Degassing Lake Nyos

SIR — Lakes in volcanic regions can absorb high concentrations of magmatic CO_2, and spontaneous degassing can occur if the pressure is reduced. On 21 August 1986, Lake Nyos in Cameroon released an estimated 0.12 km^3 (240,000 tonnes) of CO_2 (ref. 1) which swept downhill and killed more than 1,700 people. Many specialists believe that the surface water, cooled by rain, became denser than a CO_2 rich layer and convective overturn occurred[1,2]. Whatever started the movement, the rising water became supersaturated at reduced pressure and degassed. The gas/water mixture was very buoyant, and gas-driven circulation started, entraining deeper CO_2-rich layers, which also degassed, frothing over a 75-m-high promontory[3]. Input of CO_2 is estimated to be at least 10 m^3 min^{-1} (ref. 4) so the estimated loss in 1986 will be replaced in, say, 20 years. A method of controlled degassing of Lake Nyos and similar lakes is needed for the safety of the local population[5]. The remote nature of the lakes requires that the method is simple, cheap and maintenance-free.

The latent energy of dissolved gas could be used to power a gas-lift in a tube extending from near the lake bed to the surface. When upwards flow is started by a pump, effervescence within the tube would reduce the density of the fluid, and flow would continue passively, an elegantly simple solution. Some sediment in the water would nucleate bubbles and increase the efficiency of degassing. A 9-mm tube has been used analytically in this way[6] and large-scale experiments are also being undertaken. If flow stops for lack of CO_2, the lake is safe. Flow can be controlled by tube diameter or a valve at the top. Semi-rigid polythene tubing of 10–20-cm diameter would be convenient for degassing the lake. The top will need to be firmly anchored to resist the jet propulsion effect.

The deep water contains about 6,000 mg kg^{-1} CO_2, or about 3 l CO_2 at atmospheric pressure at 20 °C, and would become supersaturated at depths of less than 27 m. Bottom water may contain two or three times as much CO_2 (ref. 7). An input of 20 kg CO_2 min^{-1} would be equalled by degassing or removing about 3,500 l water per min. Given the volume increase to 14,000 l gas/water mixture at the surface, many tubes will be needed. Larger volumes with less CO_2 content must be degassed to reduce CO_2 to safer levels. Selective removal of the most buoyant upper part of the CO_2-rich water would also help to stabilize the lake.

The degassed water must be disposed of carefully to maintain the stability of the lake and avoid triggering another uncontrolled degassing. Most lakes have cold dense deep water and a buoyant warm surface layer. Lake Nyos, however, is heated geothermally, with warm, possibly CO_2-saturated water percolating in through the bottom[7]. The coldest water layer (about 22.5 °C) is at about 25 m, and temperature increases to around 24 °C at the lake bed (200 m). Surface temperature varies seasonally around 24 to 26 °C. The stability is almost entirely due to the mass of CO_2 dissolved in the bottom water increasing its density. A decrease in temperature of the CO_2-poor circulating surface layer by only 3.5 °C would cause it to sink below water containing 3,000 mg kg^{-1} CO_2 at a depth of 100 m (ref. 1) and start massive degassing. Degassed water can only be added to the surface if it increases buoyancy there. This depends on extent of degassing, and reduction in temperature by exsolution and expansion of gas, and will only be determined experimentally on site. The gas-lift can raise water until the volume of water in the column above the lake surface almost equals the volume of gas below the surface, practically perhaps 10 m. On sunny days in the dry season, degassing water could be lifted onto the land and warmed by solar heating at it trickled back. The heat input to the surface would increase stability.

This stability problem can be overcome by discharging the water outside the lake, which also avoids problems of incomplete degassing. More than 7,500 tonnes of water per day need to be degassed, and normal outflow is 50,000 tonnes per day in August/September[2], the rainiest period, so lake levels can be maintained. Also, the less warm surface layer would be decanted from the spillway, so lake stability would increase further. At 50,000 tonnes a day it would take 10 years to flush the 175 million tonnes of water in the lake. Reducing the level of the lake will reduce its capacity for CO_2. Removing water from the bottom will not reduce pressure within the water column, but there are likely to be greater quantities of CO_2 in the sediments and rock beneath. This should degas readily because of the nucleating action of solids. It would be advantageous in the long term to lower the lake level, but only at a time and rate such that degassing sediment will not upset the waters above.

CO_2 concentration in Lake Nyos has been increasing since the last limnic eruption, and must be released eventually. As soon as any layer becomes saturated, any disturbance will cause a degassing disaster. While the risks and effect of degassing must be monitored carefully, the risks of delay are clear.

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Scientific Correspondence

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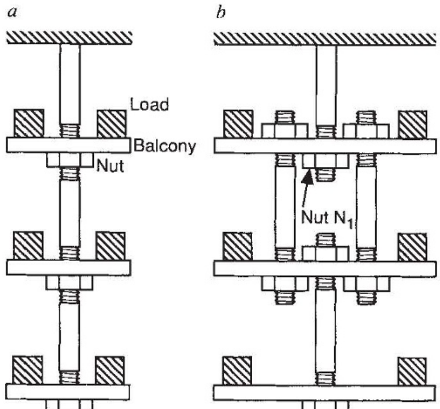
Real-life failure

SIR — The paradoxical behaviour of a network of springs and strings reported by J. E. Cohen and P. Horowitz (*Nature* **352**, 699–701; 1991) recalls an analogous situation that resulted in considerable loss of life through the structural failure of a Kansas city hotel.

The true world is even more confusing. The diagram illustrates a paradoxical situation which resulted in considerable loss of life in the Kansas City hotel disaster.

A 'routine' engineering change during constuction from *a* to *b* tripled the shear



load on nut N_1, causing three hotel balconies to fall when N_1 split. Note that *b* distributes the load over seven nuts instead of the three nuts of *a*. This structural failure, as in the case of the springs and electrical circuits described by Cohen and Horowitz, falls into the category of series-to-parallel transformations.

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