CHAPTER 10

MINING, MINERALS, AND THE ENVIRONMENT

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One of the ideas at the heart of sustainable development is that of 'capital formation'. In this report, five main forms of capital are discussed: natural, manufactured, human, social, and financial. In theory, determining whether the world is on the path of sustainable development is measured by the net gain or loss in the total of these capital stocks over time. There is as yet no common currency between all the forms of capital, so the judgement is bound to be subjective.

Many people hold the view that natural 'capital' should not be used at a rate that exceeds the capacity for replenishment or that reduces environmental quality, regardless of whether in the process other capital stocks are increased.[1] Others believe that when natural capital is reduced, the conditions for sustainable development may still be met so long as other forms of capital, such as manufactured and human capital, increase.[2] This is the debate over 'hard' versus 'soft' views of sustainable development described in Chapter 1.

There is obviously change in nature even without human activity; ecosystems are not static. The 'hard' view of sustainable development does not demand that ecosystems be unchanged, or that humans not alter them, but instead that some limits on that alteration be observed, to keep change within the ability of ecosystems to self-correct. This is a difficult position for this sector to live by if it includes resources laid down over geological time. Thus all depends on what is considered to be 'critical natural capital' that has to be maintained to keep the system in balance, and that must therefore not be traded for improvements in other capital stocks.

Part of the problem is that the make-up of natural systems and how they work – let alone their resilience to perturbation – is not well understood. This in turn leads to the idea of precaution, but that too brings methodological problems – how precautionary is enough?

It is hard to argue that mineral extraction, processing, and use generally benefits the local ecosystems concerned or makes them more productive. There may be a few cases when such direct benefits do occur, such as the mining of areas previously degraded that in the process reclaims them, or rare species of bats surviving because old mine tunnels replace habitat humans have destroyed. Indeed, part of the flora of the Cornish peninsula in the UK owes its presence to the mining that has gone on there since Roman times. But these are exceptions.

Taking a wider view, it can be argued that the use of metals, say, in the production of sewage pipes reduces the impact of people on their environment in our cities and in many other places. It is possible to imagine wood pipes – but at what cost to the forest? The arguments will no doubt continue.

Overall, the ability of local ecosystems to provide biological benefits has often been seriously impaired by mining and mineral processing. In the most modern mines, smelters, refineries, recycling centres, and landfills, there may be a considerable reduction in the damage done to natural capital per unit of output versus the past. But growing demand for minerals also means that total output is higher and so in absolute terms the damage function may be increasing. It is not known because it has never been measured for a nation, let alone the world.

'Best practice' in environmental management has a long way to go before it reaches the last operation. And then the best operations still have some impact, although their contribution is smaller per unit of output and no doubt will be reduced further. The worst are still bad from an absolute environmental point of view, but progress is apparent. For example, the best modern surface coal operations may leave behind sites at which casual observers may not even realize that mining has occurred. However, it is hard to contest that past mining methods have led to environmental damage that will take a very long time, if ever, for nature to repair.

In some of the world's famous mining regions, it is hard to accept that there has been some kind of gain that offsets the obvious loss of natural capital. Potosi, in Bolivia, has been mined for five centuries, producing a phenomenal amount of silver but at a great human, cultural, and environmental cost. Bolivia is still a poor country today, and the region around Potosi is one of the poorest in the nation, though mining still provides some of the better livelihoods for local people.[3] The legacy of colonial buildings is a World Heritage site that attracts some tourism, but the built or human capital that would compensate in some way for the losses must be largely found elsewhere.

When evaluating the undoubted environmental impacts of the minerals industry, the first question to ask is whether the impact is within the self-correcting capacity of the ecosystem. Is the duration of the impact short-term or long-term, and if it is long-term, is it reversible or irreversible? Second, is it worth it in terms of some other 'capital accumulation'? These bigger questions are touched on throughout this report. They cannot be answered in any rigorous way, as the metrics for doing so are not available. Thus this chapter is not about taking stock of the overall position but about how to reduce impacts, wherever they occur, to a minimum. Even so, much has had to be excluded.

Since it is obviously impossible to catalogue all the environmental impacts that may occur as a result of some aspect of the minerals chain, this chapter will focus on the issues that are widespread – that occur worldwide or with great frequency – and that have long-term implications. Some impacts that may meet these criteria are not included, however.

The use and management of cyanide in the gold industry will not be dealt with because during the MMSD Project, there has been a major discussion on this issue promoted by the UN Environment Programme (UNEP), which led to the development of a Cyanide Code (described later in this chapter). Most of what can be said on that issue was said by the parties to that debate and there is little that can be added.[4] The radiological and other downstream impacts of mining uranium are also excluded because they relate to a limited class of minerals, and the issues, while important, are complex and were beyond the chosen scope of MMSD.

Finally, issues related to water are only included where associated with other impacts such as acid drainage. This is partly because water consumption in minerals production, while an important impact, ends when operations end and thus does not present a long-term liability. But it is also because weighing up competing water demand issues was beyond the project's scope. Note, however, that some regional reports have gone further on this question because the competition for water imposes critical developmental constraints.[5]

This chapter covers seven principal areas of discussion where the impacts are serious and long-term and thus most likely to be considered impairment of the natural capital base:

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- large-volume waste,
- mine closure planning,
- mining legacies,
- environmental management,
- energy use in the minerals sector,
- managing metals in the environment, and
- threats to biological diversity

The first step towards managing and mitigating the negative environmental impacts of mining involves identifying where responsibilities lie. Results of the MMSD research and consultation suggest that such responsibilities should be shared far more broadly, particularly since civil society will perceive impacts in different ways depending how much they benefit and how much they individually shoulder the costs. At the moment, however, it is rarely local people who have the power to decide whether the trade-offs are worthwhile.

The majority of the content, views, and recommendations contained in the following section, Managing the Mining Environment, were developed based on the working papers prepared for MMSD on large volume waste, mine closure, and abandoned mines; the proceedings of the workshop held to discuss these topics; and comments received from an independent review committee and workshop participants.[6] These background papers document some of the existing best practice guidelines, including those developed by the International Council on Metals and the Environment (ICME)/UN Environment Programme (UNEP), the Mining Association of Canada, Australian Minerals and Energy Environment Foundation, and the Chamber of Mines of South Africa.

Managing the Mining Environment

Large-Volume Waste

Large-scale mining operations inevitably produce a great deal of waste. One of the most important environmental considerations at any mine is how to manage these large volumes of waste so as to minimize the long-term impacts and maximize any long-term benefits. On land, the physical footprints of waste disposal facilities are often significant, and these operations are rarely designed for a beneficial end-use. When they occupy land that was previously productive as wildlife habitat, farmland, and so on, it may be a very long time before the previous level of productivity is achieved if they are not rehabilitated adequately.

In addition to loss of productivity, these wastes can have a profound effect on the surrounding ecosystems. Where they are not physically stable, erosion or catastrophic failure may result in severe or long-term impacts. Where they are not chemically stable, they can serve as a more or less permanent source of pollutants to natural water systems. These impacts can have lasting environmental and socio-economic consequences and be extremely difficult and costly to address through remedial measures.

This is perhaps the principal reason for the widespread belief that mining, unlike many other land uses, is a permanent commitment of land. The visible evidence that land has in fact been rendered sterile and unproductive through past mining activities is such a powerful message that it is unlikely to be changed by anything short of a concerted effort at rehabilitating the worst of these sites.

In recent years, there have been significant advances in best practice in the environmental management of mine sites. This includes the introduction of operating procedures that have improved the methods of waste disposal and rehabilitation methods that reduce the likelihood of long-term impacts. But in the majority of cases there is still a long way to go before a mine can be seen as contributing to ecosystem improvement.

The volume of mine waste produced depends on the geological characteristics of the ore body, the type of mining (underground versus open pit), and the mineral being mined as well as the size of the operation.

Mine wastes are produced in a number of different categories, including:

- *overburden* – the soil and rock that must be removed to gain access to a mineral resource,
- *waste rock* – rock that does not contain enough mineral to be of economic interest,
- *tailings* – a residual slurry of ground-up ore that remains after minerals have been largely extracted, and
- *heap leach spent ore* – the rock remaining in a heap leach facility after the recovery of the minerals.

A key factor in deciding on the location of mine waste disposal facilities is cost. The cheapest option is often to deposit waste as close as possible to the mine site, or in a location where it can be transported by gravity. Selection is also heavily affected by climate: the options are very different for Escondida in the Chilean desert, where it almost never rains, and Grasberg or Batu Hijau in Papua (formerly Irian Jaya), where annual precipitation may total 8–11 metres.[7] Mining engineers also have to take into account the topography, hydrology, and geological characteristics of an area. The options may be different where there is a high risk of earthquakes. Other considerations include local communities, existing land use, protected areas, and biodiversity.

These decisions can have an enormous impact on the future of local people, who will have to live with the consequences long after the mine is closed and the company has gone. A company on its own simply does not have the information about local ecosystems or the details of local social and economic life that qualifies it to make these decisions unilaterally. This underlines the importance of consulting closely with local governments and communities while planning and constructing waste disposal facilities.

Land Disposal

The most common place to dispose of mine waste is on land. A variety of methods are used, which depend among other things on the type of waste.

- *Overburden and Waste Rock*

Overburden and waste rock are typically broken up sufficiently to be moved to the allocated disposal site, where the material is usually dumped and any excess is bulldozed over the edge, forming slopes at the natural angle of repose. The most important considerations are to produce stable slopes and control the flow of water in and around the waste so as to minimize erosion, protect the structure, and try to prevent infiltration. The most pervasive problem associated with waste dumps is acid drainage, an issue considered in greater detail later. Where precipitation rates are high, there needs to be particular care to ensure the physical stability of waste rock facilities, as they can fail with catastrophic consequences.

In some climates, too little water can be a problem and the surface of the facility may require regular wetting to reduce the generation of dust. Wetting is not a practical long-term solution and, at the time of closure, a permanent method of rehabilitation needs to be established. In some climates this can take the form of a vegetative cover, while in more arid regions it may be necessary to form a crust on the surface.

- *Tailings*

Tailings are the finely ground host rock from which the desired mineral values have been largely extracted using chemical reagents. This residue takes the form of a slurry that is at least half water and can be transported by pipeline. Tailings are usually discharged into storage facilities and retained by dams or embankments constructed of the tailings themselves, mine waste, or earth or rock fill. (See Figure 10–1.) When the tailings are discharged into the facility, the solid fraction settles – forming a beach enabling the slurry water to be decanted and discharged or recycled. As tailings are deposited they are often used to increase the height of the tailings embankment.

Given that tailings storage facilities usually contain residual chemical and elevated levels of metals, it is vital to ensure their chemical and physical stability. These structures are prone to seepage, which can result in the contamination of the ground and surface water and, in the worse cases, can fail catastrophically – an issue considered in greater detail later. Because tailings are made up of fine particles, when dry they can be a source of serious dust problems: in the Bay of Chañaral in Chile, there is a real concern about lead-rich mine tailings that blow over the local town.[8] In Gauteng, South Africa, old tailings storage facilities generate dust that can be blown over several kilometres. During the dry months the dust is overpowering, and local people are forced to tape up their windows and doors in an effort to keep it out.[9]

Mining often takes place in areas where water is scarce. In these regions, the consumption of water for mineral processing can have a severe impact on aquifers. At some mine sites the tailings may be thickened prior to disposal and the liquid reused in the processing circuit. In many cases this has the added benefit of recycling process chemicals. Water may also be decanted from the storage facility and recycled to the processing plant. Any recycling of tailings water reduces the discharge to the surrounding environment and the potential for negative impacts.

Tailings may also be thickened to improve the method of disposal. Conventional tailings are 30–50% solids, while ‘thickened tailings’ are 55–75% and ‘paste tailings’ are over 75% solids. Thickened tailings can be stored with minimal water retention, creating a more stable structure both physically and chemically, while paste tailings can be used to backfill underground mines.

- *Heap Leach Spent Ore*

A third type of waste deposited on land is the residue of heap leaching. Here the crushed ore is placed on a membrane-lined ‘pad’ and irrigated with the appropriate reagent – cyanide in the case of gold or silver, and sulphuric acid in the case of copper or uranium. (See Box 10–1 for information on a new cyanide management code.) The leach solutions are then collected in channels around the pad and pumped to the processing plant. (See Figure 10–2.) The effluent is then re-charged with reagent and reused.

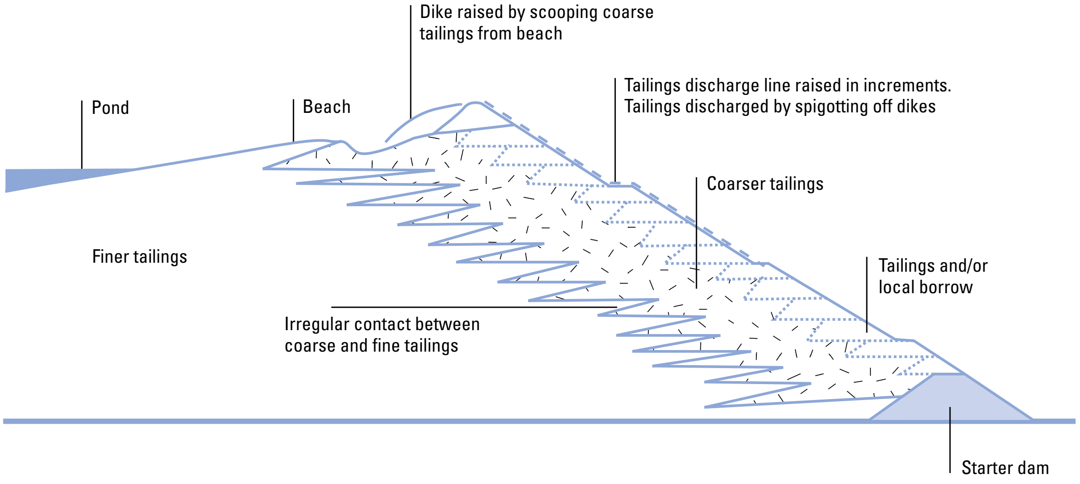
The goal is to operate a closed system that does not discharge any of the solution into the natural water systems. However, all liners leak to some extent, and current best practice is to build the pads with multiple liners and to incorporate systems for leak detection.[10]

After recovery of the metals from the ore, the heap is rinsed to remove any remaining chemicals. Even after rinsing, however, some of the chemicals and elevated levels of metals may remain, so the facilities need to be designed to control surface drainage to prevent erosion, seepage, or failure.

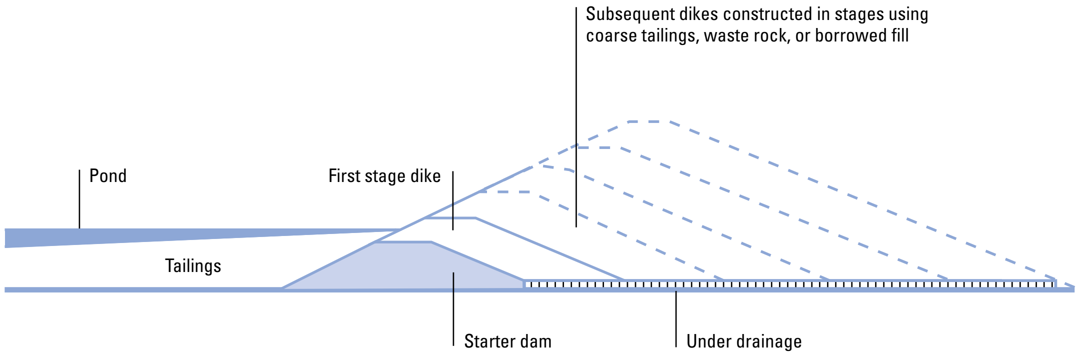
While overburden, waste rock, tailings, and spent heap leach facilities display some issues in common, each type of waste has its own separate set of concerns. By mixing some of these waste products, it may be possible to compensate for the problems associated with each: waste rock is porous and prone to acid

Figure 10–1. Tailings Dam Geometry Definitions
Source: Martin et al. (2001)

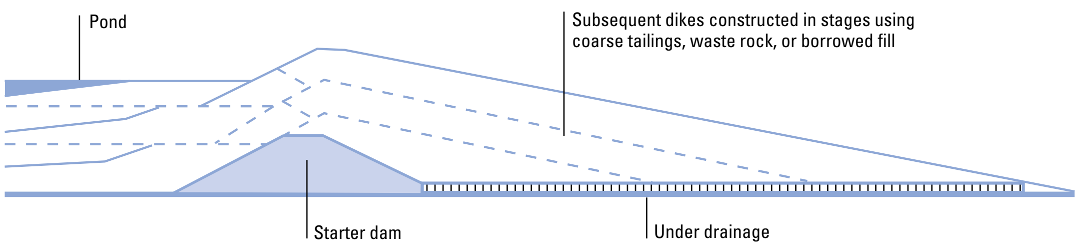
Upstream Method of Tailings Dam Construction



Downstream Method of Tailings Dam Construction



Centreline Method of Tailings Dam Construction



Box 10–1. International Cyanide Management Code

At the present time, there is no economically viable, environmentally sound alternative cyanide to using the reagent in the production of gold. Cyanide is also an hazardous chemical that requires careful management.

To address public concerns about cyanide use and management, UNEP and the International Council on Metals and the Environment (ICME) co-hosted a two-day multistakeholder workshop in May 2000. Participants confirmed the importance of a Code of Practice 'to drive improved performance in mining through high standards of technology, management and control to provide the public with confidence that their concerns were being addressed'. The Code's mission statement is 'to assist the global gold mining industry in improving cyanide management, thereby minimizing risks to workers, communities and the environment'.

Developed by a committee of 14 participants from large and small gold producers, the financial sector, environmental groups, governments from industrial and developing countries, labour, and chemical suppliers with broad public consultation, the code sets out nine principles, each with specific Standards of Practice to protect workers, the environment, and the public. The principles address responsible production, safe transport, proper handling and storage, operations, the need for decommissioning plans, worker safety, emergency response strategies and capabilities, training, and public dialogue. At present, an adoptive institution is being sought for the code, and a third-party audit has been planned but not yet started. Mechanisms are still being developed with respect to loss of certification, dispute resolution, and periodic updating.

For further information, see http://www.cyanidecode.org and http://www.mineralresourcesforum.org/cyanide.

generation, while tailings are very fine and prone to instability. One idea is that the co-disposal of these two wastes could create storage facilities that are both chemically and physically more stable. (See Box 10–2.) The International Network for Acid Prevention (INAP) has embarked on sponsored research to investigate various aspects of co-disposal. These include constructing facilities for the co-disposal of waste rock and tailings and the use of co-disposal to construct covers for waste rock retention facilities.

Mine wastes are occasionally seen as a resource and may be suitable as aggregates for road construction and

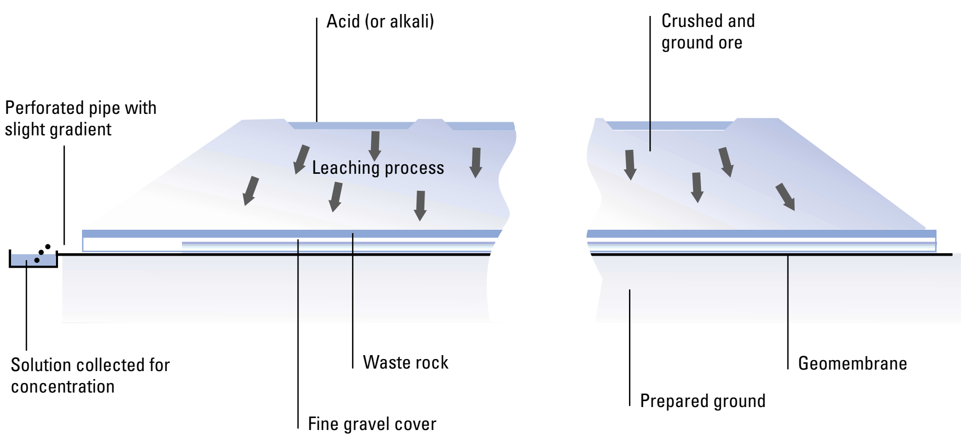
Box 10–2. Co-disposal

Co-disposal mixes waste rock with tailings. This has the advantage of filling in the gaps between the particles of waste rocks. If consolidation characteristics are right, this excludes some of the air, thereby reducing the potential for acid drainage and also reducing dust problems with wind-borne tailings. The total amount of land needed for disposal is reduced, less water is used, and the deposits can provide a better substrate for growth of vegetation and other biota. However, this kind of 'co-disposal' also carries risks. If the proportion of tailings is too high, the deposit will be physically unstable; if it is too low, air and water can penetrate more easily, leading to increased dangers of acid rock drainage. Co-disposal is currently mainly used in the coal mine sector, particularly in Australia.

Sources: Van Zyl et al. (2002); discussions at MMSD Vancouver workshop, 2001; http://www.inap.com.au/inap/homepage.nsf.

Figure 10–2. A Heap Leach Facility

Source: Adapted from IAEA (1993)



building materials. A number of projects are looking at a range of end-uses. However, the volume of wastes is so great it is hard to see more than a small fraction of them being used in this way. They should also be used with care, especially in the construction industry, as contaminants in the waste have sometimes caused long-term problems.

Backfilling mine waste into underground workings or open pits has certain advantages and disadvantages. The main advantages are the reduction in the use of land and the stabilization of underground workings. However, the increase in the volume of waste when excavated means that it is not possible to backfill all the material removed. As a result, only around 60% can be returned and the rest placed in surface disposal facilities.

Backfilling open pits during operations is only possible where there are separate pits or an elongated pit. Double-handling of waste materials is rarely economically feasible, and environmental problems can occur during the temporary storage of the waste. However, the environmental impacts of a partially backfilled open pit may be considerably greater than a surface storage facility. Some critics argue that the companies reject backfilling without sufficiently serious analysis, and this may at times be true.

Waste may also be disposed of under water in either natural or artificial lakes or flooded open pits. (See Box 10–3.)

Acid Drainage

The most serious and pervasive environmental problem related to mining is acid drainage (AD).[11] AD occurs in many major mining regions, particularly those with temperate rainfall, and regional studies show that it is a widespread problem.[12] Where it does occur it can have a serious impact on the productivity of ecosystems. AD can be a long-term problem and may result in a reduction in natural capital.

Box 10–3. Lake Disposal

Lake disposal can be used for waste rock, as the lack of exposure to bacterial action and oxygen reduces acid drainage. It needs to take into account the chemical composition of the waste, however, and artificial structures have to be carefully monitored. Some pits expose acid-producing rocks, and adding more acid-producing rocks can alter water quality and lake biota dramatically.

Source: http://www.nrcan.gc.ca/mets/mend/.

Acid generation begins in the circumneutral pH range when iron sulphide minerals are exposed to, and react with, oxygen and water. This is a process that occurs in nature, and there are cases where it has reached problem levels without any help from humans. But by exposing these materials and breaking them up, mining can greatly accelerate the rate at which these reactions take place. Other factors that influence the oxidation of sulphide minerals are temperature, acidity levels (pH), ferric/ferrous iron equilibrium, and microbiological activity, especially in the form of *Thiobacillus ferrooxidans*. Mining exposes sulphide-rich materials in the walls of open pits, mine tunnels, waste rock, tailings, and so on. AD is of less concern where mines exploit oxidized ore bodies. Because these deposits are less numerous and seem to be exploited more readily than sulphide deposits, some argue that the problem will increase as industry exhausts the oxide sites.[13]

AD is characterized by depressed pH values and elevated concentrations of dissolved heavy metals; the sulphuric acid easily dissolves metals such as iron, copper, aluminium, and lead. One of the most serious aspects of acid drainage is its persistence in the environment. An acid-generating mine has the potential for long-term, severe impacts on surface and ground water and aquatic life. Once the process of acid generation has started, it is extremely difficult to stop. The combination of acidity and dissolved contaminants is known to kill most forms of aquatic life, rendering streams nearly sterile and making water unfit for human consumption.[14]

AD is not a problem at every mine, even in sulphide-rich zones. In some circumstances the reaction may be inhibited by a lack of water or oxygen. In others the surrounding soils may have ‘buffering’ qualities that help neutralize the acid.[15] But in some cases metals and sulphates may still be mobilized even though acid conditions do not appear.

In some cases the problems may be evident from the outset and steadily increase during the life of the mine. In others, AD may only appear after the mine has closed and the company has left the area. Once started, however, the process can endure for centuries or even millennia. For example, acid generation in the Rio Tinto mining district in Spain is believed to have been caused by Roman or perhaps even Phoenician miners.[16]

- *Treatment*

Dealing with AD effectively is very difficult. There are known management methods to minimize the problem. Effective mine design can keep water away from acid-generating materials and help prevent AD from occurring. But in many cases this is not adequate to prevent it altogether.

AD can be treated actively or passively. Active treatment involves installing a water treatment plant. Here the AD is first dosed with lime to neutralize the acid and then passed through settling tanks to remove the sediment and particulate metals. The costs involved in operating a treatment plant can be high and require constant maintenance and attention.

The goal of passive treatment is to develop a self-operating system that can treat the effluent without constant human intervention. An example would be passing the water through an artificial wetland in which organic matter, bacteria, and algae work together to filter, adsorb, absorb, and precipitate out the heavy metal ions and reduce the acidity.[17]

So far no one has designed a passive system that will operate indefinitely without human intervention. It is therefore not free of ongoing costs. Treatment will be needed not just during the mine life, but indefinitely into the future. A number of research initiatives and programmes are currently aimed at the prevention and control of acid drainage. The best known of these are Mine Environment Neutral Drainage and INAP.[18]

- *Sustainable Development and Acid Drainage*

There could be a debate about the extent to which the reduction in natural capital represented by AD can be outweighed by the addition to human capital. The debate could become even more complex if it focused on who has the right to make those trade-offs – governments of developing countries, the more environmentally focused North, or those who can speak for the next generation. The legislature in Wisconsin in the United States has taken the dramatic unilateral step of requiring – as a condition of issuing a mine permit – verification that one or more sulphide mining operations have been undertaken in full compliance with pertinent environmental laws and without causing any 'significant environmental pollution' before issuing a new mining permit. (See Box 10–4.) More than 50 mines have been studied in an effort to find a site that can be shown to comply with these requirements; all have been rejected. Failure to show that there is any site that can meet these criteria could have serious consequences for the future of the mining industry, in Wisconsin and elsewhere.

The science that allows prediction of the occurrence of AD in advance is imperfect and is oriented more towards a range of probabilities than precise answers. In addition, the science that is available is not always used, particularly when regulatory authorities lack the capacity or the understanding to ask the right questions and demand the best answers. The debate largely takes place out of public view because the issues are thought to be too technical for the public to understand, because the regulatory process occurs in an environment without a tradition of public participation, because the issues are cloaked in scientific jargon, and perhaps because the benefits may come now while the costs will come later, which puts a premium on optimism. The trade-offs among competing criteria are therefore not made consciously, explicitly, or transparently.

Box 10–4. Wisconsin Legislation on Mining

The law requires the Wisconsin Department of Natural Resources to make two key determinations before issuing a mining permit:

- that a mining operation has operated in a sulphide ore body that, together with the host rock, has a net acid-generating potential in the United States or Canada for at least 10 years without pollution of the groundwater or surface water from acid drainage at the tailings site or at the mine site or from the release of heavy metals, and
- that a mining operation that operated in a sulphide ore body that, together with the host rock, had a net acid generating potential in the United States or Canada has been closed for at least 10 years without pollution of the groundwater or surface water from acid drainage at the tailings site or at the mine site or from the release of heavy metals.

Source: State of Wisconsin (1997); Wisconsin Statute 293.50. The Mining Moratorium Law.

Waste Storage Failures

Any human activity that involves shifting large volumes of rock, cyanide, acid, and other hazardous reagents will inevitably be subject to accidents. Accidents have occurred throughout the chain of mineral production and use, though there has been enormous progress in the best companies in reducing the frequency. This does not mean that more cannot be done. Accidents that occur later in the minerals cycle, at smelters and refineries, are discussed to some extent in Chapter 6. This section addresses accidents at mine sites and focuses on those with serious and potentially long-term environmental consequences.

At the global level, the greatest single concern is the failure of tailings storage facilities.[19] Although it is difficult to arrive at total numbers, given different monitoring and reporting systems, one estimate suggests that there are 3500 tailings storage facilities in active use and many thousands of others that are closed, at least some of which could still pose serious risks.[20] Since 1975, tailings storage facility failures have accounted for around three-quarters of major mining-related environmental incidents.[21] Major accidents seem to occur on average once a year, but there are many other smaller events that fall beneath the threshold of government reporting requirements.[22]

As a specific example of this, in 1996 Rio Tinto initiated a two-year review into the disposal of mine waste at 75 sites world-wide. The review included a desk top study of all sites followed by inspections at 26 sites. The results of the survey showed that in the 10 years prior to the survey, there had been a total of 16 structural failures (21% of the sites), 10 of which involved tailings and 5 involved waste dumps. In addition, 10 facilities were classified as 'high hazard' under the Western Australian criteria.[23]

The failure of tailings storage facilities can have devastating consequences.[24] In 1965, an earthquake in Chile destroyed 11 facilities, one of which released 2.4 million cubic metres of tailings that ran 12 kilometres downstream – burying the town of El Cobre and killing 300 people.[25] Such incidents naturally provoke fear and anger, but even the threat of failure can cause severe anxiety to the local population. Major incidents also bring calls for tighter regulation. In Chile, the El Cobre failure resulted in new regulations for tailings storage facilities. In the United States, the Buffalo Creek disaster overcame years of industry opposition and led to the enactment of national environmental standards for coal mines.[26] The list is a long one and includes incidents other than tailings failures, but the connections between highly publicized accidents, of which tailings failures are the most frequent, and new and tighter regulations is inescapable.

As indicated earlier, the location of large tailings storage facilities is a land use decision with what are effectively permanent consequences. If the facility is a hazard, this risk does not always end when the mine closes. If the facility is badly sited, designed, or constructed, rains, floods, or earthquakes can cause failure long after operations cease.

- *Why Do Tailings Storage Facilities Fail?*

The main problem is that tailings storage facilities are built over long periods. Often the embankment is constructed from the waste itself. Unlike water storage dams, which are usually built in one operation and can then be given a rigorous final inspection, tailings storage facilities are built continuously, possibly over the many years of the mine's life. This means quality control is much more difficult. During this time the ownership or management may have changed, and there will have been considerable turnover in staff. So even if the original design parameters were sound, they may be lost, they may not be followed with sufficient care, or the originally planned height may be exceeded. Meanwhile, the properties of the tailings may also have changed as the mine enters new ore zones or as processing technology is adjusted.

The leading large international companies usually employ qualified consultants, send their staff to international meetings, and keep abreast of developments in design. This is not to say that there are never errors at the outset, resulting from poor site selection or flaws in design. But these at least can be minimized if companies follow the latest best practice and use an independent design review committee.

The most serious problems affect big and small companies alike. Organizations are notoriously poor at ensuring quality management over long periods of time. It is surprising how often there is no single responsible person in charge of the facility. Having a competent person in charge with clear authority is an absolute requirement for safety; too often it is absent. Someone with the correct training is needed to ensure that the company carries out any necessary adjustments in design as conditions change.[27] But even good personnel have problems managing if they do not know the original assumptions on which the dam was designed, so that they can tell if these are exceeded. Too frequently the original design parameters are forgotten and the people managing the facility are no longer clearly aware of the limits they are supposed to observe. The level of on-site expertise usually falls once the project receives a permit and commences normal operations.

In principle, even the smaller companies should be monitored by lenders, governments, and local communities. But these external agents rarely provide effective oversight. Insurance companies have a clear interest in better practice in this area, but are often deterred from conducting their own reviews by the cost. Governments, too, pay most attention to the early stages – ensuring perhaps that there are suitable regulations about initial design but making few stipulations about ongoing stewardship.[28] In any case, governments rarely have sufficient skilled staff to monitor conditions or step in when problems arise. Under these circumstances inspection can be more dangerous than inattention, since it will give the management a false sense of security.[29]

Finally, both companies and local administrations frequently fail to ensure effective risk assessment and emergency planning. This includes measures to ensure the protection of both the settled local communities and also any informal squatters who may have been drawn to the area by the mine.

- *Best Practice for Tailings Storage Facilities*

Tailings storage facilities require not just good design but also close, consistent, routine attention over a long period. Those in charge need to be well trained and aware that they are being monitored, otherwise their performance is likely to deteriorate. This close surveillance is difficult to achieve, particularly in remote locations.

The first priority should be to ensure that all designs are based on the highest design standards possible. One option would be to have an international system of certification for designers, or at least some formal pronouncement by engineering bodies as to the minimum qualifications for undertaking such a task.

Companies should also establish a second layer of protection elsewhere in the system, probably at company headquarters through geo-technical review boards.[30] This would ensure periodic review and audit of safety conditions, including a thorough review of the original design, any new factors that might require adjustments, and an assessment of how the management system is being implemented in the field.

The third layer of protection should be external and involve governments, local communities, and insurers. Governments should be able to ensure frequent inspection by adequately qualified people. Some countries already have this capacity, but others do not.

Neither the first nor the second layer of protection will be fully effective if appropriate instrumentation is not incorporated into the facility from the beginning.

Marine Disposal

Though most mining waste is deposited on land, some companies discharge waste rock or tailings in the sea at depths varying from the shoreline to the deep sea. The greatest known impacts of this practice appear to be found in shallower waters.

Shoreline or surface-water disposal typically occurs where depths are less than 20–30 metres. This is the zone of highest biological productivity, and impacts can be severe. The waste increases water turbidity and smothers the organisms that live on the seabed. The sediment may also get washed up on the shore.

Shallow-water disposal generally involves releasing tailings from submerged pipelines into fjords, sea channels, and coastal seas at depths of between 30 and several hundred metres. In Canada, the Island Copper Mine and the Kitsault Mine have deposited tailings at such depths in sheltered fjords, and these appear to have remained mostly at the intended deposition area.[31]

Due to the problems associated with shoreline or shallow-water tailings disposal, greater interest has recently been shown in deep-sea tailings disposal. This involves depositing wastes below the maximum depth of the surface mix layer, the euphotic zone (the depth reached by only 1% of the photosynthetically active light) and the upwelling zone, on the assumption that the waste will not be re-mobilized in the surface water.[32] When the waste is discharged from the pipeline, it continues to flow downwards, eventually settling on the sea floor at perhaps 1000 metres or deeper. (See Box 10–5.)

Pipelines have the same risks of accidents under the water as they do on land. At Newmont's Minahasa Raya gold mine in Indonesia, for example, the tailings are piped out 800 metres from the shore to a depth of 82 metres.[33] But the pipe has broken more than once and released tailings to the surface, which is said to have caused a serious loss of fishing resources and destroyed some of the surrounding coral reefs.[34]

Box 10–5. Marine Disposal from the Misima Mine in Papua New Guinea

One example of deep-sea marine disposal of tailings is found at the Misima open-pit gold and sliver mine in Papua New Guinea (PNG) – a joint enterprise between Placer Dome Inc (80%) and a state-owned company. Mining began there in 1989 and ended in 2001, though processing of stockpiled ore will continue for another four years.

The company has disposed of overburden and waste rock (around 53 million tonnes in total) and tailings (15,000 tonnes per day) in the sea. This option was chosen following five years of environmental investigations as well as extensive consultation with landowners and the government. After the tailings are washed with fresh water in thickeners, they are mixed with sea water and de-aerated before being discharged into the sea, via pipeline, at a depth of 112 meters. The depth of the sea floor in the area of deposition is 1000–1500 metres.

So far, this method of disposal appears to have had relatively little environmental impact. A systematic review carried out since 1993, using direct observation, acoustic sensing, and analysis of water samples, indicates no permanent damage to the marine environment. Tailings appear to have stayed in place and, after five years of deposition, bacteria and meiobenthos had recolonized the sediment.

Nevertheless, it is still too early to come to final conclusions. The Misima operation is still 'young', and there is relatively little research on the long-term effects of such methods on tropical marine areas. Moreover, the current information has been funded entirely by the company and has yet to be verified by independent research.

Source: Van Zyl et al. (2002); Jones and Jones (2001).

Deep-sea disposal remains a controversial option, however, and there is little agreement on or evidence about its long-term effects. Some industry studies suggest that the risks are minimal and that within several years of closure the sea floor can be recolonized by benthic fauna.[35] Other research suggests that deep-sea ecosystems might be more complex and biodiverse than comparable terrestrial fauna.[36] Relatively little is known about deep-sea ecosystems and the interaction among marine species at different depths.

In some circumstances deep-sea marine disposal might be an option deserving serious consideration – when the mineral deposits are on islands that have little spare land, when available space is at risk of flooding, or when the stability of land disposal facilities is uncertain because of high rainfall or seismicity. Nevertheless, since relatively little is known about the long-term environmental implications of deep-sea marine disposal, many observers are demanding that this option be considered only after far more extensive and rigorous scientific investigation. And in light of some of the tailings pipe failures that have occurred, the problem of how to get the tailings into deeper water without undue risks to shallower near-shore environments would have to be addressed.

Riverine Disposal

Even more controversial than marine disposal is the practice of disposal of waste rock and tailings into river systems. In this case, however, a good deal is already known about the impacts, and almost all of this experience is negative. Miners have tipped waste into rivers throughout history, and at numerous sites the legacy of riverine disposal will endure for a very long time.

There are only three currently operating large mines where international companies use rivers for waste disposal. These are the Ok Tedi copper and gold mine in Papua New Guinea (see Box 10–6), Placer Dome's Porgera gold mine in PNG, and Freeport's Grasberg copper and gold mine in Papua (formerly Irian Jaya), Indonesia.[37] Riverine disposal is also currently used by many small-scale and artisanal miners around the world, by a number of small or medium companies, and at an unknown number of sites in Russia and China. The main advantage of riverine disposal is that it is cheap and convenient, and it may also appear less hazardous than constructing a tailings storage facility, especially in high-rainfall areas with little stable land and a risk of seismicity. In the case of Ok Tedi, the

Box 10–6. Riverine Disposal from the Ok Tedi Mine in Papua New Guinea

The riverine disposal of tailings and waste rock at Ok Tedi gold and copper mine in PNG is highly controversial. It has involved lengthy legal disputes and there have been extensive efforts by downstream communities to close the mine. The company that held a majority share in the mine, BHP Billiton, decided to withdraw from the project because it no longer wished to be associated with this method of waste disposal. (The socio-economic impacts of this project are considered in Chapter 14.)

The original proposal included two stable waste dumps and a conventional tailings storage facility. During the early stages of construction, a massive landslide destroyed the site of the tailings storage facility. To keep production on schedule, an interim tailings scheme was approved that allowed for the retention of 25% of the tailings, the remainder being released into the Ok Tedi river. An alternative site for a tailings storage facility was never identified, and the construction of a permanent waste disposal facility was deferred. At present, approximately 80,000 tonnes of tailings and 120,000 tonnes of waste rock are discharged daily into the Ok Tedi. Waste material has reached the Fly River, into which the Ok Tedi flows.

The Ok Tedi mine has led to a four- to fivefold increase in the suspended sediment concentrations in the Fly River. This exceeds the sediment transport capacity of the river system, resulting in the build-up of sediment in the river bed in the Ok Tedi and middle Fly River, which in turn has increased the incidence and severity of overbank flooding. The flooding has resulted in the deposition of mine waste and abraded waste rock on the flood plains, causing the die-back of vegetation. The area affected by 'dieback' increased from 18 square kilometres in 1992 to about 480 square kilometres in 2000. A risk assessment carried out by the company stated that the area ultimately susceptible to dieback induced by mining ranges from 1278 to 2725 square kilometres.

Dredging has been attempted along part of the Ok Tedi river bed in an effort to reduce the impacts of the flooding. This has reduced the frequency of flooding, but the problems of vegetation dieback continue.

Source: Van Zyl et al. (2002); Kirsch (2002).

government of Papua New Guinea accepted this option because the only alternative was to shut the mine – with severe economic implications.[38]

Riverine disposal has caused many types of environmental damage. These include a change in the morphology or physical form of rivers and an increased risk of flooding, resulting in the die-back of vegetation and damage to the aquatic ecosystems. The finer sediments can also have impacts further downstream when they reach estuaries or deltas. In Chile, 150 million tonnes of mine sediments disposed of in the Salado River from the El Salvador mine have created a new 3.6-square-kilometre beach many kilometres downstream in the Bay of Chañaral.[39]

These impacts may have serious consequences for communities downstream – particularly for people's health. As well as changing the physical character of the river, mine wastes may also increase the levels of minerals and process chemicals to the water. Overbank flooding may increase the incidence of malaria. Local people may find their livelihoods affected if deposits reduce the potential for fishing or cultivating riverside gardens.

There has been a long and often bitter debate over whether in some circumstances riverine disposal might be acceptable. Some companies and governments argue that it should be accepted if the alternative is to have no mining at all. Other companies have stated that they will no longer consider riverine disposal an option.

Mine Closure Planning

For a mine to contribute positively to sustainable development, closure objectives and impacts must be considered from project inception. The closure plan defines a vision of the end result of the process and sets concrete objectives to implement that vision. This forms an overall framework to guide all of the actions and decisions taken during the mine's life.

Critical to this goal is ensuring that the full benefits of the project, including revenues and expertise, are used to develop the region in a way that will survive after the closure of the mine. To achieve this, a mine closure plan that incorporates both physical rehabilitation and socio-economic stability should be an integral part of the project life cycle and designed to ensure that:

- future public health and safety are not compromised,
- environmental resources are not subject to physical and chemical deterioration,
- the after-use of the site is beneficial and sustainable in the long term,

- any adverse socio-economic impacts are minimized, and
- all socio-economic benefits are maximized.

At the time of mine decommissioning and closure, not only should physical environmental rehabilitation be completed in a satisfactory manner, but the community should have been developed to maintain a sustainable existence.

Closure planning was first used as an environmental tool but was quickly expanded to include socio-economic issues.[40] Best-practice planning for closure involves integrating the closure design for the entire mine area, identifying the timing of the planning process, and considering issues that relate to specific disposal methods and post-mine economic and community activities, as well as financial planning.

There are significant costs when a mineral project closes. Workers may be unemployed or need to pay to relocate somewhere they can get a job. Someone needs to pay to keep the roads open or the schools running. Someone needs to pay to close the mine shafts, remove hazardous reagents from the site for safe disposal, stabilize the slopes, rehabilitate the facilities, and ensure that long-term environmental and social problems are minimized.

If there is no understanding in advance as to who will be responsible for what, and no planning for the day of closure, many of the benefits of development will be lost. This has clearly happened in many instances in the past, and these negative post-mining conditions have contributed to the industry's current public reputation.

If mine closure comes with little advance warning, the company will no longer have any revenues from which to fund anything. Government revenues are also likely to be affected, the local economy depressed, and individuals out of work.[41] The result is that no one can afford to do much. Public services fall apart, the benefits of infrastructure are lost, and the community is dislocated. Many companies in the past kept the results of operations and consideration of closing confidential as proprietary business information. Some of them are now starting to believe that the more open this discussion is, the more it allows other economic actors such as government, workers, and local businesses to make rational plans for their own future. This lets them rely more on their own resources and foresight and means they may turn less to the company to solve problems.

Unemployed mine and minerals processing workers have destabilized numerous governments over the years, including in Bolivia, the Ukraine, and Serbia. They have been a major political factor even where governments did not fall, in countries such as the UK, South Africa, and Germany. As a result, governments often subsidize mining operations to keep them open. This may be in the form of open subsidies to unprofitable state enterprises, such as the payments that nearly exhausted Romania, the years of Bolivian subsidy of the tin industry, or the mines at Lota in the south of Chile.

Companies have their own reasons for wanting to keep mines open even after they have stopped being good performers. Some of this may simply result from a hope that prices will improve if the company just continues long enough. Additionally, many of the reasons may have to do with accounting rules, balance-sheet pressures and the effect on a company already in the economic doldrums of having to write off assets or recognize costs. But some of it also has to do with a lack of clarity about what the company will be expected to pay when it closes and a desire not to press the issue unduly. Some of the high-profile issues on which the industry is currently being criticized are controversial precisely because some feel that the companies are not paying their fair share of long-term liabilities at closure. (See the discussion of Marcopper and Ok Tedi in Chapter 14.)

A framework for closure agreed at the outset could significantly ease these problems for government, companies, and communities. That would make it easier to preserve the social and economic benefits of development and to avoid long-term charges against the natural capital account. It might also remove some of the excess production and help to stabilize commodity prices.

Closure Planning Today

The modern concept of closure planning is based on the following key considerations:

- *Pollution prevention* – It is cheaper to prevent problems than to try to fix them later. If a company has an obligation to deliver the site in a specified condition at the end of the mine life, it will create strong incentives for pollution prevention during the whole life of the mine.

- *Changing expectations* – Companies can reduce the risks of the rules of the game changing midstream by entering into a binding agreement on the end results they need to achieve. This makes costs more predictable, and they can be recognized on balance sheets.[42]
- *Continuity* – Mines get bought and sold, companies merge or are acquired, and management changes. The ultimate objective must be to develop an understanding about what the site will be like at the end of mining, in a form that will survive all these events, and not depend on the good intentions of individual managers who are likely to have moved on by the time closure occurs.
- *Financial surety* – Given that many mine closures have occurred as a result of poor market conditions, low profitability, or even bankruptcy, there is a need for some kind of financial surety to make certain that closure costs are funded. To ensure that the funds are available for these closure activities, the company is generally required to post a financial surety or bond.[43]
- *Public participation* – Some form of public consultation process is required that allows for dialogue over the long-term issues and end-use of the site.

Post-Closure Costs

Sometimes there will be ongoing costs that have to be paid after closure occurs. One of a number of examples is the cost of operating a water treatment plant to abate acid drainage, as described earlier. But decisions on mining projects have to be made long in advance of this point, on imperfect knowledge, and usually based on probabilities rather than a clearly known outcome. This provides decision-makers and the public with three alternatives, all of which are highly unpalatable to at least some actors. First, there could be a decision that the risks are too high and mining will just not be permitted. Second, there could be a decision that the risks are acceptable and the project will proceed. If the company cannot be induced to pay whatever long-term liabilities result, society will assume them. And third, government could set a guarantee or bond requirement sufficiently high to cope with identified future problems.

This latter method of funding has proved quite effective in some countries, though it has failed in others. Bonding is a government function, and it is hard to know how to proceed when a government does not want to take that role. A number of governments in the developing world have chosen, at least to this point, not to follow that route:

- Even if multinationals can post bonds, many local companies do not have the resources, and in many cases these smaller local companies provide more employment than the big ones.
- Effective closure planning requires considerable skill and capacity on the part of both government and companies, and this is sometimes not available.
- Many developing countries have recently undertaken comprehensive review and revision of mining legislation to attract foreign investment, and this is seen as a backward step and an economic disadvantage in competition for investment with other countries that have no such requirements.
- Effective planning requires considerable flexibility to develop appropriate solutions to site-specific problems. This implies discretion in government officials, which is seen as a disincentive to investment and a source in some places of potential corruption.

Although the polluter pays principle requires the company to pay the costs, this does not necessarily mean that the company should itself maintain the site in perpetuity. Perhaps the best solutions are those where the company pays a local institution to take the responsibility. This does not imply that the company should necessarily be absolved of all responsibility if things do not go according to plan. There are now private companies emerging that will assume the liability for ongoing site maintenance for a fee.

There is a clear need to integrate the accounting profession into any discussions of long-term financial arrangements to ensure that accounting rules do not drive companies away from best practice.

The primary responsibility for mine closure lies with companies and the governments that regulate them. But this responsibility should also extend to the lenders. Neither private lenders nor multilateral lending or funding agencies have given this matter sufficient attention, perhaps in part because closure will not occur until long after their loans have been repaid.

One way forward could be the promotion of Community Sustainable Development Plans as a part of the project process. (See Chapter 9.) These would involve local communities, national governments, and companies working out their respective roles and obligations during the project life and at closure.

In addition, there is a role for accounting professionals to improve handling of these issues. There should be a review of the accounting and tax treatment afforded closure costs, to ensure that if negative balance sheet implications of proper approaches to closure or awkward tax consequences are a disincentive to best practice, these issues are identified and dealt with.

The TRAC programme (Transfer Risk and Accelerate Closure) is a risk-based, fixed-price approach used in South Africa and the US in which the mining company enters into a fixed-price contract for the purpose of transferring the risks and responsibilities for mine closure to a contractor.[44] This may be a helpful model in some circumstances.

Mining Legacies

The environmental issues of current and prospective mining operations are daunting enough. But in many ways far more troubling are some of the continuing effects of mining and smelting that occurred over past decades, centuries, or even millennia. These sites have proved that some impacts can be long-term and that society is still paying the price for natural capital stocks that have been drawn down by past generations.

It is impossible to estimate how many former mining sites exist around the world or how many of these carry environmental risks. For one thing, there is no clear way to define a former mine site. Using a fairly inclusive definition, it has been estimated that in the US there are more than 500,000 abandoned hard rock mine sites.[45] Certainly not all of them present environmental problems. In the UK, most of the problems are related to tin mining in the counties of Devon and Cornwall, where there are some 1700 abandoned mine workings, most of them very small, that continue to affect the water in some 400 kilometres of classified rivers.[46] In most countries with a long history of mining, there are relatively few data on former mines or their environmental legacy, though there is enough information to know that problems are widespread.[47]

Given the uncertainty about the numbers and the state of abandoned mines, it is impossible to estimate with any precision what it would cost to rehabilitate them. Moreover, the cost depends very much on what 'rehabilitation' consists of and to what standard it is pursued. Information available from sites with serious problems that have been investigated suggest daunting sums. Since 1980 the US has had a 'Superfund' programme administered by the Environmental Protection Agency to locate, investigate, and clean up the worst hazardous waste sites, a number of which are the result of mining, smelting, or refining minerals. In the Clark's Fork River region of Montana , for example, where gold and silver mining started in the late nineteenth century and continued until the early 1950s, rehabilitation measures have been roughly estimated at US$1 billion.[48] The Summitville mine in Colorado is likely to cost some US$225 million to clean up, and the Yerington copper mine in Nevada, around US$200 million. The US-based Mineral Policy Center, a non-governmental organization (NGO), suggests that it will cost US$50–60 billion to clean up abandoned mine sites in the US alone.[49]

Paying for the Legacy

One way to create a credit in the current natural capital account would be to deal with the worst environmental problems at abandoned mine sites. Improving these sites could create benefits, which could offset or perhaps even exceed any deficits attributable to current operations. And at some of these sites even a relatively small investment can have a big environmental payback.

It would clearly be in the interest of the industry to get this done. These sites are effectively advertising against the industry. In some places, they are highly visible and effective advertising. It might be that a dollar spent in reducing the amount of this kind of advertising might be more effective than one spent on promoting positive corporate image.

The issue is who will pay the costs. Good economic policy suggests that identifiable environmental costs be internalized on one principal condition: that all other companies have to do the same. If a company fails to obey the law, penalties should be used to make it comply. At the other end of the spectrum, the only prospect for cleaning up a historic mine site is with public funds.

Between these clear cases, there is a wide range of intermediate scenarios based on how long ago the mine was abandoned, whether the laws applicable at the time were complied with, who owns the site now, and the succession of companies operating it. (See Table 10–1.) In some cases of US litigation, such as the Smuggler Superfund proceedings, millions of dollars have turned on whether a modern company is the successor in interest to a firm that operated a particular mine many decades ago.

It may still be difficult to make the polluter pay even for recent mining operations. In industrial and developing countries, there are sometimes quite different attitudes and values towards past liabilities for environmental damage.

This raises the question of the source of public funds. One option is to take the money from general government funds. This might be equitable if most of the minerals were used within national borders – and assuming that the use of mineral products is distributed roughly according to the payment of taxes. On the other hand, many poor countries, including ones with significant adverse legacies, cannot afford this.

Alternative ways of generating a fund for abandoned mine work are discussed in Chapter 16.

Priorities for Action

Clearly, far too little is known about the extent of mining's environmental legacy or what it would cost to remedy the problems. But these uncertainties are no excuse for inaction. The worst sites have already been identified: they are fairly hard to miss. There is plenty of work to be done while the parameters at the less blatant sites are debated.

The first global priority must be for the public authorities to identify and register abandoned mines and assess the risk they pose. Given the scale of the problem and the limited capacities of public agencies, they will need to establish priorities – the registration process, for example, would need to be set beyond some agreed threshold of mine size. They would also have to concentrate the immediately available resources at the most dangerous sites, where clean-up will offer the greatest benefits.

The second priority at the national and international levels should be to develop new funding mechanisms that will be sufficiently robust and sustainable to tackle problems that will be a burden on future generations.

Table 10–1. Possible Allocation of Responsibility for Dealing with Mining Legacies

Scenario	Responsibility
Ancient mine workings.	Rehabilitation with public funds.
Historic mine with no identifiable owner.	Rehabilitation with public funds.
Mine closed and former operator can be identified, but no longer owns the site.	Former owner could be liable or rehabilitation could be a public responsibility.
Mine closed but former owner still owns the site.	Owner/operator is responsible for preventing damage to neighbouring property and controlling hazards.
Mine is still operating.	Owner/operator is responsible through an agreed closure plan.
Operating mine early in project life.	Owner/operator is responsible through an agreed closure plan
Permits granted but no operations have yet started.	Costs fully internalized to the extent current scientific and technical understanding permit.
Mine has not yet received necessary permits.	Costs fully internalized to the extent current scientific and technical understanding permit.

Environmental Management

Environmental Impact Assessment

Environmental impact assessment (EIA) is perhaps the most widely used tool of environmental management in the minerals sector. This is due in part to people in the minerals sector and in the World Bank who have been instrumental in spreading its use. Even in its origins, social and economic factors tended to creep into this environmental exercise. This is now being deliberately promoted with the development and integration of tools such as social impact assessment (SIA) and cost-benefit analysis into the EIA process.

The need for EIAs is well established, and they are now mandatory for most large-scale development projects. (See Box 10–7.) However, their implementation is often poor. One of the core problems is that the international community has yet to set firm technical standards on, for example, gathering baseline hydrological data, assessing archaeological remains, predicting acid drainage, or identifying key flora and fauna. This uncertainty allows EIAs to drift down to the lowest common denominator. It also discourages professional excellence. Reputable consultants who insist on sound methodology in carrying out such assessments find it difficult to compete on price with people who are willing to take short cuts – especially if regulators are not sufficiently well informed to be able to reject substandard work.

Box 10–7. EIA Leads to Mining Refusal in South Africa

The eastern shores of St. Lucia Lake in South Africa contain valuable reserves of titanium, and in the 1970s and 1980s the government granted mining rights to Richards Bay Minerals. In addition, this area of forested dunes is a valuable source of biological diversity. In 1986 it was designated as a wetland area of international importance within the International Convention on Wetlands.

Between 1989 and 1993 the post-apartheid government in South Africa undertook an environmental impact assessment. The research was entrusted to over 50 scientists and other experts and was presented in the form of individual reports that were commented on by the various stakeholders. A Review Panel was charged with using this information to determine whether mining would be compatible with nature conservation and tourism. As a result of this rigorous exercise, mining permission was refused and in 1999 the area was declared a World Heritage Site. Not all believe that this was the ‘right’ decision, given South Africa’s current economic situation.

Source: Porter (2000); King (2000).

Environmental impact assessment has proved a successful tool and has been expanded to include social concerns – sometimes within the EIA process, sometimes in a separate SIA. There is now considerable interest in ensuring that other issues, like the potential for spreading HIV/AIDS or for local economic development, are included in the assessment.
An integrated impact assessment should incorporate analysis of all relevant variables in a single coordinated process. (See Chapter 9.)

Environmental Management Systems

To gain the full benefits of an EIA, it should become part of an environmental management system (EMS) that seeks to integrate environmental responsibilities into everyday management practices through changes to organizational structure, responsibilities, procedures, processes, and resources. An EMS provides a structured method for company management and the regulating authority to have awareness and control of the performance of a project that can be applied at all stages of the life cycle – from identification of a deposit to mine closure. The stages in an environmental management system cycle are:

- organizational commitment,
- environmental policy,
- socio-economic impact assessment,
- environmental impact assessment,
- community consultation,
- objectives and targets,
- environmental management plan,
- documentation and environmental manual,
- operational control and emergency procedures,
- training,
- emissions and performance monitoring,
- environmental and compliance audits, and
- reviews.

The EMS is a repetitive cycle, with each stage being continuously revisited and improved on each visit. Although it is designed as a tool for the company, an effective system provides an easy way for the regulatory authority to check compliance. The responsibility for setting up and running an EMS lies with the company.

Compliance with the EIA can be monitored through an EMS.

Best Practice

The mining industry operates in a highly dynamic business climate that increasingly demands successful adaptation to changes in social values and public expectations of corporate behaviour. At the corporate level, respect for both the physical and social environment is now considered to be an essential element of good business practice. (See Box 10–8.) Most major mining companies are committed to the continuous improvement of their environmental and social performance, often going beyond the legal requirements to include voluntary industry codes of practice and management systems.

At the international level, for example, ICME established an Environmental Charter that was developed and endorsed by its members. The charter originally encompassed environmental stewardship and product stewardship. Following consultation with its stakeholders, ICME adopted a Sustainable Development Charter. At the national level, in 1996 the Minerals Council of Australia launched a Code for Environmental Management on behalf of the Australian minerals industry. This code was reviewed in 1999 and has recently been revised. (See Chapter 14.)

At the 'local' level, the method and level of interaction between the company, the regulatory authorities, and the community can be critical to the success of the project. At the Lisheen mine in Ireland the company, Anglo American, spent five years collecting baseline data and communicating with the relevant groups in order to design a project that was acceptable to all and met the legislative requirements. (See Box 10–9.)

Box 10-8. What Is Best Practice?

The concept of best practice dominates discussion of improving environmental performance in the mining industry and making decisions on waste management options and mine closure more inclusive. Unless the meaning of best practice is agreed on, however, the term is meaningless and its use is often misleading. Best practice may be defined as the methods and techniques that have proved to lead to successful outcomes through their application, but different interest groups will almost certainly have different views of what constitutes 'success'.

Box 10–9. The Lisheen Zinc/Lead Mine in Ireland

Before construction could start on the Lisheen mine the company had to obtain a planning permit, an Integrated Pollution Control (IPC) Licence, and a mining lease. They also had to convince the local community and the regulatory authorities that a mine at Lisheen would bring considerable benefit to the region and not cause any environmental damage. The mine is located in the rural heartland of Ireland.

The main areas of concern were the deposition of tailings and the potential contamination of the groundwater.
It was agreed that 51% of the tailings would be mixed with cement and used as backfill underground, while the remaining 49% would be deposited in a fully lined tailing storage facility located on a peat bog. The company also undertook to sink replacement boreholes for the farmers. Before granting the IPC Licence, the authorities required the company to lodge a bond worth in excess of US$16 million to pay for closure and rehabilitation costs.

The company decided to adopt a policy of transparency, and held meetings and consulted some 20 local groups. As a result, the company received positive support from the local communities and the licences were granted without the need for a public hearing.

Source: MEM (1998); Stokes and Derham (2000).

However, this level of commitment is often due to the personality of one individual and the continuity may be broken when that person leaves the project.

In addition, many international organizations, such as the UN, the World Bank Group, the World Health Organization, and financial institutions now have their own operating guidelines that include environmental and social issues. However, there does need to be a push for higher standards in the production of an EIA and for the incorporation of the EIA into an EMS. This will make a major contribution not just to better practices in mining, but also to sustainable development generally.

Risk Assessment and Emergency Response

Risk assessment and management are becoming increasingly important in the development of a mining project, where the uncertainties associated with environmental (and social) prediction are potentially higher than those of other industrial sectors. The process of risk management incorporates many different elements: from the initial identification and analysis of potential risks to the evaluation of tolerability and the identification of potential risk reduction options through to recommendations regarding the selection, implementation, and monitoring of appropriate control and reduction measures.

Although risk assessment has a wide application in the mining industry, there would be little value in investing in detailed risk analysis if the potential outcomes did not influence development or operational decision-making. Recent catastrophic failures of a number of tailings storage facilities have shown that in many cases the response bodies, the community, and the companies were not fully prepared to deal with such emergencies. In response UNEP has published an Awareness and Preparedness for Emergencies at a Local Level handbook for mining (known as APELL).[50] This publication is aimed at improving emergency preparedness in the mining industry, particularly in relation to potentially affected communities. It looks at a number of hazards and risks and identifies 10 steps required to prepare adequately for an emergency.

Recommendations on Managing the Mining Environment

These recommendations should be read in conjunction with those in Chapter 16, which contains the integrated Agenda for Change.

- *Large-volume waste* – The International Council on Mining & Metals (ICMM) and other appropriate convenors such as UNEP should initiate a process for developing guidance for the disposal of overburden, waste rock, and tailings and the retention of water. This should be incorporated into the industry Sustainable Development Protocol proposed in Chapter 16. The views of all stakeholders should be solicited from the outset for the design of this process. Long-term and short-term risk assessment and financial considerations should be included.
- *Land disposal* – The mining industry should re-examine its land disposal practices to include alternative uses for waste, and the long-term future of the site. An integrated approach should be taken to water management, including water supply, dewatering activities, tailings, and heap leach water management.
- *Management of tailings facilities* – The industry should establish a method of international certification for the designers of tailings storage facilities. Governments and funding agencies should require regular independent audits of all tailings storage facilities and establish a method of implementing the findings of the audit.
- *Marine disposal* – Industry, governments, and NGOs should agree on a programme of independent research to assess the risks of marine and, in particular, deep-sea disposal of mine waste. A shared and reliable information base on which optimal decisions can be made is required.
- *Riverine disposal* – A clear commitment by industry and governments to avoid this practice in any future projects would set a standard that would begin to penetrate to the smaller companies and remoter regions where this is still accepted practice. Whether that is done in the context of a protocol process or otherwise, industry is more likely to accept this idea if it gains confidence that other options will be looked at on their merits.
- *Consultation* – Before a mine proposal is accepted, all concerned – especially the local community – should be consulted on the proposed development. (See Chapter 9.)
- *Capacity* – A source of technical expertise and advice must be made available to government, insurers, communities, companies, and others to ensure that they can build their capacity for best practice.
- *Monitoring* – Industry, government, and other stakeholders should establish the best method of conducting environmental and socio-economic monitoring and of incorporating the results into the management of environmental and socio-economic impacts.
- *Legislation* – Industry, government, and other stakeholders, perhaps under UNEP auspices, should prepare best practice guidelines for all aspects of environmental and social issues. These guidelines should include, but not be limited to, mine closure in the context of sustainable development, acid drainage, tailings management, and risk assessment and emergency planning.
- *Lenders* – All lenders, including funding agencies and multilateral banks, should encourage more rigour in dealing with closure issues in mining proposals. This should include a well-developed closure plan that identifies the resources that will be required and a system of independent review.
- *Abandoned sites* – The industry should cooperate with international organizations and bilateral donors to develop an inventory for abandoned mines and identify sites for priority action.

- *Funding mechanism* –A funding mechanism should be developed to pay for remedial action programmes at abandoned sites. Alternative funding mechanisms are discussed in Chapter 16.

Associated Environmental Issues

Energy Use in the Minerals Sector

Responsibilities in the Minerals Sector

The current level and pattern of energy use is a critical factor affecting global environmental conditions. Climate change is a central concern for sustainable development. It has the potential to cause major impacts on the productivity of ecosystems and is hard to reverse once established.

Current scientific data indicate that human activities have modified the global climate over and above what may be associated with the fluctuations caused by natural cycles. The signing of the Framework Convention on Climate Change in 1992 was a turning point in public and inter-governmental awareness of this potential. Since then, mounting scientific evidence shows that a root cause of global climate change is gases emitted from the burning of fossil fuels and other sources, such as the release of methane gases from agriculture and oil and gas production.[51] It is widely acknowledged that developing countries will have the least capacity to adapt to a climate change.

Responsibilities for these problems are shared among the public and private sectors. Governments, industry, and the public in the most industrialized countries play a key role in both contributing to global energy use and providing policies for addressing the resulting problems. Currently, some companies in the oil and gas industry (such as BP and Royal Dutch Shell) are addressing this issue and have reaped financial benefits from proactively establishing greenhouse gas reduction programmes.

There are many reasons why the minerals sector is particularly implicated in the aspects of potential global environmental change that are related to energy use:

- Production of mineral commodities from primary sources involves the movement and processing of large volumes of material, all of which requires a source of energy.
- Many finished products that depend on mineral commodities to function consume considerable amounts of energy, such as motor vehicles and electronic goods.
- Due to its energy requirements, the mining and minerals industry may influence decisions about investment in power sources.
- Several mineral commodities, most notably coal, are used as fuels.

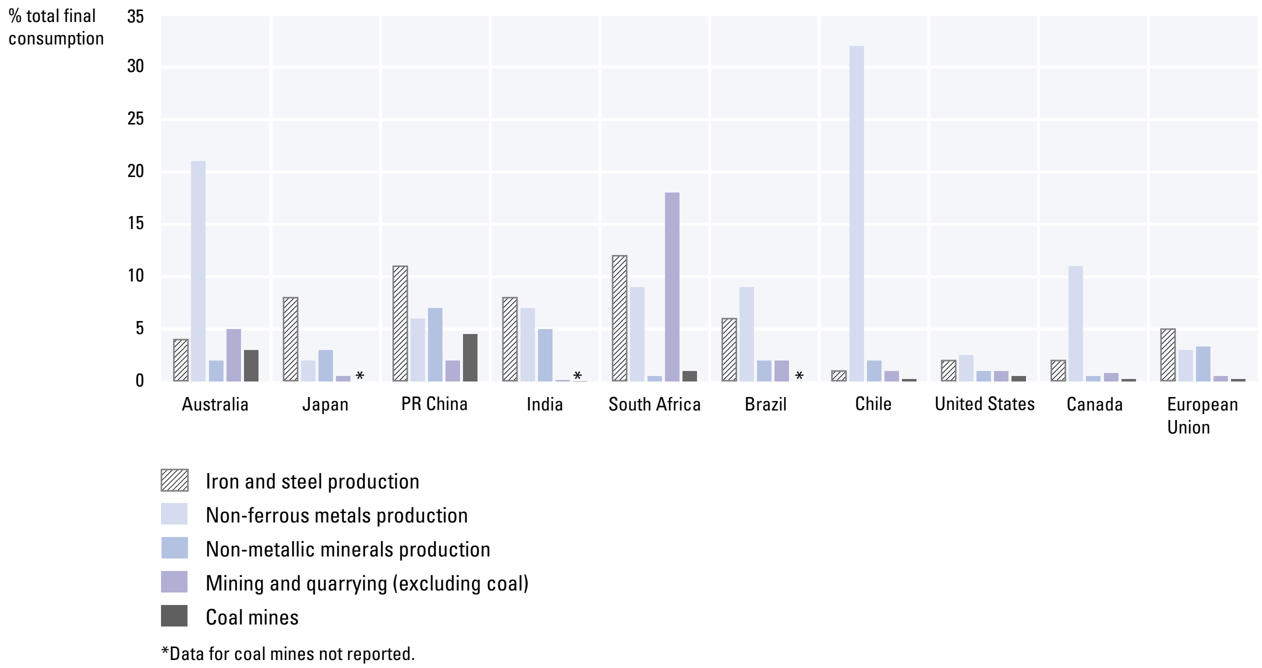
The last of these reasons is of profound importance for sustainable development and has already been the subject of a critical debate among NGOs, industry, academics, and energy policy specialists. Despite its importance, this issue is beyond the scope of this report for two reasons. First, in the limited time available, involvement in these issues was beyond project resources. Second, there were already a number of participatory processes, some of them larger than MMSD, looking at these specific issues, and it was unclear that MMSD could add anything significant to the ongoing debates.

Although it is sometimes said that 4–7% of global energy demand comes from 'mining', the boundaries are not sufficiently defined to determine an accurate universal figure.[52] The best estimates relate to individual mineral commodities, but even then the figure depends on where and how they are produced. Estimates of use of energy through the whole minerals cycle are even harder to develop.

Figure 10–3 illustrates some of the variation among countries in the importance of electricity consumption in different minerals industry sectors. Total electricity consumption in mining and quarrying by countries in the Organisation for Economic Co-operation and Development (104,000 gigawatt-hours) is comparable to that of rail (89,000 gigawatt-hours).[53] Electricity is, of course, only one of many forms of energy used in these industries. Put together, the five minerals industry divisions used 11.3 million tonnes of diesel in 1998, which is only 4% of the total used in road transport (286 million tonnes).

The impact of electricity production on climate change depends to a significant extent on the source of the power for electricity; if electricity is primarily produced in coal-fired plants, then the impact is greater than if it comes from some renewable sources.[54]

Figure 10–3. Percentage of Total Electricity Consumption Used by Mining and Minerals Industries, Selected Countries and the European Union, 1998
Source: IEA (2001a) and IEA (2001b)



Energy Efficiency in the Production of Mineral Commodities
The minerals sector has a critical interest in reducing its use of energy per unit output, because of obvious implications for production costs. Depending on the specific operation in question, energy costs for different unit operations vary considerably in relation to total operating costs. For minerals processing, it may be up to one-quarter of the total. (See Table 10–2.) Considering the whole process of making primary aluminium, expenditure on energy may account for one-third of the total cost of production.[55]

During the twentieth century, the sector achieved dramatic advances in energy efficiency by means of technological innovation. Over the last 50 years, for instance, the amount of energy required to produce 1 tonne of primary aluminium has decreased by 40%.[56] Motors and pumps used for minerals extraction have become more efficient. The target is not, however, just to increase the efficiency with which energy from any one source is used. A key priority is to reduce direct and indirect releases of greenhouse gases. Mitigation options vary between different sectors of the industry. In the case of aluminium, iron, and steel, there is a diverse set of emission sources, including both power generation and process-oriented ones. Security of supply is a critical issue to consider in the selection of energy sources.

The future role of technology in reducing emissions within minerals businesses is discussed in Chapter 6. There are, however, a large number of options for increasing the efficiency of current production processes. These range from relatively straightforward updates of portable mine site equipment (see Box 10–10) to those that depend on significant long-term capital investment and policy changes affecting the industry (see Box 10–11).

The price of energy may increase as a result of commitments made at government level under the Kyoto Protocol (part of the Framework Convention on Climate Change). This may be either because of the switch to low-carbon energy sources or because of the need to pay carbon taxes or purchase emission permits. Energy price increases could mean that pressures to cut costs in the minerals sector may become even greater in the future. Cost increases could range from 10%

Table 10–2. Estimates of Energy Costs as a Share of Total Operating Costs, Selected Ore Mining Operations (based on US price data for 1999)

Type of operation	Detail	Size of operation	Percentage of operating costs		
		(tonnes per day[a])	Fuel	Electricity	Total
		Ore output			
Surface mine	Stripping ratio 1:1	1000	0.3	6.4	7
	Stripping ratio 8:1	8000	2.1	8.7	11
Underground mine	Room and pillar adit	8000	nd	nd	6
	Room and pillar shaft	8000	nd	nd	5
		Feed input			
Hydrometallurgical mill	Cyanide leach mill	2000	nd	nd	27
Flotation mill	one concentrate product	1000	0.0	27.5	28
	three concentrate products	8000	0.0	28.4	28

[a]Estimates are only approximate as they are based on only one group of theoretical models for mine costs.

Source: Schumacher (1999), with the help of additional decoding by O. Schumacher nd: not determined.

Box 10–10. Cost and Energy Savings from Basic Technology Application

The Blue Circle Aggregates Lithonia Quarry in Georgia, US, produces 1 million tonnes per year of aggregate and manufactures sand for construction and road building. Based on an assessment conducted by the George Institute of Technology, the quarry implemented a series of motor system upgrades, which reduced the energy use of 4 million kilowatt-hours by 6.2% and cut the electricity demand of 500 kilowatts by 16%. This saved the company US$21,000 per year.

The greatest energy savings resulted from reducing the capacity of three large water pumps and changing the source from which they drew water. A second modification was simply to physically lower another pump by 25 metres. This particular upgrade had a simple payback of 1.5 years. A third innovation was to replace four motors with more efficient versions once they reached burnout. It is predicted that this will have an average payback period of about 2.4 years.

Source: US Department of Energy (1999).

Box 10–11. Energy Efficiency in India's Primary Aluminium Sector

Although aluminium production accounts for only 0.5% of the value of output within the manufacturing sector, it is one of the most energy-intensive industries in India. In 1993, its share in total fuels consumed was 2.6%. Energy costs in this sector are the highest of all manufacturing sectors in India, from 35% of total production costs upwards. Aluminium demand is expected to increase to 1.06 million tonnes in 2006–07. In order to sustain competitiveness for both internal and export markets, retrofitting and efficiency improvements have been undertaken, based on state-of-the-art technology. Despite this, a detailed study of the productivity of the aluminium industry in India has estimated that energy-saving potentials of 20–40% could be achieved at some alumina manufacturing plants. At the smelting stage (conversion of alumina to aluminium), energy saving potentials range from 16% to 30%. The barriers to energy efficiency concern access to capital, lack of information on the savings and benefits of the required technologies, and national policy changes affecting the industry.

Source: Lawrence Berkeley National Laboratory; Schumacher and Sathaye (1999) p.31.

to 50%, and may have a major impact on mining company cost structures and competitiveness.[57] This will produce winners and losers, since companies that increase their energy efficiency most rapidly will gain a competitive edge. There will also be shifts at the international level. Companies mining in the most industrialized countries will feel the impact first under the Kyoto Protocol, while those working in many developing countries will not be subject to limits for the next decade or so.

For the extraction of metal ores, one of the greatest challenges for energy efficiency is that of declining grade. Lower grades inevitably require greater amounts of material to be moved per unit of product. In this context, it is important to acknowledge that the amount of metal in recyclable materials is often greater than the ores currently being mined. Key challenges to advancing recycling for mineral commodities are discussed in Chapter 11. Once collected and sorted, the production of scrap metals often requires a fraction of the energy used in production from primary sources.

Making the Use of Mineral Commodities More Energy-Efficient

As highlighted in Chapter 2, mineral commodities are fundamental components of numerous products, and thus play a significant role in global energy use by enabling the existence of a product in the first place and by making products more or less energy-efficient.

The energy efficiency of products has significant implications for the amount and type of metal used. The way in which mineral commodities are used also has significant implications for their re-use. Product design for recycling, re-manufacture, or extended product life has significant implications for energy use. Clearly, product designers, recyclers, and manufacturers need to work together much more effectively to exploit the business opportunities provided by this. Manufacturing processes can be substantially improved in order to avoid waste material being generated (whether or not it is then recycled).

In some cases, greater energy efficiency for some products may result in the use of greater amounts of a mineral commodity. (See Chapter 11.) Increased emphasis on efficiency in the use of electricity is likely to increase the demand for copper, as more-efficient electric motors have a higher amount of copper winding.[58] Energy efficiency can be increased through the use and application of metals – such as the use of zinc in increasing the durability of steel through corrosion protection and the better energy efficiency of electrical equipment achieved by increasing mass or volume.

Recommendations on Energy Use

- Initiate a global advisory body to address the lack of comprehensive, consistent, and regular data on energy use in the mining and minerals industry and the role of recycling. This body should make recommendations to all minerals and mining trade groups publicly available. It should assess the best means of making non-proprietary, audited data concerning energy use in the minerals sector available to the public.
- Convene a task force to report on the implications of climate change policies for the safety and security of mining and minerals processing operations.

Managing Metals in the Environment

A number of metals are of great environmental concern because of their potential chemical toxicity. These concerns extend to metalloids – non-metallic elements, such as arsenic, that in some respects behave like metals. Indeed, the toxic properties of many metals and metalloids have been exploited in the design of pesticides or antiseptics. For many people, the fear of harm is as important as the damage they know has been caused. This is a significant issue with respect to risk communication and may have social and economic consequences. For example, the value of land is depreciated if there is a risk of contamination. It is therefore possible to argue that metals and metalloids can reduce natural capital not only through their toxic action and persistance, but also by their presence at concentrations that cause unease.

Many opinions are rooted in the catalogue of infamous incidents where metals and metalloids have, beyond reasonable doubt, caused serious human health effects. One such case was the debilitating bone disease called *Itai itai* ('cry of pain') that broke out among people in lower part of the Jinzu river basin in Japan. While the nutritional status of the people was an important factor in determining the magnitude of the disease outbreak, a significant underlying cause was cadmium discharged to the river from a lead-zinc mine. River water was used to irrigate rice crops, which accumulated high concentrations of this element. Consumption of the rice was an important cadmium exposure route for the people of the area.[59]

There are numerous other cases of concern. Among these are arsenic as a by-product of copper production in some parts of the world, and the effects of mercury on artisanal and small-scale gold miners. (See Chapter 13.) Concerns are, of course, not just restricted to sites of metals production. The use of lead in gasoline and paint (now phased out in many countries), which caused concentrations of this metal in blood to exceed health guidelines, is another example. The mercury pollution caused by discharges from a chemicals factory at Minamata, Japan, resulted in a shift in public perceptions of this element. Manufacturing processes, recycling, and waste disposal can be equally contentious because of the contamination they may cause. This includes occupational exposure, such as the respiratory diseases affecting workers involved in the processing of beryllium ores and production of the various chemical forms of this element.[60]

In many cases, the actual detection of toxic effects may not be relevant; it is the presence of a metal or metalloid above a threshold for the health of humans or ecosystems that causes the alarm or is used to cause alarm. As with all chemical hazards, demonstrating actual harm beyond reasonable doubt, and setting the thresholds, is an entirely separate and formidable task. Managing metals in the environment must involve dealing with scientific uncertainty and deciding on appropriate levels of precaution. This is not just the realm of scientists and politicians. Perceptions of the benefits of use of a metal, the merits of alternative materials, and the likelihood of mismanagement are fundamental determinants of the chance of harm. They also affect the willingness to act.

A key feature of most contamination and pollution incidents is that responsibilities for harm are poorly defined and slow to be taken up. This is often the case with the use of metals and metalloids, which can be released into the environment at all stages of the so-called minerals cycle. For instance, are mining companies responsible for the ultimate environmental fate of the materials they produce? Should recyclers accept a share of responsibility equal to the proportion of world demand that they supply? Clearly, the

Photograph not shown

problem is ensuring that all actors in the minerals sector clearly allocate and share responsibilities for managing the risk of harm.

Allocating responsibilities is no easy task. First and foremost, this is because metals and metalloids are naturally ubiquitous both above and below Earth's surface.[61] This is particularly true for mining areas, where ores have been present at or near the surface for millions of years. Furthermore, the absolute concentrations of any metal or metalloid are usually less important, in terms of the risk of harm, than the chemical and physical form in which it is present. Not all forms are bioavailable, and some forms may become more stable over time. However, some fear that the reverse is also true and promote the idea of 'chemical time bombs'.[62] Some metals have truly global cycles, and human modification of the environment (such as through acidification and climate change) can alter their behaviour without additional releases by humans. At the local and regional level, land use change can be equally important. The case of mercury in the Brazilian Amazon exemplifies this. Here evidence now shows that mercury concentrations in soils are greater than can be attributed solely to gold mining.[63]

Progress in the Management of Metals

The world has steadily learned more about the environmental chemistry of metals and metalloids.[64] Today's greater understanding has been the basis of a number of global initiatives to manage the production and use of these elements, including international forums on the safety and management of chemicals. Metals have also been the subject of international agreements, including the 1998 Heavy Metals Protocol of the Convention on Long-Range Transboundary Air Pollution (an international agreement that governs emissions and uses of lead, cadmium, and mercury) and the 2001 International Convention on the Control of Harmful Antifouling Systems (which controls the use of tributyltin on ships). An important part of all these efforts is maintaining up-to-date information systems. The International Union of Geological Sciences and UNESCO are making a global contribution to this with the International Geochemical Mapping Project. The International Council on Metals and the Environment (now ICMM) has played a role in encouraging work in the scientific community on assessing the risks to the health of ecosystems and humans associated with the production of these elements.

These, and a number of national efforts, have helped reduce some of the most harmful emissions. For example, the dispersion of arsenic has dropped significantly over the last two decades. In 1983, an estimated 10,000–15,000 tonnes were being released in Europe, the United States, Canada, and the Soviet Union.[65] But by the mid-1990s the total had fallen to around 3500 tonnes for the world as a whole.[66]

These gains have not been evenly shared, however. While, however many people in industrial countries benefit from reduced risk of exposure, there are still severe problems in many developing countries. These often relate to the legacies of contaminated mining sites, as in Southern Africa.[67] Acid drainage and the generation of mining wastes, discussed elsewhere in this chapter, are means by which some of this continues. The transport of materials also poses serious hazards, as demonstrated by the spillage of mercury on its way from Yanacocha mine in Peru.[68] Landfill sites containing batteries and electronic equipment continue to affect aquifers world-wide.

Strategies for Managing Responsibilities More Effectively

The list of technical requirements for managing the risk of harm caused by metals and metalloids is unending. For the mining and minerals industry, these relate mainly to acid discharges and atmospheric emissions. This section discusses strategies for managing metals in the environment more effectively; the focus here is on prevention rather than clean-up.

While there is a continuing role for penalties and incentives to reduce metal emissions, additional strategies are emerging to manage the risk of harm more effectively. The most recent is the growing interest in product-oriented public policy, particularly in Europe; the general usefulness and success of such a policy will have to be evaluated over time. One advantage of this policy is that it takes into account the entire supply chain, from extraction through processing and use to (if necessary) disposal. This 'cradle-to-grave approach', also known as life-cycle analysis, is discussed further in Chapter 11.

The precautionary principle (see Chapter 1) must lie at the heart of the management of metals and metalloids for sustainable development. Those advocating or exercising precaution in the light of uncertainty must do so on the basis of transparent and wide debate. Workers and communities are often simply unaware of the harm that may be caused or the possible impacts of a precautionary policy on their livelihood. It is important to appreciate that harm may be caused by exceptional cases of the mismanagement of products or materials (such as illicit dumping, transport disaster, or failure of a waste facility) rather than when policies and strategies of governments and businesses go according to plan.

There is clearly pressure on dispersive uses of metals, namely uses that put these metals into the environment in ways where they cannot be recalled, recovered, or recycled. Examples of dispersive uses that have been or are in the process of being phased out are many: lead in gasoline and paint, arsenic and mercury in fungicides, cadmium as a dye. These pressures come from two directions. First, there is the environmental concern that their presence in the biosphere will have negative effects on human health or on plants or animals. Second, there is the growing demand for stewardship over metals in use for reasons of resource recovery. Caught between these demands, the remaining dispersive uses will increasingly be questioned.

This approach should not be followed for all metals and metalloids without wider considerations. Many elements that are potentially toxic at high concentrations are also essential nutrients. Removing them completely from the environment would entail supplements in the human diet to replace them. This can be illustrated by the growing awareness of the dangers of zinc deficiency.[69] The approach so often followed with synthetic organic pollutants, for example, of recognizing no lower threshold of human health effects and assuming 'the lower the better' for environmental concentrations is not appropriate for elements that are ubiquitous in Earth and necessary for many forms of life.

Recommendations on Metals in the Environment

- ICMM should identify the priority areas of uncertainty regarding the contribution of the mining and minerals industry to the global cycle of potentially toxic elements. It should seek to initiate collaboration between industry associations, international agencies, and academia to ensure that such knowledge is generated and effectively communicated to all interested parties. The aim should be to establish links between specific sources and the likelihood of human health impacts or effects on ecosystem function.
- All industries associated with the metals life cycle must work together more effectively to ensure that data are available in order to undertake risk assessments for the uses of their products and by-products in society. This should be part of their product stewardship activities. Industry associations should play an active role in facilitating this.

Biological Diversity: Threats and Opportunities

Biological diversity (or biodiversity) is a critical part of our natural capital endowment. Defined by the UN Convention on Biological Diversity (CBD) as 'the variability of all organisms from all sources…and the ecological complexes of which they are part…[including] diversity within species, between species and of ecosystems', it is an abstract concept.[70] (See Box 10–12.) Biodiversity issues have been overlooked frequently in planning and decision-making, and the term has often been interpreted too crudely as the sum total of living things and the ecological processes associated with them. But it is much more than just 'goods' and 'services'. Biodiversity – and its inherent variation – fuels living organisms' ability to adapt (or to be adapted by an human intervention, such as plant breeding) within an ever-shifting environment. It is therefore best understood as the living world's capacity to change – variability – and the wealth of biological forms and processes that

Box 10–12. The Principal International Framework for Action on Biodiversity

The UN Convention on Biological Diversity is a key instrument of the global programme for sustainable development. It represents a concerted attempt to provide a legally binding policy framework for biodiversity based on international consensus. Now ratified by more than 180 countries, it provides the minerals sector with a politically sound basis for engaging in constructive dialogue and partnerships with the biodiversity community.

The CBD has three key objectives:
- the conservation of biological diversity,
- the sustainable use of its components, and
- the fair and equitable sharing of the benefits arising out of the utilization of genetic resources.

The CBD translates these guiding objectives into a series of Articles that contain substantive provisions on in-situ and ex-situ conservation of biodiversity; the provision of incentives for the conservation and sustainable use of biodiversity; research and training; public awareness and education; assessment of the biodiversity impacts of projects and minimization of adverse impacts on biodiversity; regulation of access to genetic resources; access to and transfer of technology; and the provision of financial resources. Most of these provisions are equally applicable at a mine site, to a government department's work programme, or at international level. Thus the CBD provides governments, NGOs, and the private sector with a most useful conceptual framework.

The CBD has established institutional arrangements for its further development and monitoring of progress. The key institutions include the Conference of the Parties, which meets biannually; the Subsidiary Body on Scientific Technical and Technological Advice; and a Secretariat. Industry bodies can attend CBD-related meetings as observers.

Other relevant legislation at international, regional, and national levels that needs to be taken into consideration includes the RAMSAR Convention on Wetlands of International Importance and the World Heritage Convention.

Source: The Convention on Biological Diversity (1992). For the definition of biodiversity see Article 2 of the Convention. See also Secretariat of the Convention derive as a result – variety. Biodiversity is therefore found everywhere, albeit in different concentrations and configurations.

Biodiversity's critical value lies in the choices or options that it supports, for both present and future benefits – whether this relates to the alternative food sources it provides, to the range of bio-chemicals and processes that underpin modern and traditional medicinal products, or to the way it increases the resilience of the biosphere's myriad natural processes, from pollination to watershed protection. Humans are all somehow dependent on biodiversity, so its loss is likely to affect everyone. But those most likely to suffer the consequences of biodiversity loss are indigenous peoples' or rural dwellers, many of whom continue to remain directly dependent on wild habitats and natural ecosystem services for their entire livelihood needs, whether by choice or through lack of alternatives.[71]

In the past, trade-offs between human activities and biodiversity were made unconsciously – some land was set aside for strict protection, irrespective of impacts on local populations, and the rest was converted to other uses, irrespective of any biodiversity loss.[72] Today the context of operations has changed dramatically. Escalating populations and consumption needs are placing ever-greater demands on land and natural resources; protected areas – which have been the principal biodiversity conservation instruments – unable to withstand these mounting pressures suffer regular encroachments, whether through agriculture, forestry, fishing, or mining-related activities. It is clear that protecting these areas will not conserve biodiversity if the rest of the land base is poorly managed. Thus the focus of attention must fall as much on addressing all three objectives of the CBD, or biodiversity's 'triple bottom line' – conservation of biodiversity, sustainable use of its components, and equitable sharing of the benefits arising from its use – as on all three dimensions of biodiversity (ecosystems, species, and genes). The CBD framework can therefore help link biodiversity much more effectively to the economic and social dimensions of sustainable development.

Encroachments into protected areas have, however, raised many controversial debates related to land access and ownership (see Chapter 7) and what is considered 'best' for biodiversity conservation. Community conservation has been promoted as an alternative – and complementary – approach on lands held outside or adjacent to protected areas. But there are many policy and institutional issues constraining its wider adoption. On the more technological side there is ex-situ conservation, which focuses on the collection and storage of specimens in gene banks, zoos, or botanical gardens. There is much the mining sector could do to support such approaches further, in concert with other sectors, in addition to mitigation of their direct impacts on all biodiversity wherever it is found.

Clearly, much more still needs to be done if such biodiversity is to be maintained. Although the CBD demonstrates a growing commitment towards the cause, its implementation is constrained by, among other things, a serious lack of resources, inappropriate economic tools and incentives, and insufficient capacity, especially in developing countries. The minerals sector has a key role to play in biodiversity maintenance, given that some mining ventures can eliminate entire ecosystems and all their endemic species and that its activities are increasingly prolific in relatively undisturbed high-biodiversity-value areas.[73] Lasting success, however, will depend on coherent remedial actions of all sectors, including economic planning, agriculture, fishing, energy, infrastructure, and tourism. It will also depend on wealthier consumers' understanding of the social and ecological impact of their consumption patterns.

Identifying Areas of Valuable Biodiversity

Not all areas are of equal biodiversity conservation concern. Thus any 'intrusive' sector, be it agriculture, mining, commercial logging, or infrastructure, must be informed on the specific locations of zones of greatest biodiversity value or most critical conservation concern, so that appropriate mitigation measures can be taken. Biologists and the conservation sector invest heavily in such identification and priority-setting exercises, and at the global level there are now various descriptions of global biodiversity priority areas based on different approaches such as hotspots, endemic bird areas, important plant areas, and eco-regions.[74] Some of these coincide with protected areas; others do not. The conservation sector has, however, singled out protected areas (IUCN Management Categories I–IV) and UNESCO World Heritage Sites as areas to be avoided by the mining sector at all costs. This recommendation has raised many difficult dilemmas. (See Chapter 7 for more detailed information on mining and protected areas.)

While such priority setting exercises are a useful first approximation, they are not always spatially coincident, and they use different proxies for biodiversity, making it difficult for outsiders to know which to give priority to. Scientists disagree about which proxies to adopt, mainly because biodiversity per se cannot in all its complexity be quantified by any known all-embracing measure, and knowledge of it is constantly evolving. Given that everyone has different interests in and understanding of biodiversity, whether any chosen proxy is the 'right' one is always open to debate. For instance, aspects of biodiversity that have compelling value to one group may mean little or nothing to another: a hunter-gatherer's view of which plants warrant conservation may vary markedly to that of a western botanist or a specialist in traditional Chinese medicine. Selection of proxies is therefore predicated on value judgments and scientific assumptions about which facets of biodiversity matter more than others.[75]

Global mapping exercises have also proved too coarse a resolution for use in local land use planning or zoning. At the same time, valuable information that is available at the site-specific level has often not been systematically catalogued or peer-reviewed and is not therefore accessible to decision-makers. Innovative mechanisms, such as the use of the internet, for peer review of such data and for ensuring that it remains within the host institution's memory are necessary, especially given the rapid decline in the availability of resources for systematics and ethnobiological survey activities.

Progress in presenting more coherent and up-to-date thinking on priority biodiversity conservation areas and methodologies for their identification and assessment have also been seriously hampered by progressive underinvestment by the public sector in a number of related research areas, particularly in systematics and taxonomy (the identification and enumeration of different species). Only 1.7 million species have yet been named out of a possible 20–100 million.[76] Existing taxonomic expertise is also skewed towards certain groups such as mammals rather than invertebrates or the plant kingdom. Links between western and indigenous classification and assessment mechanisms are weak as well. Governments in both industrial and developing countries have lost interest in such activities and are at times openly sceptical about their importance. Perhaps there is some cause for scepticism – especially in the developing-country context where other demands on already scarce resources are intense – but it may also stem from inappropriate previous public support for this discipline.

The consequence is that many scientific institutions that previously housed invaluable expertise, herbaria, or zoological collections have run short of finance, and irreplaceable knowledge and data have been lost. Such information gaps produce uncertainty, and it is impossible to draw conclusions about what is being lost – or the consequences. At the same time, the funding and execution of survey, research, and publication on biodiversity has been largely taken over by international NGOs, multilateral agencies, and the private sector. (See Box 10–13.) While such institutions should continue to play a key role in these activities, they need strong central coordination and independent peer review. Otherwise, individual agendas are likely to dominate, reducing the objectivity of science.

How Mining Affects Biodiversity

Measuring the impacts of mining and biodiversity – and defining their effects and implications – also presents certain challenges, for reasons similar to those described in the preceding section. When assessing impacts on biodiversity, the key question is, Which proxy is best, as not all species are of equal value? Some species will increase, others will decrease, and some will not change at all following mining disturbance (assuming the entire ecosystem is not being removed). And peoples' perceptions of the effects of these changes will also vary. The proxies most commonly selected are rare, endemic, or threatened species, or protected areas, and there are good reasons why these are chosen. But they are by no means representative of all biodiversity. In conducting biodiversity impact assessments and drawing conclusions about their implications, it helps to articulate clearly which proxy was chosen and why. There also needs to be thorough analysis of whether or not the 'new' combination is better, worse, or unchanged, and for whom.

The mining and minerals sector is not necessarily the most important influence on biodiversity in a particular region. Figures released by the National Parks and Wildlife Service in Australia suggest that mining was responsible for 1.1% of presumed extinctions of endangered plant species, compared with

Box 10–13. Partnerships in Biodiversity Survey and Research

Partnerships between companies and research institutions could provide some interesting new opportunities for biological and ethno-biological research. When companies explore for minerals they are often entering pristine regions, unexplored by science. Given the current public funding crisis, there is clearly potential for greater cooperation between researchers and mining companies – not just for providing financial resources but for the necessary access and infrastructure that rigorous survey and research activities require. While the time frames may not always coincide, especially at the exploration stage, the potential should not be rejected.

An interesting example for such industry support to science is a series of studies funded by PT Freeport Indonesia (a subsidiary of Freeport-McMoRan Copper and Gold Inc. and Rio Tinto plc) during the 1990s in the company's area of activity near the Lorenz National Park in Indonesia. A highly controversial mine by many accounts, this operation has managed to make a major international contribution to increasing understanding of the flora of New Guinea through the collection of materials of poorly known species and of species new to science. About 5600 plant collections now form the basis for the database of 9500 collections. Eight papers have been published describing new species, and the total number of species estimated from the region is 8400, with 500 or more occurring at over 3000 metres. Of the estimated species in the area, probably less than 40% are found in Kew Gardens' collections.

None of this valuable information would have been created if not for the support of PT Freeport Indonesia. Many will certainly argue that this simply cannot offset the mine's social and environmental impacts. Certainly the trade-offs have been enormous, and the benefits of biological information generated are small in comparison. Still, there are some opportunities here that, even in apparently adverse circumstances, could yield collateral benefits to science if suitably pursued.

Source: Dr Robert Johns, Herbarium, Royal Botanic Gardens, Kew.

38.2% attributed to grazing and 49.4% to agriculture.[77] Nevertheless, mining does almost always have an impact on biodiversity; in some cases the effects can be huge and, where global extinctions are at stake, they can be irreversible. Surface mining often results in total clearance of vegetation and topsoil, often leading to accelerated desertification, and while better-managed operations make provisions for rehabilitation, mining impacts can be more far-reaching than those of other sectors.[78] There is a great deal of detailed published material on the impacts of mining on biodiversity and natural ecosystems, including Conservation International's Guide to Responsible Large-scale Mining, IUCN and the World Wide Fund for Nature's review of mining and forest degradation in Metals from the Forest, the Minerals Policy Center's review of the damage hardrock mining has done to US aquatic ecosystems, and the Australian Minerals and Energy Environment Foundation's contribution to the MMSD project, not to mention the many relevant academic and company-sponsored papers.[79]

Generally, the greatest risks to biodiversity are when mining ventures enter relatively remote and undisturbed areas. The very act of building access roads for exploration purposes brings significant risks to biodiversity – as the raised expectations of potential large-scale benefits often trigger rapid in-migration. Large-scale biodiversity loss occurs as colonizers must clear land for settlement and farming and take out economically valuable wild species to supplement their income or for food. (See Box 10–14.) Sometimes new people and activities in an area can also bring in alien pests and diseases that have hugely detrimental effects. It is worth noting that this may all be at its most intense before mining starts and before any major mining company is on the scene, and activities are frequently ungoverned and unregulated. In cases where the mine does not get developed, such activities frequently continue unabated, as there are few alternative livelihood sources to fall back on.

'Junior' exploration companies – which may not be involved in mining at all – do a great deal of the world's exploration. In areas of emerging mineral interest, there may be many such companies on the scene. Given that grassroots exploration is high-risk and capital-intensive, with finance often hard to get, success can depend on speed: getting in, getting results, and getting out, with a minimum number of days of drill crews in the field. It may also depend on not letting competitors know what is being surveyed or where. This can present distinct challenges for mitigating negative impacts, as dealing effectively with intense bursts of mineral interest, where multiple actors are moving quickly and into remote areas far from government scrutiny, is a daunting task. Furthermore, instituting evaluation and permitting processes can lead

Box 10–14. Coltan and the Conservation Crisis

Until relatively recently, few people had heard of columbite-tantalite ore or 'coltan', which contains the rare metals tantalum and niobium that are widely used in the manufacture of capacitors for electronic devices. (See Chapter 11.) Between 1997 and 2000 the price of coltan rose from US$100 to US$800 per kilo. Significant deposits of this ore are found in the east of the Democratic Republic of the Congo, where it is easy to extract from shallow pits using picks and shovels.

The result has been a modern-day 'gold rush' into this region. This has triggered a dramatic decline in the wildlife population, notably of the Grauer's gorilla, which has been hunted for food and for trade. Recent evidence suggests that over the past five years the gorilla population has dropped by 80–90%, and the animal is soon likely to be classified as critically endangered.

This well-publicized case has dramatized the need to find ways of conserving biodiversity in the face of economic pressures. On a good day a miner can produce a kilogram of ore a day worth around US$80 – in a region where most people live on 20 cents a day. It is unrealistic to expect people to forgo income on this scale. The only solution must be to find ways of paying individuals or countries for conserving such areas. The Global Environment Facility has provided some help in the support of biodiversity, and UNEP has a Great Apes Survival Project, but such efforts have not yet had much impact in this area.

Source: Harden (2001); Redmond (2001).

to costly delays. Despite these challenges, there have been some attempts to implement good practice in exploration – as in the Asarco Ltd Camp Caiman Gold Project in French Guiana.[80] There is clearly an urgent need to create the conditions whereby good practice in exploration becomes more widely adopted.

Mining processes themselves also have serious implications. Clearing vegetation, shifting large quantities of soil, extracting large volumes of water, and disposing of waste on land or through water systems often lead to soil erosion and sedimentation and the alteration of the flow of watercourses. This can change the spawning grounds of fish and the habitats of bottom-dwelling creatures. Acid drainage, as described earlier, may be the most widespread negative impact on aquatic species. Such effects can instigate extinctions, or they can restrict access to species that local communities depend on, such as snails, mushrooms, medicinal plants, and so on. Local extinctions can be caused by any sectoral activity, but there is one group of plants that is likely to go extinct as a result of mining activity alone. These plants – metallophytes – grow in areas where soils are heavily loaded with metals, and are often of very restricted distribution. They often grow on or very near mining deposits, hence mining activities can easily obliterate them, resulting in the loss of a potentially valuable resource.

Mining can sometimes boost some aspects of biodiversity. This can happen through the creation of new habitats or even from disturbance. Abandoned mineshafts, for example, serve as sanctuaries for many of North America's largest populations of bats. Sand and gravel pits in the UK have attracted many varieties of wildlife. Many of these benefits may have been random or accidental, but some companies are now making concerted efforts to enhance habitats, which may help to enhance biodiversity. Others have taken steps to protect certain species during the mining process. Viceroy Gold Corporation of British Columbia, for instance, helped The Nature Conservancy create a 150,000-acre Desert Tortoise reserve as a mitigation measure for California's third largest gold mine.[81] If all companies made the effort to identify habitat needs critical for the survival of species of concern, to protect them during their operations, and to enhance them wherever possible, there could be many more biodiversity success stories.

Abandoned mine sites are generally seen as a liability, as they are often a major source of pollution. However, they sometimes offer some interesting biodiversity phenomena. If a former mining area and surrounding tailings are naturally recolonized by vegetation, the unwanted legacy can become a resource base of unique genetic materials and plant and animal behaviour. The study of these organisms and their colonization behaviour and evolution observable on former mine sites can enhance closure and rehabilitation strategies. Their cataloguing and conservation is a priority. This is to be done not only prior to mining activity but also throughout a mine's life since these plants and animals have revealed a remarkable adaptive capacity to changing metal environments.

Others have taken care to encourage flora and fauna as part of the process of rehabilitation of mine sites.[82] Here the best practice is usually to introduce native species that are able to survive in that environment. Well-intentioned attempts to revegetate sites disturbed by mining have been a source of introduction of exotic species that have had many deleterious effects on native plants and the ecosystem. In some cases, however, local communities have asked companies to revegetate with non-native species that might yield better livelihood benefits, such as pine trees for fuel or timber. Even where a species is requested by the local population, careful assessments should be carried out to understand and avoid other potential negative effects.

There are also a number of interesting examples of a new use being found for an abandoned mine that has significantly enhanced biodiversity and local livelihoods. These include the BHP Billiton mine in the Cape in South Africa, where the company has supported the opening of the 700-hectare West Coast Fossil Park with both fossils and wildlife to attract tourists.[83] In Cornwall in the UK, a former china clay quarry is now the site of the spectacular Eden Project, which includes one of the world's largest greenhouses.[84] Other good examples of mine closure include rehabilitation of the bauxite mines in Western Australia by Alcoa, which was listed on UNEP's Global 500 Roll of Honour for its achievements.[85]

Managing Biodiversity

Some of the larger mining companies have begun to take steps towards addressing biodiversity issues. Many have formulated biodiversity policies; some have followed this up with innovative actions within planning, design, and operating management. (See Box 10–15.) Evidence of such remedial actions is encouraging, but still they remain largely restricted to a few major players, and even within this group, some are doing much more than others. Adopting 'biodiversity-friendly' practices remains hugely challenging, especially for smaller companies and peripheral players. This is partly because governments, while perhaps committed on paper to biodiversity, have found it difficult to create the incentives and apply the necessary regulations that could encourage all players, from the individual miner to the large company and the other economic sectors, to conserve biodiversity.

Box 10–15. Balancing Biodiversity Conservation with Economic Development

Since 1986, Rio Tinto and its subsidiary QIT Madagascar Minerals S.A. (QMM) have been assessing the potential for a 50–60 year ilmenite (titanium dioxide) mine near Fort Dauphin in southeastern Madagascar. The project is potentially the most important in the industrial history of the island – a US$350-million investment with US$20 million in annual revenue predicted for the state, including mining royalties, of which 70% is to be returned to the region. Together with the possible 30% local employment commitment, it appears that the project has the potential to bring some economic benefits to the region.

However, the mineral deposit is located on or near remnant fragments of a unique littoral ecosystem that contains several endemic species. Elsewhere, these forests have been largely degraded or removed, so the sections, while patchy, have gained conservationists' attention. They raised serious concerns about the proposed mine, and requested a two-year moratorium during which alternative development options, such as ecotourism, were to be explored. But no significant eco-tourism developments materialized.

QMM commissioned a team of specialists to undertake various social and environmental baseline studies – perhaps one of the lengthiest such exercises ever conducted in the mining industry. This information was summarized and presented as a social and environmental impact assessment (SEIA). Some of the basic assumptions in the SEIA have been questioned, however – such as the speed at which forest will be depleted. Conservation International believes that a significant slowing of forest reduction could also be achieved in the absence of the mine. Overall, however, the SEIA has certainly covered new ground in linking both social and environmental issues, and in tackling biodiversity issues explicitly.

The SEIA concluded that the forest fragments are already under pressure for charcoal and building materials, and that given current depletion rates, and without any new planting of fast-growing species, the remaining forest would be destroyed within the next 20–40 years. These facts and predictions were key in the pro-mining argument – that is, that the forests would disappear anyway and the mine could help reduce local dependence on forest resources. QMM has proposed various activities that would help offset further impacts, such as planting of various fast-growing species to provide a sustainable alternative source of fuel and timber. Various tests have been conducted to identify the most suitable species, as there are distinct ecological constraints, such as the thin and fragile topsoil, as well as social challenges regarding the management of these forests. QMM also intends to protect almost 1000 hectares of littoral forest remnants in three or four conservation blocks, rehabilitate all wetland areas and about 600 hectares of native forest, and establish monitoring procedures for the forest. These are encouraging steps, but while the plantations are likely to offset some of the demands it is unlikely that, given the intense pressures, they can offset them all. Additional planting, in concert with governmental efforts to tackle root causes of forest loss, will be necessary for more lasting and widespread success.

Some observers continue to believe mining is simply not a viable option here, so all mitigation attempts will be inappropriate. The social and environmental plans are ambitious and the constraining factors great. If the mine goes ahead – currently it is in its feasibility study stage – there is no guarantee that they can be overcome. QMM intends to invest in a Regional Planning Process, but, as experience from all over the world shows, these do not always meet their original expectations. However, QMM seems determined to try and get it right. Their significant social and environmental investment in the project seems to be indicative of a genuine intention to implement a considered and responsible project. If the mine does go ahead, it should provide some valuable lessons and, if the various programmes are successful, perhaps it will set some precedents for other companies.

Sources: QMM S.A. (2001); Porter et al. (2001); Nostromo Research (2001).

In principle, mining companies should be operating according to planning decisions and biodiversity criteria set by governments and should be monitored by appropriate agencies. In practice, few governments – especially in developing countries – have the necessary capacity, even though they may have ratified the CBD and developed a National Biodiversity Action Plan. The onus falls instead either on the companies themselves or on conservation organizations. It is therefore far too easy for companies and organizations to exploit this vacuum and implement measures they consider best fit.

In some cases governments have introduced appropriate laws and regulations but have not enforced them because they have no capacity to do so. Despite various biodiversity planning processes required under the CBD, there is frequently insufficient information on the status of biodiversity on the ground. As a result, they find it difficult to make informed decisions on trade-offs – on alternative uses for the same land.

But there are also issues of power balance within administrations. Since the extractive industries bring in revenue and employment, the voices in the Ministry of Mines arguing for mining are usually stronger than those in other ministries arguing for the protection of biodiversity. For this to change, there needs to be much stronger incentive to act on biodiversity, which often means additional financial resources.

One area causing great concern is the weakness of environmental impact assessments. As indicated earlier, these are now required for most large-scale industrial projects, including mining. But they generally afford doubtful protection – using the term 'biodiversity' very loosely and giving little indication of how it is to be interpreted. The recent report commissioned by the International Association of Impact Assessment has gone some way towards addressing the integration of biodiversity into EIA systems, but further work is needed.[86] Often the EIA is not carried out until after detailed exploration or even development drilling, by which time the site can be covered by a network of roads, making it impossible to establish true baseline data. It is essential that at least rapid biodiversity surveys be carried out prior to this stage.[87] Clearer international standards for EIA practice need to be developed in a variety of areas to begin to make EIA a more effective tool of environmental management.

The weakness of governments tends to put the burden for managing biodiversity on NGOs and particularly on international conservation organizations. While these may act as a line of defence for biodiversity, they cannot really claim to act on behalf of civil society in general, especially when they are based in industrial countries. NGOs often claim to speak 'on behalf of' those who will suffer from a loss of biodiversity, in much the same way that companies will speak 'on behalf of' those who have most to gain economically. Thus far, unfortunately, there have been too few well-informed and empowered local organizations willing or able to take appropriate decisions.

Recommendations on Biological Diversity

These recommendations are based on discussions at two MMSD Mining and Biodiversity Workshops in October and June 2000.[88]

- *Strengthen government capacity to manage biodiversity, especially in developing countries* – The CBD presents a challenging agenda for action, especially in terms of managing the trade-offs between poverty reduction and biodiversity conservation. At the national level, the CBD should provide the necessary framework within which economic sectors could operate. However, more resources and a strong political commitment are needed if enabling policy, institutional, and regulatory mechanisms are to be developed successfully. Without strong government inputs, governance falls to the private sector or NGOs.

- *Develop tools for more inclusive and integrated land use planning, especially in developing countries* – Rigorous analytical tools for weighing up the social, ecological, and economic costs and benefits of different land use options and for arrangements that support participatory decision-making processes on land use need to be developed to support better-informed and more inclusive decision-making processes. This work should also build on existing relevant concepts, such as UNESCO's Man and Biosphere Reserve or the Ecosystem Approach of the CBD. Tools development must happen in parallel with strengthening the capacity of and incentives for developing-country governments and civil society groups to participate in land use planning. (See also Chapter 7.)
- *Address funding shortfalls for biophysical science* – If rigorous decision-making on biodiversity and conservation is to continue, and if conflicts are to be minimized, governments – especially in industrial countries – must acknowledge true responsibility in this scientific area. There are many opportunities for mining companies (and the private sector in general) to stimulate and contribute towards research partnerships on biodiversity conservation, such as through contributing to taxonomy in remote areas. But private funding alone cannot solve the rapid decline in independent scientific capacity – hence the urgent call to governments to reverse this decline.
- *Improve access and coherence of information on biodiversity priorities* – Relevant conservation organizations, academic institutions, the mining industry, and other key sectors (such as energy) need to work towards establishing user-friendly, regularly updated and linked information systems on global and local biodiversity priority areas as a matter of priority. Holding a workshop on 'Information for Conservation' could be a first step forward. In order to improve coherence, it is particularly important to achieve some level of consensus between specialists on which proxies are best used for biodiversity, and why. Such work could also feed into biodiversity indicators development for EIA.
- *Articulate and enhance biodiversity better practice within the mining industry* – There have been no industry-wide attempts to articulate the industry's biodiversity principles. The mining companies, through ICMM and in collaboration with conservation specialists and organizations representing local community interests, should work towards producing a series of guiding principles on mining and biodiversity for the different stages of the mine cycle, along with appropriate training manuals. This could involve, among other things, multistakeholder reviews of better practice, workshops, and lessons learnt analyses from existing cases. If considered appropriate, such principles could eventually become 'codes of practice'.

The Way Forward

All the environmental issues raised this chapter pose complex problems that test the capacities of mining companies, governments, NGOs, and civil society. This is partly because of the inherent complexity of technical and ecological processes whose outcomes are difficult to predict. It includes envisaging the quality of water in a lake that will not be filled for decades, for example, or the likely stability of a tailings storage facility in the event of a once-in-a-lifetime storm or seismic event. Some of them also require close attention over a long period of time; something it is hard for any organization to achieve.

Companies can help strengthen society's ability to solve environmental problems of all kinds. For example, mining company expertise in the rehabilitation of disturbed lands has often been useful to other industries with less experience. Companies can support capacity building on environmental issues by providing access to information and the funds to make this information more readily available, by supporting stronger school and university curricula and helping educate their own future employees, and by developing important new skills and perspectives in their current managers, professionals, and workers.

This chapter has focused on a series of priority environmental areas for the minerals sector. They are not the only ones, but they are among the most pressing – and the ones where the consequences are greatest. Industry is not yet at the point of providing a net positive contribution to the natural capital, whatever its contribution to other forms of capital. There is, however, undoubted progress towards better recognition of environmental problems and their effective management.

There are some clear dilemmas. Employment in the sector, especially in mining, is highest in smaller enterprises, which are financially the weakest and often have the least capacity to deal with complex new and continuing challenges. There is a concern that pressure for environmental progress may threaten a large number of livelihoods. Those whose livelihoods are threatened will not receive the environmental message well if they see it as unsympathetic to their problems and hostile to their immediate and long-term interests. The only way they are likely to embrace change is if it is coupled with opportunity. Perhaps this is an affirmation of the principles of sustainable development: there will be little progress in one dimension unless there is progress in all.

Another dilemma is that of the level playing field. Resistance to taking on greater environmental costs is much less when companies perceive that everyone is taking on the same costs. On the other hand, when they are selling in a global market, the requirement for cost internalization for everyone is a daunting task. All companies need to face consistent guidelines for environmental management if the mining industry is to avoid a 'race to the bottom'.

It is important to acknowledge that not all governments are ready to promote the more stringent environmental management of the industry. In poorer countries, governments may have other priorities and may fear that higher standards (and direct costs) may drive the industry away. In many cases progress towards better environmental management is at a rate that the economy can absorb or is instigated by international loans or aid.

Governments of industrial countries where mining takes place generally have sophisticated regulatory systems that can cover most eventualities, or they can draw on extensive local expertise as required. But the situation is quite different in developing countries, where small and overstretched government departments can be called on to make rapid decisions

Photograph not shown

on the basis of relatively little information or technical knowledge. To help fill that gap, MMSD proposes the establishment of a Sustainable Development Support Facility to provide technical support, on request, to governments, insurers, lenders, or companies in order to help them build their capacity and to ensure that there is a viable, meaningful system of external inspection and the resources to fund it. This facility can be used as a source of information and advice on such issues as:

- integrating the local community and civil society into decision-making,
- development of detailed technical criteria for EIAs and supporting studies,
- the review and approval of designs for tailings storage facilities,
- inspections of tailings facilities,
- prediction and control of acid drainage,
- development of standards and procedures for mine closure planning,
- risk assessment and emergency responses,
- development of techniques to survey abandoned mines and set priorities on remediation, and
- rehabilitation plans for abandoned mine sites.

Details of the proposed Sustainable Development Support Facility are provided in Chapter 14.

It is also important to address the problem of how to manage exploration better, most especially how to deal with the in-rush of exploration companies (or sometimes artisanal miners) when an area suddenly becomes 'hot'. A great deal of damage can be done to biodiversity and other values before there is a proposal to mine anything, or even where no mining ever occurs. Examining how to undertake exploration effectively should be a focus for research funding. Perhaps industry associations in the countries important in exploration, and those governments, could take a lead in the establishment of a modest research project to better understand some of the more well-known case studies.

Endnotes

[1] UNDP/UNEP/World Bank/WRI (2000) p.389.

[2] Pearce et al. (1994).

[3] Centro de Estudios y Proyectos SRL and Netherlands Embassy (1999).

[4] See http://www.cyanidecode.org.

[5] Ashton et al. (2001).

[6] All of this material is collected in Van Zyl et al. (2002), which covers many of these issues in more detail than space here allows.

[7] Phelps (2000).

[8] Van Zyl et al. (2002).

[9] Mokopanele (2001).

[10] Cale (1997).

[11] Mitchell (2000).

[12] Ashton et al. (2001).

[13] Mitchell (2000).

[14] Ashton et al. (2001).

[15] See for example Ashton et al. (2001) p.308.

[16] Mitchell (2000).

[17] Colorado School of Mines website, at http://www.mines.edu/fs_home/jhoran/ch126/amd.htm.

[18] Details of these initiatives are provided in Van Zyl et al. (2002), at http://www.mend2000@gc.ca, and at http://www.inap.com.au.

[19] UNEP (1996).

[20] Martin et al. (2001); see also Mining Association of Canada (1998).

[21] UNEP (2000).

[22] ICOLD (2001).

[23] Richards (2000).

[24] Ibid.

[25] Castillo (1998).

[26] In 1972, at Buffalo Creek, West Virginia, in the United States, 125 people died in a coal waste rock failure. See Antenna website at http://www.antenna.nl/wise/uranium/mdaf.html.

[27] Martin et al. (2001).

[28] Ibid.

[29] ICOLD (2001).

[30] Martin et al. (2001).

[31] Ellis et al. (1995).

[32] NSR Consultants (2001) Overview of Deep Sea Tailing Placement for BHP Minerals.

[33] Data from the Newmont website at http://www.newmont-indonesiaoperations.com/html/environmental_issues_nmr.html.

[34] Data from http://www.jatam.org/std/inggris/english.html.

[35] Ellis and Robertson (1999).

[36] Grassle (1991).

[37] Van Zyl et al. (2001).

[38] Sassoon (2000) pp.108–09.

[39] Castilla (1983).

[40] Ricks (1994).

[41] The Summitville mine closed on less than a week's notice. The company declared bankruptcy (leaving unpaid a large local tax bill), laid off the workers, and stopped vital environmental maintenance at the mine.

[42] Danielson and Nixon (2000).

[43] Miller (1998).

[44] UNEP/Standard Bank (2002) p.46.

[45] Lyon et al. (1993).

[46] Sol et al. (1999).

[47] See, for example, Ashton et al. (2001).

[48] Bob Fox, of US EPA Montana, personnel communication, January 2002.

[49] Mineral Policy Center (1993).

[50] UNEP (2001).

[51] Houghton et al. (2001).

[52] Lovins et al. (2002).

[53] IEA (2001).

[54] According to the World Commission on Dams (2000), significant greenhouse emissions may also arise from reservoirs associated with hydroelectric power plant.

[55] ICF (2000) p.78.

[56] Ibid.

[57] Lovins et al. (2002).

[58] Ibid.

[59] International Programme on Chemical Safety (1992).

[60] International Programme on Chemical Safety (1990).

[61] Thornton (1995) p.103.

[62] Lacerda and Salomons (1998).

[63] Roulet et al. (1999)

[64] Nriagu (1996).

[65] Nriagu and Pacyna (1988).

[66] Pacyna and Pacyna (2001).

[67] MMSD Southern Africa (2001).

[68] Compliance Advisor Ombudsman (2000) p.57.

[69] See http://www.zinc-health.org or http://www.izincg.ucdavis.edu.

[70] Convention on Biological Diversity (1992).

[71] Koziell (2001).

[72] IIED (1994).

[73] A recent mapping exercise by Conservation International indicated that areas where mining and mineral exploration are active and where mineral potential is highest show a high degree of overlap with those areas where biodiversity 'value', however defined, is considered greatest.

[74] Hotspots are areas characterized by both high levels of endemism and high levels of threat; see Myers et al. (2000). Endemic bird areas contain two bird species that have a breeding range of less than 50,000 sq. km; see ICBP (1992). Ecoregions are large units of land or water with distinct climate, ecological features, and plant and animal communities. They are considered to be some of the richest, rarest, and most endangered areas, and hence of critical conservation concern; see http://nationalgeographic.com/wildworld (a WWF initiative called Global 200).

[75] Vermuelen and Koziell (forthcoming).

[76] May (1998).

[77] Leigh and Briggs (1992).

[78] IUCN (2002).

[79] Rosenfeld Sweeting and Clarke (2000); IUCN and WWF (1999); Lloyd et al. (in prep.); Minerals Policy Centre (1997). See also Cooke (1999).

[80] IUCN, UNESCO World Heritage Centre, and ICME (2001).

[81] See http://ceres.ca.gov/biodiv/newsletter/v2n4/mining_company_reclaims_biodiversity.html.

[82] Jenkin (2000).

[83] See http://www.billiton.com/newsite/html/annual/98/HSEPolicy.htm and http://www.indabadailynews.co.za/tuesday/article04.html.

[84] See http://www.edenproject.com/.

[85] See http://www.alcoa.com.au/environment/miner.shtml.

[86] The International Association of Impact Assessment has developed a Proposed Conceptual and Procedural Framework for the Integration of Biological Diversity Considerations within National Systems for Impact Assessment.

[87] See outputs of workshop held in Gland: International Union for the Conservation of Nature, UNESCO World Heritage Centre, and International Council on Metals and the Environment (2000).

[88] See the minutes at http://www.iied.org/mmsd.