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HEALTH ISSUES RELATED TO VOLCANIC ACTIVITY

INTRODUCTION

It has been estimated that more than one million people have died as a result of volcanic activity over the past 2,000 years. The estimate is necessarily inexact because records and evidence are commonly destroyed during eruptions. The death toll for the twentieth century is thought to be close to 100 000 (Decker and Decker 1991). These figures must be increased many times to estimate the numbers of people whose health has been adversely affected by volcanic eruptions. The potential problems have grown to the present time. Nine percent of the world's population, some 455 million people, currently live within 100 km of a volcano which has been active in historical times and are thus potentially at risk from health problems. In this paper, we describe some

Table 1. Some health effects of eruptions at a distance from the volcano.

Eruptive event Ashfall	Consequence	Health impact
	Respiratory	
	Inhalation of fine ash	Asthma, exacerbation of pre-existing lung disease
	Inhalation of siliceous dust (presence of crystalline silica)	Silicosis, if exposure is heavy and continuous (years)
	Toxic	
	Ingestion of water contaminated with fluoride, possibly also heavy metals (e.g. Co, As)	Gastrointestinal upset, even death in vulnerable (chronic sick)
	Ingestion of contaminated food (as above); incl. milk	As above
	Ocular	
	Foreign bodies in eyes	Conjunctivitis, corneal abrasions
Gaseous emissions	Acid rain	Eye and skin irritation: possible toxic contamination
	CO_2 bursts	Possible death by poisoning

Modified from Baxter *et al.* (2006), table 3.

of the principal health effects of eruptions, which are listed in Table 1. We also briefly discuss certain aspects of the psychological effects of such activity.

ASHFALL

RESPIRATORY

Ash inhalation

Of all eruptive hazards, ashfall can affect the most people because the ash (defined as pyroclastic fragments ≤2 mm in diameter; see Pańczyk, this issue) can be distributed over wide areas around the erupting centre, commonly tens or hundreds of kms downwind. Even where eruptions are relatively short-lived, ashfall deposits remain in the environment for decades and can be remobilised by human activity, such as agriculture, construction or motor vehicles (Fig. 1), or resuspended by the wind. Martin *et al.* (2009) noted that the hazard associated in the Argentinian town of Esquel with resuspended ash from the 2009 eruption of Chaitén volcano, Chile, remained high for several months, even when the traffic activity was low and the air not notably dusty.

Fig. 1. Cars mobilising ash fall from the 1980 eruption of Mount St Helens. From http://vulcan.wr.usgs.gov/Volcanoes/MSH/SlideSet/ljt_slideset.html

Evaluation of the health risk from long-term exposure to ash due to persistent eruptive activity is particularly complex, made more difficult by the fact that information on key properties of the ash, such as the grain size distribution or morphology of the particles, is not always reported (Horwell and Baxter 2006). We now discuss some of the factors which are critical in determining the toxicity of volcanic ash.

Role of particle size

The grain size of volcanic ash particles is of major importance in health studies, being the major determinant of where a particle will locate in the respiratory tract. When breathing through the nose, the majority of particles >10 m in diameter are trapped in the nose. Particles less than 10 μm in diameter (PM_{10}) have the potential to penetrate into the lower respiratory tract. Such particles are classified as *thoracic*, and *respirable* when <4 μm. The finer respirable particles have the greatest toxic potential because they can be breathed into the alveolar region of the lung, where pathogenic reactions can be triggered (Fig. 2a, b).

The percentage of respirable material in the ash varies greatly between volcanoes (Table 2). It is not simply related to distance from the vent; the Merapi, Montserrat and Mount St. Helens material had similar volumes but were collected at very different distances from the vent. Nor is it a simple function of the magnitude and explosivity of the eruption, expressed in Table 2 as the Volcanic explosivity index, where 6 represents the most intense eruption listed. Thus it is not a simple matter to predict accurately the proportion of respirable ash which will fall at any specific location. The UK air quality standard for PM_{10}, which is routinely monitored because of pollution by motor vehicles, is 50 μg m^{-3} over a 24-hour averaging period. Concentrations of PM_{10} during and after a heavy ashfall can be in the mg m^3 range, unless or until rainfall clears ash from the air (Baxter 2000).

Events in the alveolar region, shown in Fig. 2, depend on the form, size, chemical composition and surface state of the particles (Fubini and Fenoglio 2007). (1) The particles may damage type 1 epithelial cells, which constitute the wall of the alveoli and through which gases are exchanged. (2) The particles activate immune defences, causing signals to be sent to alveolar macrophage cells, which are charged with clearing the body of foreign substances. If clearance is not successful, the activated macrophage will die, releasing the engulfed particles and factors to recruit new immune-defence cells.

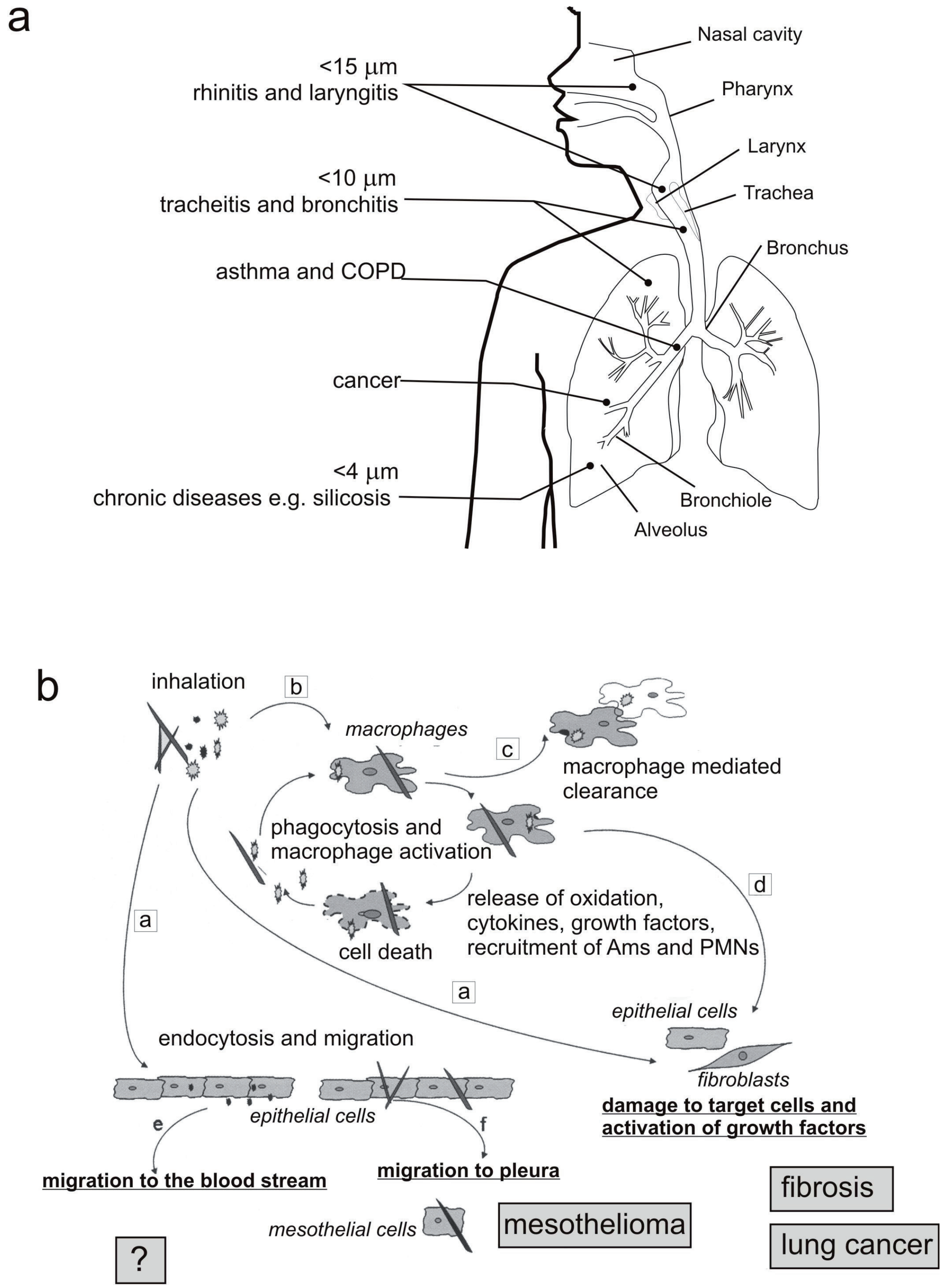

Fig. 2. (a) Potential distribution of variably sized ash particles within the lungs (from HORWELL and BAXTER 2006). (b) Effects of shape, size and surface reactivity on the destiny of inhaled particles (from FUBINI and FENOGLIO 2007).

The cycle of recruitment and cell death so established can result in sustained inflammation of the lung. The inflammation is caused by substances released during activation of the macrophage cells, namely reactive oxygen species (ROS), cytokines and growth factors. All contribute to damaging the surrounding epithelial cells and to stimulating

Table 2. Variations in respirable material (<4 μm diameter) with volcano, distance from vent and explosivity.

Volcano	Eruption date	Distance from vent	Respirable material (cumulative vol.%)	Volcanic explosivity index
Merapi, Indonesia	11–19 July 1998	200 m	12.7	2
Soufriere Hills, Montserrat	5 June 1999	4 km	10.7	3
Sakurajima, Japan	1 Jan 1994	4 km	0.9	3
Vesuvius, Italy	24 Aug AD79	6 km	16.9	5
Etna, Italy	4 Nov 2002	11 km	1.8	3
Pinatubo, Philippines	4 July 1991	20 km	9.8	6
Cerro Negro, Nicaragua	30 Nov 1995	20 km	0.6	2
El, Reventador, Ecuador	3 Nov 2002	90 km	4.9	4
Mount St. Helens, USA	18 May 1980	378 km	11.7	5

From HORWELL and BAXTER (2006)

abnormal growth of fibroblasts. The long-term result may be lung cancer or fibrosis.

HORWELL and BAXTER (2006) have distinguished acute (short-term) and chronic (long-term) respiratory effects of volcanic ash. *Acute effects* include attacks of bronchitis and asthma, manifested in increases in coughing, breathlessness and wheezing due to irritation of the lining of the airways by fine particles. Asthma attacks can be fatal, especially among older people. Inhalation of fine ash can also exacerbate existing diseases, such as chronic bronchitis or advanced heart problems. Generally, such effects are felt mostly by people with pre-eruption lung disease. The most worrying *chronic* health condition is silicosis, a diffuse nodular fibrosis (scarring) of the lungs. Development of silicosis requires three conditions to be met: (1) a high proportion of fine particles in the ash; (2) a high concentration of crystalline silica (see below); and (3) exposure to significant quantities of ash over a long period, typically years to decades. HORWELL and BAXTER (2006) were unable to find any record of human cases of silicosis or other chronic lung disorders resulting from volcanic ash but noted that few studies have included the long-term health consequences of exposure. Potentially at greatest risk are children because little is known of their susceptibility to silicosis.

Physiochemical properties and toxicity

Newly erupted ash differs from other natural dusts in having particle surfaces which are unweathered and, therefore, not leached or oxidised, a rarity in the natural environment. As a result, they can carry condensed volatiles such as acids and trace metals (HORWELL *et al.* 2003). Some effects of these components are discussed below. The surfaces of both covalent and ionic solids have sites, related to imperfections in the crystal structure, which may react with biological molecules. Defective particle surfaces may expose surface charges, surface-bound radicals or poorly coordinated ions, all of which may contribute to adsorbing biomolecules at cell membranes (FUBINI and OTERO ARÈAN 1999). The potential health hazard of volcanic ash is enhanced by the formation of fresh surfaces by fragmentation during eruption (HORWELL *et al.* 2003). Fracturing of crystalline silica, for example, produces surface radicals, such as $Si^{\bullet}$ and $Si\text{-}O^{\bullet}$. The radicals increase surface reactivity and can be highly reactive in the lung. Free radicals may also be generated on particles in aqueous suspensions, including reactive oxygen species such as the superoxide radical $O_2^{-\bullet}$ and the hydroxyl radical $HO^{\bullet}$. These may cause oxidative stress, which can be defined as an imbalance between the production of reactive oxygen species and the body's ability to detoxify the reactive intermediate products, and may eventually result in cell mutation.

Recent work has shown that Fe (as Fe^{2+} or Fe^{3+}) in volcanic ash can impart a high reactivity by generating hydroxyl free radicals (HORWELL *et al.* 2003). Generation of free radicals occurs when Fe is present on the surface of crystalline silica particles or other silicates. The hydroxyl radical ($HO^{\bullet}$) is produced in the reaction series, which is part of the Haber-Weiss cycle (Fubini and Otero Arèan 1999):

$$Fe^{2+} + O_2 \rightarrow Fe^{3+} + O_2^{-\bullet}$$
$$O_2^{-\bullet} + 2H^+ + e^- \rightarrow H_2O_2$$
$$Fe^{2+} + H_2O_2 \rightarrow Fe^{3+} + OH^- + HO^{\bullet}$$

Trace amounts of Fe can drive this catalytic reaction, generating abundant amounts of $HO^{\bullet}$ radicals from $O_2^{-\bullet}$ radicals and hydrogen peroxide, which are produced both by this reaction and in the body. $HO^{\bullet}$ radicals get their missing electron by extracting one hydrogen atom from C-H bonds in molecules such as DNA, causing damage. The process is involved in both lung inflammation and carcinogensis. The ability of Fe^{2+} to act as a catalyst for toxic reactions in the lung has a further implication for health hazards. Iron-rich basaltic ash, normally thought of as being of lower toxicity than more silica-rich ashes due to a lack of crystalline silica, but may in fact interact more readily with hydrogen peroxide in the lung (Horwell *et al.* 2007).

Fragmentation of silica polymorphs produces particulates with transient piezoelectric charges (Williamson *et al.* 2001). This may cause strong reaction with atmospheric gases and, by interaction with surface charges, can lead to the formation of dangerous radicals, which will have deleterious effects on the lungs.

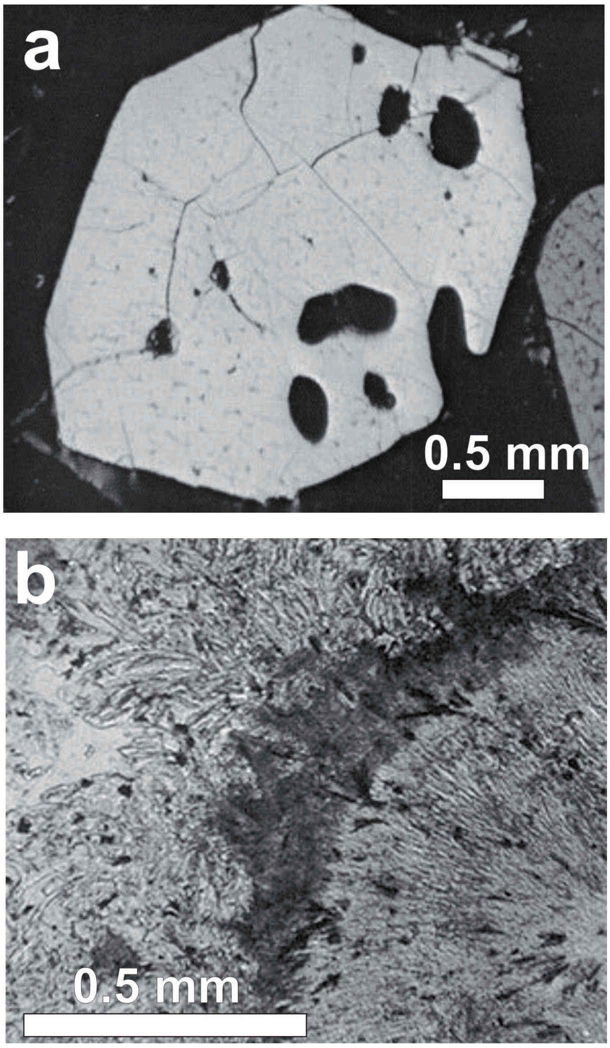

Fig. 3. (a) Well-formed quartz crystallizing from a high-silica magma and typical of quartz erupted in high-silica ash and pumice. (b) Cristobalite in a spherulite (rounded structure) formed by devitrification of a high-silica lava.

Morphology of ash particles

Long-term exposure to fine, silica-rich volcanic ash can potentially cause chronic fibrotic diseases such as silicosis, especially in vulnerable individuals (Horwell and Baxter 2006). The morphology of the ash particles has significance for health risk. Insoluble fibrous particles can present a respiratory hazard similar to that of asbestos, the most dangerous being those with a length to diameter ratio >3, with a diameter <3 μm and a length >5 μm (Horwell and Baxter 2006). Of particular concern is the silica polymorph cristobalite (Fig. 3b). Unlike the quartz crystals normally found in erupted ash and pumice, cristobalite has a fibrous morphology (Fig. 3a, b). Whilst not abundant in ash erupted during the initial stages of eruptive activity, it can subsequently form in lava domes, filling cracks and vesicles, probably through vapour-phase crystallization (crystallization from volcanic gases). Horwell *et al.* (2010), for example, showed that early-erupted ash from the May 2008 eruption of Chaitén volcano, Chile, contained ~2 wt.% cristobalite, whereas ash erupted after initiation of dome growth contained 13–19 wt.%. They found similar concentrations in the ash formed by the 1999 dome-collapse in the Soufriere Hills, Montserrat. Although the dimensions of the particles conform to the definition of fibres noted above, their form is as needle-shaped single crystals rather than as bundles of fibres which separate into individual fibrils (asbestiform or fibrous habit). At Chaitén, the fibre shape indicates breakage into brittle particles which can be more easily cleared by microphages. Horwell *et al.* (2010) conclude that inhalation of the ash is unlikely to increase the potential respiratory effects of the ash but suggest

Table 3. Volcanic ash-water leachate concentration ranges for some important ions.

Ion	Number of studies	Range of concentrations (mg/kg ash)	Calculated water concentrations (mg l^{-1})	WHO drinking water guideline levels (mg l^{-1})
Al	16	2.4–2117	0.096–84.68	–
As	8	0.01–<4	0.0004–0.16	0.01
Cl	42	3.8–11,160	0.152–446.4	250[a]
F	30	0.1–2043	0.004–81.72	1.5
Fe	22	0.01–91	0.004–3.64	–
Hg	3	0.0001–0.0087	4×10^{-6}–3.48×10^{-4}	0.001
Pb	12	0.001–17.56	4×10^{-5}–0.7024	0.01
SO_4	33	2.4–21,775	0.096–871	500[b]
Se	6	0.001	4×10^{-5}–0.27	0.01

The calculated water concentrations for each ion are derived using an ash-to-water ratio of 1:25. a No WHO guideline value but concentrations of this level can give rise to a detectable taste in water. b No guideline value but gastrointestinal effects can result from ingestion of high levels. From Witham *et al.* (2005).

that until more data are available on the toxicity of cristobalite fibres, careful monitoring of at-risk populations is justified.

A new volcanic hazard has been identified recently. Over the period 1988-1997, the town of Biancavilla, on the lower flanks of Mt Etna volcano, Sicily, experienced high mortality rates from malignant pleural mesothelioma, a rare and highly fatal disease specifically induced by inhalation of asbestiform fibres. The people affected had never had an occupational exposure to asbestos. BURRAGATO *et al.* (2005) identified, as a possible source of the fibres, local stone quarries working a lava dome and associated pyroclastic rocks, which have been used extensively in building construction. For example, dust obtained from the rocks had been widely used to white-wash houses. The carcinogenic asbestiform mineral was found to be a member of the amphibole group called fluoro-edenite ($NaCa_2Mg_5(Si_7Al)O_{22}F_2$), which occurs in rock cavities in lavas and probably crystallised from high-temperature volcanic fluids. Biancavilla is the first known occurrence of asbestiform amphibole in a volcanic environment and BURRAGATO *et al.* (2005) caution that other "unsuspectable" situations may harbour major health hazards.

Potential hazards from nanoparticles

A considerable body of new research is attempting to define the toxic effect of nanoparticles (1–100 nm) in such areas as biomedicine and air pollution. Studies reported in FUBINI and FENOGLIO (2007) have shown that when going from micron- to nano-sized particles, greater toxicity has been found in experimental animals and cell cultures. The increased toxicity may be because a given mass of nanoparticles has larger exposed surface areas than the same mass of larger particles. The reduced size may cause the formation of a large number of corner and edge sites, enhancing the reactivity per surface area. Volcanic eruptions produce nanosized particles, although they have not been routinely monitored, and it would seem prudent to initiate studies targeted at assessing the potential effect on populations at risk (FUBINI and FENOGLIO 2007).

TOXIC EFFECTS

The potential for contamination of water supplies by ashfall depends on the quantity and composition of the ash and the volume of water available for dilution of the soluble components. Table 3 presents the ash-leachate concentration ranges for some of the more important health-related ions. In a review of historic eruptions globally, STEWARD *et al.* (2006) concluded that, from a public health perspective, an area of particular concern is high fluorine concentrations, given that fluoride from HF is readily leached from fresh ash. Potentially most worrying is chronic contamination of water supplies by ashfall due to semi-continuous activity. For example, following small ash eruptions in 2005 from Ambryn, Vanuatu, the mean fluoride content of over 180 water tanks was raised from ~1.0–1.5 mg/L to 4.1 mg/L, with some tanks exceeding 10 mg/L (CRIMP *et al.* 2005, reported in STEWARD *et al.* 2006). These values exceed the World Health Organisation's (1993) primary drinking water standard for fluoride of 1.5 mg/L and when consumed on a long-term basis, may cause dental fluorosis, where the fluoride rearranges the crystalline structure of a tooth's enamel as it is still growing. Some doctors cite this as evidence of fluoride's ability to cause physiological changes in the body, and have raised concerns about similar damage that may be occurring in the bones. For example, World Health Organisation (1993) guidelines suggest that concentrations above 10 mg/L (by volume) may lead to skeletal fluorosis.

As for other soluble elements, STEWARD *et al.* (2006) suggested, on the basis of the effects of ash from the 1995–1996 eruptions of Ruapehu, New Zealand, that the contaminants of possible concern are acidity (pH), Al, Fe and Mn (Table 3). None is currently considered to pose a health risk. However, elevated levels can cause water to have a bitter metallic taste and dark colour, making it undrinkable. Following ashfalls, therefore, the main concern is likely to be a shortage of drinking water rather than health risks.

Leaching of materials adsorbed on ash is not all bad news; some can be beneficial to the environment. Eruptions from the Ruapehu volcano, New Zealand, on 11 and 14 October 1995 covered an area of 31000 km^2 in North Island with at least 30×10^6 m^3 of tephra. Another eruption, on 17–18 June 1996, covered a total land area of 16000 km^2 with at least 6×10^6 m^3 of tephra. Some 27000 km^2 of the affected land is in primary production (CRONIN *et al.* 1998). A small number of livestock deaths were caused by chronic fluorosis resulting from the F contents of the tephra and from starvation when pastured were covered by tephra. However, the Ruapehu tephra added beneficial amounts of Se, K, Mg and S (30–1500 kg ha^{-1}) to the soil, reducing the need for fertiliser in agricultural regions (CRONIN *et al.*, 1998).

OCULAR

Following the 1980 eruption of Mount St. Helens, ophthalmologists in four western US states reported seeing 1523 patients with eye complaints thought to be related to the ashfall (BUIST *et al.* 1986). They considered that the majority of the problems were anxiety reactions or caused by foreign bodies in the eye. About half of the patients had developed an irritative conjunctivitis, probably due to exposure to ash, but less than 20% required removal of conjunctival or corneal foreign bodies. No patient showed evidence of a major secondary infection of the eyes or a significant decrease in vision. The study confirmed much subjective experience, some based on personal anecdote, that whilst ash can cause irritation to mucous membranes, the effects of low to moderate exposure resolve fairly quickly. People at most risk appear to wearers of contact lenses; the ash acts as an abrasive, scratching the hard lenses and, when it lodges behind the lenses, it can result in corneal abrasion.

GASEOUS EMISSIONS

ACID RAIN

The principal volcanic gases are H_2O, CO_2, SO_2, HCl, HF and H_2S. Sulphur dioxide is probably the gas of most interest in health studies because it can trigger asthma attacks in asthma patients, even at the low concentrations that can occur at long distances from the eruptive centre (BAXTER 2000). Near the Masaya volcano, Nicaragua, about 50000 people live in an area where WHO air quality guidelines are regularly exceeded in years of strong degassing. Sulphur dioxide emissions from Pu'u O'o, Hawaii, have caused concern at times during the activity which started in 1983, creating a haze of gas, sulphuric acid, and ammonium sulphate aerosols termed VOG (volcanic smog). Sulphuric acid adsorbed from gases in the eruptive plume will add to the irritancy of the ash in the airways.

Increases levels of emission were recorded during the 1986–1995 activity of Poas volcano, Costa Rica. The lake in the crater of the volcano began to dry out during the dry season, increasing the acidity of the lake water. Gas emissions through the lake carried highly concentrated acid aerosols that triggered respiratory complaints in downwind villages (BAXTER 2000).

Possibly the best-known example of toxic gases is the 7-month-long eruption of Lakagigar (Iceland) in 1783 (AWDANKIEWICZ and KARAMUZ and ROMANOWICZ, this issue). Emissions of SO_2, SO_3, CO_2 and HF destroyed woods 200 km away from the eruptive centre and damaged the grass crop to such an extent that 70% of the livestock died, contributing to starvation among the human population, 20% of whom perished. The effects of the eruption were felt over much of western Europe, being manifested as worsening of asthma and bronchitis, headaches, and eye irritation and damage. The mortality rate in England over the period July 1783–June 1784 was 10-20% above the 51-year moving mean, which has been ascribed to the Lakagigar eruption (GRATTAN *et al.* 2003). As we have found twice in the past few years, western Europe is well within the zone potentially affected by Icelandic eruptions.

CARBON DIOXIDE

Nyos is a small but deep lake occupying a volcanic crater in western Cameroon. On August 21, 1986, it unexpectedly released massive amounts of CO_2, forming a cloud 50 m thick. The cloud moved 16 km down a valley to the village of Lower Nyos, killing 1700 people and 3000 animals, before it was dispersed by winds and rain. Rescue workers who reached the area a few days later said that it looked like it had been hit by a neutron bomb – it seemed that all life had been obliterated. Subsequent research showed that, over hundreds of years, toxic gases from volcanic sources, chiefly CO_2, had accumulated in the deep layers of the lake water, which eventually became supersaturated with dissolved gas. An undetermined mechanism, possibly a small landslide from the flanks of the crater, prompted overturn of the lake water, causing release of the gas cloud.

Two years earlier, in August 1984, Lake Monoun in Cameroon also expelled a CO_2-rich gas cloud but with similar but less lethal consequences — 37 people died. Of 37 similar systems along the same volcanic lineament in Cameroon, only Monoun and Nyos show the CO_2 anomaly. Globally also, the occurrence of density-stratified, gas-charged lakes is not common, despite the fact that CO_2 is leaked into most crater lakes. Most such lakes are in temperate zones where the water is stirred and mixed by seasonal temperature variations. At Nyos, the surface water is constantly warmed by the tropical sun and is thus less dense, inhibiting mixing with deeper waters. The colder water at the bottom of the lake is able to absorb more and more gas. Whilst such gas-bursts are uncommon in modern times, we have little idea of how often they have occurred in the past, because they leave no geological evidence of their existence.

A semi-continuous hazard from CO_2 comes from soil gas emissions (BAXTER 2000). Studies at the volcanic areas of Furnas (Azores, Portugal), Vulcano (Italy) and Mammoth Lake (California) found that sufficient gas can be released from the soil into buildings and other structures, where it accumulates in confined spaces or in parts of the buildings below ground level and forms an asphyxia hazard, i.e. death from lack of oxygen. Carbon dioxide at levels of 5–10% in the air promotes distressed breathing and eventual unconsciousness. At levels above 10–15%, it can cause immediate loss of consciousness; since the gas is odourless, this can occur before the affected person is aware of the danger. There are reports of people in cellars and caves on the flanks of Vesuvius having been overcome by CO_2 during various eruptive phases of the volcano (BAXTER 2000).

As a further hazard, CO_2 is a carrier of radon gas from the magma. At Furnas, levels of radon daughters can accumulate indoors in sufficient concentrations to be a health hazard. In conjunction with tobacco smoke, radon is a cause of lung cancer.

PSYCHOLOGICAL PROBLEMS

Those who were caught up in the air traffic chaos resulting from the eruption of the Icelandic volcano Eyjafjallajökull in April 2010 will have gained some small insight into the psychological distress suffered by people more directly affected by eruptive activity. On top of the traumas related to the death of family members and friends and to structural damage and economic loss, a range of symptoms have been reported, including anxiety, tension, insomnia, anergia and social dysfunction. Indeed, some studies have shown that the psychological effect was the worst response shown by people. Unfortunately, these responses have often been made worse by misinformation from the media. After the Mount St. Helens eruption in 1980, people were unnecessarily frightened by news reports of high acidity leading to radiation burns (SAARINEN and SELL 1985).

A study in 1983 of communities strongly affected by the 1980 eruption of Mount St. Helens reported elevated incidences of general anxiety, major depression and post-traumatic stress disorder (SHORE *et al.* 1986). A measure of the extreme stress under which people observed the eruption was the inconsistency of the accounts of those who experienced the most intense effects of the eruption (ROSENBAUM and WAITT 1981). Unanticipated effects were felt at considerable distance from the eruptive centre. The heavy ash fall in eastern Washington promoted distress from prolonged darkness, isolation from road closures, and other disruptions to normal daily life (SAARINEN and SELL 1985). In the community of Othello, post-disaster utilization patterns increased for, *inter alia*, emergency room visits (21%), domestic violence (45.6%) and arrests (up to 27%) (SHORE *et al.* 1986).

Another effect of stress may be to change behavioural patterns, sometimes with disastrous consequences. For example, in response to a widespread ash fall in the early 19th century, the Sanpoli and Nespelem Indians of northeast Washington and Idaho spent much of the summer in prayer. They did not perform the normal food-gathering, resulting in an elevated mortality rate in the following winter (MOODIE *et al.* 1992, reported in CASHMAN and GIORDANO 2008).

Recovery of a community from a disaster requires psychological as well as physical recovery, including restoration of individual and community aims and cultural and spiritual values. As an interesting example of the hindering of psychological recovery from a volcanic disaster, survivors in the community affected by the Lake Nyos gas-burst have failed to come to terms with the event because they have not been able to find a culturally acceptable explanation for the sudden deaths.

CONCLUDING REMARKS

Volcanoes are parts of the natural environment; interactions between humans and volcanoes are inevitable, especially given the increase in global urbanisation. Whilst coping mechanisms to volcanic disruption, including engineering solutions, evacuation plans, monitoring systems and land-use restrictions, have been developed, implementation of adaptations related to minimising health risks and aiding community recovery from the psychosocial impacts of eruptions has lagged behind (CASHMAN and CRONIN 2009). Developing sustainable strategies for mitigation of volcanic risks, including risks to health, is vitally important for communities in volcanically active areas (CASHMAN and GIORDANO 2008).

HEALTH ISSUES RELATED TO VOLCANIC ACTIVITY

Summary

Health problems related to volcanic eruptions are caused mainly by ashfall. Ash inhalation, especially during long-term exposure, can result in respiratory disease, including attacks of bronchitis and asthma. Long-term exposure to fine, silica-rich ash can potentially cause chronic fibrotic diseases such as silicosis. Ash may also contain carcinogenic asbestiform minerals. Ashfall has the potential to contaminate water supplies, of particular concern being high fluorine concentrations, which may lead to dental fluorosis or possibly even skeletal fluorosis. Sulphur dioxide emitted in volcanic gases can trigger asthma attacks, even at low concentrations. Carbon dioxide emissions are also known to have caused an asphyxia hazard. Ocular problems from ashfall include irritative conjunctivitis. Psychological effects of eruptions may last for many years, symptoms including anxiety, tension, insomnia, anegia and social dysfunction.

MEDYCZNE ASPEKTY WPŁYWU DZIAŁALNOŚCI WULKANICZNEJ NA ZDROWIE CZŁOWIEKA

Streszczenie

Według ostatnich ustaleń wynika, że ponad milion osób zmarło w ciągu ostatnich 2 tysięcy lat w wyniku oddziaływania szeroko pojętej działalności wulkanicznej. Dokładniejsze dane za ostatni wiek dokumentują śmierć ok. 100 tysięcy istnień ludzkich. Wartość tą należałoby zwielokrotnić, aby otrzymać liczbę ludzi dotkniętych przez różnego rodzaju choroby związane z oddziaływaniem wulkanów. Na-

leży tu pamiętać, że ok. 8%, czyli prawie 500 mln populacji ludzkiej zamieszkuje tereny oddalone nie więcej niż 100 km od centrów współczesnej aktywności wulkanicznej czyli stref bezpośrednio narażonych na oddziaływanie produktów działalności pobliskich wulkanów.

Główne produkty aktywności wulkanicznej powodujące schorzenia to opady popiołu (pyłu wulkanicznego) oraz ekshalacje (emisje gazów wulkanicznych). Te pierwsze powodują choroby związane z oddychaniem (przede wszystkim astma oraz krzemica – odmiana pylicy płuc spowodowana długotrwałym wdychaniem drobin krzemionki). Pyły wulkaniczne powodują również zanieczyszczenie wód (głównie we fluor i niektóre metale ciężkie jak Co czy As) oraz pokarmów, wpływają one również na powstawanie chronicznego zapalenia oczu poprzez dostawanie się doń mikroskopijnych ciał obcych. Emisje gazów w przypadku wysokich ich stężeń prowadzą nawet do śmierci w wyniku zatrucia, opady kwaśnych deszczy powstających często w wyniku kondensacji pary wodnej na cząstkach popiołu prowadzą do poparzeń, chorób skóry czy oczu. Zupełnie inną grupą chorób wynikającą ze skali i ogromu niektórych zjawisk wulkanicznych są problemy natury psychicznej.

Wzrost populacji, ciągła urbanizacja obszarów w pobliżu ciągle aktywnych wulkanów, a z drugiej strony kurczenie się obszarów możliwych do zamieszkania prowadzą ciągle do zasiedlania przez ludzi coraz bardziej niebezpiecznych stref, gdzie prawdopodobieństwo aktywnej działalności wulkanicznej jest duże. Zapobieganie tragediom, które mogą potencjalnie nastąpić wymaga wzmożonej czujności służb odpowiedzialnych za bezpieczeństwo oraz ciągłego rozwijania monitoringu i systemów szybkiego ostrzegania przed katastrofami, których dokładne przewidywanie jest niesłychanie trudne a nawet niemożliwe.

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