Participant Notes

Session 2.1. A background on mining for auditors

Overview.

This session deals with information related to mining activities and their impact on the environment .The information obtained in this session may help the participants at the planning stage of mining and mineral audits.

Learning Objective

At the end of this session, the participants will be in a position of understanding the environmental, social and economic problems associated with mining activities. Also, the participants will understand whether there are obligations that influence national policies.

Basic Concepts.

- **Mining:** According to UNEP definition, mining could simply be "the extraction of minerals from the earth". The word "minerals" in this case would cover a wide variety of naturally occurring substances extracted for human use. Although this definition is adequate for our purposes, mining can also be seen as a process that begins with the exploration and discovery of mineral deposits and continues through ore extraction and processing to the closure and remediation of worked-out sites. Environmental impacts occur at all of these stages.

Minerals are usually classified into four main groups

- metals;
- industrial minerals (such as lime or soda ash, valued for certain special properties),
- construction materials, and
- energy minerals (i.e. coal).

- **Tailings:** The combined wastes generated by extraction and milling.
- **Beneficiation:** Is the entire process of crushing, grinding, sizing, and separating ore into waste and value.

Types of Mining

There are basically three types of mining as follows:

- **Open pit mining:** Is a surface excavation, usually conical in shape, dug for the purpose of extracting near-surface bodies of ore. The rock overlying the ore, called the *overburden*, is drilled and/or blasted and loaded into trucks that carry it away from the pit. The ore is then removed for initial processing.

- **Underground mining:** Takes place when minerals lie deep beneath the surface is only economical for high-grade ore. To get to the ore, a vertical shaft, horizontal entrance or passage (adit), or inclined passageway (winze) must be drilled for ore and waste removal, as well as to provide ventilation.
- **Placer mining:** Is a widely used technique for extracting precious metals from sand or gravel deposits at or near the surface. The sand or gravel is mixed with water, which is then agitated so that the metals sink. The lighter unwanted material is then washed away. Panning for gold is a simple, small-scale example of placer mining.

.

Key Teaching Point 1.

- What is mining and what are the main concerns:

The definition of what is mining is as given above. However, the main concerns on mining are based on the environmental effects of mining which vary with the type of minerals and the kinds of mine being extracted. Mining is inherently a destructive activity involving the taking of a non-renewable resource. Some environmental damage is inevitable in any mine – the goal should be to minimize the extent of the effects. Mining effects can be sub-divided for convenience into four categories: the effects of the mine itself, the disposal of mine wastes, the transport of the mineral, and the processing of the ore, which often involves or produces dangerous materials. These activities may take place at the same site, in which case the effects are combined or they may be separated by considerable distances.

Key Teaching Point 2.

- What are the main threats of mining activities to the environment?

Air pollution

The main air quality issue is the dust produced by the working of open pits and by crushing and grinding operations. Dust can also be given off by tailings dams. Workers and nearby communities can be affected by dust in the atmosphere. In addition, particle fall-out around mine sites can contaminate

soils and water and damage vegetation. Mines are also sources of greenhouse gas emissions. CO2 is produced by energy use and methane is sometimes released from underground operations, especially in coal mines. In the past, some deep mines used ozone-depleting chlorofluorocarbons (CFCs) in refrigeration systems. This practice has now largely ceased. Smelting (the process in which ore is heated for the purpose of separating it from the gangue) produces very large amounts of air pollutants. Worldwide, the smelting of copper and other nonferrous metals releases an estimated 6 million tones of sulphur dioxide (SO2) into the atmosphere each year – 8 per cent of total worldwide emissions. On-ferrous smelters also emit large quantities of arsenic, lead, cadmium and other heavy metals (except where highly efficient pollution control equipment is used). Smelters may also be regional pollution "hot spots", whose emissions cause severe local environmental damage as well as contributing to more distant or global phenomena such as acid rain and climate change. The photograph below refers some of common greenhouse gases emitted in mineral processing and other pollutant.

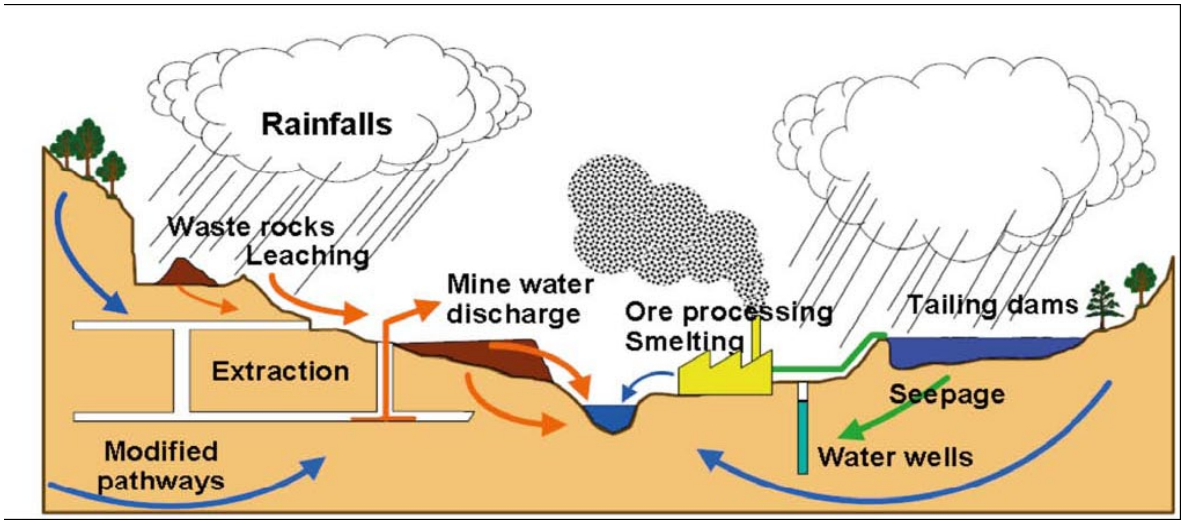
Photo of Kara bash copper smelter (Russia)
Source: 1st MINEO Workshop 25-27 October 2001, GBA, Vienna, Austria

Water pollution

Potential sources of water pollution from mining include drainage from surface and underground mines, wastewater from beneficiation, and surface run-off (see Figure below). A particular problem is acid mine drainage. Many mining operations, especially those extracting ores that contain sulphides such as nickel, copper, iron, zinc, cadmium, lead and coal (if pyrites are present), may produce acidic and metal-bearing solutions resulting from the natural oxidation

of the sulphides through exposure to air and water. The combination of acids and metals can have severe effects on the ecology of local watercourses, and the metals can enter and accumulate as they work their way up the food chain. Acid mine water can be a problem for drainage from both underground and surface workings, as well as drainage from waste rock stock piles and concentrated tailings deposits. It can occur while the mine is operating and long after the mine closes, unless specific measures are taken.

Below is a simplified mining process and global impacts on water:



Source: Francis Cottard

Mining causes water pollution in a number of ways:

- The mining process exposes heavy metals and sulphur compounds that were previously locked away in the earth. Rainwater leaches these compounds out of the exposed earth, resulting in "acid mine drainage" and heavy metal pollution that can continue long after the mining operations have ceased.
- Similarly, the action of rainwater on piles of mining waste tailings) transfers pollution to freshwater supplies.

- In the case of gold mining, cyanide is intentionally poured on piles of mined rock (a leach heap) to chemically extract the gold from the ore. Some of the cyanide ultimately finds its way into nearby water.

- Huge pools of mining waste "slurry" are often stored behind containment dams. If a dam leaks or bursts, water pollution is guaranteed.

(Reference is also made to Handout 2).
Mines and mineral wastes

By nature, mining involves the production of large quantities of waste; the amount of waste produced depends on the type of mineral extracted, as well as the size of the mine. Gold and silver are among the most wasteful metals, with more than 99 percent of ore extracted ending up as waste. By contrast, iron mining is less wasteful, with approximately 60 percent of the ore extracted processed as waste. Disposing of such large quantities of waste poses tremendous challenges for the mining industry and may significantly affect the environment. The impacts are often more pronounced for open-pit mines than for underground mines, which tend to produce less waste.

Biodiversity and habitat

Mining may result in additional indirect impacts far from the mine site. The most obvious impact on biodiversity from mining is the removal of vegetation, which in turn alters the availability of food and shelter for wildlife. At a broader scale, mining may affect biodiversity by changing the composition and structure of species in an area.

Forests

The key direct impact of mining on forest ecosystems is the removal of vegetation and canopy cover. Indirect impacts include road-building and pipeline development, which may result in habitat fragmentation and increased access to remote areas. While larger intact forest ecosystems may withstand the impacts of mining, smaller forests are likely to be particularly sensitive to clearing.

(Refer Handout 3.)

Wetlands and mangroves

Mining can also contribute to the destruction of mangroves and wetlands through altering upstream watersheds and increased sedimentation. Hilson and others described that the United States has lost at least 54 per cent of its wetlands, and
European countries have lost up to 90 per cent of their wetland ecosystems.

Arid environments

Water scarcity is the primary constraint in arid environments. Vegetation is limited, but biodiversity is high among insects, rodents, and other invertebrates, especially in semi-arid regions. The main impact of mining on these ecosystems is the alteration of the water regime, especially lowering of the water table and
depletion of groundwater. These impacts may result in increased Salinisation of the soil and erosion, which eventually lead to a decline in vegetation and

wildlife species. In densely populated areas, the competition for scarce water resources makes these ecosystems especially fragile.

Tailings

The tailings that remain after extraction and processing are mostly mud and slurries containing a very high proportion of extremely finely ground material.

Acid drainage, which exacerbates contamination by heavy metals, is often a problem when tailings are exposed to the atmosphere. It arises from the sulphide minerals that are often associated with the commonly mined ores of many metals including copper, gold, lead, nickel and zinc. Tailings are usually dumped in heaps, released into ponds, or retained by tailings dams. In some cases, submarine disposal or release into rivers occurs. This avoids acid generation but introduces large amounts of suspended solids and contaminants directly into aquatic habitats. Tailings dams, the most common form of disposal, can be large engineering works. The "World Register of Mine and Industrial Tailings Dams" lists eight higher than 150 meters, 22 higher than 100 meters and 115 higher than 50 meters. Six impoundments are known to have a surface area greater than 100 km2 and a storage volume of over 50,000,000 m3. Experience
has shown that tailings dams represent a potentially serious safety and environmental hazard.

(Refer also Handout-4)

Key teaching Point 3.

- Social, Economic impacts of mining

Displacement of People

For opencast as well as underground mining, the surface must be cleared of all buildings, structures, and vegetation – not only in the area designated for mining but also in a large area nearby, which is required for external dumps and associated activities. Therefore, all the people living in the immediate area
are often displaced or affected

Loss of livelihood

The people living in the designated areas generally depend on the land for their livelihood. When land is taken for mining and associated activities, these people lose their livelihood

Changes in population dynamics

Invariably, all the managerial, skilled, and semi-skilled people required for mining and associated activities come from outside the area, because trained personnel are usually not available populations that rely on the land for their livelihoods. Other people come to the mining areas for trade and other purposes. Thus, the population of the area undergoes a major change over the years, diluting the ethnic population and their culture religion, reducing the ratio of women to men, and so on. The population may decrease at a faster rate when the mining
activities come to an end.

Cost of living

Societies dependent on agriculture and forests usually have low income levels. The development of industrial and other activities in the area increases the economic activity. Increased industrial and economic activities generate more money and increase the buying power of the people directly and indirectly associated with these activities. This leads to an increase in the cost of living, which adversely affects any local people who are not associated with these activities.

Water scarcity

Mining either by opencast or underground methods damages the water regime and reduces the overall availability of water in and around the mining areas. In the sedimentary deposit mining areas, the water table and aquifers are damaged and the availability of water from these sources is substantially reduced.

Health impacts

The health and well-being of the people living in and around a mine are affected due to the pollutants in the air and water, noise and vibrations. The people in the mining complex have to bear the various costs of abating the effects of environmental pollution in various ways. The people working in the mines and associated facilities also get affected by the workplace environment, which can cause various problems, e.g. skin problems, lung diseases, hearing loss, and so on.

Infrastructure facilities

Mining and associated activities in the mineral-bearing areas bring about infrastructural development, i.e. roads are constructed, schools and hospitals are established, and communication facili-ties are developed. These changes tend to improve the quality of life of those living within the mining complexes.

Employment opportunities

Mining and associated activities offer employment opportunities to eligible people from the local population. People affected by the mine are often given jobs and trained for self-employment as a result of provisions in any

rehabilitation and resettlement schemes. People are also employed in other developmental and mineral-based activities in and around the mining complexes.

Key teaching Point 4

- Life cycle of Mining

The exploration phase of mining

The exploration stage (surveys, mapping, drilling, and so on) generally produces the least-pronounced adverse environmental effects. Still, these can include the clearing of trees and vegetation, displacement and death of wildlife, and landform change through construction of access roads, camps, excavations, pads, pits, holes and shafts. While frequently dismissed as localized, the impacts of the exploratory phase can displace people, foreclose alternative land uses, create social conflict, and, by building roads, open up sensitive ecosystems to unplanned population influxes.

The potential environmental effects of exploration depend on a number of factors, notably:

• constructing new access routes,
• the proximity of surface water to drill sites (particularly those used for potable water abstraction),
• the ecological significance of the affected habitat, and the extent to which access has been improved as a result of exploration,
• the proximity to, and intrusion upon, existing settlements or resources used by local or indigenous people,
• the extent to which local or indigenous communities are voluntarily isolated, Or have been exposed to diseases prevalent among exploration workers.
Potential environmental impacts during the exploration phase of mining include
• land alienation from protection options,
• disruption of habitat and harvesting and fishing activities,
• pollution of water sources from drilling,
• camp garbage, and
• deforestation.

The development phase of mining

The development phase may include such activities as
• overburden stripping and placing,
• road/trail, building and/or helicopter transport,
• drilling and trenching,

- erecting treatment plants, preparing disposal areas, and constructing services, infrastructure such as power line or generating plants, railways, water, supplies and sewerage, laboratories and amenities.

Potential environmental impacts during the development phase

The development and operational stages (extraction) magnify the environmental impacts. In this stage, large areas of vegetation and topsoil are cleared, and the excavations create potential hazards that include landslides, slope failures, cave ins, erosion and subsidence. The environment is disturbed by many human developments. Ecosystems and other users of water are deprived by water-intensive practices, and the extraction produces noise, dust, and quantities of solid waste in the form of tailings and waste rock disposal sites (as much as 1,000 units of waste for a single unit of mineral yield).Toxic chemicals (xanthenes, cyanides, sulphates, and so on) are used in primary processing, and some base metals are themselves toxic (lead, mercury, cadmium). Toxic and otherwise harmful gases can be released (for example, methane - a major greenhouse gas - is released in coal mining). Water quality (surface water, wetlands, groundwater and oceans) can be adversely affected by this extraction phase. Acid drainage from mines and tailings/waste dumps, toxic leaks and overflows from tailings dams or reagent ponds, leaching of metals from waste piles, and sedimentation/ erosion from de-vegetated sites and excavations can cause serious localized problems as well as extend for hundreds of kilometers, causing trans-border impacts on people and nature.

The mining and milling phase

This stage generates even more risks to human health and the environment, as explained below.

- Air pollution includes direct emissions of compounds such as sulphur, carbon, nitrogen, and toxic metal particulates, indirect emissions from the fossil fuels used for energy, releases of potentially hazardous dusts and gases in the workplace, and the generation of acidic deposition (acid rain, etc.).

- Water pollution includes all of the above acidic substances; toxic and sedimentary process discharges, leaks, spills, leaching, and surface runoff. Solid and hazardous waste treatment, storage, and disposal issues multiply with the metallurgical residues.

The impact of water pollution arising from mining activities could result into any of the following:

- Wildlife and fisheries lose their habitats.
- There are changes in the local water balance.

- There is increased erosion and sedimentation of lakes and streams.
- Toxins are contained in tailings ponds or leaching solutions.
- Tailings ponds or leaching pads can be unstable and fail.
- There is the potential for acid generation from waste rock and pit walls.
- Heavy metal can leach from acid mine drainage systems.
- Cyanide solutions can be contained at heap leach operations.
- Surface water and ground water can be contaminated from the discharge of acid mine drainage, including heavy metals originating in ore and tailings, and organic chemicals and cyanide originating from milling processes.
- Alienation of land occurs as a result of waste rock piles and tailings disposal areas.
- The mine generates noise and wind-borne dust.

The smelting and refining phase of mining

The potential environmental impacts during the smelting and refining phase of mining include:

- heavy metals, organics and sulphur dioxide emissions to air,
- discharges of toxic chemicals, such as sulphuric acid and ammonia used during processing,
- alienation of land as a result of the generation of slag, and
- high energy consumption resulting in indirect environmental impacts.

Mine decommissioning.

Factors contributing to cessation of mining activities include:

- depletion of reserves that can be mined,
- changes in market conditions,
- changes in the financial viability of the company; or adverse environmental or political conditions.

The potential environmental impacts during the mining decommissioning and closure phase of mining include:

- seepage of toxic contaminants, such as heavy metals, into surface and ground water from acid mine drainage,
- wildlife and fisheries habitat loss,
- alienation of land; re-vegetation failure,
- wind-borne dust, and
- slope and tailings impoundment failure, causing discharge of contaminants and sediments to water.

(Refer handout 5)

Abandoned mines

According to the UNEP working paper on abandoned mining, some elements that contribute to the legacy of abandoned mines include: Regulation – few governments had mine reclamation policies and regulations until the latter part of the twentieth century. Nothing was in place to provide governments with financial security if a mining company was declared bankrupt and was unable to cover the costs of rehabilitation. Ineffective government enforcement, usually due to a lack of capacity, also contributed to the number of abandoned mines. Governments control the permitting system and have a duty to keep updated records and ensure that operators do not abandon operations irresponsibly.

- Loss of mine data – information that was not well stored. The loss of data may be due to a disaster or unscheduled closure.

- Local political problems – in some regions, political problems led to the unscheduled closure of a number of mines. For example, the Kilembe copper mine in Uganda was abandoned in the early 1980s due to political unrest. The Bougainville mine in Papua New Guinea was abandoned in 1989 due to a landowner rebellion.

- Small scale mining – the uncontrolled occupation of mine sites by artisanal or illegal miners has occasionally led to a site being abandoned.

Since abandonment is usually sudden and unplanned, or the mining company has gone out of business, governments are often left responsible for mine closure and rehabilitation. According to the UNEP working paper on abandoned mines, the closure and rehabilitation costs "must be directly or indirectly born by the State. As such the abandoned mines represent not only a major liability for the government but for the affected communities, adjacent areas and society at large: the latter must ultimately bear the financial burden of ensuring appropriate closure."

Physical considerations

Some abandoned mines present only physical concerns. These concerns include public health and safety, visual impacts, stability issues and dust problems. Accidents related to vertical openings or deteriorating structures are the most common cause of death and injury in abandoned mines. Lethal concentrations of explosives and toxic gases like methane, carbon monoxide and hydrogen sulphide can accumulate in underground passages. It is also possible to encounter pockets of oxygen-depleted air in such workings.

Rock falls and cave-ins from adits or pit walls can be a safety hazard. Unsafe structures include support timbers, ladders, cabins and other related features. These may seem safe but due to weathering they may easily crumble under a person's weight. Sometimes, unused or misfired explosives are triggered.
Many abandoned mines become flooded and shallow water can conceal other hazards like tunnels and sharp objects.

Environmental considerations
Abandoned mines and associated features can have a detrimental effect on soil, water, plants and animals. The extent of the effects is not fully known because inventories are incomplete and some abandoned mines are still being evaluated. Generally, the common environmental consequences associated with abandoned mine sites include altered landscape, unused pits, shafts and adits, land no longer useable due to loss of soil or soil contamination, spoil heaps covering the land, abandoned tailings disposal facilities, contaminated aquatic sediments, subsidence, derelict works sites with compacted and polluted soil, burning coal waste dumps and workings, and changes in vegetation.

Socio-economic considerations
The most important socio-economic concern caused by abandoned mines is the loss of employment and business activities in the community, due to the unscheduled closure. The other socio-economic considerations of abandoned mines mostly arise from the physical and environmental considerations.
These include the safety hazards caused by abandoned mines that usually result in the loss of lives. The physical impacts of abandoned mines like slope stability, contamination of soils by acid drainage, and other metals released from waste piles usually cause the loss of productive land. Disturbed lands and unprotected slopes are susceptible to erosion. Uncontrolled surface drainage and subsidence can remove soils and may make large areas unstable. Abandoned mines are often used for the dumping, both legally and illegally, of industrial and household waste, which adds to the problems with contamination.

Financial implications
Funds are required for the rehabilitation of abandoned mine sites. The questions when dealing with abandoned mines include who provides these funds, what mechanisms exist in various jurisdictions to raise these funds, and who is ultimately responsible for the rehabilitation work and the long-term care of the sites?

In some cases, governments are forced to take on the task of rehabilitating abandoned mines when there are no identifiable owners or if the owners have

no funds to pay for rehabilitation. In some countries, legislation may be designed to fund the rehabilitation of abandoned mines. The costs are affected by the lack of agreed criteria as to what conditions need to be mediated and what the goals of rehabilitation should be.

Mine closure legislation can enable the regulating authority to control and prevent operating mines from becoming abandoned mines by setting up funds for rehabilitation. The cost estimates to rehabilitate abandoned mine lands are very uncertain. In 2004, Mining and Mineral Sustainable Development report (www.iied.org/mmsd) estimated that between US$32.7 billion and US$71.5 billion would be needed to reclaim the 557,650 abandoned mines they listed in the USA. The biggest cost range was associated with 14,400 mines where surface water contamination was estimated to cost between US$14.4 billion and US$43.2 billion. The Canadian Institute for Environmental Law and Policy estimated in 1999 that it would cost more than C$3 billion to rehabilitate the more than 5,000 abandoned mines in Ontario.

Societies often question who should pay for the rehabilitation of these mines. One opinion is that the government should pay for rehabilitation. Others believe that the previous owners (or their heirs) should be held responsible for such clean-up actions (i.e. the polluter-pays principle in its purest form).