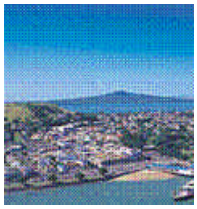
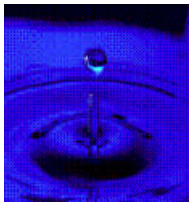
Auckland Engineering Life Lines

Auckland Engineering Lifelines Group
Project AELG-7





HEALTH AND SAFETY ISSUES IN A VOLCANIC ASH ENVIRONMENT

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AUCKLAND ENGINEERING
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AELG/7: HEALTH AND SAFETY ISSUES IN A VOLCANIC ASH ENVIRONMENT

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Health and Safety Issues in an Ash Environment

Executive summary

- Auckland may be affected by volcanic ash from a local eruption in the basaltic Auckland Volcanic Field or a distal eruption from any of the andesitic to rhyolitic volcanoes of the Central North island. The extent of ash impact will depend strongly on prevailing wind directions during the eruption.

- Drill cores recovered from ancient lake sediments show that Auckland has been impacted by ash on average about once every 500 years. This figure must be considered a minimum, as many eruptions will not result in preserved ash at these drilling locations.

- In order to maintain critical services the staff of lifeline organisations are likely to have to carry out a variety of activities in the event of ash fall in Auckland. Many of these activities, especially when outdoors, would result in occupational exposure to volcanic ash and therefore potentially adverse health and safety effects.

- Short-term health effects of exposure to volcanic ash include abrasion, inflammation and irritation injuries to the respiratory system (nose, throat, lungs) and eyes, and may result in abnormal stress levels amongst staff.

- The health effects of long-term exposure to volcanic ash are not yet known, but may include chronic respiratory diseases such as Silicosis, Lung Cancer, Pneumoconiosis and Chronic Obstructive Pulmonary Disease (COPD). Long-term exposure may also cause Tuberculosis reactivation.

- Ash can cause roofs to collapse and machinery to malfunction, as well as vehicle accidents, electric shocks and increased incidences of workplace slips and falls. These problems are exacerbated if the ash is wet.

- The basic strategy to reduce occupational health and safety risk in an ash environment is to:
  - avoid unnecessary exposure to airborne ash, and take extreme care when working or driving outdoors
  - wear the correct respiratory and other protective equipment when exposed to ash, especially during clean-up operations
  - seal buildings as much as possible to exclude ash
  - train staff in the use of personal protective equipment and what to expect

- In our opinion, the legislation outlined in the Civil Defence and Emergency Management (CDEM) and Health and Safety in Employment (HSIE) Acts requires lifeline utility employers to:
  - plan for foreseeable emergencies such as a volcanic ash fall
  - plan for safe working during such an emergency
  - include in that planning how the occupational health of their employees will be protected.

  The information and guidance given in this report will enable Auckland lifeline utilities to focus on their specific planning needs and improve their plans for occupational health and safety during a volcanic emergency.

- The recommendations at the end of this report highlight several gaps in Auckland's preparedness for an effective response to working in an ash environment and stresses the importance and urgency of developing protocols and procedures at a national level in the following areas:
  - Rapid response in the collection and analysis of ash
  - Air quality monitoring in an ash environment
  - Personal exposure monitoring in an ash environment
  - Ash transportation and disposal

Introduction

The Auckland Engineering Lifelines Group (AELG) has previously supported a number of projects concerning volcanic impacts on infrastructure (e.g. Johnston and Becker 2001; Johnston et al. 2004). To continue to support coordinated research on volcanic impacts, particularly on infrastructure, the AELG established the Volcanic Impacts Study Group (VISG) in 2003. One of the objectives of VISG is to recommend projects to AELG for funding. This report, *Health and Safety Issues in a Volcanic Ash Environment*, is the result of one such project which was considered to directly benefit lifelines as well as to meet the criteria established in the VISG project charter (2004).

Volcanic ash is the fine material (<2 mm in diameter) produced during volcanic eruptions. It is usually the most widespread of all hazardous volcanic phenomena, and even very small thicknesses of ash fall can cause considerable disruption, often at great distances from the vent. Ash is a major component of pyroclastic flows and surges, and inhalation of the hot ash associated with these phenomena almost always results in death from burns or asphyxiation. This report focuses on the effects of ash produced during ash falls, which is generally not hot when it lands. Ash falls are produced during explosive eruptions (from eruption columns) as well as effusive eruptions (from lofting plumes associated with dome-collapse pyroclastic flows, or during basaltic fire fountaining). Although the physical health effects of ash from ash fall are quite minor, especially when compared with volcanic phenomena closer to the vent (e.g. ballistic ejecta, lava flows, pyroclastic flows and surges), past research has shown that ash can cause respiratory and other health problems and also lead to significant accidents and injuries in ash-inundated communities.

PROJECT OBJECTIVES

The specific objectives of this report are to provide AELG members with information that:

- Allows them to understand the health and safety issues for their staff working in a volcanic ash environment
- Provides advice on steps employers and staff can take to keep themselves safe in varying levels of ash exposure (e.g. what safety equipment is needed; what safety procedures need to be followed)
- Explains these issues in the context of New Zealand's health and safety legislation, and
- Identifies any gaps in knowledge or in preparedness for safely carrying out activities in an ash environment, and makes recommendations for further work and research to fill these gaps.

Contractors

As appropriate, planners and managers of lifeline organisations should include contractors in their planning for occupational health and safety of staff in a volcanic ash environment.

Volcanic ash and occupational health and safety

POTENTIAL SOURCES OF VOLCANIC ASH

The city of Auckland may be affected by volcanic ash from a local eruption from the basaltic Auckland Volcanic Field, or an eruption from any of the large andesitic to rhyolitic volcanic centres located >190 km away in the central North Island. Recent coring through ancient lake sediments at Onepoto Basin, Pukaki Lagoon and Lake Pupuke in Auckland (Shane and Hoverd 2002, Shane 2005) indicates that Auckland has been impacted by an eruption resulting in preserved ash on average once every c. 560 years. This recurrence rate must be considered a minimum, as not all eruptions will be preserved in the geologic record, and certainly not all eruptions will be represented by ash at these three coring locations.

The Auckland Volcanic Field

Auckland city is built upon a basaltic volcanic field, in which activity has occurred from scattered vents during the past 250 thousand years. The field comprises about 50 discrete volcanoes, each of which may be the product of a single eruption. The most recent eruption occurred from Rangitoto about 600 years ago (Froggatt and Lowe 1990). The volcanic hazards of the Auckland Volcanic Field (AVF) are summarized in Cassidy et al. (1986), Smith and Allen (1993) and Johnston et al. (1997). Hazardous phenomena expected during a future eruption from the AVF include pyroclastic falls (eg. ash falls), pyroclastic surges, lava extrusions, volcanic gases, volcanic earthquakes and atmospheric effects.

Of all the hazards likely to occur during a local Auckland eruption, ash fall will be the most widespread. The lateral extent and thickness of any ash fall will depend on eruption style and duration, wind direction, and distance from vent. Cores through ancient lake sediments reveal that Auckland has been impacted by significant ash fall (represented by >1 mm of preserved ash) from a local eruption on average once every 2,900 years (Shane and Hoverd 2002). It is highly likely that the actual frequency of local eruptions is significantly higher than this, given that not all eruptions will have left a record in the cored localities, and small eruptions may in fact leave no record at all.

From an occupational health and safety point of view, the main thing to note in the event of a local eruption from the AVF is that such an eruption is likely to:

- be relatively small in size (0.1-2 km^3 of erupted magma)
- be short-lived (days to months), although recent research indicates more prolonged activity at some centres, including Rangitoto
- produce basaltic ash fall, which will not contain free crystalline silica but will contain abundant iron
- produce ash deposits that may be quite thick (several meters) at near vent locations, decreasing to only trace amounts several kilometers from the vent
- result in ash deposits that are dispersed over a fairly small area if the eruption is quite small, and wind conditions are favourable.

The location of the vent together with the prevailing wind direction will therefore greatly determine the impact of ash on lifelines.

Central North Island Volcanoes

In addition to local eruptions, Auckland may also be affected by ash from eruptions at other volcanoes in the North Island. There are two main volcano types in the central North Island:

- (i) andesitic stratovolcanoes (e.g. Egmont/Taranaki, Tongariro, Ngauruhoe, Ruapehu and White island)
- (ii) rhyolitic calderas (e.g. Taupo, Okataina, Rotorua and Mayor Island)

Eruptions from New Zealand stratovolcanoes occur, on average, every 50 to 300 years from approximately the same vent area, and are typically characterised by a succession of small to moderate-sized eruptive episodes over a long period of time (weeks to months) (Johnston and Becker 2001). Activity at caldera volcanoes is characterised by far less frequent (on average every 1000 to 2000 years) moderate to large-sized eruptions. These eruptions are capable of generating huge volumes of material that can be distributed over wide areas many hundreds of kilometers downwind.

Ash layers originating from these distal volcanoes are numerous and widespread in the Auckland region. They range in thickness from <1 mm to >60 cm (Shane and Hoverd 2002). Drill cores recovered from several sites in Auckland reveal at least 38 ash layers erupted over the past 27,000 years that have originated from five distal North Island volcanoes (Mayor Island, Taupo, Okataina, Tongariro, and Egmont/Taranaki) (Shane and Hoverd 2002; Shane 2005). This record of distal ash suggests a return period of about 700 years, however, many smaller eruptions from these volcanoes have undoubtedly resulted in thin ash falls on the Auckland region that were not preserved in the geologic record. This was seen for example during the 1996 eruption of Ruapehu when a light ash fall resulted in the closure of Auckland International Airport on 18 June 1996, but no record of the ash fall was preserved.

Eruptions from distal volcanoes are likely to:

- be longer lived than local eruptions (lasting weeks to months or even years)
- produce either andesitic or rhyolitic ash fall, both of which could contain significant amounts of free crystalline silica
- produce ash fall thicknesses <1 cm, except in the very unlikely event of a large caldera-forming eruption which may result in >50 cm of ash fall. The thickness of ash fall will depend on the size of the eruption and wind direction
- Produce ash fall deposits which are thinner than those from a local eruption, but which may be spread over a much wider area

Whether or not Auckland is affected by ash fall from distal volcanic eruptions will depend strongly on prevailing weather conditions, especially wind direction.

PHYSICAL PROPERTIES

Volcanic ash is composed of various proportions of glass shards, crystals and fragments of older material caught up in the eruption. It is very abrasive and (when wet) a conductor of electricity. Freshly fallen ash grains commonly have surface coatings of soluble components (leachates), which can make ash mildly corrosive. After ash deposition, these leachates can by washed away by water, potentially resulting in changes to local water chemistry and hence quality.

Large particles fall out closest to the volcano but small particles can be carried considerable distances downwind. The thickness of ash deposits is therefore generally greatest near to the volcano and decreases quickly with increasing distance from the vent. The smallest particles (<10 μm in diameter) are inhalable, and may cause lung irritation and inflammation. Particles less than 4 μm in diameter are respirable, and have the greatest toxic potential as they can be breathed into the alveolar region of the lung (Horwell and Baxter, in review). Different mineral assemblages in ash reflect the different magma compositions at individual volcanoes: of particular interest from an occupational health point of view for example is the proportion of free crystalline silica (SiO_2), the long-term inhalation of which can cause chronic lung disease. Recent research has shown that the generation of radicals via reaction with iron in the form of Fe^{2+} may cause a similar chain reaction in the lung as silica, also resulting in chronic respiratory disease (Horwell et al. 2003a). Crystalline silica can be present in considerable quantities in andesitic and rhyolitic ash but is usually absent in basaltic ash. Iron, on the other hand, is more abundant in basaltic ash than in andesitic or rhyolitic ash.

Whether or not ash is wet or dry will have considerable effect on health and safety issues encountered. The risk of roof collapse increases when the ash is wet, due to the increase in ash density; and ash-coated roads and surfaces become dangerously slippery when wet. However, rainfall can also contribute dramatically to clearing the air and reducing levels of suspended fine ash.

Staff activities likely to be undertaken in a volcanic ash environment

The activities that staff of lifeline organisations may have to carry out in the event of an eruption involving ash are outlined below. These activities can be broadly divided into two groups: general activities and sector-specific activities. General activities are those that are applicable to all AELG sectors, and relate to overall response to a volcanic ash fall during an eruption and the cleaning up of volcanic ash during and after an eruption. Note that the lists below are not all inclusive, undoubtedly many other (including unforeseeable) activities will also need to be carried out.

GENERAL ACTIVITIES

- Travelling to and from sites, including between home and workplace
- Responding to ash fall warnings (including in some instances evacuating the workplace)
- Issuing information to staff and contractors
- Keeping ash out of buildings, machinery, computers, vehicles, electrical switchboards, pumps, water supplies, stormwater drains, sewers, air intakes, air conditioning air intakes, electrical panels, gutters etc
- Closing off/sealing non-essential equipment
- Interfacing with Civil Defence and the Emergency Operations Centre
- Collaboration with other utilities and lifeline providers, for example during termination and reinstatement of services (e.g. electricity, fuel, gas, water supply)
- Removing ash (e.g. sweeping ash from affected surfaces, especially roofs)
- Assisting with disposal of ash by moving it to roadside pick-up points

WATER SECTOR

Wastewater and Sewage

- Monitoring of all treatment plant processes for introduction of grit and ash, and removing ash (where possible) from treatment plants, clarifiers, digesters
- Increased maintenance of pumps and removal of ash from wetwells
- Monitoring acidity of sewer slurry (environmental discharges)
- Removing ash from sewers (hydro-blasting, sucker/eduction trucks to move slurry)

Stormwater

- Monitoring of clean-up activities involving the introduction of ash into storm-water drains (if necessary, hydro-blasting, sucker/eduction trucks to move slurry)
- Monitoring ability of pumps to handle sludge
- Monitoring soakage holes for blockages

- Monitoring detention dams for blockages and development of anaerobic environment

Water Supply

- Keeping ash out of water-supply equipment and monitoring (preventing where possible) contamination of filtration systems
- Cleaning ash from roof structures of pump stations, reservoirs and treatment plants
- Intensified water-quality monitoring e.g. on water supply lakes (including boat work)
- Closing water supply intakes
- Maintaining clear water channels
- Monitoring of clean-up activities that may result in the introduction of ash into catchment areas and waterways
- Responding to increased demand for water during possible city-wide ash clean up whilst experiencing possible water shortages (due to dam and Water Treatment Plant closures)
- Locating ash-buried fittings (ie valves and hydrants) for network operation and control
- Locating ash-buried fittings (ie water meters) for revenue purposes
- Meter reading for customer billing
- Maintaining tight control of water entering open pipes whilst undertaking repairs

ENERGY SECTOR

Transpower and electricity lines companies

- Removing ash from insulating surfaces (using de-ionised water if possible) to avoid insulator flashover problems
- Intensive servicing of substation equipment to avoid mechanical damage
- Checking for trees heavily loaded with ash near power lines
- Repairing distribution lines damaged by falling wet ash-laden trees
- Cleaning of transmission towers
- Maintaining protection and cleaning programmes until threat of windblown ash is over

Electricity generation

- Shutting down and mothballing generation plant (especially gas turbines) and auxilliary equipment to keep out abrasive ash
- Removing ash from insulating surfaces in switchyards to avoid insulator flashover problems

LPG and natural gas distribution

- Safely shutting down LPG distribution depots (bulk and retail)

- Isolation of compressor stations and gas networks to minimise air entry into networks and consequential need to purge lines before recommissioning

COMMUNICATIONS SECTOR

- Keeping ash out of telecommunications equipment
- Visiting sites to establish and monitor degree of ash impact and penetration
- Repairing customer faults and affected equipment
- Removing ash from telecommunications equipment; e.g. blowing or vacuuming out radio equipment, cleaning out microwave dishes etc

TRANSPORTATION SECTOR

Roading

- Closing roads and motorways
- Assisting police with road closures and during clean-up operation
- Suspending public transport in hardest hit areas until roads are cleared
- Clearing roads of ash and clearing drainage systems
- Clearing ash from textured road surfaces (especially motorways) using captive water blasting machinery to restore porosity
- Installing sediment capture devices to prevent ash from settling in road drainage systems
- Assisting with transportation of ash to disposal sites
- Distributing a thin layer of crushed aggregate on roads to stabilize surface

Air traffic - Auckland International Airport Ltd (AIAL)

- Responding to ash warnings and airspace restrictions issued by the Civil Aviation Authority (CAA)
- Announcing and facilitating airport closures prior to an impending ash fall
- Interracting with NZ Police and AIAL Skygate security section on security issues
- Clean-up operations including clearing ash from runways, taxiways, aprons, airport infrastructure
- Cleaning of all infrastructure on Airport and assisting with cleaning of Air NZ jet base
- Carrying out friction testing on the runway to ensure safety of runway upon reopening
- Disposal of ash to collection areas on Airport, using both AIAL vehicles and contractors
- With Airways Corporation ensure functionality of navigation equipment on the Airfield
- Maintaining and assisting with any closures of AIAL roads, as well as traffic control leading to the State Highways

Air traffic – Airways corporation and airlines

- Clearing aircraft and rescheduling flights
- Diversion of aircraft away from Auckland as required

Railways

- Intensified monitoring and maintenance of track signals and automated electrical barriers as ash combined with rain can lead to short-circuiting of signal equipment

Occupational health and safety risks

SUMMARY

Many of the tasks outlined in the previous section would result in occupational exposure of staff to volcanic ash, particularly those tasks involving working and driving in an outdoors environment. Lifeline staff engaged in emergency activities during ash fall from a volcanic eruption may therefore suffer some adverse health and safety effects. These, together with some possible controls, are discussed below and summarised in Table 1.

Much of the information given below is based on a compilation of international experience available at http://volcanoes.usgs.gov/ash/health/index.html. Readers should use this source for current information. The health and safety precautions suggested here are indicative and need to be developed for the specific circumstances that a lifeline utility and its staff are working in.

HEALTH AND SAFETY RISKS – GENERAL ASSESSMENT

Based on historical eruptions both overseas and in New Zealand, short-term exposures to ash are not known to pose a significant health hazard. However, ash-filled air commonly causes short-term abrasion, inflammation and irritation injuries to the respiratory system (nose, throat, lungs) and eyes (Baxter et al. 1999; Baxter 2000; Cowie et al. 2001; Searl et al. 2002) and may result in abnormal stress levels amongst staff working in an ash environment. The health effects of long-term exposure to volcanic ash are not yet known, but may include silicosis, pneumoconiosis, lung cancer and Chronic Obstructive Pulmonary Disease.

One of the most commonly reported health effects within communities receiving light ash fall is broken limbs resulting from falls and slips (from ladders, roofs etc) during ash clean up. Vehicle accidents, resulting from poor visibility and slippery roads, are also common.

Table 1. *Summary of volcanic ash fall health and safety effects and precautions*

Part of body affected	Resulting from	Potential health effect	Monitoring	Preventative measures
Mental Health	Concerns arising during an emergency situation	Stress, inability to continue with duties	Monitor hours worked, tasks, and whether work conflicts with care of whanau or family	Rotate staff out of front line work; Provide extended support and assistance for staff
Respiratory system (short term exposure)	Inhalation of ash less than 10 microns in diameter	Lung irritation, difficulty breathing, asthma, bronchitis Exacerbation of pre-existing lung disease	Air quality monitoring of ash <10 micron in diameter	Provide respiratory protective equipment; Minimise exposure; Protect home and offices from ash infiltration
Respiratory system (long term exposure)	Long-term respiration of free crystalline silica or iron in ash <4 microns in diameter	Silicosis - a fibrous (scarring) reaction of the lungs Lung cancer Tuberculosis reactivation Pneumoconiosis Chronic obstructive pulmonary disease (COPD)	Determine free silica and iron content of respirable ash; Monitor exposure in high exposure individuals and jobs	Provide respiratory protective equipment; Limit personal exposure where possible; Use earth-moving equipment designed for dust conditions
Eyes	Foreign bodies in eyes	Conjunctivitis, corneal abrasions	Monitor wind direction and ash production for early warning to people downwind	Provide goggles for heavy exposure; Remove contact lenses
Whole body (roof collapse and falls from roofs)	Ash loading, slippery surfaces, poor visibility	Trauma, including death	Monitor ash fall thickness on roofs, and whether wet or dry	Prevent excessive accumulation of ash on roofs
Whole body (road traffic accidents)	Slippery roads and poor visibility	Trauma, including death	Monitor areas that will receive ash fall and issue announcements regarding expected conditions and road closures	Traffic control; Pre-eruption notification of what to do when driving during or following an ash fall
Whole body (slips, trips and falls)	Poor visibility, slippery surfaces	Trauma, including death	Monitor conditions generally	Portable lighting; Safe operating procedures
Whole body (electric shock)	Ash in electrical equipment	Trauma, including death	Monitor conditions generally, especially presence of wet ash	Permit-to-work procedures; Safe operating procedures

SHORT-TERM HEALTH EFFECTS

Stress

Background

- Increased pressure in maintaining service levels, situation monitoring and problem solving are likely to result in increased stress levels among some staff during and after an emergency
- Staff may behave abnormally during an evacuation or emergency in general, particularly if they have concerns for whanau/family and friends and for their homes
- Stress may be exacerbated if staff are confined to offices with malfunctioning/shut-down air conditioning or heating systems

Those at risk

- All staff involved in a volcanic emergency

Stress factors

- Probably similar to general occupational stress risk factors

Stress precautions

- Management will need to be aware of these abnormal stressors and provide appropriate support for all staff during and after the emergency

Respiratory health effects

Background

- Ash falls can contain a large component of particles less than 10 μm in diameter (sometimes called PM_{10}), the size of most concern in health studies of air pollution due to its inhalable nature
- Inhaling ash 4-10 μm in diameter in large amounts will irritate the lungs, and provoke symptoms in asthma and bronchitis sufferers (Baxter 2000)
- Inhaling ash <4 μm in diameter (the respirable fraction) in large amounts over a long period of time may result in chronic respiratory disease (see section on '*Long term health effects*' below)

Those at risk

- People carrying out heavy work (e.g. clearing ash) that stirs up ash (e.g. gardeners, cleaners and road workers) are likely to be most at risk
- Light work is much less likely to cause harm although people working outside near roads (e.g. police at roadside checkpoints) may also be at risk

Risk factors

Potential respiratory symptoms from the inhalation of volcanic ash depend on a number of factors including:

- airborne concentration of total suspended particles (TSP)

- proportion of inhalable and respirable particles in the ash (i.e. those <10 µm and <4 µm in diameter, respectively)
- frequency and duration of exposure
- presence and abundance of free crystalline silica and acidic volcanic gases or aerosols mixed with the ash
- presence and abundance of iron in the ash
- weather conditions
- individual health factors (including existing respiratory conditions, such as asthma, bronchitis, cystic fibrosis, emphysema) and the propensity of those exposed to incur respiratory problems
- the use of respiratory protective equipment

Respiratory health symptoms

The acute respiratory symptoms commonly reported by people during and after ash falls include:

- nasal irritation and discharge (runny noses)
- throat irritation and sore throat, sometimes accompanied by dry coughing
- severe bronchitic symptoms (e.g. hacking cough, production of sputum, wheezing, or shortness of breath), often lasting some days beyond exposure to ash in people with existing chest complaints
- airway irritation of people with asthma or bronchitis; common complaints of asthmatics include shortness of breath, wheezing, and coughing
- uncomfortable breathing

These short-term effects are not considered harmful for people who have no existing respiratory conditions

Respiratory health precautions

- Use of appropriate respiratory protective equipment (see next section and *Appendices 1* and *2*)
- Employees with chronic bronchitis, emphysema, asthma and cystic fibrosis should avoid exposure to ash particles. For them, use of any respirator other than a single-use (disposable) respirator may cause additional cardio-pulmonary stress (Elmes 1994)
- Limiting exposure to ash as much as possible

Eye health effects

Background

- The abrasive nature of ash can lead to eye irritation, conjunctivitis and corneal abrasions in ash-affected populations (e.g. Baxter et al. 1981; Hickling et al. 1999)
- Freshly fallen ash is often coated with soluble volcanic gases or aerosols, which can make ash mildly corrosive, increasing the level of eye, nose, throat and lung irritation

- No chronic effects of ash on eyes have been noted

Those at risk

- All people exposed to ash may experience eye discomfort or irritation during and after ash fall, especially those who use contact lenses or suffer from Dry Eye (sicca) Syndrome

Risk factors

- Use of contact lenses and poor personal hygiene including rubbing the eyes with dirty hands

Eye health symptoms

- eyes feel as though there are foreign particles in them
- eyes become painful, itchy or bloodshot
- sticky discharge or tearing
- corneal abrasions or scratches
- acute conjunctivitis or the inflammation of the conjunctival sac that surrounds the eyeball due to the presence of ash, which leads to redness, burning of the eyes, and photosensitivity

Eye health precautions

- Provision of eye protection that will exclude ash and dust (e.g. safety goggles)
- Provision of facilities for washing and cleaning the eye protection
- Provision of portable eye baths or eye wash facilities
- Limiting exposure to ash as much as possible
- Removal of contact lenses

Skin irritations

Background

- Volcanic ash may be acidic and can be embedded in the skin where it causes irritation

Those at risk

- All lifeline staff exposed to ash

Risk factors

- Exposed and sensitive skin

Skin health symptoms

- Irritation and reddening of the skin
- Secondary infections due to scratching

Skin health precautions

- Keeping the skin protected from ash (overalls, gloves)
- Protective clothing with close-fitting, elasticated cuffs

- Portable hand washing facilities (could be combined with face washing facilities for eye protection)

LONG-TERM HEALTH EFFECTS

Silicosis

Background

- In an eruption of andesite or rhyolite magma, the respirable (<4 μm) fraction of volcanic ash may contain high levels of free crystalline silica, a mineral that is known to cause silicosis, a disabling and potentially fatal lung disease, in industrial circumstances. Silicosis is typically found in workers exposed to high concentrations of siliceous dust (eg. miners and quarry workers) over long periods of time (HSE 1998, HSE 2003, Baxter 2000)
- Exposure to respirable-sized free crystalline silica from most ash falls is typically of short duration (days to weeks), and is unlikely to cause silicosis. However, although there have been no documented cases of silicosis attributed to free crystalline silica in volcanic ash from eruptions in the past few decades, detailed studies for lengthy periods of time necessary to determine the potential long-term effects of ash are notably lacking
- The generation of radicals due to inhalation of iron may affect the lung in a similar way to silica, also resulting in chronic respiratory disease

Exposure limits

- The US recommended exposure limit for respirable free crystalline silica in ash is 50 $\mu g/m^3$ (0.05 mg/m^3) for an extended period of time (40 hours per week for 46 weeks per year for 40 years) (NIOSH 2002). This figure is also recommended by ACGIH TLV (American Conference of Government Industrial Hygenists Threshold Limit Values and Biological Exposure Indices) and quoted in the OSH New Zealand "Workplace Exposure Standards Effective from 2002" (see www.osh.dol.govt.nz/order/catalogue/329.shtml)

Those at risk

- Only those workers with high levels of exposure over a long period of time (many months to years) are likely to be at risk (Elmes 1994, Cowie et al. 2003, HSE 2003)

Risk factors

- Previous work in dusty atmospheres and smoking may be risk factors
- Poor lung function test results or chest x-rays are also indications of risk factors
- Presence and abundance of free crystalline silica and iron in the PM_4 (<4 μm) fraction

Silicosis health symptoms

- Breathlessness (in acute silicosis)
- Breathing difficulties and difficulty walking short distances (progressive silicosis)

Silicosis health precautions

- Limiting exposure to ash as much as possible
- Use of respiratory protective equipment (see next section and *appendices 1* and *2*)
- Positive ventilation respiratory protection for heavy work (but this level of protection may limit the time someone can work without discomfort)
- Use of earth-moving equipment designed for dust conditions, e.g. agricultural tractors with air conditioning

Other chronic respiratory diseases

Background

- Long-term exposure to volcanic ash may cause a number of other chronic respiratory diseases such as Lung Cancer, Pneumoconiosis and Chronic Obstructive Pulmonary Disease (COPD). It may also cause Tuberculosis reactivation
- Pleural disease has previously been associated with long-term low-level exposure to mixed fibrous dust of volcanic origin in Turkey (Rohl et al. 1982)

Those at risk

- As for silicosis

Risk factors

- As for silicosis

Health precautions

- As for silicosis

OCCUPATIONAL SAFETY RISKS

Overview

- Falling ash can turn daylight into complete darkness
- Accompanied by rain and lightning, the gritty ash can lead to power outages, make surfaces slippery, prevent communications, and disorient people
- Radio, TV and telephone communications are extremely vulnerable to disruption during a volcanic ash fall and may fail completely in eruption-affected areas

Slips, trips and falls

Background

- Ash will make surfaces slippery (especially when the ash is wet)
- Tripping and falling will probably be common causes of injuries, especially in extreme environments or when washing ash from large and or dangerous structures
- Falls from ladders and roofs may be common if these are coated with ash (particularly wet ash)

Those at risk

- All staff working in or on ash contaminated places

Risk factors

- Poor visibility during a heavy ash fall will make it more difficult to see changes in ground level, footholds, etc
- Power outages leading to low or no lighting

Safety precautions

- Portable lighting
- Robust footwear with good grip
- Safety lines and harnesses when working at heights

Electric shocks from ash-contaminated electrical equipment

Background

- Ash is an electricity conductor

Those at risk

- Maintenance staff and contractors

Risk factors

- Tracking of electricity across otherwise safe equipment should be expected, especially when the ash is wet
- Apparently “dead” electrical equipment may become live when power is restored; if opened up or damaged, such equipment may be an electric shock risk

Safety precautions

- Permit-to-work procedures including lock-off and tagging
- Safe operating procedures

Collapse of structures

Background

- A heavy build up of ash or the wetting of ash of more moderate thickness can result in overloading of structures, typically roofs (see Figure 1)

Those at risk

- Staff inside buildings when a roof collapses
- Staff working on a structure when it collapses

Risk factors

- The risk of roof collapse increases when the ash is wet, due to the increase in ash density
- An additional temporary load such as a person cleaning the roof may then cause the structure to collapse

- Fragile roof coverings (eg. asbestos cement) may fail without any warning signs if they are overloaded with ash

Safety precautions

- Early clearing of ash before there is dangerous overloading
- Signposting of fragile roofs
- Use of access equipment if a load is too dangerous to climb on to

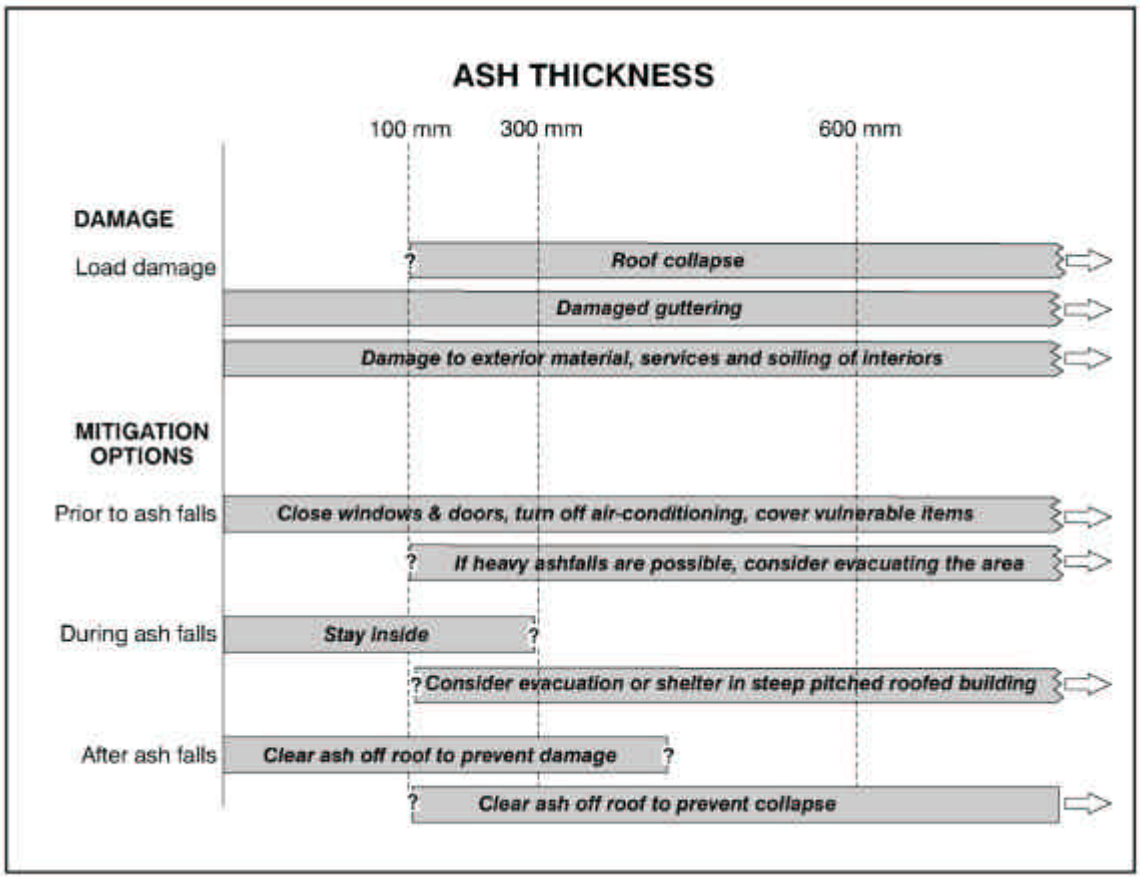

Figure 1. Graph relating ash thickness to roof damage (adapted from Johnston 1997)

Vehicle accidents

Those at risk

- Drivers and pedestrians near moving vehicles
- Staff working from boats (e.g. monitoring water supply lakes)

Risk factors

- Ash in the air or on roads may result in poor visibility and disorientation
- Ash-coated roads and surfaces become particularly slippery when wet

Safety precautions

- Avoid driving if possible
- Allow more time for journeys, drive slowly

- Travel with headlights and fog lights on
- Regularly stop and clear windscreen
- Limit or ban boat work. If unavoidable, then staff should not go out alone

Malfunctioning machinery, including vehicles

Background

- Ash has the potential to cause all machinery to malfunction

Those at risk

- Staff working near machinery, especially automated equipment

Risk factors

- Electrical tracking across circuit boards and control equipment can result in automatic equipment performing unpredictably

Safety precautions

- Mothballing equipment not needed
- Wrapping or sealing ash entry points (but beware of overheating)
- Clean and protect air filters (e.g. pantyhose on air engine filters may assist in the short term)

Occupational health and safety risk reduction measures

People are rarely evacuated from an area because ash is endangering human health (unless, for example, ash has blocked drainage and flood-flow paths putting low-lying areas at risk of flooding). However, the presence of ash may make the workplace unsafe for occupational safety reasons. For example, roofs may be overloaded with ash, air-conditioning or heating units may malfunction, or electrical equipment contaminated with ash may become unsafe.

The basic strategy is therefore to:

- avoid unnecessary exposure to airborne ash, and take extreme care when working or driving outdoors
- wear the correct respiratory and other protective equipment when exposed to ash, especially during clean-up operations
- seal buildings as much as possible to exclude ash
- train staff in the use of personal protective equipment and what to expect

Note also that a sustained ash fall may keep people housebound for hours or even days. Be prepared for the possibility of employees being either confined to the workplace or confined to their homes for indefinite periods of time. Plan appropriately for the former case by stocking up on food, water, safety equipment, torches, first aid supplies, radios etc.

The importance of clear and rapid response in the area of ash collection, transportation and disposal cannot be overstated. Such organised rapid response will speed up all recovery processes and thus reduce the amount of ash the population is exposed to. This, in turn, will reduce related occupational health and safety hazards. It is therefore critical that procedures regarding ash collection, transportation and disposal be included in national plans in advance of an emergency.

There is a wealth of information available from the Occupational Health Service of the Department of Labour regarding many general and specific aspects of risk reduction, from stocking a basic first aid kit to reducing the risk of falls in the workplace. We recommend that OSH resources be referred to in conjunction with the information below. Most are available from their webpage: www.osh.dol.govt.nz.

PLANNING WORK

When a volcanic eruption is likely but before it has started:

Management planning

- Appoint a senior manager and enough knowledgeable support staff to plan for and coordinate the following activities

Employees

- identify those people who have existing respiratory problems (e.g. chronic bronchitis, emphysema and asthma) and how they need to be protected or evacuated
- identify staff who wear contact lenses and encourage them to get glasses
- Arrange for employee assistance for staff expected to work away from their family
- Arrange for extended support for families who may have to be evacuated

Respiratory protective equipment

- Obtain enough respiratory protective equipment to cover all staff working in an ash environment. Dust masks should be chosen with the occupation of the people and the airborne dust concentration in mind. Heavy-duty ash removal work will require masks with greater protection
- In the event of an impending eruption or ash fall in Auckland there will be a huge demand for dust masks. It may therefore be wise to stockpile these in advance, although attention should be paid to the product's shelf life (e.g. 3M masks are not covered by the 3M warranty after 3 years). With this limited shelf life in mind it may not be practical for lifeline organisations to maintain individual supplies of dust masks. It may in fact be more appropriate for Civil Defense Groups to maintain a supply of dust masks to be made available as required.
- For workers involved in ash clean-up operations, the International Volcanic Health Hazard Network (IVHHN) recommends the use of high-efficiency, light-weight, preferably folded, disposable respirators of FFP2 or FFP3 (UK standard) or N95 (US standard) efficiency (see *Appendix 1*). This is equivalent to a P2 or P3 mask in New Zealand (see *Appendix 2*)
- To further assist purchasing decisions, reference should be made to Australian/New Zealand Standards AS/NZS 1715 (Selection, Use and maintenance of Respiratory Protective Devices) and AS/NZS 1716 (Respiratory Protective Devices), and the "Guide to Respiratory Protection" published by the Department of Labour, OSH Service (see www.osh.dol.govt.nz/order/catalogue/534.shtml)

Other protective equipment

- Obtain enough eye protection (e.g. safety goggles) that will keep out fine ash and cover glasses
- Obtain enough disposable overalls with elasticated wrist and ankle cuffs

Safety equipment

- Obtain safety equipment required during a clean up including portable lighting, ladders, shovels and brooms
- Obtain food, bottled water, torches and portable toilets for use during clean up
- Ensure high structures including roofs have adequate anchoring systems

Training

- All lifeline utility staff will need to be properly informed and instructed in the risks to their health before they start any ash control or clearance work. Staff working in a supporting role will also need to be properly informed
- Training will need to be planned in advance by simulating the tasks to be undertaken and developing safe operating procedures. This should be done in close consultation with staff and their representatives
- Train staff in the correct use and maintenance of respiratory protective equipment (especially) and personal protective equipment (generally) in an ash environment
- Train staff in stress avoidance and coping with an emergency situation
- Train staff in handling demands for help that are outside planned critical restoration or protection work

- Sector-specific training of staff may be necessary, for example flight crews and dispatchers in the air transportation sector will need to be trained in what to do if ash is encountered in-flight (e.g. Casadevall and Murray 1999)

First aid

- There may be more injuries than usual. Ensure enough trained first aiders are available
- Obtain additional first aid equipment including portable eye wash equipment and disposable anti-bacterial wipes

Dust exclusion from workplaces and equipment

- Obtain large sheets of clear plastic film and heavy duty tape that can be used to cover windows and doors
- Obtain large mats to lay inside external doors and that can be shaken clean outside
- Plan to reduce the number of external doors that need to be opened (but maintain fire exits)
- Plan for dust proofing of mobile plant and equipment including vehicles

Maintenance, examination and testing of control measures

It is critical that all control measures, including respiratory protective equipment, are properly maintained; planning should include how this will be done. For example:

- Revise evacuation procedures from buildings to include possible non-arrival of the Fire Service, and train staff in the revised evacuation procedures
- Regularly check supply of personal protective equipment and safety equipment and replace where necessary

DURING ASH FALL AND ASH CLEAN-UP OPERATION

The following are possible actions needed during an ash fall and clean-up; specific actions will be identified by each lifeline utility as part of the planning process.

Employees

- Staff not essential to emergency activities should be kept inside and instructed to strictly observe all safety precautions
- Advise people with existing respiratory conditions (eg. bronchitis, emphysema, asthma, cystic fibrosis) to remain indoors to avoid unnecessary exposure to ash
- As long as radio and microwave communications remain intact, remotely operate field equipment as much as possible to reduce the level of staff field activity
- Implement employee assistance and heightened supervision

Personal protective equipment

- Distribute personal protective equipment that is relevant to the tasks staff will perform and remind them about cleaning and maintenance of it
- If the correct respiratory protective equipment is not available make a fabric mask improvised from handkerchiefs, cloth, or clothing to filter out the larger ash particles. Dampen the fabric with water to improve its effectiveness

- Advise staff not to wear contact lenses in order to protect eyes from irritation
- Advise staff to remove outdoor clothing before entering a building

Buildings and workplaces

- Seal up as many doors and windows as possible to reduce dust entry points
- Keep all doors closed when there is a heavy accumulation of ash
- Keep clear any air intakes
- Monitor ash build up on roofs

Ash removal and clean-up

- Be aware of official city-wide procedures for ash collection and disposal, and plan local clean up accordingly (e.g. move ash to designated pick-up points etc)
- Form and assemble ash clean-up teams
- Distribute safety harnesses, ladders, brooms and shovels
- Distribute food, bottled water and portable toilets for use during clean up
- Begin roof clean up as soon as is safely possible to avoid structural weakening (see Figure 1)
- Where possible, handle the ash in open, well-ventilated areas
- Moisten thick ash deposits whenever possible and place in bags (to prevent its movement)
- Cover loads of ash with tied down tarpaulins to stop it being spilled or blown out of skips, trucks, etc

Driving

- Reduced visibility and slippery roads will increase likelihood of vehicular and industrial accidents. Avoid driving if possible
- If driving is necessary, drive slowly, use headlights on low beam, use ample windscreen fluid, and ensure a proper distance is maintained between vehicles
- Change oil, oil filters and air filters frequently (every 50-100 miles in heavy dust; every 500-1000 miles in light dust)
- Do not drive without an air filter. Install vent filters on outside air intakes in all vehicles that staff will be using in an ash environment, and run the heater blower on high. Blower will slightly pressurize inside of vehicle and keep dust from entering through body gaps or holes
- Clean air filters by back-flushing filter paper with compressed air (30 psi), blowing from inside (clean side) to outside (dirty side). Do not change the filters until you notice a loss of power to the engine, as a dirty filter is more effective than a clean one

Water supply

- Use water sparingly as public supplies may be low. It will be critical to manage water supplies during an ash clean up (e.g. Johnston et al. 2004)
- Do not drink tap water if there is ash in the water supply. Let the ash settle before use for other purposes

Exposure monitoring

- Monitor staff exposure to volcanic ash based on professional advice from the Occupational Health Service of the Department of Labour and the Auckland Regional Public Health Service of the Ministry of Health
- Keep abreast of any results of air quality monitoring carried out by official organisations. In an emergency situation such monitoring and reporting thereof is likely to be coordinated by the Ministry for Civil Defense and Emergency Management (MCDEM). Ideally, OSH should be able to provide practical advice in interpreting these results (see '*recommendations'* below)
- Existing studies of the effects of volcanic ash on respiratory health are considered by the experts to be inadequate for developing detailed air quality guidelines and occupational exposure limits to ash in volcanic eruptions (Horwell and Baxter, in review). Some general guidelines do, however, exist. For example, the US recommended exposure limit for respirable free crystalline silica in ash (50 µg/m^3), together with the UK standard for PM_{10} of 50 µg/m^3 calculated as a 24 hour rolling average, was used to develop airborne particulate safety levels on Montserrat (Searl et al. 2002). These are discussed in Horwell and Baxter (in review) and outlined in Table 2.

Table 2. *Air quality alert levels (one hour averages, µg/m^3) for PM_{10} on Montserrat (from Horwell and Baxter, in review).*

PM_{10} (µg/m^3)	**Ash alert level**	**Recommended action**
< 50	Low	None
51-100	Raised	Those who have experienced effects on health during past dusty episodes, especially asthma sufferers, should ensure they have masks available
101-300	Very High	Masks should be worn
>300	Alert	Masks should be worn and efforts made to reduce exposure

Health surveillance

- Health surveillance of staff will need to be carried out regularly during exposure and should be ongoing post-event. It is difficult to give precise guidance on timing (especially in an emergency) it but may include a respiratory questionnaire and lung function testing. Employees with heavier duties and longer exposures may need frequent medical examination

Legal requirements

This section provides summaries of relevant legislation. It is not an authoritative interpretation of the law. For legal advice, readers should consult their lawyer.

The summaries are followed by our opinion of how the law may apply to a lifeline utility whose employees, operations or plant are being affected by volcanic ash fallout.

CIVIL DEFENCE & EMERGENCY MANAGEMENT ACT 2002

The Civil Defence and Emergency Management Act 2002 (CDEM Act) was passed to update the administration of civil defence and emergency management in New Zealand. In relation to lifelines utilities it requires in section 60 that every lifeline utility must:

(a) ensure that it is able to function to the fullest possible extent, even though this may be at a reduced level, during and after an emergency

(b) make available to the Director in writing, on request, its plan for functioning during and after an emergency

(c) participate in the development of the national civil defence emergency management strategy and civil defence emergency management plans

(d) provide, free of charge, any technical advice to any Civil Defence Emergency Management Group or the Director that may be reasonably required by that Group or the Director.

Schedule 1 of the Act then defines what constitutes a lifeline utility as either a specifically named entity or an entity that carries on a named type of business.

HEALTH AND SAFETY IN EMPLOYMENT ACT

Object of the Act

The object of the Health and Safety in Employment Act (HSIE Act) is to promote the prevention of harm to all people at work and other people in, or in the vicinity of, a place of work. This is to be done by:

- promoting excellence in health and safety management
- imposing various duties on people who are responsible for work and those who do the work
- setting flexible requirements to take *all practicable steps* to ensure health and safety

Who is covered

The Act covers:

- paid employees while they are working for their employer or loaned to another employer
- volunteers doing work activities for other people.

Enforcement

Inspectors can use a range of enforcement methods, including various notices and prosecution, to achieve an appropriate response to non-compliance.

General duties

Employers duties to employees

Section 6 of the Act imposes general duties on employers under section 6. These are to:-

- provide and maintain for employees a safe working environment
- provide and maintain facilities for employees for their safety and health while they are at work
- ensure that plant used by any employee at work is so arranged, designed, made and maintained that it is safe for the employee to use
- ensure that employees are not exposed to hazards arising out of the arrangement, disposal, manipulation, organisation, processing, storage, transport, working or use of things in their place of work; or near their place of work and under the employer's control
- develop procedures for dealing with emergencies that may arise while employees are at work.

Sections 7 to 10 require the:

- identification of hazards
- elimination of significant hazards
- isolation of significant hazards where elimination is impracticable
- minimisation of significant hazards and the protection of employees where elimination and isolation are impracticable.

Principal and contractors

Section 18 deals with the duties of an employer when acting as the principal in a contract and having engaged contractors. The principal must take all practicable steps to ensure that no employee of a contractor or subcontractor is harmed while doing any work that the contractor was engaged to do.

Hired equipment

Section 18 of the Act also covers plant that is hired out and that can be used in a place of work. Such plant must be designed, made and maintained so that it is safe for its intended use.

Employees

Section 19 requires all employees to take all practicable steps to ensure their own safety while they are at work and not to endanger any other person.

Section 53 imposes a "strict liability" to comply with the General Duties and sections 7 to 10. This is generally modified by the requirement to take *all practicable steps*. These words are defined in section 2 of the Act (see below).

Section 15 requires the employer to take all practicable steps to protect *"any other person"* who could be affected by work activities.

Section 16 deals with the responsibility of a person who has control of a place of work or equipment in that place of work to ensure the safety of people in that place of work or in the vicinity of that place of work.

Consultation and refusal to work

An employer must consult employees about their occupational health and safety. Employers must also give information about foreseeable emergencies and how to respond to them.

If employees have genuine concerns about their safety they have the right to stop work.

Key definitions

The Act refers to:

- all practicable steps
- hazard
- significant hazard

We have interpreted these words and phrases as follows:

All practicable steps

This means all steps to protect a person from *harm* that are *reasonably practicable* to take in the circumstances, having regard to:

- the nature and severity of the harm that may be suffered
- the current state of knowledge about the likelihood that harm will be suffered
- the current state of knowledge about such harm
- the current state of knowledge about protection from such harm
- the availability and cost of each of such protection.

Harm

Means illness or injury and includes physical or mental harm caused by work-related stress

Reasonably practicable

The words “reasonably practicable” have been given a special meaning in the Courts. An employer must assess the level of risk and the “sacrifice” in terms of money, time or effort to avert the risk. If the sacrifice exceeds the level of risk, the person on whom the duty is laid has discharged burden of proving that action was not reasonably practicable. On the other hand, if the risk exceeds the sacrifice action must be taken before any injury occurs. In such cases the amount of action and sacrifice is scaled to the level of the risk.

Hazard

The definition is very broad and covers any activity, arrangement, circumstance, event, occurrence, phenomenon, process, situation, or substance (whether arising or caused within or outside a place of work) that is an actual or potential cause or source of harm.

Significant hazard

A hazard that is an actual or potential cause or source of serious harm, either now or in the future, taking into account the vulnerability of the person who is exposed to the hazard.

THE LEGISLATION IN RELATION TO LIFELINE UTILITIES

The following is our interpretation of the above legislation as it relates to lifeline utilities during a volcanic eruption that produces ash fallout.

The CDEM Act requires lifelines to be ready for an emergency and function as fully as possible during and after that emergency. The HSIE Act requires that all practicable steps be taken to protect employees from harm, including in emergency situations. Taken together, we believe that the legislation requires lifeline utility employers to:

- plan for foreseeable emergencies such as a volcanic ash fall
- plan for safe working during such an emergency

- include in that planning how the occupational health of their employees will be protected.

The information and guidance given in this report will enable Auckland lifeline utilities to focus on their specific planning needs and improve their plans for occupational health and safety during an emergency.

SIMPLE VOLCANIC ASH RISK ASSESSMENT TOOL

In order to comply with the Health and Safety in Employment Act a lifeline utility must carry out a risk assessment of work to be carried out during and after a volcanic eruption and implement the actions identified in the assessment as necessary. The following risk assessment methodology provides a simple approach that is "quick and dirty". It is intended to show either that:

- work is probably safe; or
- work is probably not safe; or
- a more detailed risk assessment (probably with dust measurement monitoring) is required.

Some key things to remember

Personal protection such as dust masks only works effectively if:

- it fits the user properly
- the user knows how to put it on and how to keep it clean
- it is regularly serviced or changed in accordance with the manufacturer's instructions.

How to use the matrix in Table 3

Workers have the right to refuse to work if they think their health or safety could be endangered. Carry out risk assessments with employees and contractors so that they better understand the risks they may be exposed to and why the risk controls are important.

1. First:
   - EITHER identify the ash consequence of most immediate concern OR
   - work through all of the consequences to assess the health and safety of a given activity or job.
2. Using the scales in Table 3, analyse the risk as if there were no controls; think of the worst consequence first and then the likelihood that a worker will be exposed to that level of harm.
3. Record your findings.
4. Repeat the analysis with the planned controls; think of the worst consequence first and then the likelihood that a worker will be exposed to that level of harm.
5. Record your findings.
6. Is this level of risk acceptable? If it is acceptable, the difference in the level of risk that the controls give will show you how much you need to monitor the use of the controls.
7. If it is not acceptable, repeat the analysis with additional controls; think of the worst consequence first and then the likelihood that a worker will be exposed to that level of harm.

8. Is this level of risk acceptable?
9. If it is not acceptable, ask why a person needs to be exposed to this level of risk to their safety or health (whether short- or long-term). If it is very important that the work is done, get specialist help (e.g. for protection of people or with dust monitoring) before proceeding with the work.
10. Record your findings.
11. Keep your records somewhere safe.

Table 3. *Risk analysis tool*

Likelihood of risk factors existing	**Almost certain**	**Medium**	**High**	**High**	**Extreme**	**Extreme**
	Possible	**Medium**	**Medium**	**High**	**High**	**Extreme**
	Unlikely	**Low**	**Medium**	**High**	**High**	**High**
	Rare	**Low**	**Low**	**Medium**	**Medium**	**High**
	Almost incredible	**Low**	**Low**	**Medium**	**Medium**	**High**
Consequences of risk factors		**Negligible**	**Minor**	**Moderate**	**Major**	**Severe**
Short-term harm to physical health includes lung irritation, difficulty breathing, asthma, bronchitis and exacerbation of pre-existing lung disease		Long distance from eruption, little/no local fallout		Moderate distance from eruption, some local fallout		Close to eruption with heavy local fallout
Long-term harm to physical health		Employee not engaged in work in dust		Employee often engaged in work in dust		Employee engaged in work in dust for 8 hours/day
Mental health and stress		Employee not working in stressful conditions or frequently rotated out of dusty area		Employee often working in stressful conditions and only occasionally rotated out of dusty areas		Employee continuously working in stressful conditions and only rarely rotated out of dusty areas
Immediate risk of bodily injury – slips, trips and falls		Walking surfaces clean and generally free of dust		Walking surfaces generally covered with dust		Walking surfaces covered with dust to s significant depth
Immediate risk of bodily injury – roof collapse or falls from roofs		Roofs generally free from ash – less than 50 mm depth	Roofs covered with up to 100 mm dust	Roofs covered with up to 300 mm dust	Roofs covered with up to 500 mm dust	Roofs covered with more than 500 mm dust
Electric shock		Equipment is lightly contaminated or clean		Equipment is moderately contaminated with dust		Equipment is heavily contaminated with dust

Notes: *1. The assessment must be done with the consequence scale that has the worst description. If a consequence is in doubt, use the next worst and design controls accordingly.*

2. The matrix is developed from HB 436 Risk Management Guidelines published by Standards New Zealand.

Who can accept the risk?

When the risk assessment is complete, confirm with management and workers and their representatives that they accept or reject the risk as follows (Table 4).

***Table 4**. Levels of risk acceptance*

Level of risk with controls	Risk acceptance
Extreme	Nobody can be asked to work if a risk will be extreme with controls in place; it cannot be carried out legally; ask why this job or task needs to be done at all
High	A risk that will be high with controls in place is probably not acceptable to workers, their representatives and their managers; it probably cannot be carried out legally; ask why this job or task needs to be done at all
Medium	A risk that will be medium with controls in place may be acceptable to workers, their representatives and their managers
Low	A risk that will be low with controls in place should be acceptable to workers and their managers

Outcomes

This approach should result in the reduction of the *potential* for harm to a level that is acceptable to workers, their representatives and management.

Conclusions and Recommendations

CONCLUSIONS

Outside the immediate area of destruction around a volcanic eruption there will be a zone where there are occupational health and safety risks related to volcanic ash fall. Broadly speaking, these risks will reduce with distance from the eruption. Most occupational health and safety risks are short-term and can be managed with adequate planning. If long-term exposure is likely then ongoing monitoring of air quality and personal exposure will be needed.

RECOMMENDATIONS

1. **Risk-mitigation measures**. Lifeline organisations should integrate the risk mitigation measures suggested in this report into their practices. Ideally this could be carried out in conjunction with Department of Labour OSH representatives, who may be able to assist with training and preparation activities.

1	Risk-mitigation measures
REQUIREMENTS	• Integration of the risk mitigation measures suggested in this report into the practices of Lifeline organisations.
ACTION	• The report has been presented to the AELG steering committee.
PROPOSED ACTION	• Development of guidelines by the MoH • Training of Department of Labour OSH representatives • Training of CDEM and other agencies • MCDEM to establish timeframes for all actions to be completed

2. **Respiratory protective equipment.** In the event of an impending eruption or ash fall in Auckland there will be a huge demand for dust masks, which may result in shortages. Despite this, the limited shelf life of dust masks may make it difficult for lifeline organisations to justify maintaining individual supplies of masks in advance of an eruption. It may in fact be more appropriate for Civil Defense Groups (for example) to maintain a supply of dust masks to be made available to lifeline organisations as required.

2	Respiratory protective equipment
REQUIREMENTS	• Sufficient approved dusk masks and other protective equipment for at risk personnel in responding agencies to avoid shortages when an event creates a surge in demand. • Overcome issue of limited shelf life though supply strategy.
ACTION	• The report has been presented to the AELG steering committee.
PROPOSED ACTION	• Development of required equipment lists by MCDEM • Collation of required inventory by Lifelines Groups • Development and implementation of supply strategy by MCDEM and MoH • Training of CDEM and other agencies • MCDEM to establish timeframes for all actions to be completed

3. **Collection and analysis of ash, and air quality monitoring.** Rapid collection and analysis of ash and reporting of its properties (e.g. leachates, surface reactivity, characterisation of composition, TSP, PM_{10} and PM_4 content, percentage of iron and free crystalline silica in the PM_4 fraction) are required in order for the suggested risk-reduction measures in this report to be carried out. It is vital that ash samples are collected properly and that ash collection sites are set up prior to the ash fall event (see *Appendix 3*). Current arrangements regarding such rapid response are being reviewed by GNS, the Wellington School of Medicine and MCDEM. The statutory responsibility for volcano monitoring and advice rests with GEONET, operated by GNS, and the capacity for rapid sampling, analysis and reporting of actual volcanic ash deposits (e.g. leachates, composition) exists at the Wairakei Research Centre of GNS. The situation regarding monitoring of ash for OSH and public health purposes is a little less straightforward. During the 1995/1996 Ruapehu eruption most ash monitoring was carried out by GNS, with air quality monitoring undertaken by regional councils, under funding from the MCDEM. In addition to coordinating monitoring, the MCDEM also coordinated all health advice during this event with the assistance of other Government Departments and universities. However, no formal protocols currently exist which clearly define the monitoring and advisory roles of GNS, MCDEM, MoH, MAF and the Occupational Health Service of the Department of Labour in the event of a future ash emergency. The opportunity exists for ash analysis protocols and reporting procedures to be addressed, based on international best practice (see for example *Appendix 3*), within the framework of both the National Civil Defense Plan and the CDEM Group plan (and/or supporting SOP), and this should be done as soon as possible.
4. **Personal exposure monitoring.** It seems likely that in the event of an ash emergency individual organisations will be responsible for carrying out their own personal exposure monitoring, based on advice provided by OSH and MCDEM regarding exposure limits and air quality, respectively. At present, however, it is unclear just how this monitoring should be carried out, and provision should be made for this aspect of monitoring during the preparation of the ash analysis and reporting procedures recommended above.

3 & 4	**Rapid response protocols**
REQUIREMENTS	• A protocol for the rapid collection and analysis of ash, and the reporting of its properties to lifeline organisations. • A protocol for air-quality and personal exposure monitoring.
ACTION	• The report has been presented to the AELG steering committee.
PROPOSED ACTION	• Appoint someone to coordinate development of the protocols • Consultation with international experts on such protocol • Consultation with relevant organisations (GNS, MCDEM, MoH, MaF) • Preparation of protocols • Integration of protocols into the National Civil Defense Plan and CDEM Group plan • MCDEM to establish timeframes for all actions to be completed

5. **Ash transportation and disposal**. In order to speed up all recovery processes and thus reduce related occupational health and safety hazards a clear and rapid response in the area of ash collection, transportation and disposal is required. These procedures need to be included in national plans in advance of an emergency. Johnston and Becker (2001) address the issues of transportation and disposal of ash in the event of ash fall in Auckland. In that report the recommendation was made that more thought be given to the method and location of disposal of ash in Auckland, and a more recent report (Dolan et al. in press) outlines a useful protocol for selecting ash disposal sites. It seems likely that the overall responsibility of transportation and disposal of ash will fall with the CDEM Group, with assistance from the transportation sector. However, to date no official procedures have been put in place. It is critical that the recommendations made in Johnston and Becker (2001) and Dolan et al. (in press) be taken on board in order to develop a clear allocation of responsibility for these activities prior to an emergency.

5	**Ash transportation and disposal**
REQUIREMENTS	• Clear procedures regarding ash collection, transportation and disposal.
ACTION	• The report has been presented to the AELG steering committee.
PROPOSED ACTION	• Adopt the recommendations set out in Johnston and Becker (2001) and Dolan et al. (in press) • Prepare protocols based on these recommendations • Integration of protocols into the CDEM Group plan • MCDEM to establish timeframes for all actions to be completed

6. **Regional resources**. Individual AELG organisations should include in their plans the possibility of tapping into regional resources (e.g. staff from out of town) to assist with both clean-up operations as well as day to day functioning of the lifeline organisations during a volcanic emergency. Plans will have to be put in place to accommodate out of town staff.

6	**Regional resources**
REQUIREMENTS	• An awareness that lifelines may be required to tap into regional resources during an emergency
ACTION	• The report has been presented to the AELG steering committee.
PROPOSED ACTION	• Lifeline emergency plans should address accommodation of out of town staff and resources

7. **Health and Safety in Employment Act**. The Department of Labour could consider referring to this report in sections of the HSIE Act applicable to occupational health and safety in an ash environment.

7	**HSIE act**
REQUIREMENTS	• That Department of Labour OSH representatives be made aware of this report
ACTION	• The report has been presented to the AELG steering committee.
PROPOSED ACTION	• Circulation of completed report to interested parties by AELG representative

8. **IVHHN guidelines**. The International Volcanic Health Hazard Network comprises a consortium of international experts coordinating research on volcanic health issues. Recommendations regarding these issues (including health in an ash environment), are regularly updated. AELG organisations should remain abreast of this ongoing research, and continue to update their procedures based on the latest IVHHN information. Guidelines currently in preparation that may be of interest are:

    a. Ash clearance and preparedness techniques: A guide for the general public

    b. The health hazards of volcanic ash: A guide for the general public

    c. The health hazards of volcanic ash: A guide for medical and veterinary practitioners.

    See http://www.ivhhn.org for further information.

8	**IVHHN guidelines**
REQUIREMENTS	• The AELG remain abreast of ongoing research by the IVHHN
ACTION	• The report has been presented to the AELG steering committee.
PROPOSED ACTION	• VISG representatives to report new developments to AELG (ideal forum = annual seminar)

Bibliography

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Useful websites:

IVHHN:	http://www.ivhhn.org
USGS Volcanic ash web resource:	http://volcanoes.usgs.gov/ash/health/index.html
GEONET:	http://www.geonet.org.nz/
OSH, Department of Labour:	http://www.osh.dol.govt.nz

Appendix 1 – IVHHN recommended dust masks for protection from volcanic ash

This document contains recommendations for respiratory protective equipment to be used in a volcanic ash environment. Masks that comply with UK, US and Japanese standards are listed. In order to put these masks into a NZ safety standard context, reference should be made to Australian/New Zealand Standards AS/NZS 1715 (Selection, Use and maintenance of Respiratory Protective Devices); and AS/NZS 1716 (Respiratory Protective Devices). Note that 3M product numbers are used internationally and most of the 3M masks listed here are available in NZ (see *Appendix 2*).

INTERNATIONAL VOLCANIC HEALTH HAZARD NETWORK

IVHHN RECOMMENDED DUST MASKS FOR PROTECTION FROM VOLCANIC ASH

Introduction

Following an eruption, volcanic ash can cause irritation of the airways and lungs and, if breathed in over many years, could cause lung disease. Whilst volcanic ash is suspended in the air, it is vital that the population exposed protects themselves by wearing masks. For the public, use of masks is only necessary whilst the levels of suspended dust are above background levels. For those involved in clean-up operations, garden maintenance or even people who are cleaning houses and property, masks should be worn at all times whilst the ash is mobile in the atmosphere.

Mask types and standards

For protection against volcanic ash, high-efficiency, light-weight disposable masks/respirators are appropriate. The mask must provide protection at the highest concentration the person will experience. Suitable disposable masks are 'CE' marked to show that the design has been tested to a recognised standard. They will also be marked with the standard (e.g. EN 149:2001 in the EU or N95 in the US) and an additional code such as FFP1 (low efficiency), FFP2 (medium efficiency) or FFP3 (high efficiency) (FFP = Filtering Face Piece) is shown on EU masks. The US N95 standard is roughly equivalent to FFP2 or 3 as it is efficient up to 10 x the local occupational exposure limit (see Table 2). The higher the FFP number, the more protection the respirator can provide if it is used properly. Pre-2001 masks may also distinguish between those suitable for solids and liquids e.g. FFP2S. Disposable masks cover the nose, mouth and part of the chin. Some of them contain exhaling valves. An elastic band around the head and neck keeps them in place.

Figures 1 & 2. Masks may either be fitted with or without valves.

Valve masks are more comfortable, especially for those wearing spectacles which might otherwise mist up. They are appropriate for hot and humid climates.

Recommended masks

The following tables give examples of appropriate respirators provided by the company 3M. There are many other manufacturers (e.g. Willson, Moldex, Uline, Pyramex, see web addresses in References section) who make similar masks.

Table 1. Maintenance-free respirators from 3M, UK and EU models. All conform to EN149 standard. LOEL = Local Occupational Exposure Limit.

UK 3M Product No.	Mask shape	Efficiency	Occ. Limit	Valve present	Information
8011	Hard cup	FFP1	4 x LOEL	No	Basic mask
8812	Soft cup	FFP1	4 x LOEL	Yes	
8710E	Soft cup	FFP1	4 x LOEL	No	
9312	Folded	FFP1	4 x LOEL	Yes	
9310	Folded	FFP1	4 x LOEL	No	
8822	Soft cup	FFP2	10 x LOEL	Yes	Good in humid
8825	Soft cup	FFP2D	10 x LOEL	Yes	Good in humid
8810	Soft cup	FFP2	10 x LOEL	No	
9322	Folded	FFP2	10 x LOEL	Yes	Good in humid
9320	Folded	FFP2	10 x LOEL	No	
8835	Soft cup	FFP3D	20 x LOEL	Yes	Good in humid
9332	Folded	FFP3	20 x LOEL	Yes	Good in humid

Table 2. Maintenance-free respirators from 3M, US/Canada models. All conform to NIOSH 42 CFR84 N95 or N100 standards. LOEL = Local Occupational Exposure Limit.

US 3M Product No.	Mask shape	Efficiency	Occ. Limit	Valve present	Information
8000	Hard cup	N95	-	No	Short duration
8210 & 8110S	Soft cup	N95	10 x LOEL	No	
8511 & 8211	Soft cup	N95	10 x LOEL	Yes	Good in humid
9210	Folded	N95	10 x LOEL	No	Good for comfort
9211	Folded	N95	10 x LOEL	Yes	Good for humid
8233	Soft cup	N100	10 x LOEL	Yes	99.97 % filter efficiency

Table 3. Maintenance-free respirators from 3M, Japan models. All conform to the industrial safety and health law (Law No. 57 of 1972). Efficiency: D = disposable; S = solid; L = liquid. 1,2,3 roughly equivalent to FFP1,2,3.

Japan 3M Product No.	Mask shape	Efficiency	Time Limit for use	Valve present	Information
8511	Soft cup	DS2	27 hours	Yes	
8812	Soft cup	DS1	12 hours	Yes	
8233	Soft cup	DS3	38 hours	Yes	
8577	Soft cup	DL2	23 hours	Yes	Good in humid
8210J	Soft cup	DS2	13 hours	No	
8710	Soft cup	DS1	14 hours	No	
9913	Soft cup	DS1	11 hours	No	
8000J	Hard cup	DS1	3 hours	No	
9322	Folded	DS2	18 hours	Yes	
9312	Folded	DS1	19 hours	Yes	

The UK/EU respirators are tested for penetration of particles > 0.5 μm diameter and the US respirators are tested to > 0.3 μm diameter. We recommend that valved respirators are used in hot or humid climates although they will aid comfort in all environments. The respirators distributed to a population should be chosen with the occupation of the people and the airborne dust concentration in mind. For example, for the general population exposed to suspended volcanic dust, the FFP1 mask might be appropriate if the dust levels do not exceed 4 x the local occupational exposure limit. For workers involved in clean-up operations, gardening or other high-exposure jobs, FFP2 or FFP3 are recommended. We recommend folded masks as

they are individually packed, allowing clean storage, and easy and hygienic distribution. However, the folded masks can fit less well on people with small faces or chins.

Finding a good mask
A respirator must pass three tests:

- It must be capable of providing adequate protection
- It must fit you properly and it must be compatible with any other personal protective equipment that you wear at the same time.
- In addition, you must always use it correctly for it to be fully effective.

Respirators only protect you if they fit properly without any leakage around the nose or chin. Even expensive respirators are unsuitable if they do not give a good seal with the face. A good fit relies on close contact between the respirator and smooth skin without hair in the region of the seal. Consequently a beard or beard stubble can affect the fit and reduce protection. Many manufacturers make respirators in different sizes to allow for variations in the shape and size of faces. You should not expect one respirator to fit everyone. **If you are responsible for providing masks for a community, you should order them in several different sizes and types**. It will not be possible to individually fit masks to every person in a population, however. If resources allow, special effort should be taken to fit masks for occupationally-exposed individuals and other high-exposure groups.

A good fit
To check if a respirator fits properly, ensure that the straps and any strip for moulding the respirator around the bridge of your nose are correctly adjusted. Then hold the respirator in place and breathe in or out sharply. If you detect any leakage around your face you should readjust the respirator and retest. See bottom of document for further instructions.

Children
Unfortunately respirators are not made to fit children's faces. For this reason, children must be kept indoors and stopped from playing in dusty environments whilst ash is present.

Occupational exposure
For continuous labour in dusty conditions, full-face non-disposable respirators with changeable filters will be more appropriate and are also more comfortable to wear in hot, humid conditions. For extreme conditions see: http://www.3m.com/intl/za/ohes_airstream.html for Airstream Powered Helmets.

Storage
Although the masks are disposable, if supplies are limited they can be stored for re-use in a clean bag or box to ensure that dust from the outside does not contaminate them. They should not be hung in a dusty environment. They must be replaced at the first sign of breathing difficulty.

Warning
It is possible to buy cheap masks called 'nuisance dust masks', 'comfort masks' or 'hygiene masks'. They may look similar to lightweight disposable masks but they are not intended for use in dusty environments and are not marked 'CE' or 'EN149/N95'. Instead, the package may say something like 'This product does not provide respiratory protection'. Unless the product clearly states that it conforms to a recognised standard, do not use these masks for protection from volcanic ash.

Web references
Dust mask manufacturers:
3M Worldwide. http://www.mmm.com/ with links to pages for the US, Canada, UK, Europe, Japan, China, Korea, Brazil.
Moldex. http://www.moldex.com/applications/dusty.htm
Willson. http://www.safetyinfo.com/equipment/wilson-respirator-images-pages/wilson-disposable.htm
Uline. http://www.uline.com/Group_230.asp
Pyramex.
http://www.pyramexsafety.com/html/modules.php?name=Product&sel=prod&product=Respiratory
Vilene. http://www.vicre.co.jp/mask/0101.html
Koken. http://www.koken-ltd.co.jp/boujin.htm

Mask fitting instructions:
http://multimedia.mmm.com/mws/mediawebserver.dyn?SSSSSSAzK12S4vTSevTSSScTScNtyt&9-
http://www.moldex.com/fittinginstructionsexamples/adjustablestrap.htm

Health & safety guidelines:
Japanese Standards: http://www.jicosh.gr.jp/english/law/DustMask/index.html
European Standards: http://www.bsi-global.com/Health/PPE/bsen149.xalter
US Standards: http://www.cdc.gov/niosh/pt84abs2.html

Acknowledgements
This document was written by a panel of IVHHN expert members. IVHHN is grateful to the Leverhulme Trust, UK, for funding associated meetings.

IVHHN is also grateful to the following people:
Yasuhiro Ishimine, National Research Institute for Earth Science and Disaster Prevention, Bosai, Japan for researching Japanese health and safety guidelines.
Jim Chisholm, UK Health & Safety Executive, for reviewing the document.

The following diagram of fitting instructions is courtesy of 3M (see next page).
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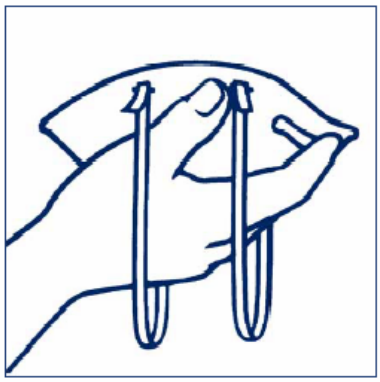
Fitting Instructions



1. Cup the respirator in your hand with the nosepiece at your fingertips allowing the headbands to hang freely below your hand.

2. Position the respirator under your chin with the nosepiece up.

3. Pull the top strap over your head resting it high at the top back of your head. Pull the bottom strap over your head and position it around the neck below the ears.

4. Place the fingertips of both hands at the top of the metal nosepiece. Mould the nosepiece to the shape of your nose by pushing inward while moving your fingertips down both sides of the nosepiece. Pinching the nosepiece using one hand may result in less effective respirator performance.

5. The seal of the respirator on the face should be fit-checked prior to wearing in the work area.
a) Cover the front of the respirator with both hands, being careful not to disturb the position of respirator.
b) Inhale sharply.
A negative pressure should be felt inside the respirator. If any leakage is detected, adjust position of respirator and/or tension of strap. Retest the seal. Repeat the procedure until the respirator is sealed properly.

Appendix 2 – 3M (NZ) Maintenance-free Respirators

The distinctive 9300 series foldable respirators answer the wearers' call for comfort without compromising the performance safety professionals look for. There are four respirators in the 9300 series, designed for use across a wide range of applications and industries.

3M™ Maintenance Free Foldable Respirators

Features of the 9300 Series:

- 3-panel foldable design
- Soft cover web on inner panel ensures greater comfort against the skin
- Exhalation valve avoids heat build-up and makes breathing easier and cooler
- Lightweight and foldable for easy storage and portability
- Individually packed to avoid contamination during storage
- Foam nosebridge absorbs sweat and enhances face seal.

3M™ 9310 Dust Respirator (P1)

The **3M 9310** respirator is for use against dusts found in a wide variety of industrial applications and other work situations, requiring P1 protection.

Applications include: Dust or mist from rubber and plastics, quarrying, paint manufacture, engineering, construction, agrochemicals laboratories, pottery/chemicals, market gardening, agriculture and sawmills.

3M™ 9312 Valved Dust Respirator (P1)

The **3M 9312** respirator can be used in many hot and humid environments where the application requires P1 level dust protection.

Applications include: Dust or mist from rubber and plastics, sawmills, quarrying, engineering, construction, agrochemicals, laboratories, pottery/chemicals, agriculture, market gardening and paint manufacture.

3M™ 9320 Dust/Mist Respirator (P2)

The **3M 9320** respirator is designed for use against fine dusts and water-based mists found in construction, industrial and many solid chemical handling applications, requiring P2 protection.

Applications include: Dust or mist from base metal manufacture, foodstuffs e.g. bagging, pharmaceuticals, ship building/repair, laboratories, powdered chemicals and powdered additives.

3M™ 9322 Valved Dust/Mist Respirator (P2)

The **3M 9322** respirator is for use in hot and humid environments and where P2 protection is required.

Applications include: Dust or mist from base metal manufacture, pharmaceuticals, ship building/repair, construction iron and steel foundries, potteries, brickclay/refractory materials, foodstuffs, powdered chemicals and agriculture.

3M New Zealand Ltd
PO Box 33-246, Takapuna 1332
250 Archers Road, Glenfield,
Auckland, New Zealand.

3M Australia Pty Ltd
950 Pacific Highway
Pymble NSW 2073,
Australia.

3M Innovation

3M Maintenance Free Respirators

Solutions for your workplace

3M Respirators

Breathing Solutions

3M Innovation

3M continually strive to improve the fit performance and comfort of this versatile product range. Chose from valved, un-valved or foldable. All maintenance free respirators can be used for up to 10 x the Workplace Exposure Standard.

- *Select a **Class P1** respirator when airborne material is produced through mechanical means eg. sawing, sanding, crushing and grinding.*
- *Select a **Class P2** respirator when there are thermally produced fumes such as those from welding and oxy cutting.*

3M™ Maintenance Free Respirators

All 3M maintenance-free half face particulate respirators provide the following features:

- Easy-to-use, one-piece design
- Lightweight and comfortable
- Low-profile for better visibility
- Easy-breathing
- Filter media is easy to talk through without removing the respirator
- Nose clip contours to a wide variety of face shapes and sizes
- Protects against a wide range of hazards found in N.Z industry
- Products are approved to AS/NZS 1716

3M™ 8710 Dust/Mist Respirator (P1)

For excellent balance of performance and cost.

Applications: The 8710 is used throughout general industries such as foundry, steel, battery manufacturing, textiles, grain handling, paper mills, coal-fired utility plants, and other industries where respiratory protection from dusts and mists is needed.

3M™ 8210 Dust/Mist Respirator (P2)

Designed to help provide lightweight, comfortable Protection against mechanically generated particles.

Applications: Workplace applications include grinding, sanding, sweeping, bagging, foundries and other dusty operations.

3M™ 8110S Small Dust/Mist Respirator (P2)

Ideal for those with a smaller face for a better fit to enhance protection against dusts and mists.

Applications: Grinding, sanding, sweeping, bagging, woodworking, foundries and other dusty operations.

3M™ 8812 Dust/Mist Valved Respirator (P1)

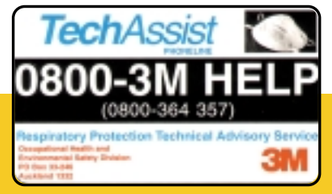
With 3M's patented, unique Coolflow™ valve, which enhances comfort by maintaining a cool atmosphere within the respirator.

Applications: Ideal for use in hot and humid environments such as mining, construction, sawmills, laboratories, pottery/ceramics and foodstuffs where dusts and mists are generated.

3M™ 8822 Dust/Mist Valved Respirator (P2)

Ideal for use in hot and humid conditions where P2 protection is required.

Applications: Iron and steel foundries, base metal manufacture, pharmaceuticals, agriculture, potteries, powdered chemicals, bagging and construction.



For further advice phone our *TechAssist* line:

0800 3M HELP (0800 364 357)

3M™ 9913 Dust/Mist Respirator (GP1)

Approved for agricultural chemicals*. Recommended for nuisance level organic vapour**.

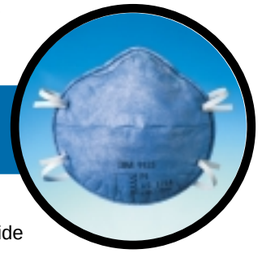
Applications: Used in foundries, under-coating, petrochemical, printing, tobacco processing, agricultural and other situations where dust/mist protection is needed and workers are bothered by nuisance organic vapours.

3M™ 9913V Dust/Mist Valved Respirator (GP1)

Offers the same protection as 3M 9913 plus it features the 3M Coolflow™ exhalation valve.

Applications: Ideal for hot or humid conditions.

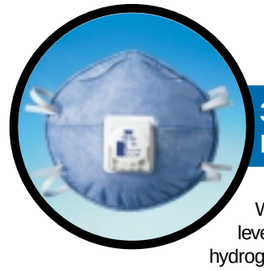
3M™ 9915 Dust/Mist Respirator (P1)



With 3M recommended nuisance level** relief from hydrogen fluoride, sulphur dioxide and chlorine acid gas.

Applications: Used in industries including aluminium reduction, chemical processing, coal fired plants, glass etching, paper mills, petrochemical, etc., where dust/mist protection is needed and workers are bothered by nuisance levels of acid gases.

3M™ 9916 Dust/Mist Respirator (P1)

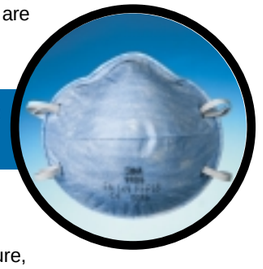


With 3M recommended nuisance level** acid gas relief from chlorine hydrogen fluoride and sulphur dioxide.

Features include: • Coolflow™ exhalation valve
• Nose foam cushion wedge
• Collapse resistant shell.

Applications: Used in industries including aluminium reduction, chemical processing, coal fired utility plants, glass etching, paper mills, and petrochemicals.

3M™ 9906 Hydrogen Fluoride Dust/Mist Respirator (P1)



With 3M recommended nuisance level** relief from hydrogen fluoride.

Applications: Used in fertiliser manufacture, glass etching, aluminium reduction.

* Agricultural chemicals with low vapour pressures (ie: less than 0.01mm Hg at 25˚).

** Nuisance levels are those levels below the Worksafe Exposure Standards. Note: for specific use/limitations, refer to packaging or call 3M.

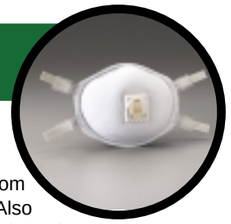
3M™ Maintenance Free Welding Respirators

Dusts, mists and fumes given off during welding can cause a variety of ailments such as fatigue, throat irritations, coughing and conditions like Metal Fume Fever.

3M Welding Respirators feature:

- Low profile design allowing respirators to be worn with comfort under welding shields
- Patented exhalation valve provides cooler dryer comfort
- Flame retardant coating for added safety
- Cake resistance filter media provides longer life and easier breathing
- 3M Advanced Media - electrostatically charged micro-fibres make breathing easier and cooler

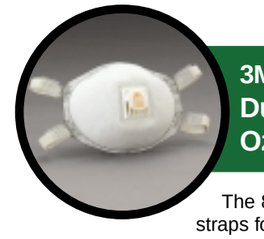
3M™ 8512 Welding Dust/Mist/Fume (P2)



The 8512 has fully adjustable straps for a comfortable secure fit.

Applications: Use for solids such as those from processing minerals, coal, iron ore and flour. Also welding, brazing, soldering, torch cutting, metal pouring, grinding, sanding, sweeping and other dusty/hot operations .

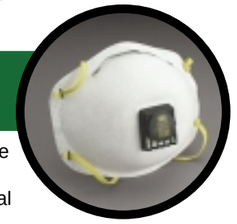
3M™ 8514 Deluxe Welding Dust/Mist/Fume/ plus Ozone Protection (P2)



The 8514 has fully adjustable straps for a comfortable secure fit and odour removing filter material.

Applications: Use for metal fumes from welding, cutting and other metal heating. Ozone protection, nuisance level** organic vapour relief, solids from processing minerals, coal, iron ore and flour. Also foundry or petrochemical operations, grinding, sanding, sweeping and other dusty/ hot operations.

3M™ 8515 Particulate Welding Dust/Mist/Fume (P2)



Applications: The 8515 is designed to provide comfortable worker protection for applications such as welding, soldering, cutting, grinding and sanding. Also brazing, metal pouring, sweeping and other dusty/hot operations.

Appendix 3 – IVHHN ash sample collection procedures

INTERNATIONAL VOLCANIC HEALTH HAZARD NETWORK

IVHHN ASH SAMPLE COLLECTION PROCEDURES

Introduction

The methods recommended for ash collection depend on the purpose intended for the ash. For evaluation of health hazard, the grain-size distribution and composition of the ash may be assessed and the leachates may be analysed. If chemical analyses are carried out, ash should be dried at < 40 ^{o}C, but for compositional or grain-size analysis, the temperature is not crucial. If research is to be carried out on the leachates and surface reactivity of samples (e.g. for toxicological analysis) it will be important to know the exact post-eruptive history of the ash in terms of rainfall and exposure. The quantity of ash needed should be assessed before collection. For example, grain-size analysis or compositional analysis may need small quantities (< 10 g) of ash whereas several kg may be required for toxicological analysis, particularly if a sample is to be shared between different laboratories. The following procedures should be adapted for the particular hazard assessment or research to be carried out but ensure that the ash samples can be used for grain-size analysis, characterization of composition and leachates, and assessment of volume of erupted material / total accumulated tephra (formation of isopach maps) etc.

Implements for ash collection

- The most cost-effective technique for ash collection is using plastic trays (or buckets) which are cheap and easily cleaned. Trays should have a high rim (> 5 cm) in order to avoid contamination and rain-water overflow. The tray should be large enough to collect a significant quantity of ash (ideally > 0.1 m^2). Netting may be secured across the opening to avoid contamination by birds, insects or plants. Metallic trays should be avoided due to possible contamination in contact with rain water.
- Commercial collection devices are available, such as the 'frisbee gauge' which consists of an open-bottomed dish fitted with a dry-foam trap to reduce sample contamination from organic matter. The sample is collected in a collection bottle at the base of the unit. The gauge is fitted with a bird guard and a tripod (lighter for 'new style' gauges) which can be spiked to the ground for increased stability. The frisbee gauge relies on precipitation to wash particles through the dish into the collection bottle. The ISO gauge, by the same manufacturer, conforms to ISO standard ISO/DIS 4222 for consistent performance but does not have the foam trap. Information on these products is available on the internet (see References section).

Fig. 1 & 2. Ash collection buckets used by the USGS.

Fig. 3. Frisbee Gauge. Courtesy of www.hanby.co.uk

Routine ash monitoring

- A network of clean trays should be set up around a volcano to form a grid that covers the area of possible ash dispersal.
- Particular attention should be given to the direction of prevailing wind. In the case of a very large area of possible ash dispersal, trays should be distributed at least along the most-likely dispersal axis at increasing distances from the vent.
- Trays should be emptied daily to avoid contamination from organic or minor-eruptive material, ash re-suspension by wind and rain-water overflow.
- If water is present in the trays following eruption, both ash and water should be collected in a bag and then dried in the oven. Trying to remove water from the tray may result in loss of fines, which are crucial in the context of assessing health hazard.

Ash collection following an eruption

- Following an ash fall, samples should be collected as soon as possible to avoid re-suspension of fines by wind, water or human activity.
- If a tray network is not in place, ash should be collected on flat surfaces that were known to be clean before the eruption. Ash collection on grass and ground should be avoided.
- In the case where grass or ground areas are the only surfaces available, ash should be removed carefully, leaving a few mm at the ash-surface interface to avoid contamination.
- Ash can be sprayed or wetted with water to avoid loss of fines during collection (unless original un-contaminated particle surfaces are needed for analysis).
- In the case of heavy ash fall, a core can be taken using, for example, a 30 cm section of drainpipe, to retrieve a representative section of ash. This technique is most effective for compact deposits.
- Store ash in bags. One can use either ‘Kraft’ paper bags or plastic sealable bags. We recommend Kraft bags as fines may adhere more to the surface of plastic bags (see Kraft bag section).

Labelling of samples

In both routine monitoring and ash collection after an eruption, the following should be recorded:

- Time of eruption.
- Time of collection.
- Location of collection (including grid reference or GPS location).
- Note if the ash is just from one or from multiple events and how long since tray last emptied.
- Area of the tray used or of the surface sampled - ash accumulation is best recorded as mass per unit area.
- State of deposit – dry, wet, contains accretionary lapilli, lithics, pumice, organic matter etc.
- Information on the history of the sample between deposition and collection (e.g. rainfall).
- Distance from vent.
- Distance from main dispersal axis, if well defined.
- Assign a sample number.

After collection

- Dry ash in oven at < 40 ^{o}C. If ash is collected in 'Kraft' bags, they can be put directly in the oven without the need for removal from bags. In hot climates, the ash can be dried naturally by leaving it in Kraft bags.
- Weigh the ash sample.
- For safety and transport, store the ash within several sealed bags. Recommended – 'zip lock' bags which are easily re-sealable.

Kraft Bags

Kraft bags can be any sort of tough brown paper bag. For ash collection we recommend bags designed specifically for geochemical soil sampling. For example, the bags manufactured and internationally distributed by Siliconpak (www.charapak.co.uk) are made of high wet-strength Kraft paper using waterproof adhesives and can withstand collection of wet samples and subsequent drying. The bags are available in the following sizes: 3x5, 4x8, 5x10 inches.

Figure 4. 4x8 inch and 5x10 inch Kraft bags.

References

Frisbee Gauge and other similar instruments:
http://www.york.ac.uk/inst/sei/dust/mines1.html which also provides a downloadable protocol for use of the frisbee gauge.
http://www.hanby.co.uk/ - website of the manufacturer of the frisbee gauge and other similar dust collectors.

Kraft Bags: Siliconpak Ltd, UK (www.charapak.co.uk)

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