstructive pulmonary disease and hyperventilation (Castranova *et al* ., 1982; Lin *et al.*, 2006).

Pyroclastic flow ash caused hazards

Ash effect in pyroclastic flows that caused death was thermally induced fulminant shock and not suffocation.

Voluntary self-protective reaction or agony contortions, articulated fracture, increased intracranial pressure, incineration, thermally induced nociceptive or flexor reflex, spine extension of the skeletons, and tendons and muscles shortening, all above are the different forms of disease or injure related to the thermal effect of ash within a pyroclastic flow (Baxter, 1990; Baxter *et al.*, 2005; Mastrolorenzo *et al.*, 2001).

Baxter *et al.* (1998) presented a numerical modelling of pyroclastic flow in terms of the physical parameters (temperature, ash in air concentration, and dynamic pressure) that are most critical for human survival (Baxter *et al.*, 1998). Including survival limits on exposure to heat and inhalation of hot air and air containing high concentrations of hot particles, simulation shows that the proximal area always undergoes complete devastation, with both the temperature and the ash concentration rising to above lethal values. Crater obliteration, burial and dismemberment will be inevitable, whilst further out the effects of heat and the trauma from the dynamic pressure causing body displacement are the main cause of death. In distal area, primary risk to life is asphyxiation from ash inhalation rather than thermal injury, severe abrasion from a sandblasting effect, where buildings should therefore be more likely to resist the dynamic pressure of the flow and remain sufficiently intact to protect the occupants. Threshold values for temperature of 200℃ and ash concentration of 0.1 kg/m^3, above that, human survival was likely to be impossible. Deaths from the effects of heat and asphyxia in pyroclastic flows were reported at Vesuvius, Anno Domini (AD) 79 and AD 1631 (Rosi *et al.*, 1993), and Krakatau, AD 1883 (Baxter *et al.*, 2008; Carey *et al.*, 1996).

Weinhold *et al.* (2013) tested a possible interactions between volcanic ash and samples of several infectious agents - human airway epithelial cells, rat alveolar epithelial cells, and human and rat alveolar macrophages, reflecting the ability of volcanic ash to stimulate bacterial growth and interfere with innate immunity. Thyroid cancer, lung inflammation, inflammasome, and cytokine disease could be related to the air pollution from airborne volcanic ash, which also increase vulnerability to the coronavirus. Aguilera *et al.* (2018) assessed the biological impact of Pichincha volcanic ash on cell culture and inflammation in murine lung tissues that will contribute to the understanding of the hazards (Aguilera *et al.*, 2018). The ash effects are the marked cellular toxicity (cancer) dependent on the concentration of ash and the time of exposure and the imbalance of the regulation of reactive oxygen species by deactivating the activity of the antioxidant enzyme (Arnbjörnsson *et al.*, 1986; Russo *et al.*, 2015; Salazar-Vega *et al.*, 2019).

Vulnerability also increases to the coronavirus, especially to the population living and working in the shadow of the ash fallout of the active volcanoes (Toulkeridis *et al.*, 2021). Assessment of the biological impact of Pichincha volcanic ash on cell culture and inflammation in murine lung tissues that will contribute to the understanding of the ash hazards (Aguilera *et al.*, 2018). They found the ash effects are the marked cellular toxicity dependent on the concentration of ash and the time of exposure and the imbalance of the regulation of reactive oxygen species by deactivating the activity of the antioxidant enzyme.

Ash caused digestive problems

Digestive health issues caused by volcanic ash exposure include: (1) Acute gastroenteritis caused by ingestion of ash-contaminated water/food or physical irritation from abrasive ash particles as nausea, vomiting, diarrhea, abdominal pain; (2) Heavy metal poisoning because of ash leaches toxic metals (*e.g.*, arsenic, lead) into water and soil, leading to ingestion in forms of acute gastrointestinal (GI) distress and chronic exposure caused liver and kidney damage; (3) Fluoride toxicity because of a high fluoride level in ash-contaminated water caused acute GI symptoms (vomiting, diarrhea) or chronic skeletal/dental fluorosis (Allibone *et al.*, 2012); (4) Chemical irritation from sulfur compounds in ash mixed with water to form acids, causing chemical burns in the GI tract; (5) Exacerbated peptic ulcers as stress from eruptions or physical irritation by ash may worsen ulcers. It is worthy to point out the volcanic ash introduces environmental toxins and mechanical irritation, leading to unique risks like heavy metal poisoning and fluoride toxicity. They impact entire populations during the disasters, requiring public health interventions (Sigurdsson *et al.*, 2015).

Preventive health and wellness approaches

To strengthen the health promotion framework and to enhance immune function, nutritional interventions are very useful in volcanic environments. Physical activity and exercise recommendations should be given to the volcanic region residents. Psychologically stress management and mindfulness techniques are also effective for disaster preparedness. Holistic wellness approaches compose physical, mental, and social health. A comprehensive health and wellness model for the people in a volcanic community maybe come into being in the future, in which health equity and social determinants of health in volcanic communities in accordance with the World Health Organization (WHO) definition of health as "complete physical, mental and social well-being".

THE TOXIC VOLCANIC GASES

Volcanic gases are the invisible but continuous products of volcanic activity, even in a state of quiescence (Baxter *et al*., 1982; Burton *et al*., 2013). Eruptions can produce lethal quantities of toxic gases while long-term exposure to a lower level can also pose a significant hazard. They have an important effect on the regional and global environment and may contribute greenhouse gases to the atmosphere. Indirectly, through the destruction of crops, volcanic gas emissions have resulted in starvation and disease.

The composition of volcanic gases depends on the type of volcano and its eruptive state. The most common volcanic gases are H_2O, CO_2, SO_2, Rn, H_2, H_2S, CO (Hansell & Oppenheimer, 2004; Rose *et al*., 1995). Some of these, when emitted from active vents, react in the atmosphere or volcanic plume to form aerosols, the most important being HCl, HF and H_2SO_4. Exposure to these has been the cause of the majority of volcanic gas-related fatalities (Pyle & Mather, 2009; Stoiber *et al*., 1980; Symonds *et al*., 1988).

The long-term health effects of volcanic gases may be responsible for epidemic diseases because of their irritant and depressing effects that reduce the resistance of ocular, respiratory, and digestive systems to microbial attack. A permissible exposure limit (PEL) to a given chemical compound, above which health risks may occur, is recommended.

Environmental cooling and heating volcanic gases

A greenhouse effect from volcanic gas species such as CO_2 and CH_4 can be modified by a cooler agent, such as SO_2 in the aerosol. For example, Mt Pinatubo in the Philippines 1991 put about 20 Metric Ton (MT) of SO_2 into the lower stratosphere, the 1982 El Chicho´n eruption injected 7 MT of SO_2 into the atmosphere, three eruptions in 2008 Kasatochi in Alaska; in 2009 Mt Sarychev in Kamchatka Peninsula; and in 2011 Nabro in Eritrea, each put about 1.5 MT of SO_2 into the lower stratosphere, and all the above eruptions contributed to the reduced global warming trend of the first decade of the New Century, which left a long-tern effect to the human health (Sigurdsson *et al*., 2015).

Problems related to crater Lake and deep discharged gases—quiescent emission

Some crater lakes can also pose significant risk due to the accumulation of CO_2 and CH_4 in thermally stratified waters, when it perturbed can lead to limnic eruptions or catastrophic gas discharge from the lakes. Lake Kivu, on the border between Rwanda and the Democratic Republic of Congo and Lake Nyos in Cameroon, are the best examples (Baxter *et al*., 1989). The CO_2 is believed to have originated from cold springs degassing below the lakes. These two events may have been triggered by landslides, which caused the deep gas-rich layer to rise to a point in the lakes where the hydrostatic pressure was insufficient to keep the CO_2 in solution. Then the CO_2 gas that was released formed a large density current flowing over the crater rim and downslope, killing 1700 people and lots of wild animals.

Beginning in 1990, extremely high levels of CO_2 soil degassing on the flanks of Mammoth Mountain have resulted in a > 500, 000 m^2 tree-killed areas with no eruption (Farrar *et al*., 1995). The CO_2, which kills the trees during the winter by inhibition of root function and oxygen deprivation, originates from the degassing process of intruded magma and gas release from magmatically heated carbonate rocks beneath the Long Valley caldera. When the CO_2 gas leaves the ground, its relatively high density causes it to collect in hollows, wells, and confined places and creates a serious asphyxia disease to the local people.

At Masaya volcano located in northwestern Nicaragua, the long-term degassing activity from the active crater has had a significant impact on the surrounding vegetation: high concentrations of SO_2 disturb stomatal respiration and cause necrosis. The presence of this gas, as well as HCl and HF, has led to extensive fumigation and contamination of > 1200 km^2 downwind of the volcano. Concrete and metal fences, telephone wires, and other metal equipment are also severely damaged in the affected areas. Mixing of rain from Hurricane Mitch (late 1998) with the volcanic gas plume produced concentrated acid rain, acid smog or vog, which caused a damage to young palm trees and complete destruction of a soya field during a single afternoon. This volcanic haze may also act as cloud condensation nuclei and even as sites for the catalytic destruction of ozone with obvious global implications (Beerling *et al*., 2007).

Other example of hydrochloric acid being solely and directly responsible for volcano-related fatality is few, but it is an important component because of its effects on the environment. WHO recommended *F* concentration in drinking water is 1 ppm. This has led up to 96 % of the people suffering from moderate to extreme dental fluorosis, prolonged exposure to *F* concentrations of 4–6 ppm can lead to skeletal fluorosis (Allibone *et al*., 2012).

DISCUSSION AND CONCLUSION

Effusional volcanism rarely damages the human life, but they can expel a great number of toxic gases from the giant erupted magma volume. The Laki fissure eruption in Iceland lasted from June 8, 1783 to May 26, 1785, resulting in an atmospheric loading of 219 MT of SO_2, ~7.0 MT of HCl, and 15.0 MT of HF over an 8-month period. A gas haze caused grasses contaminated by fluorine to be stunted, leading to the loss of over 50% of Iceland's grazing livestock. This consequently lead to the "Haze Famine", which, in combination with various diseases and two severe winters, caused 10, 521 people, 22% of Iceland's population, died. The injection of ash, gases, and aerosols into the lower stratosphere also affected parts of Western Europe, North Africa, and Western Asia and resulted in cooling of the Northern Hemisphere by 1–2℃ (Oman *et al*., 2006; Thordarson & Self, 1996).

Large igneous provinces (LIPs), supereruption and mass extinction

LIPs of the world, including continental flood basalt provinces, oceanic plateaus, and silicic LIPs. It is the combination of large erupted volumes and the high frequency of eruptions that led to the rapid construction of extensive lava plateaus. LIPs represent another class of exceptionally large volcanic events (Bryan & Ferrari, 2013; Rampino, 2010; Rampino & Stothers, 1988; Wignall, 2001). They are associated with repeated intrusions and eruptions, produced gigantic volumes (likely exceeding 2000 km^3) of magmas over short periods of geologic time. LIPs activity has been linked to severe disruptions of the Earth's carbon cycle, and severe repercussions for the environment and life have been speculated. The largest three continental flood basalt (CFB) province composed the Siberian Traps at 252 Mega-annum (Ma) ago, Emeishan Traps (China) at ~258 Ma ago, and Deccan Traps (India) at ~65 Ma ago. Deccan Traps may have added significant amounts of CO_2 to the atmosphere and been responsible for increased global warming and the K-Pg extinction event (Rose & Chesner, 1990; Burton *et al*., 2013; Black *et al*., 2012; Caldeira & Rampino, 1990; Courtillot, 1999; Jones & Cox, 2001; Self *et al*., 2006; Self *et al*., 2014; Svensen *et al*., 2009; Wang *et al*., 2019).

LIPs eruptions include the continental flood basalts on land and oceanic plateaus in the sea (Rampino & Stothers, 1988) and a supereruption from a supervolcano, which made the mass extinctions as well as ocean anoxic event (OAE)-a period when the deep oceans became depleted in oxygen (Courtillot & Renne, 2003), such as the Paleocene-Eocene thermal maximum (PETM): Brief period in time about 56 million years ago when Earth's temperature was several degrees warmer than present.

Positive effects of volcanoes: health literacy and empowerment in volcanic communities

Most people knows that volcanoes could be objects of awe and fascination or as agents of destruction, which also contribute to commerce and culture in myriad ways. For instance, in many volcanic regions more and more tourism developed. Geothermal resources are exploited either directly for heat or indirectly for the generation of electricity. The resulting volcanic soils have unique physical and chemical features, such as moisture retention. Life forms are reestablished as soils form and other changes occur in deposits as well as the volcanic materials in commerce and industry usage. Some of the ancient civilizations was instantly preserved by the devastating force of volcanic eruptions. Examples include the well-known Roman cities of Pompeii and Herculaneum and the Bronze Age Akrotiri in the Aegean. Volcanoes are frequently viewed as windows to the interior of the earth. Volcanoes are often used as a metaphor for power or unpredictability because of their disasters brought to the people. All these ideas show up repeatedly in popular culture in ways of books, movies, cartoons, fine art, and other forms of expression. So a world without volcanoes would be a duller, less economically viable, and certainly less interesting place.

Public education, especially for the people near a volcano, knowledge of volcanology, the causes of death, injury, and disease during and after volcanic eruptions has increased greatly alongside the recent advances in volcanological study (Bourne *et al*., 2016; Gudmundsson, 2011; Sierra *et al*., 2016). A whole range of injury agents are involved in eruptions and these are described for pyroclastic flows and surges, lahars, explosions, tephra falls, and gas emissions. Burgeoning human populations have formed high-density settlements in volcanic areas, some of which were populated 100 years ago. Recent eruptions have provided insights into the mitigation measures for the management of volcanic crises (Baxter *et al*., 2014).

Although difficult but it is necessary to change the health behavior customs in the communities citizen near an erupting volcano. High quality mask, for instance, is prepared and worn at any time during the volcanic crisis. Community stuffs are responsible for distributing of emergency supplies, communicating with officers and scientists for participating the education lectures and health planning preparations. Family-centered health management approaches are recommended, especially for the young students. After training at school, the student can help their families and neighbors to learn how to effectively manage the key points to protect from a dangerous situation and to become health and wellness after the crisis. A personal new habit or citizen custom maybe set up after a time span like the COVID-19 crisis.

Montserrat 1997, example of successfully implemented health and wellness program

The Soufriere volcano located on the island of Montserrat in the West Indies is the most thoroughly studied volcano in terms of volcanology and volcanic hazard studies since the eruptions of Mount St. Helens in the United States in the 1980 and Mount Pinatubo in the Philippines in the 1990 s. A world-class volcanic research team led by Professor Sparks, based on detailed volcanic researching and monitoring data, conducted volcanology and volcanic hazard studies that provided the local government and residents with solid useful volcanic disaster reducing suggestions. With the help of local administrative and community workers, effective work was carried out to restore the physical and mental health of the residents in the affected areas during the post-disaster reconstruction process.

The eruption of this volcano began in the late 1990 s and composed of five eruption periods until 2011, with the most intense eruption occurring in 1997. Residents in the northern and southern communities of Montserrat Island all faced severe volcanic ash fall disasters, which caused a series of respiratory and digestive system-related diseases. Regarding the pathogenic mechanism of specific volcanic ash, under the guidance of volcanologists, medical workers and community workers provided detailed person-to-person services to the local vulnerable groups- the elderly, children, patients with basic respiratory system diseases, and economically disadvantaged groups- and achieved good social assistance significance. Particularly worth mentioning is that in the health and wellness programs, policymakers in the government decision-making department provided rehabilitation and reconstruction support to the economically disadvantaged groups as timely as possible in the form of insurance assistance.

Mitigating volcanic hazards and role of scientists

The disaster caused by volcanic eruption is obvious, especially for large-scale explosive volcanism, which has caused great loss of human life and property in history. There are three main methods to reduce volcanic disasters: (1) Study the present and past eruptions of volcanoes by means of science and technology and monitoring methods, find out their activity rules and apply them to the prediction of volcanic activities (Aguilera *et al.*, 2018; Ban-Nai & Muramatsu, 2003; Newhall & Hoblitt, 2002; Scarpa & Tilling, 1996; Toulkeridis *et al.*, 2007); (2) Use the above information to assess the type of volcanic hazards and their risk levels and to circle out danger areas; (3) Develop plans for the protection of the population in the event of a volcanic emergency (Baxter *et al.*, 2008).

The emergency response system for volcanic hazard education should include: (1) in areas where volcanic eruptions are likely, volcanologists should meet regularly with municipal and corporate leaders, law enforcement officials, hospitals and journalists; (2) Mass presentations through newspapers, television and radio stations, museum exhibitions and other occasions: teaching about volcanoes to school students is particularly effective, because parents also acquire knowledge about volcanoes through their children.

Development of an emergency management plan (hazards zonation map) and its components in the event of a volcanic crisis

When an evacuation order is issued by the executive leadership, there must also be a related assurance plan—hazards zonation map. (1) Detailed routes and means of transport for evacuation; (2) A destination that is reliably safe; (3) Logistical arrangements for emergency personnel, such as specific tasks, means of transport and means of communication; (4) Temporary supplies for evacuees, such as accommodation, food and sanitation; (5) Treatment of injured persons; (6) Protection and safety of property in the evacuation area; (7) If search and rescue is required, a series of divisions and responsibilities must be defined. Volcanologists should be involved in the development of these plans to ensure that they are feasible and appropriate for the actual possible volcanic behavior.

In human history we have made great efforts to mitigate volcanic disasters, including Japan, the United States and other volcanic countries, and achieved good results, but there are also some profound lessons worth learning, such as the Nevado del Ruiz, Colombia (Pierson *et al.*, 1990).

From volcano to community—health problems and well-being

The holistic health approaches consisted of physical, mental, and social well-being aspects for the residences in volcanic area. Community empowerment and participatory health planning is necessary to build resilient and healthy communities and cities. Understanding of volcanology and hazard mitigation helps a lot to the benefits of the people living in a shadow of volcanic eruption. It is needed in future for volcanologists to work together with the professionals and stuffs experienced in human health and wellness.

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