1. Overview of Mining and its Impacts

Proposed mining projects vary according to the type of metals or materials to be extracted from the earth. The majority of proposed mining projects involve the extraction of ore deposits such as copper, nickel, cobalt, gold, silver, lead, zinc, molybdenum, and platinum. The environmental impacts of large-scale mining projects involving these metal ores are the subject of this Guidebook. The Guidebook does not discuss the mining of ores that are extracted using strip mining methods, including aluminum (bauxite), phosphate, and uranium. The Guidebook also does not discuss mining involving extraction of coal or aggregates, such as sand, gravel, and limestone.

1.1 PHASES OF A MINING PROJECT

There are different phases of a mining project, beginning with mineral ore exploration and ending with the post-closure period. What follows are the typical phases of a proposed mining project. Each phase of mining is associated with different sets of environmental impacts.

1.1.1 Exploration

A mining project can only commence with knowledge of the extent and value of the mineral ore deposit. Information about the location and value of the mineral ore deposit is obtained during the exploration phase. This phase includes surveys, field studies, and drilling test boreholes and other exploratory excavations.

The exploratory phase may involve clearing of wide areas of vegetation (typically in lines), to allow the entry of heavy vehicles mounted with drilling rigs. Many countries require a separate EIA for the exploratory phase of a mining project because the impacts of this phase can be profound and because further phases of mining may not ensue if exploration fails to find sufficient quantities of high-grade mineral ore deposits.

1.1.2 Development

If the mineral ore exploration phase proves that there is a large enough mineral ore deposit, of sufficient grade, then the project proponent may begin to plan for the development of the mine. This phase of the mining project has several distinct components.

1.1.2.1 Construction of access roads

The construction of access roads, either to provide heavy equipment and supplies to the mine site or to ship out processed metals and ores, can have substantial environmental impacts, especially if access roads cut through ecologically sensitive areas or are near previously isolated communities. If a proposed mining project involves the construction of any access roads, then the environmental impact assessment (EIA) for the project must include a comprehensive assessment of the environmental and social impacts of these roads.

Erosion near a mining road, Pelambres mine, Chile
PHOTO: Rocio Avila Fernandez

1.1.2.2 Site preparation and clearing

If a mine site is located in a remote, undeveloped area, the project proponent may need to begin by clearing land for the construction of staging areas that would house project personnel and equipment. Even before any land is mined, activities associated with site preparation and clearing can have significant environmental impacts, especially if they are within or adjacent to ecologically sensitive areas. The EIA must assess, separately, the impacts associated with site preparation and clearing.

1.1.3 Active mining

Once a mining company has constructed access roads and prepared staging areas that would house project personnel and equipment, mining may commence. All types of active mining share a common aspect: the extraction and concentration (or beneficiation) of a metal from the earth. Proposed mining projects differ considerably in the proposed method for extracting and concentrating the metallic ore.

In almost every case, metallic ores are buried under a layer of ordinary soil or rock (called 'overburden' or 'waste rock') that must be moved or excavated to allow access to the ore deposit. The first way in which proposed mining projects differ is the proposed method of moving or excavating the overburden. What follows are brief descriptions of the most common methods.

1.1.3.1 Open-pit mining

Open-pit mining is a type of strip mining in which the ore deposit extends very deep in the ground, necessitating the removal of layer upon layer of overburden and ore.

In many cases, logging of trees and clear-cutting or burning of vegetation above the ore deposit may precede removal of the overburden. The use of heavy machinery, usually bulldozers and dump trucks, is the most common means of removing overburden. Open-pit mining often involves the removal of natively vegetated areas, and is therefore among the most environmentally-destructive types of mining, especially within tropical forests.

Open-pit mine in Cerro de Pasco, Peru
PHOTO: Centro de Cultura Popular LABOR, Peru

Because open-pit mining is employed for ore deposits at a substantial depth underground, it usually involves the creation of a pit that extends below the groundwater table. In this case, groundwater must be pumped out of the pit to allow mining to take place. A pit lake usually forms at some point in time after mining stops and the groundwater pumps are turned off.

1.1.3.2 Placer mining

Placer mining is used when the metal of interest is associated with sediment in a stream bed or floodplain. Bulldozers, dredges, or hydraulic jets of water (a process called 'hydraulic mining') are used to extract the ore. Placer mining is usually aimed at removing gold from stream sediments and floodplains. Because placer mining often occurs within a streambed, it is an environmentally-destructive type of mining, releasing large quantities of sediment that can impact surface water for several miles downstream of the placer mine.

1.1.3.3 Underground mining

In underground mining, a minimal amount of overburden is removed to gain access to the ore deposit. Access to this ore deposit is gained by tunnels or shafts. Tunnels or shafts lead to a more horizontal network of underground tunnels that directly access the ore. In an underground mining method called 'stoping' or 'block caving,' sections or blocks of rock are removed in vertical strips that leave a connected underground cavity that is usually filled with cemented aggregate and waste rock.

Although underground mining is a less environmentally-destructive means of gaining access to an ore deposit, it is often more costly and entails greater safety risks than strip mining, including open-pit mining. While most large-scale mining projects involve open-pit mining, many large underground mines are in operation around the world.

1.1.3.4 Reworking of inactive or abandoned mines and tailings

Some mining projects involve the reworking of waste piles (often tailings) from inactive or abandoned mines, or older waste piles at active mines. Typically, this is proposed when more efficient methods of metal beneficiation have made it economical to re-extract metals from old mining waste. The material from the piles may be sent to processing facilities on-site or off-site. Mining projects that only involve the reworking of abandoned mine waste piles avoid the environmental impacts of open-pit mining and placer mining, but still entail environmental impacts associated with purification (beneficiation) of metals from the waste piles.

1.1.4 Disposal of overburden and waste rock

In almost every project, metallic ores are buried under a layer of ordinary soil or rock (called 'overburden' or 'waste rock') that must be moved or excavated to allow access to the metallic ore deposit. For most mining projects, the quantity of overburden generated by mining is enormous. The ratio of the quantity of overburden to the quantity of mineral ore (called the 'strip ratio') is usually greater than one, and can be much higher. For example, if a proposed mining project involves the extraction of 100 million metric tons of mineral ore, then the proposed mining project could generate more than one billion metric tons of overburden and waste rock.

These high-volume wastes, sometimes containing significant levels of toxic substances, are usually deposited on-site, either in piles on the surface or as backfill in open pits, or within underground mines. Therefore, the EIA for a proposed mining project must carefully assess the management options and associated impacts of overburden disposal.

1.1.5 Ore extraction

After a mining company has removed overburden, extraction of the mineral ore begins using specialized heavy equipment and machinery, such as loaders, haulers, and dump trucks, which transport the ore to processing facilities using haul roads. This activity creates a unique set of environmental impacts, such as emissions of fugitive dust from haul roads, which an EIA for a proposed mining project should assess separately.

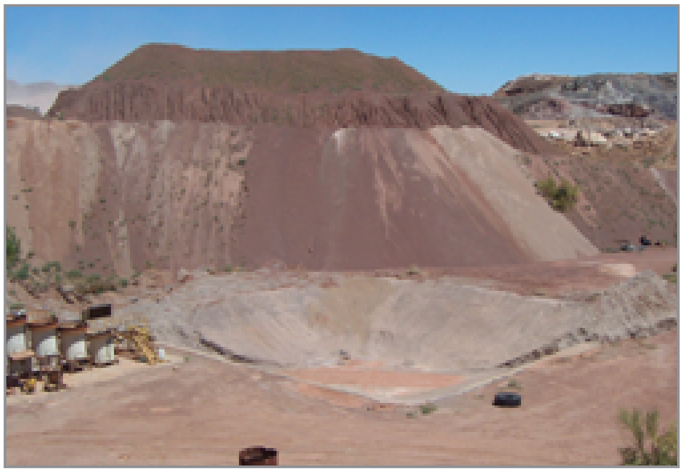
1.1.6 Beneficiation

Although metallic ores contain elevated levels of metals, they generate large quantities of waste. For example, the copper content of a good grade copper ore may be only one quarter of one percent. The gold content of a good grade gold ore may be only a few one-hundredths of a percent. Therefore, the next step in mining is grinding (or milling) the ore and separating the relatively small quantities of metal from the non-metallic material of the ore in a process called 'beneficiation.'

Milling is one of the most costly parts of beneficiation, and results in very fine particles that allow better extraction of the metal. However, milling also allows a more complete release of contaminants when these particles become tailings. Tailings are what remains following milling of the ore to fine particles and extraction of the valuable metal(s).

Beneficiation includes physical and/or chemical separation techniques such as gravity concentration, magnetic separation, electrostatic separation, flotation, solvent extraction, electrowinning, leaching, precipitation, and amalgamation (often involving the use of mercury). Wastes from these processes include waste rock dumps, tailings, heap leach materials (for gold and silver operations), and dump leach materials (for copper leach operations).

Leaching involving the use of cyanide is a kind of beneficiation process, usually used with gold, silver, and copper ores, that merits separate attention because of the serious environmental and public safety impacts. With leaching, finely ground ore is deposited in a large pile (called a 'leach pile') on top of an impermeable pad, and a solution containing cyanide is sprayed on top of the pile. The cyanide solution dissolves the desired metals and the 'pregnant' solution containing the metal is collected from the bottom of the pile using a system of pipes.



Heap leach, Bighorn gold mine, CA
PHOTO: Bender Environmental Consulting

1.1.7 Tailings disposal

As previously discussed, even high-grade mineral ores consist almost entirely of non-metallic materials and often contain undesired toxic metals (such as cadmium, lead, and arsenic). The beneficiation process generates high-volume waste called 'tailings,' the residue of an ore that remains after it has been milled and the desired metals have been extracted (e.g., with cyanide (gold) or sulfuric acid (copper)).

If a mining project involves the extraction of a few hundred million metric tons of mineral ore, then the mine project will generate a similar quantity of tailings. How a mining company disposes of this high-volume toxic waste material is one of the central questions that will determine whether a proposed mining project is environmentally acceptable. The key long-term goal of tailings disposal and management is to prevent the mobilization and release into the environment of toxic constituents of the tailings.

An entire section of this Guidebook is devoted to a detailed comparison of tailings disposal options (see Section 3.2.1.3). These options include: (1) the use of a wet tailings impoundment facility or 'tailings pond'; (2) dewatering and disposal of dry tailings as backfill; and (3) sub-marine tailings disposal.

The first option (a tailings pond) is by far the most commonly used option, but the second option (dry tailings disposal) is, in most circumstances, the environmentally-preferable option. The third option (sub-marine tailings disposal) is sometimes proposed with mine sites located near deep sea environments, or in rare instances in freshwater lakes. Sub-marine tailings disposal has a poor environmental record in the few instances where it has been practiced.

Before the adoption of environmental laws and standards, many mining companies simply dumped tailings in the nearest convenient location, including nearby rivers and streams. Some of the worst environmental consequences of mining have been associated with the open dumping of tailings, a practice now nearly universally rejected. The International Finance Corporation (IFC)/World Bank Group explains:

> *"Riverine (e.g., rivers, lakes, and lagoons) or shallow marine tailings disposal is not considered good international industry practice. By extension, riverine dredging which requires riverine tailings disposal is also not considered good international practice."*[1]

Wet tailings disposal at a mine in Peru
PHOTO: Centro de Cultura Popular LABOR, Peru

1.1.8 Site reclamation and closure

When active mining ceases, mine facilities and the site are reclaimed and closed. The goal of mine site reclamation and closure should always be to return the site to a condition that most resembles the pre-mining condition. Mines that are notorious for their immense impact on the environment often made impacts only during the closure phase, when active mining operations ceased. These impacts can persist for decades and even centuries. Therefore, the EIA for every proposed mining project must include a detailed discussion of the mine Reclamation and Closure Plan offered by the mining proponent.

Mine reclamation and closure plans must describe in sufficient detail how the mining company will restore the site to a condition that most resembles pre-mining environmental quality; how it will prevent – in perpetuity – the release of toxic contaminants from various mine facilities (such as abandoned open pits and tailings impoundments); and how funds will be set aside to insure that the costs of reclamation and closure will be paid for.

An entire section of this Guidebook is devoted to a discussion of how to evaluate whether the Reclamation and Closure Plan offered by a mining proponent is adequate (see Section 3.7).

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[1] IFC/World Bank (December 2007) "Environmental, Health and Safety Guidelines for Mining." http://www.ifc.org/ifcext/sustainability.nsf/AttachmentsByTitle/gui_EHSGuidelines2007_Mining/$FILE/Final+-+Mining.pdf

1.2 ENVIRONMENTAL AND SOCIAL IMPACTS OF MINING

The remainder of this chapter describes the most important environmental impacts of mining projects.

1.2.1 Impacts on water resources

Perhaps the most significant impact of a mining project is its effects on water quality and availability of water resources within the project area. Key questions are whether surface and groundwater supplies will remain fit for human consumption, and whether the quality of surface waters in the project area will remain adequate to support native aquatic life and terrestrial wildlife.

1.2.1.1 Acid mine drainage and contaminant leaching

The potential for acid mine drainage is a key question. The answer will determine whether a proposed mining project is environmentally acceptable. When mined materials (such as the walls of open pits and underground mines, tailings, waste rock, and heap and dump leach materials) are excavated and exposed to oxygen and water, acid can form if iron sulfide minerals (especially pyrite, or 'fools gold') are abundant and there is an insufficient amount of neutralizing material to counteract the acid formation. The acid will, in turn, leach or dissolve metals and other contaminants from mined materials and form a solution that is acidic, high in sulfate, and metal-rich (including elevated concentrations of cadmium, copper, lead, zinc, arsenic, etc.)

Leaching of toxic constituents, such as arsenic, selenium, and metals, can occur even if acidic conditions are not present. Elevated levels of cyanide and nitrogen compounds (ammonia, nitrate, nitrite) can also be found in waters at mine sites, from heap leaching and blasting.

Acid drainage and contaminant leaching is the most important source of water quality impacts related to metallic ore mining.

Acid mine drainage
PHOTO: SOSBlueWaters.org

As Earthworks explains:

> *"Acid mine drainage is considered one of mining's most serious threats to water resources. A mine with acid mine drainage has the potential for long-term devastating impacts on rivers, streams and aquatic life.*
>
> *"HOW DOES IT FORM? Acid mine drainage is a concern at many metal mines, because metals such as gold, copper, silver and molybdenum, are often found in rock with sulfide minerals. When the sulfides in the rock are excavated and exposed to water and air during mining, they form sulfuric acid. This acidic water can dissolve other harmful metals in the surrounding rock. If uncontrolled, the acid mine drainage may runoff into streams or rivers or leach into groundwater. Acid mine drainage may be released from any part of the mine where sulfides are exposed to air and water, including waste rock piles, tailings, open pits, underground tunnels, and leach pads.*
>
> *"HARM TO FISH & OTHER AQUATIC LIFE: If mine waste is acid-generating, the impacts to fish, animals and plants can be severe. Many streams impacted by acid mine drainage have a pH value of 4 or lower – similar to battery acid. Plants, animals, and fish are unlikely to survive in streams such as this.*

> *"TOXIC METALS: Acid mine drainage also dissolves toxic metals, such as copper, aluminum, cadmium, arsenic, lead and mercury, from the surrounding rock. These metals, particularly the iron, may coat the stream bottom with an orange-red colored slime called yellowboy. Even in very small amounts, metals can be toxic to humans and wildlife. Carried in water, the metals can travel far, contaminating streams and groundwater for great distances. The impacts to aquatic life may range from immediate fish kills to sub-lethal, impacts affecting growth, behavior or the ability to reproduce.*
>
> *"Metals are particularly problematic because they do not break down in the environment. They settle to the bottom and persist in the stream for long periods of time, providing a long-term source of contamination to the aquatic insects that live there, and the fish that feed on them.*
>
> *"PERPETUAL POLLUTION: Acid mine drainage is particularly harmful because it can continue indefinitely causing damage long after mining has ended. Due to the severity of water quality impacts from acid mine drainage, many hardrock mines across the west require water treatment in perpetuity. Even with existing technology, acid mine drainage is virtually impossible to stop once the reactions begin. To permit an acid generating mine means that future generations will take responsibility for a mine that must be managed for possibly hundreds of years."*[2]

1.2.1.2 Erosion of soils and mine wastes into surface waters

For most mining projects, the potential of soil and sediment eroding into and degrading surface water quality is a serious problem.

According to a study commissioned by the European Union:

> *"Because of the large area of land disturbed by mining operations and the large quantities of earthen materials exposed at sites, erosion can be a major concern at hardrock mining sites. Consequently, erosion control must be considered from the beginning of operations through completion of reclamation. Erosion may cause significant loading of sediments (and any entrained chemical pollutants) to nearby waterbodies, especially during severe storm events and high snow melt periods.*
>
> *"Sediment-laden surface runoff typically originates as sheet flow and collects in rills, natural channels or gullies, or artificial conveyances. The ultimate deposition of the sediment may occur in surface waters or it may be deposited within the floodplains of a stream valley. Historically, erosion and sedimentation processes have caused the build-up of thick layers of mineral fines and sediment within regional flood plains and the alteration of aquatic habitat and the loss of storage capacity within surface waters. The main factors influencing erosion includes the volume and velocity of runoff from precipitation events, the rate of precipitation infiltration downward through the soil, the amount of vegetative cover, the slope length or the distance from the point of origin of overland flow to the point where deposition begins, and operational erosion control structures.*
>
> *"Major sources of erosion/sediment loading at mining sites can include open pit areas, heap and dump leaches, waste rock and overburden piles, tailings piles and dams, haul roads and access roads, ore stockpiles, vehicle and equipment maintenance areas, exploration areas, and reclamation areas. A further concern is that exposed materials from mining operations (mine workings, wastes, contaminated soils, etc.) may contribute sediments with chemical pollutants, principally heavy metals. The variability in natural*

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[2] Earthworks Fact Sheet: Hardrock Mining and Acid Mine Drainage. http://www.earthworksaction.org/pubs/FS_AMD.pdf

site conditions (e.g., geology, vegetation, topography, climate, and proximity to and characteristics of surface waters), combined with significant differences in the quantities and characteristics of exposed materials at mines, preclude any generalisation of the quantities and characteristics of sediment loading.

"The types of impacts associated with erosion and sedimentation are numerous, typically producing both short-term and long-term impacts. In surface waters, elevated concentrations of particulate matter in the water column can produce both chronic and acute toxic effects in fish.

"Sediments deposited in layers in flood plains or terrestrial ecosystems can produce many impacts associated with surface waters, ground water, and terrestrial ecosystems. Minerals associated with deposited sediments may depress the pH of surface runoff thereby mobilising heavy metals that can infiltrate into the surrounding subsoil or can be carried away to nearby surface waters. The associated impacts could include substantial pH depression or metals loading to surface waters and/or persistent contamination of ground water sources. Contaminated sediments may also lower the pH of soils to the extent that vegetation and suitable habitat are lost.

"Beyond the potential for pollutant impacts on human and aquatic life, there are potential physical impacts associated with the increased runoff velocities and volumes from new land disturbance activities. Increased velocities and volumes can lead to downstream flooding, scouring of stream channels, and structural damage to bridge footings and culvert entries. In areas where air emissions have deposited acidic particles and the native vegetation has been destroyed, runoff has the potential to increase the rate of erosion and lead to removal of soil from the affected area. This is particularly true where the landscape is characterised by steep and rocky slopes. Once the soils have been removed, it is difficult for the slope to be revegetated either naturally or with human assistance."[3]

Overburden drainage at an Australian mine
PHOTO: Peripitus

Environment Australia summarizes the problem as follows:

> *"Potentially adverse effects of inadequate minesite water management and design include: unacceptably high levels of suspended solids (Non-Filterable Residue) and dissolved solids (Filterable Residue) in surface runoff [and] bed and bank erosion in waterways. It is self-evident that a Sediment and Erosion Control Plan is a fundamental component of a Minesite Water Management Plan."*[4]

1.2.1.3 Impacts of tailing impoundments, waste rock, heap leach, and dump leach facilities

The impacts of wet tailings impoundments, waste rock, heap leach, and dump leach facilities on water quality can be severe. These impacts include contamination of groundwater beneath these facilities and surface waters. Toxic substances can leach from these facilities, percolate through the ground, and contaminate groundwater, especially if the bottom of these facilities are not fitted with an impermeable liner.

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[3] MINEO Consortium (2000) "Review of potential environmental and social impact of mining" http://www2.brgm.fr/mineo/UserNeed/IMPACTS.pdf

[4] Environment Australia (2002) "Overview of Best Practice Environmental Management in Mining." http://www.ret.gov.au/resources/Documents/LPSDP/BPEMOverview.pdf

Tailings (a by-product of metallic ore processing) is a high-volume waste that can contain harmful quantities of toxic substances, including arsenic, lead, cadmium, chromium, nickel, and cyanide (if cyanide leaching is used). Although it is rarely the environmentally-preferable option, most mining companies dispose of tailings by mixing them with water (to form a slurry) and disposing of the slurry behind a tall dam in a large wet tailings impoundment. Because the ore is usually extracted as a slurry, the resulting waste contains large amounts of water, and generally forms ponds at the top of the tailings dams that can be a threat to wildlife. Cyanide tailings in precious metals mines are particularly dangerous.

Ultimately, tailing ponds will either dry, in arid climates, or may release contaminated water, in wet climates. In both cases, specific management techniques are required to close these waste repositories and reduce environmental threats.

During periods of heavy rain, more water may enter a tailings impoundment than it has the capacity to contain, necessitating the release of tailings impoundment effluent. Since this effluent can contain toxic substances, the release of this effluent can seriously degrade water quality of surrounding rivers and streams, especially if the effluent is not treated prior to discharge.

Dozens of dam breaks at wet tailings impoundments have created some of the worst environmental consequences of all industrial accidents. When wet tailings impoundments fail, they release large quantities of toxic waters that can kill aquatic life and poison drinking water supplies for many miles downstream of the impoundment.

1.2.1.4 Impacts of mine dewatering

When an open pit intersects the water table, groundwater flows into the open pit. For mining to proceed, mining companies must pump and discharge this water to another location. Pumping and discharging mine water causes a unique set of environmental impacts that are well described in a study commissioned by the European Union:

> *"Mine water is produced when the water table is higher than the underground mine workings or the depth of an open pit surface mine. When this occurs, the water must be pumped out of the mine. Alternatively, water may be pumped from wells surrounding the mine to create a cone of depression in the ground water table, thereby reducing infiltration. When the mine is operational, mine water must be continually removed from the mine to facilitate the removal of the ore. However, once mining operations end, the removal and management of mine water often end, resulting in possible accumulation in rock fractures, shafts, tunnels, and open pits and uncontrolled releases to the environment.*
>
> *"Ground water drawdown and associated impacts to surface waters and nearby wetlands can be a serious concern in some areas.*
>
> *"Impacts from ground water drawdown may include reduction or elimination of surface water flows; degradation of surface water quality and beneficial uses; degradation of habitat (not only riparian zones, springs, and other wetland habitats, but also upland habitats such as greasewood as ground water levels decline below the deep root zone); reduced or eliminated production in domestic supply wells; water quality/quantity problems associated with discharge of the pumped ground water back into surface waters downstream from the dewatered area. The impacts could last for many decades. While dewatering is occurring, discharge of the pumped water, after appropriate treatment, can often be used to mitigate adverse effects on surface waters. However, when dewatering ceases, the cones of depression may take many decades to recharge and may continue to reduce surface flows …. Mitigation measures that rely on the use of pumped water to create wetlands may only last as long as dewatering occurs."*[5]

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[5] MINEO Consortium (2000) "Review of potential environmental and social impact of mining" http://www2.brgm.fr/mineo/UserNeed/IMPACTS.pdf

1.2.2 Impacts of mining projects on air quality

Airborne emissions occur during each stage of the mine cycle, but especially during exploration, development, construction, and operational activities. Mining operations mobilize large amounts of material, and waste piles containing small size particles are easily dispersed by the wind.

The largest sources of air pollution in mining operations are:

- Particulate matter transported by the wind as a result of excavations, blasting, transportation of materials, wind erosion (more frequent in open-pit mining), fugitive dust from tailings facilities, stockpiles, waste dumps, and haul roads. Exhaust emissions from mobile sources (cars, trucks, heavy equipment) raise these particulate levels; and
- Gas emissions from the combustion of fuels in stationary and mobile sources, explosions, and mineral processing.

Once pollutants enter the atmosphere, they undergo physical and chemical changes before reaching a receptor (Figure 1). These pollutants can cause serious effects to people's health and to the environment.

Large-scale mining has the potential to contribute significantly to air pollution, especially in the operation phase. All activities during ore extraction, processing, handling, and transport depend on equipment, generators, processes, and materials that generate hazardous air pollutants such as particulate matter, heavy metals, carbon monoxide, sulfur dioxide, and nitrogen oxides.

1.2.2.1 Mobile sources

Mobile sources of air pollutants include heavy vehicles used in excavation operations, cars that transport personnel at the mining site, and trucks that transport mining materials. The level of polluting emissions from these sources depends on the fuel and conditions of the equipment. Even though individual emissions can be relatively small, collectively these emissions can be of real concern. In addition, mobile sources are a major source of particulate matter, carbon monoxide, and volatile organic compounds that contribute significantly to the formation of ground-level ozone.

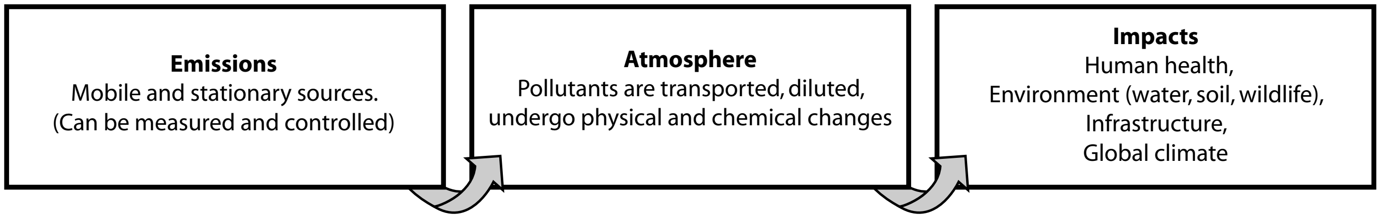
1.2.2.2 Stationary sources

The main gaseous emissions are from combustion of fuels in power generation installations, and drying, roasting, and smelting operations. Many producers of precious metals smelt metal on-site, prior to shipping to off-site refineries. Typically, gold and silver is produced in melting/fluxing furnaces that may produce elevated levels of airborne mercury, arsenic, sulfur dioxide, and other metals.

1.2.2.3 Fugitive emissions

The U.S. Environmental Protection Agency defines 'fugitive emissions' as "those emissions which could not reasonably pass through a stack, chimney, vent or other functionally-equivalent

Figure 1.



opening."[6] Common sources of fugitive emissions include: storage and handling of materials; mine processing; fugitive dust, blasting, construction activities, and roadways associated with mining activities; leach pads, and tailing piles and ponds; and waste rock piles. Sources and characteristics of fugitive emissions dust in mining operations vary in each case, as do their impacts. Impacts are difficult to predict and calculate but should be considered since they could be a significant source of hazardous air pollutants.

1.2.2.4 Incidental releases of mercury

Mercury is commonly present in gold ore. Although concentrations vary substantially, even within a specific ore deposit, mercury is found in gold ore and associated waste materials. If the content of mercury in a gold ore is 10 mg/kg, and one million tons of ore is processed at a particular mine (not unusual concentrations), 10 tons of mercury are potentially released to the environment. This is a major source of mercury and should be controlled.

In some gold mining projects, gold-containing ore is crushed and then, if necessary, heated and oxidized in roasters or autoclaves to remove sulfur and carbonaceous material that affects gold recovery. Mercury that is present in the ore is vaporized, particularly in roasters, which are some of the largest sources of mercury emitted to the atmosphere.

Following roasting or autoclaving, the ore is mixed with water and reacted with a cyanide leach solution, where gold and mercury are dissolved and solids removed via filtration. The purified solution is sent to an electrowinning process, where the gold is recovered. In this process, mercury must also be recovered and collected. If not collected by air pollution control devices, this mercury could be released to the atmosphere and impact the environment and public health.

Volatilization of mercury from active heaps and tailings facilities has recently been identified as another substantial source of mercury emitted to the atmosphere. This process should be assessed and controlled. Overall, mercury present in gold ore may be released to the land (in disposed air pollution control wastes and spent ore tailings), to the air (not removed by air pollution control devices, or from tailings or heaps), or in the gold product (i.e., as an impurity).

1.2.2.5 Noise and vibration

Noise pollution associated with mining may include noise from vehicle engines, loading and unloading of rock into steel dumpers, chutes, power generation, and other sources. Cumulative impacts of shoveling, ripping, drilling, blasting, transport, crushing, grinding, and stock-piling can significantly affect wildlife and nearby residents.

Vibrations are associated with many types of equipment used in mining operations, but blasting is considered the major source. Vibration has affected the stability of infrastructures, buildings, and homes of people living near large-scale open-pit mining operations. According to a study commissioned by the European Union in 2000:

> *"Shocks and vibrations as a result of blasting in connection with mining can lead to noise, dust and collapse of structures in surrounding inhabited areas. The animal life, on which the local population may depend, might also be disturbed."*[7]

1.2.3 Impacts of mining projects on wildlife

Wildlife is a broad term that refers to all plants and any animals (or other organisms) that are not domesticated. Mining affects the environment and associated biota through the removal of vegetation and topsoil, the displacement of fauna, the release of pollutants, and the generation of noise.

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[6] U.S. Environmental Protection Agency, Title 40 Code of Federal Regulations, Section 70.2. http://www.gpo.gov/fdsys/pkg/CFR-2009-title40-vol15/xml/CFR-2009-title40-vol15-part70.xml

[7] MINEO Consortium (2000) "Review of potential environmental and social impact of mining" http://www2.brgm.fr/mineo/UserNeed/IMPACTS.pdf

1.2.3.1 Habitat loss

Wildlife species live in communities that depend on each other. Survival of these species can depend on soil conditions, local climate, altitude, and other features of the local habitat. Mining causes direct and indirect damage to wildlife. The impacts stem primarily from disturbing, removing, and redistributing the land surface. Some impacts are short-term and confined to the mine site; others may have far-reaching, long-term effects.

The most direct effect on wildlife is destruction or displacement of species in areas of excavation and piling of mine wastes. Mobile wildlife species, like game animals, birds, and predators, leave these areas. More sedentary animals, like invertebrates, many reptiles, burrowing rodents, and small mammals, may be more severely affected.

If streams, lakes, ponds, or marshes are filled or drained, fish, aquatic invertebrates, and amphibians are severely impacted. Food supplies for predators are reduced by the disappearance of these land and water species.

Many wildlife species are highly dependent on vegetation growing in natural drainages. This vegetation provides essential food, nesting sites, and cover for escape from predators. Any activity that destroys vegetation near ponds, reservoirs, marshes, and wetlands reduces the quality and quantity of habitat essential for waterfowl, shore birds, and many terrestrial species.

The habitat requirements of many animal species do not permit them to adjust to changes created by land disturbance. These changes reduce living space. The degree to which animals tolerate human competition for space varies. Some species tolerate very little disturbance. In instances where a particularly critical habitat is restricted, such as a lake, pond, or primary breeding area, a species could be eliminated.

Surface mining can degrade aquatic habitats with impacts felt many miles from a mining site. For example, sediment contamination of rivers and streams is common with surface mining.

1.2.3.2 Habitat fragmentation

Habitat fragmentation occurs when large areas of land are broken up into smaller and smaller patches, making dispersal by native species from one patch to another difficult or impossible, and cutting off migratory routes. Isolation may lead to local decline of species, or genetic effects such as inbreeding. Species that require large patches of forest simply disappear.

1.2.4   Impacts of mining projects on soil quality

Mining can contaminate soils over a large area. Agricultural activities near a mining project may be particularly affected. According to a study commissioned by the European Union:

> *"Mining operations routinely modify the surrounding landscape by exposing previously undisturbed earthen materials. Erosion of exposed soils, extracted mineral ores, tailings, and fine material in waste rock piles can result in substantial sediment loading to surface waters and drainage ways. In addition, spills and leaks of hazardous materials and the deposition of contaminated windblown dust can lead to soil contamination.*
>
> *"SOIL CONTAMINATION: Human health and environmental risks from soils generally fall into two categories: (1) contaminated soil resulting from windblown dust, and (2) soils contaminated from chemical spills and residues. Fugitive dust can pose significant environmental problems at some mines. The inherent toxicity of the dust depends upon the proximity of environmental receptors and type of ore being mined. High levels of arsenic, lead, and radionucleides in windblown dust usually pose the greatest risk. Soils contaminated from chemical spills and residues at mine sites may pose a direct contact risk when these materials are misused*

> *as fill materials, ornamental landscaping, or soil supplements."*[8]

1.2.5 Impacts of mining projects on social values

The social impacts of large-scale mining projects are controversial and complex. Mineral development can create wealth, but it can also cause considerable disruption. Mining projects may create jobs, roads, schools, and increase the demands of goods and services in remote and impoverished areas, but the benefits and costs may be unevenly shared. If communities feel they are being unfairly treated or inadequately compensated, mining projects can lead to social tension and violent conflict.

EIAs can underestimate or even ignore the impacts of mining projects on local people. Communities feel particularly vulnerable when linkages with authorities and other sectors of the economy are weak, or when environmental impacts of mining (soil, ai, and water pollution) affect the subsistence and livelihood of local people.

Power differentials can leave a sense of helplessness when communities confront the potential for change induced by large and powerful companies. The EIA process should enforce mechanisms that enable local communities to play effective roles in decision-making. Mineral activities must ensure that the basic rights of the individual and communities affected are upheld and not infringed upon. These must include the right to control and use land; the right to clean water, a safe environment, and livelihood; the right to be free from intimidation and violence; and the right to be fairly compensated for loss.

1.2.5.1 Human displacement and resettlement

According to the International Institute for Environment and Development:

> *"The displacement of settled communities is a significant cause of resentment and conflict associated with large-scale mineral development. Entire communities may be uprooted and forced to shift elsewhere, often into purpose-built settlements not necessarily of their own choosing. Besides losing their homes, communities may also lose their land, and thus their livelihoods. Community institutions and power relations may also be disrupted. Displaced communities are often settled in areas without adequate resources or are left near the mine, where they may bear the brunt of pollution and contamination. Forced resettlement can be particularly disastrous for indigenous communities who have strong cultural and spiritual ties to the lands of their ancestors and who may find it difficult to survive when these are broken."*[9]

1.2.5.2 Impacts of migration

According to the International Institute for Environment and Development:

> *"One of the most significant impacts of mining activity is the migration of people into a mine area, particularly in remote parts of developing countries where the mine represents the single most important economic activity. For example, at the Grasberg mine in Indonesia the local population increased from less than 1000 in 1973 to between 100,000 and 110,000 in 1999. Similarly, the population of the squatter settlements around Porgera in PNG, which opened in 1990, has grown from 4000 to over 18,000.10 This influx of newcomers can have a profound impact on the original inhabitants, and disputes may arise over land and the way benefits have been shared. (These were among the factors that led to violent uprisings at Grasberg in the 1970s and the 1990s.)*
>
> *"Sudden increases in population can also lead to pressures on land, water, and other*

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[8] Ibid.

[9] International Institute for Environment and Development (2002) "Breaking New Ground: Mining, Minerals and Sustainable Development: Chapter 9: Local Communities and Mines. Breaking New Grounds." http://www.iied.org/pubs/pdfs/G00901.pdf

> *resources as well as bringing problems of sanitation and waste disposal.*
>
> *"Migration effects may extend far beyond the immediate vicinity of the mine. Improved infrastructure can also bring an influx of settlers. For instance, it is estimated that the 80- meter-wide, 890-kilometre-long transportation corridor built from the Atlantic Ocean to the Carajas mine in Brazil created an area of influence of 300,000 square kilometres."*[10]

1.2.5.3 Lost access to clean water

According to scientists at the University of Manchester (UK) and the University of Colorado(U.S.):

> *"Impacts on water quality and quantity are among the most contentious aspects of mining projects. Companies insist that the use of modern technologies will ensure environmentally friendly mining practices. However, evidence of the negative environmental impacts of past mining activity causes local and downstream populations to worry that new mining activities will adversely affect their water supply. ...*
>
> *"There are major stakes in these conflicts, affecting everything from local livelihood sustainability to the solvency of national governments. Fears for water quantity and quality have triggered numerous and sometimes violent conflicts between miners and communities."*[11]

1.2.5.4 Impacts on livelihoods

When mining activities are not adequately managed, the result is degraded soils, water, biodiversity, and forest resources, which are critical to the subsistence of local people. When contamination is not controlled, the cost of the contamination is transferred to other economic activities, such as agriculture and fishing. The situation is made worse when mining activities take place in areas inhabited by populations historically marginalized, discriminated against, or excluded.

Proponents of mining projects must insure that the basic rights of affected individuals and communities are upheld and not infringed upon. These include rights to control and use land, the right to clean water, and the right to livelihood. Such rights may be enshrined in national law, based on and expressed through a range of international human rights instruments and agreements. All groups are equal under the law, and the interests of the most vulnerable groups (low-income and marginalized) need to be identified and protected.

1.2.5.5 Impacts on public health

EIAs of mining projects often underestimate the potential health risks of mining projects. Hazardous substances and wastes in water, air, and soil can have serious, negative impacts on public health. The World Health Organization (WHO) defines health as a "state of complete physical, mental and social well-being, and not merely the absence of disease or infirmity."[12]

The term 'hazardous substances' is broad and includes all substances that can be harmful to people and/or the environment. Because of the quantity, concentration, or physical, chemical or infectious characteristics, hazardous substances may (1) cause or contribute to an increase of mortality or an increase in serious irreversible or incapacitating illness; or (2) pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, disposed of, or otherwise managed.

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[10] Ibid.

[11] Bebbington, A., & Williams, M. (2008) "Water and Mining Conflicts in Peru." Mountain Research and Development. 28(3/4):190-195 http://snobear.colorado.edu/Markw/Research/08_peru.pdf

[12] World Health Organization. 1946. Preamble to the Constitution of the World Health Organization. Official Records of the World Health Organization No. 2, p. 100.

Frequent public health problems related to mining activities include:

- Water: Surface and ground water contamination with metals and elements; microbiological contamination from sewage and wastes in campsites and mine worker residential areas;
- Air: Exposure to high concentrations of sulfur dioxide, particulate matter, heavy metals, including lead, mercury and cadmium; and
- Soil: Deposition of toxic elements from air emissions.

Mining activities can suddenly affect quality of life and the physical, mental, and social well-being of local communities. Improvised mining towns and camps often threaten food availability and safety, increasing the risk of malnourishment. Indirect effects of mining on public health can include increased incidence of tuberculosis, asthma, chronic bronchitis, and gastrointestinal diseases.

1.2.5.6 Impacts to cultural and aesthetic resources

Mining activities can cause direct and indirect impacts to cultural resources. Direct impacts can result from construction and other mining activities. Indirect impacts can result from soil erosion and increased accessibility to current or proposed mining sites. Mining projects can affect sacred landscapes, historical infrastructures, and natural landmarks. Potential impacts include:

- Complete destruction of the resource through surface disturbance or excavation;
- Degradation or destruction, due to topographic or hydrological pattern changes, or from soil movement (removal, erosion, sedimentation);
- Unauthorized removal of artifacts or vandalism as a result of increased access to previously inaccessible areas; and
- Visual impacts due to clearing of vegetation, large excavations, dust, and the presence of large-scale equipment, and vehicles.

1.2.6 Climate change considerations

Every EIA for a project that has the potential to change the global carbon budget should include an assessment of a project's carbon impact. Large-scale mining projects have the potential to alter global carbon in at least the following ways:

Lost CO_2 uptake by forests and vegetation that is cleared. Many large-scale mining projects are proposed in heavily forested areas of tropical regions that are critical for absorbing atmospheric carbon dioxide (CO_2) and maintaining a healthy balance between CO_2 emissions and CO_2 uptake. Some mining projects propose long-term or even permanent destruction of tropical forests. EIAs for mining projects must include a careful accounting of how any proposed disturbance of tropical forests will alter the carbon budget. The EIA should also include an analysis of the potential for the host country to lose funding from international consortiums that have and will be established to conserve tropical forests.

CO_2 emitted by machines (e.g., diesel-powered heavy vehicles) involved in extracting and transporting ore. The EIA should include a quantitative estimate of CO_2 emissions from machines and vehicles that will be needed during the life of the mining project. These estimates can be based on the rate of fuel consumption (typically diesel fuel) multiplied by a conversion factor that relates units (typically liters or gallons) of fuel that is consumed and units (typically metric tons) of CO_2 that is emitted.

CO_2 emitted by the processing of ore into metal (for example, by pyro-metallurgical versus hydro-metallurgical techniques). An example is found in an assessment by CSIRO minerals of Australia which used the Life Cycle Assessment methodology to estimate the life cycle emissions of greenhouse gases from copper and nickel production, including mining. This assessment found that Life Cycle greenhouse gas emissions from copper and nickel production range from 3.3 kilograms (kg) of CO_2 per kg of metal for copper produced by smelting to 16.1 kg of CO_2 per kg of metal for nickel produced by pressure acid leaching followed by solvent extraction and electrowinning.[13] The bottom line is that metal mining generates *more than 1 kg of greenhouse gas for every 1 kg of metal that is produced,* and this does not take into account lost carbon uptake of cleared forests.

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[13] T. E. Norgate and W. J. Rankin (2000) "Life Cycle Assessment of Copper and Nickel Production, Published in Proceedings, Minprex 2000, International Conference on Minerals Processing and Extractive Metallurgy, pp133-138. http://www.minerals.csiro.au/sd/CSIRO_Paper_LCA_CuNi.htm