British Geological Survey

Minimising the impact of mine waste

Strategies to reduce the effect on the environment

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Historically, mining to extract metals has produced wastes which contain toxic chemicals. For example, water leaching from the wastes may be highly acidic or alkaline, and might carry many toxic heavy metals, such as lead, copper, zinc and cadmium. Such wastes often pose a significant risk to the health of vegetation, animals and humans. In most developed countries, such as the UK, the hazards represented by these wastes mainly reflect historical mining activities. Nevertheless, the wastes can limit the ways in which surrounding land can be used, and in extreme cases can cause major pollution incidents (e.g. from the flooding of disused mine workings, as at Wheal Jane in Cornwall in 1992).

There are many strategies that can reduce the environmental hazards posed by metalliferous mine waste. Current mines can be planned to minimise the amounts of hazardous wastes they produce, but for historical mines, where waste already exists, some kind of remedial action may be required. Hazards from such existing wastes can be reduced by using one or more of many strategies. These strategies include removing the waste to a locality where it will constitute a lower hazard, or containing it using engineered barriers such as tailings dams, reed beds, geomembranes or clay barriers.

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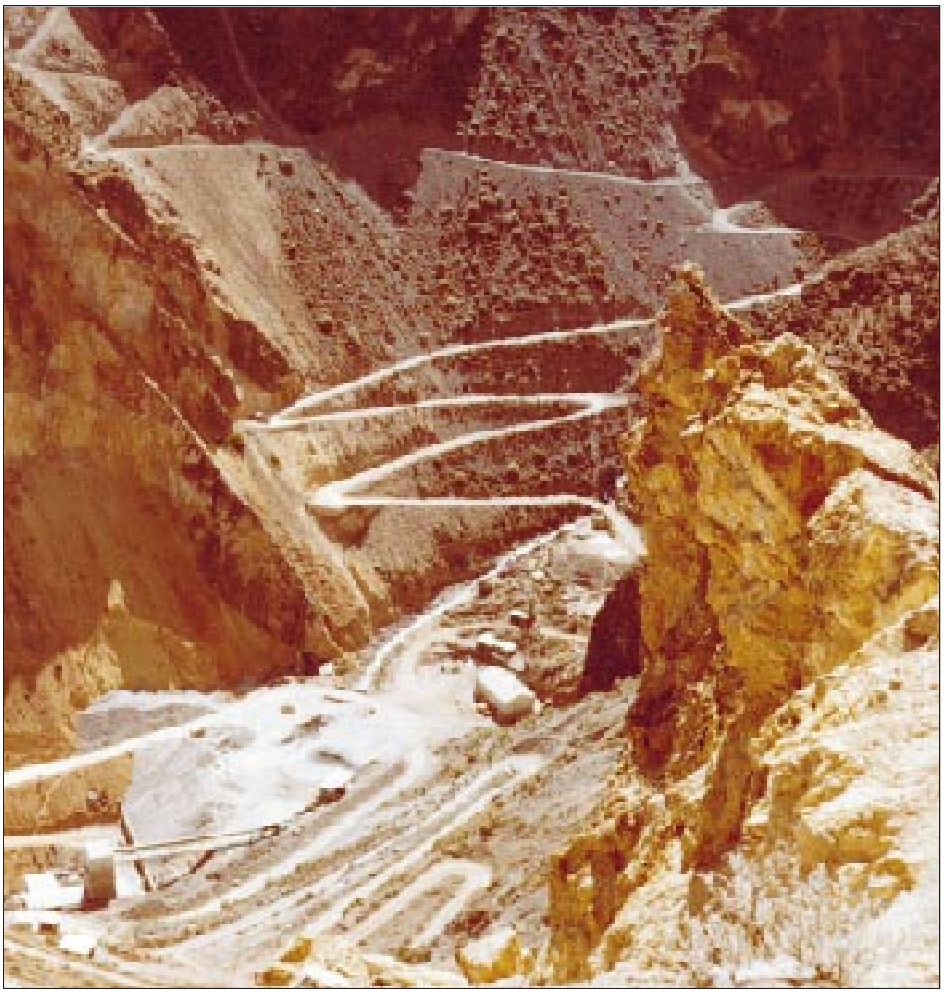
These measures may not be feasible where wastes arise from large-scale, historical mining in developing countries with scarce resources. In these circumstances, the most appropriate way to minimise the hazard may be suitable land-use planning, so as to restrict the use of the contaminated site. This approach will be most effective where the hazard will diminish naturally with time.

In practice, the resources available to minimise the hazard posed by any given mine waste are always finite. Therefore, available resources must be deployed in a manner appropriate to the size of the hazard and the risk to health that it represents. To quantify the risks, in the present and the future, it is necessary to predict the concentrations of potentially toxic elements at any point between the source (mine waste) and receptor (human populations, livestock, vegetation etc) at any time from the present onwards. These concentrations depend upon: the physical and chemical characteristics of the solid mine wastes themselves; the hydraulic conditions within and around these wastes; and the chemical processes which reduce or concentrate toxins after they have been



Tailings at a lead-zinc-silver mine in southern Peru.

leached from mine workings and solid waste deposits. To predict the risk arising from these contaminants, we need to know their partitioning between solid and aqueous phases, the migration pathways, and the rates of migration. It is necessary to quantify the metal pollutants' distributions between different dissolved forms (chemical speciation), and the nature and rates of reactions in which they take part (including adsorption, precipitation, and dissolution reactions). We must also constrain the directions and rates of movement of the transporting media, most importantly water. Thus, the estimation of risks from mine wastes draws upon the disciplines of hydrogeology, geochemistry, mineralogy and petrology.

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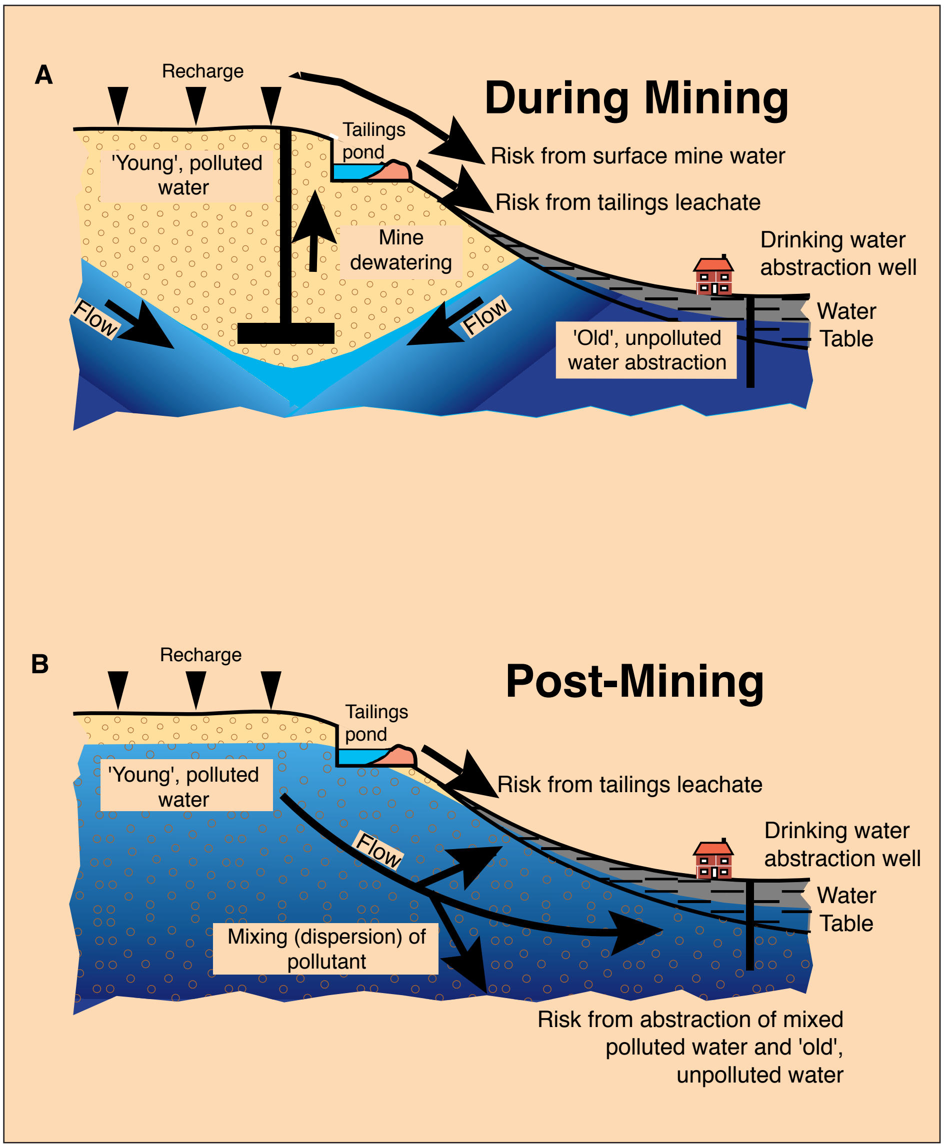
The BGS is currently developing such a holistic approach. The approach builds on experience gained by the BGS during its involvement, over several years, in projects aimed at evaluating the hazards represented by different kinds of mine waste. Past studies include projects funded by the DFID, entitled 'Environmental impacts of gold and complex sulphide mining' and 'Hazard ranking system for solid waste disposal.' The approach being adopted is novel in that it takes account of all the major interrelated chemical and physical processes and their associated uncertainties. This is achieved by conducting Monte Carlo simulations in which values of all the key parameters such as groundwater pH, oxidation state and concentration of chloride are chosen at random between limits suggested by the uncertainties on their measured values. Theoretical simulations of the mobility of each toxin are then undertaken for each set of parameters. This approach builds up a set of predictions of the mobility of each toxin, and enables an estimate to be made of the probability that any toxin will be mobile. This information is then used to estimate risk, using computer codes such as the US EPA-approved Risk Assistant™. The aim is to identify which parameters are particularly important for estimating risks under any given waste management scenario. This information will be used to devise a method for ranking the hazards posed by a specific metalliferous mine waste, using easily acquired information such as the identities of the minerals in the wastes, the levels of local water tables, and the local topography. Such a method will enable appropriate hazard remediation or avoidance strategies to be chosen. Because the approach adopted will allow a quantitative estimate of risk to be made, it will be possible to compare risks arising from hazardous mine wastes with other environmental risks. The approach will, in turn, enable resources to be targeted at the greatest risk, in accordance with the principles of BATNEEC (Best Available Technology Not Entailing Excessive Cost).



Schematic diagrams illustrating some potential variations in risk from hazardous mine wastes after a metal mine is closed. In A, water from mine pumping and a tailings pond pose a hazard, but groundwater that is abstracted near a population centre is unpolluted. In B, water from mine pumping is no longer a hazard, but water from the tailings pond continues to be hazardous; water from the disused mine has now polluted the groundwater that is abstracted for domestic use.