Toxicity hazards arising from volcanic activity

This review outlines some of the toxicity hazards to livestock from volcanic eruptions, including the threats from tephra, gas and acid rain. It reports on experience gained from the 1995 eruptions from Mount Ruapehu in New Zealand, and briefly explains the nature of these hazards with a view to improving awareness and understanding so that rational reactions can be made during times of emergency.

Tephra

Tephra, the solid matter ejected during a volcanic eruption, poses a number of threats, as it can cause:

- intense irritation in the eyes, including conjunctivitis;
- sore throats;
- uncomfortable breathing, and respiratory tract irritation;
- skin irritation (acid rash);
- gastrointestinal irritation, diarrhoea and intoxication if eaten;
- chronic bronchitis, pneumoconiosis and silicosis;
- unpalatable feed and water leading to undernutrition and dehydration;
- death in housed stock from roof collapse.

With heavy fallouts, in rare instances tephra can cause death from asphyxiation by forming an occlusive plug of ash and mucus in the upper respiratory tract. Lighter fallouts can also be fatal to stock. During the 1940s the Paricutin eruptions in Mexico killed about 4,500 cattle, 500 horses and an unknown number of sheep and goats, principally from inhalation of ash. The animals took several months to die and on post-mortem examination the lining of their lungs had an ash-mucous coating. When rats were dosed intratracheally with 10 mg of Mt St Helen's ash in 0.25 ml saline and then serially killed, researchers found an inflammatory response in the lungs, and that the ash was moderately fibrogenic and should be considered a pneumoconiosis risk[(1)].

Gases and acid rain

The main aerosols given off during and after volcanic eruptions are steam, CO_2, SO_2, HCl, H_2S, HF, CO, CS_2, CH_4 and SO_3. CO_2 has caused problems on a number of occasions when it has accumulated in low lying areas. During the Hekla eruption in Iceland in 1948, sheep succumbed to the gas, which accumulated as a 2 m thick layer of about 40% CO_2. In 1984, at Lake Monoun in Cameroon, the lakewater became saturated with CO_2 that originated from vents in the crater that supported the lake. It is thought an earthquake caused a landslip on the inner rim of the crater to plunge into the lake and this in turn caused the CO_2 to effervesce out of solution as well as setting up a moderate tsunami[(2)]. Animals and people in the vicinity succumbed to CO_2 intoxication and there were 37 human deaths. Two years later more than 1,700 people and an unknown number of animals died from a sulphurous CO_2 emission from the Nyos crater in Cameroon. In some cattle carcasses there was blood in the nose and mouth, but whether this came from the respiratory or digestive tract was not determined. Of the surviving humans 72% complained of body pains and some had coughs and headaches[(3)].

Acid gases and acid rain from volcanoes can scorch and kill off vegetation, and this may result in short to medium term feed shortages. The acids can also corrode machinery and equipment and produce skin burns. Skin damage will be noticeable in quadrupeds, firstly on the back of the ears, and, in more serious situations, over the entire back of the animal. Mild burning can be avoided or counteracted at the time with a wash of baking soda, but where this is too late, treatment should focus on reducing the risk of skin infections and allowing natural repair.

Professor Neville Gregory, author of this article

Starvation and disease

Historically, starvation has been one of the most important causes of loss of life during the holocausts of volcanic activity. In the aftermath of a sizeable eruption, the supplies of fresh cereals, vegetables and pasture will have been destroyed or cut off, and in the past humans have depended on slaughtered livestock as their main source of food. This has not always prevented famine. During the Laki eruption in 1783, half of the cattle and three quarters of the sheep population in Iceland died, and the resulting famine killed a fifth of the human population.

From the veterinary perspective the priorities should be:

- to assess the number of live animals, and despatch any severely mutilated or suffering animals;
- to assess the risk of poisoning, dehydration and starvation; and
- where these risks are high, move the stock out of the affected region, or place them in an area where they will not ingest the toxin but can be held until uncontaminated feed or water is available.

In any situation in which there is a feed shortage, there is a risk of pregnancy toxaemia to ewes in mid to late pregnancy[(4)]. Lactating ewes would stop producing milk. Offering supplementary feed a little at a time and often is appropriate under dire conditions when weaker stock are being slaughtered. Under less severe conditions, and especially where animals are not evenly matched for size, vigour and condition, it is best to offer the feed in large amounts and less frequently. This

Table I: Principal elements in water soluble extracts of Mt Ruapehu ashes; September and October 1995 (parts per billion)

600 to 10,000	10,001 to 100,000	>100,000
Boron (7,300)	Fluorine (as fluoride) (<25,000-39,000)	Aluminium (73,500-350,000)
Copper (42-820)	Iron (3,162-60,000)	Chlorine (as chloride) (18,000-1,601,000)
Manganese (2,110-4,640)		Sulphur (as sulphate) (306,000-12,000,000)
Silicon (2,980-10,400)		
Strontium (8,100)		
Titanium (196-9,000)		
Zinc **(3,069)**		

gives all the animals, irrespective of their size and ability to compete, time to feed and so the weaker stock are more likely to gain or hold condition. A balance has to be struck between the logistics of distributing food and water and the control of disease outbreaks such as gut-borne diseases and respiratory tract infections. Pneumonia and bronchitis may be significant risks if the animals have been breathing hot dust.

Fluorosis

Fluorosis is one of the most important livestock hazards during the aftermath of a volcanic eruption. It is believed that it accounted for a high proportion of the 11,500 cattle, 28,000 horses and 190,000 sheep deaths in Iceland following the 1783 Lakagigar eruption.

The fluoride present in volcanic ash is water soluble and is readily leached out by water. So, if it rains or if the tephra settles on wet ground, fluorine soon finds its way into watercourses (within 2 hours). The fluorine is present as an adsorbed outer layer on the tephra particles. The adsorption occurs by condensation of fluoride onto the tephra particles in the plume above the volcano as it cools. The smaller tephra particles have a larger surface area, so carry more absorbed fluoride than the larger particles[5]. The smaller particles are likely to be carried further from the volcanic source, and so their greater fluorine-carrying capacity extends the zone of potential fluorine poisoning considerably, even to regions where only a 1 mm thick deposit forms. It is advisable to sample and analyse the tephra or vegetation to identify hazardous regions. Poisoning in sheep is likely to occur where the fluorine content of dried grass exceeds 250 ppm. In one incident in Iceland in which there were 7,500 deaths, levels reached 4,000 ppm. The most dangerous situations for grazing animals are usually some distance from the erupting volcano where the layer of fine grained fluorine-carrying tephra is so thin that it does not deter grazing. The fine grained tephra adheres to grass and so is more likely to be eaten.

Experience after the 1970 Hekla eruption shows that acute sickness occurred where the tephra layer was about 0.5 mm thick. At 1 mm thickness, 3% of the adult sheep and 8 to 9% of the lambs died. Acute poisoning occurred in the first days after the tephra fall and was accompanied by convulsive seizures, pulmonary oedema and kidney and liver damage. Experimental trials involving NaF intoxication showed that the principal signs of acute fluorosis were depression, salivation, hyperpnoea, nasal secretions, inappetance, blindness, ataxia, coma and death[6]. The rumen, reticulum and abomasum showed epithelial necrosis and hyperaemia, oedema and haemorrhage in the lamina propria and submucosa. The kidneys showed necrosis of epithelial cells in the proximal convoluted tubules.

Chronic fluorosis occurred at Hekla where the layer of ash was 1 mm or more thick. Serious outbreaks of volcanic fluorosis have also been reported for sheep and cattle in Chile[7]. The ash contaminated 4,000 sq km of grassland, and cattle started showing clinical signs of osteofluorosis after about 4 months. The main clinical signs were weight loss and lameness. Diarrhoea, tinged with the colour of the ash, occurred in many of the sick animals. In some stock there was kyphosis, and exostoses were accompanied by intense pain when the long bones were palpated (especially the metacarpus). There was a high degree of attrition of the incisors with almost total crown loss. The fluoride content of serum and bone were elevated as was serum alkaline phosphatase activity.

In sheep, lesions are found more commonly on the jaws than on the legs. Those on the legs occur in more advanced cases. There are also lesions in the nose and mouth, and the hair around the mouth may fall out, possibly because they are 'bottom' or 'hard' grazers and are exposing their muzzles to the ash. Similarly, sheep and deer are more prone than cattle to teeth attrition, probably because they take in more ash. Another tooth condition is 'spiking', where outgrowths develop on the molars and can make chewing difficult. In Iceland a special type of pliers was used at one time for breaking off these outgrowths in sheep and horses. The teeth may also develop the 'ash teeth' condition, with yellow or black spots that may extend over the entire surface before a tooth falls out.

Soluble fluoride is readily absorbed by the gut by a passive rather than active transport process. Attempts to reduce fluorosis with various calcium, magnesium and aluminium salt drenches have met with only partial success. No effective prophylactic treatment is available.

Mt Ruapehu

In 1945 Mt Ruapehu produced ash showers that affected about a third of the North Island, extending from Rotorua to Wellington, and from Napier to Patea. Deposits 6.5 mm thick lay within 65 km of the crater. There were no reports of stock losses from eating contaminated pasture, and limited feeding trials in laboratory rats[8] and a sheep and a cow demonstrated no obvious ill-effects.

Following the 1995 eruptions there were reports of sheep deaths from either fluorosis or pregnancy toxaemia. The eruptions were interspersed with rainfall, and this is thought to have decreased the threat of chronic fluorosis. Table 1 shows the composition of the ash from the 1995 eruption. Complications from eating excessive amounts of sulphur are possible. Sulphur can cause polioencephalomalacia in sheep when consumed at 0.6% of the diet. Animals dying acutely do so with severe cerebral oedema[9]. When ruminants consume large amounts of sulphur there is also a risk of copper deficiency, which could occur in a number of ways. Firstly, rumen bacteria reduce organic or inorganic sulphur to sulphide, which has a high affinity for copper. Copper sulphide is relatively insoluble, so that the copper is rendered unavailable. In the presence of molybdenum in the rumen, sulphur forms tetrathiomolybdate, which also complexes with copper making it unavailable. Lastly, sulphur may increase the excretion of copper in bile[10].

Feeding trials in which calves were fed Mt St Helen's ash at 10% of the ration for 3 weeks, showed no impaction of the gastrointestinal tract with ash. Two lactating cows produced normal yields of milk when fed ash from the same source over a 5-week period at up to 6.3% of the ration. Day-old chicks were more sensitive; they showed a 6% reduction in growth rate for each 10% increase in ash content in the diet, compared with a 4% reduction for equivalent amounts of sand[11]. There was no increase in mortality when up to 30% ash was included in the diet. Cats may develop diarrhoea from licking ash from their fur, and this has been associated with prolapse of the rectum.

Freshwater fish deaths (eel and trout) during the 1945, 1969 and the 1995 Mt Ruapehu eruptions occurred when the sulphurous lahars entered the tributaries feeding the Wanganui River. This was probably a chemical effect, and may have been caused by a sustained low pH (the pH downstream of the crater lake has been as low as 0.8).

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NG Gregory
Department of Animal Welfare Science
Faculty of Veterinary Science
Massey University
Palmerston North
Email: AnimalWelfare@massey.ac.nz

VE Neall
Department of Agricultural and Horticultural Sciences
Massey University
Palmerston North
Email: V.E.Neall@massey.ac.nz

Professor Neville Gregory, author of this article