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MINING ENVIRONMENTAL IMPACTS---INTEGRATING AN ECONOMIC PERSPECTIVE

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I. Introduction

The following summarizes the most important environmental impacts of mining, with emphasis on those impacts commonly encountered at copper mining sites[1], and relates these impacts to the economic costs implied by prevention, remediation or economic valuation of the damages. Whereas previous works such as Ripley, E.A., R.Redman, and A. Crowder, 1996, Environmental Effects of Mining: St. Lucie Press, Delray Beach, Florida, 356 pg.; and Warhurst, Alyson and Ligia Noronha,2000, Environmental Policy in Mining: Lewis publishers, New York, 513 pg., and numerous others have summarized environmental impacts from mining, these have not been related to their associated economic costs. Thus, the work of economists and mining engineers has been conducted to a great extent on two parallel tracks without much interaction. However, since environmental regulatory staffs and budgets have been generally cut back internationally, and there is an increasing international awareness of the concept of "the polluter pays", governments have increasingly focused on the use of economic incentives to regulate environmental compliance. This has led to the increased importance of economic analysis and increased use of economic instruments in environmental policy making. The analysis of the inextricable links between the two variables, economy and environment, becomes even more compelling under the overall objective of sustainable development.

Rather than providing a comprehensive and exhaustive analysis of the aforementioned issues, this chapter provides a first brush over the subject, alluding to the general links and referring to some real world examples of these links.

In the past, operating companies frequently were not required to remediate environmental impacts to natural resources. Thus, the environmental costs usually remained economically unaccounted for, and were often assumed to be zero. As a result, the actual costs in many countries have often been subsidized by the taxpayers and impacted citizens.

Impacts have been organized into the following general categories:
--Water Quantity
--Water Quality
--Air and Soils
--Social / Cultural

A designation is also added to indicate at what mining activity phase these impacts usually occur. The activity phases are:
--Exploration / Testing / Pre-operation Phase (E)
--Operations (O)

[1] For simplicity, in this report, the term mining impacts refers to impacts associated with both mining and mineral processing activities.

--Post-closure (PC)

The last section of this chapter briefly discusses financial assurance instruments. Such approaches have commonly been used in other areas of commerce such as banking and insurance, but are relatively new in the environmental arena.

Information on the reclamation costs associated with these impacts is presented in section III.. Data on reclamation costs are often not readily available to the public since they frequently result from sensitive negotiations and / or litigation. In many countries and situations, such data are considered confidential. As a result, the costs presented in this paper are associated with considerable uncertainty, and should be considered as indicative of the approximate range of costs expected. In the information available, costs of several tasks are often lumped together, describing the cost of remediating an individual area. Thus, it is frequently not possible to identify the costs of specific activities.
In general, costs associated with correcting long-term water quality contamination impacts have been the most expensive impact category, when they have been addressed openly.

II. Principal Environmental Impacts

Mining is not a delicate activity. It generally involves moving and processing massive amounts of rock, and, in the case of copper mining, more than 80 to 90 percent of the original rock moved becomes waste. Many of the impacts discussed are more important in areas of significant precipitation than in desert regions. Nevertheless, resources in desert areas can also be severely damaged by these processes, but the costs may not be realized until many years in the future.

II.1. Mining Impacts to Water Quantity

The following activities cause impacts to water quantity:
--Water Supply Development (O)
--Mine Dewatering (O, PC)
--Storm Water / Flood Diversion Structure Construction (O, PC)

Impacts:
It is often assumed that desert areas have only one water concern---a lack of sufficient water. However, normally, even severe desert regions have usable amounts of ground water - often at significant depths - which have migrated long distances from recharge areas in the mountains. The Atacama region of Peru and Chile is typical of such a situation. These waters are usually quite valuable in such settings of scarcity, if markets are allowed to operate freely. Water may also be transported from areas many kilometers away from the mining sites to supply the various needs of mineral processing, drinking water, dust suppression, etc. Such diversions cause competition for water with other sectors of society, possibly reducing the supplies to towns, cities, and indigenous groups. Frequently these diversions will create negative impacts to lakes or salars due the reduction of water levels, reduction of fresh water inflow, and may damage local wildlife. Extraction and diversion of predominantly clean water can reduce the water quality in the lakes or ground water from which the extraction occurred. In some areas of Chile, Bolivia and Peru, such diversions are done near international borders, and can lead to serious transboundary conflicts.

Dewatering of future open pit mines inevitably lowers the local, and sometimes regional, water level. This can cause springs to dry up, and lower water levels in neighboring wells. The latter increases the costs of pumping water to the surface for those impacted, or may force them to re-drill and deepen wells. Such dewatering may reduce stream flow or lake levels. Reduction in flow of springs and streams can harm livestock uses, wildlife that use such sites for water, domestic and municipal water uses. Dewatering ceases when mining stops, but water levels may require many years to recover to original (or nearly original) levels.

The construction of flood diversion structures can be very costly, especially if an area is prone to seasonal "flash" flooding events. If such structures are not adequately designed, facilities may be destroyed and people killed when unusual "flash" or snow-melt events occur.

II.2. Mining Impacts to Water Quality

The following activities generally impact water quality:
--Drilling, geophysical activities, sampling, road building (E, O)
--Construction Activities—blasting, roads, pits, workings, facilities (E, O)
--Test Mining (E)
--Truck Hauling Activity (E, O)
--Mine Dewatering (O, PC)
--Mining (O, PC)
--Mineral Processing and Waste Disposal (O, PC)
--Maintenance of Facilities (O, PC)

Impacts:

Mineral processing produces numerous wastes and products that can cause water contamination: tailings, waste rock, laboratory wastes, chemical reagents and contaminated containers (solid wastes), blasting compounds, smelter slag / dusts, spent leached ores, ore stockpiles. In addition, the associated infrastructure that must be developed to support a large mining and processing operation generates sewage wastes, water treatment sludges, oils, petroleum, diesel fuels, etc. All can cause contamination of surface and ground waters, whether or not acid rock drainage (ARD) develops.

The various exploration, test, and construction activities may result in damage to vegetation, and most importantly, an increase of sediment loads into water bodies (rivers, lakes, oceans), which can harm water quality and aquatic organisms.

Companies may conduct underground testing operations—as in solution mining—that can contaminate aquifers or surface waters. This type of mining is often performed using hot solutions, which may have unusually high (9 to 12) or low (2 to 5) pH. Such solutions commonly leach soluble constituents out of rock, contaminating the ground and surface waters.

Extraction, diversion and dewatering of predominantly clean water can reduce the water quality in the lakes or ground waters from which the extraction occurred. In many environments, water that results from dewatering operations must be impounded or reinjected into the subsurface. These operations often result in undesirable chemical interactions between the dewatering water and the rock or sediment it later contacts, which can release elements such as arsenic, contaminating surface and ground waters.

Mining (both underground and open pit) breaks and crushes rock, creating new pathways for oxygen, air and microbes to react with the rock. Thus, both underground workings and open pit walls may generate acid rock drainage (ARD), which can contaminate ground and surface waters for decades or even hundreds of years after mine closure. This occurs where "significant" amounts of sulfide minerals are present in the ores and waste rock, and causes a lowering of water pH to about 1.0 to 4.0, which then mobilizes many other chemical constituents, such as toxic metals and non-metals. ARD-impacted waters draining from underground mine workings have negatively impacted thousands of miles of streams in the USA alone. Open pit mines that produce ARD may result in an acid, toxic lake forming within the former excavation after the dewatering wells have been shut off. Such conditions may also contaminate ground waters around the pit area. This latter process may be aggravated because open pits are often connected to older underground workings that provide preferred pathways for migration of the contaminated waters.

Simple mining processes (without ARD generation) also contaminate waters by increasing the amounts of suspended sediments (and other soluble constituents) released, and by increasing concentrations of nitrates and ammonia due to the blasting compounds used. All these processes can result in increased eutrophication and contamination of water bodies.

Indigenous / artisanal mining techniques and placer mining often greatly disturb surface gravels, causing tremendous increases in suspended sediment loads and mercury contamination. In such situations, wastes are totally uncontrolled.

Waste rock, which may account for more than 80 percent of the rock mined at many copper sites, often contains elevated concentrations of sulfide and toxic metals and non-metals. This waste rock is normally disposed of in piles on the surface of the ground at the edges of pits, or outside the workings. Many contaminants can be leached out of these waste piles, contaminating surface waters and ground waters. The main ground water aquifer outside Salt Lake City, USA, which is less than 20 miles from the Kennecott Copper operations, has been contaminated over an area of tens of square miles. This contamination was increased because waste rock was treated using heated solutions of bacteria and acid water to recover remaining copper and other metals. No barriers were constructed to capture the acid, contaminated leachates, in the past. Thus the aquifers were contaminated for many miles downgradient. Undesirable chemical releases from waste rock can occur even where acid is not added to the piles or where ARD fails to develop. Because of the increased surface area of the broken rock, chemical reaction rates are increased. Also, many contaminants may be mobile under high pH conditions (above approximately pH 8.5)---for example sulfate, arsenic, manganese, iron, mercury, lead, nickel, selenium, molybdenum, vanadium, uranium. etc. These constituents are often common in copper ores and in desert environments where alkaline waters predominate.

II.2.1. Tailings

Mineral processing activities sometimes involve grinding the ore, adding various chemicals, and possibly several physical separation processes. These processes result in wastes called tailings, which contain numerous metal and non-metal residues form the ore, but also contain high concentrations of the process chemicals. These compounds may include kerosene and other petroleum-based or organic compounds, organic acids, cyanide and related compounds, various acids, lime, etc. At modern operations, these tailings wastes are generally sent to engineered impoundments which are often lined with synthetic liners. At older operations, or in areas of lax oversight, tailings may be disposed of directly into stream channels or into the ocean. (e.g. pre-1997 Southern Peru Copper and Chanaral). Where uncontrolled, these tailings wastes obviously can cause significant contamination of all water bodies. Such solutions are often very high in pH (10 to 12), and may contain potentially toxic concentrations of numerous metals, radioactivity, non-metals, cyanide and related breakdown compounds, and organic compounds. Even where modern impoundments have been constructed, significant chances for long-term contamination exist. All liners leak to some extent, and this leakage may only be detected after several years of operation or following mine closure. Also, impoundments in Andean countries are often subject to strong seismic events that make construction details very important, and require long-term maintenance of these structures after closure — to prevent both catastrophic failures and chronic leakage from developing. Since many copper ores also contain commercial concentrations of other metals and metalloids like molybdenum, selenium, and gold, cyanide compounds are often used in the separation process. Normally, the concentrations of cyanide and related compounds in copper tailings may be toxic to fish, but are much lower than in gold tailings. Collapse of a cyanide and metal-laden tailings impoundment at a gold processing facility in

Romania recently caused tremendous damage to rivers, fish, wildlife, crops and water supplies along hundreds of kilometers of rivers in central Europe.

Tailings may contain significant concentrations of sulfide particles, such that they can develop ARD many years in the future, even where the original slurry pH was highly alkaline. This is especially true if the tailings remain in contact with salty or briny water. Old Southern Peru Copper tailings deposited near the ocean, originally had alkaline pHs, but after many years of chemical reaction show a pH in the range of 1.5 to 3.0.

Smelter wastes such as slag and dusts can also result in contamination of surface and ground waters. Smelter slags, despite numerous claims by industry, often release contaminants, especially where the reacting waters have unusually high or low pH, and / or are salty or briny.

Many copper ores are processed using various leach techniques. Here also, ground and surface water contamination can develop even where modern liners are used. Such problems normally develop over many years. The contamination is often first noted by an increase in water concentrations of non-metals such as chloride, sulfide, nitrate, etc.---depending on the leaching chemicals employed.

Many of the processes described above result in the development of facilities that require long-term maintenance to prevent deterioration and serious contamination from developing: i.e. tailings impoundments (with or without caps and liners), spent heap leach piles, waste rock piles (with and without caps), diversion / pumpback / infiltration facilities, areas of revegetation, "passive" treatment systems, etc.

In addition, several sites in developed countries now have water treatment plants operating after mine closure to correct ARD or other water quality problems. Some are anticipated to operate for decades after closure, or in perpetuity.

Such plants and facilities require continual, long-term maintenance and may be the most costly environmental activities associated with mining.

The previous impacts have been labeled water quality impacts. More correctly, these impacts may be described as damages to: domestic and municipal water supplies, livestock water uses, agricultural uses---i.e. situations where mine leachates may impact orchards or vineyards, human health, fisheries and aquatic life—freshwater and marine(fish and shellfish), and selected industrial water uses. Such impacts can also have indirect impacts on social, educational and touristic portions of an economy.

II.3. Mining Impacts to Air and Soils

The following activities generally impact air and soils:
--mining, construction, equipment operation (dust generation)
--mineral processing and smelting (gases and dusts)
--disposal of wastes (tailings, waste rock, etc.) which generate dust and gases

Impacts:
The various mining and related construction activities mobilize tremendous quantities of dust particles. These particles may produce negative impacts solely due to the *physical* nature of the particles. Such impacts include:

- reduction in visibility
- esthetic impacts, such as coating houses, cars, laundry with dust
- health impacts, such as respiratory diseases and allergies, due to airborne contaminants[2]

[2] Silicosis, for example, has contributed to the deaths of thousands of miners throughout the world in modern

- damage to vegetation—gardens, commercial crops, vineyards
- health impacts that might result from consumption of contaminated foods grown on such contaminated soils
- physical damage to equipment
- impacts to soils, water quality and aquatic life due to airborne dusts;

Some of these impacts may be more truly *chemical* in nature due to the chemical components in the dusts.

Mineral processing, and most specifically, smelting operations release massive quantities of potentially toxic airborne particles and gases. These constituents include the various sulfur, carbon, and nitrogen species commonly detected in air monitoring. In addition, they may include toxic concentrations of numerous metals such as arsenic, nickel, lead, cobalt, mercury, etc.
The U.S. EPA states in its Toxic Release inventory (May 2000) that the hardrock mining industry is the largest source of toxic pollutants in the USA. For example, this document notes that the Cyprus Miami Copper Mine in Arizona releases twice as much toxic waste (123 million pounds, based on data from 1998) as all the waste, from all industrial sources, released in New York State (60 million pounds, 1998 data).

These components may result in the following impacts, especially if the operations are located near cities or towns:

- reduction in visibility, smog, haze
- esthetic impacts: discoloration and erosion of building surfaces, cars, laundry due to acids produced
- corrosion of metals, damage to equipment and impairment of operation
- health impacts: respiratory diseases, allergies, skin rashes, toxic reactions.

These airborne contaminants can harm both mine workers and citizens at significant distances from the mine operations. The latter often have no direct economic connection to the mine operations, and did not choose to expose themselves to such impacts. Clearly, mining companies have faced significant liability costs from some of the health- related impacts, but such data were not available to the author.

The following additional impacts often occur:

- chemical damage to vegetation and soils which can impair crops, potentially rendering them toxic for human or animal consumption
- impacts to water quality and aquatic life. Such emissions from industrial sources in Europe and the USA are known to contribute to acid rain and acidification of lakes
- contamination of laboratory analyses by air pollutants
- negative impacts on tourism and development

II.4. Mining Impacts on Social / Cultural Aspects

The activities described in the previous sections may also have indirect social and cultural impacts. On the other hand, development of a mine by itself causes an influx of workers and their families to areas that, often, were previously sparsely populated. This is followed by development of support businesses and facilities that cause a great increase in economic activity and demand for all resources—all of which are often viewed as positive. Some of the more common potentially negative impacts are:

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times. Other health impacts to miners may be considered partly due to both negative physical and chemical responses, for example, incidences of lung cancer due to exposure to radon and other radioactive components. Many copper ores and wastes contain elevated concentrations of radioactive components

- growth pressures on local governments, schools
- increases in crime
- increased traffic on local roads, congestion, accidents.
- Increased costs for maintenance of roads
- inflation in costs of goods, labor, property, and taxes
- great increase in cost of water
- potentially negative impacts on tourism
- Impacts to areas or activities that are important or sacred to indigenous groups.

Historically, mining has had “boom and bust” economic cycles that are considered unsustainable. Once the economic downturn begins, the local area is inevitably unable to provide the funds necessary to pay for the impacts. This usually leads to severe economic and environmental decline, and / or requests for outside sources of funding to deal with the problems.

Accidents involving the transport of mining wastes and process chemicals can force companies to make cash payments to local citizens that may claim damages. Recently, a Canadian company mining gold in Kyrgyzstan made payments to local citizens reported to be between $US 5 and 10 million for damages due to a truck-cyanide accident.

These are only a few examples of social aspects related to mine operations.

III. Costs

This section provides some concrete examples of costs associated with remediating impacts like those discussed in the previous sections. The costs can arise in the form of preventive costs, direct treatment costs, or post-operational treatment costs. Where costs are internalized in the companies´ operations they arise primarily in the form of investment costs for environmental technology. However, even if the greatest effort is made some impacts will remain, the cost of which will potentially be borne by the taxpayers and general public.

Due to the still limited availability of data on this subject, especially in the latin-american region, most of the information presented in the following relates to US or Canadian mines.

Some of the following cost information comes from discussions with the Montana (USA) Dept. of Justice, regarding a mining “Superfund” site under litigation called the Clark Fork Basin. This is an area of historical copper (and other metal) mining / processing, where the State of Montana and the U.S. Environmental Protection Agency (EPA) have negotiated and litigated with the present property owners, predominantly ARCO, to promote reclamation of portions of this huge contaminated area. The Clark Fork site is actually composed of numerous separate contaminated areas, many of which are located along more than one hundred and twenty miles of impacted rivers.

These costs are of additional significance to the Chilean situation because ARCO purchased the holdings of the Anaconda Corporation some time in the 1970’s, including those mining properties in the USA and those in Chile, most notably Chuquicamata. (see Finn, Janet L., 1998, Tracing the Veins: Of Copper, Culture, and Community from Butte to Chuquicamata; Univ. of California Press, Berkeley, 309 pages.)

While many of the Clark Fork sites have not been remediated and are still under litigation, ARCO states that about $US 400 to 500 million has already been spent on the overall clean-up (including water, soils, air, etc.). Apparently these numbers include approximately $US100M for technical studies, but do not include legal fees. The State of Montana has already received $US210M in compensation from ARCO for damages to natural resources, plus an additional $US 15M compensation for past State studies and cleanup activities. ARCO has also paid an additional $US 18M to neighboring indigenous tribes for resource damages. The State has an additional three sites that are still being litigated, and the additional damages to ARCO are estimated to be $US180M. If the actual remedy costs exceed the amounts estimated, ARCO will be required to pay the additional costs. ARCO is presently suing their insurance company for all costs incurred.

III.1. Clark Fork Site Costs

Some of the pertinent cost details from the Clark Fork site are:
--capping of a huge tailings pile (approximately 800 feet high x 2 sq. miles, estimated cost = $US80M. Assumes a 4-foot thick cap; the technical details of the layers are unknown. The estimated (future) costs include water control / diversion structures.

--transport of approximately 1.2 M cubic yards of saturated / unsaturated tailings, some by rail = $US 2.50 per cubic yard.

--transport of above tailings by truck = approximately $US 2.00 per cubic yard if transported less than one mile; $US 3.50 per cubic yard if transported greater than one mile.

-- mixing of other tailings (further downstream) with lime and transport by truck approximately one mile = $US 1.50 per cu. yd. for lime mixing, plus $US 2.50—3.00 per cu. yd. for transport. This tailings removal activity is anticipated to occur over a period of 12 years, and cost about $US 80M.

--the receiving area for the above tailings has a pre-existing contaminated ground water plume of about 40 acres. Future costs to cap and reclaim (includes revegetation) this area is estimated to be $US100M to $150M, with approximately 50 percent of funds allocated to capping and 50 percent to reclamation. The capping is being performed largely to prevent future transport of airborne dust, since it is located near a major interstate highway. The EPA considers the most important “injured” resources to be (with most important listed first): ground water, wildlife habitat, aquatic habitats. The regulators have decided that it is not technically practical to treat the contaminated ground waters, thus the funds received will be used to provide alternative water sources, and to reclaim aquatic habitats.

--remediation of smelter dusts = approximately $US 40M. About 600,000 cubic yards of smelter wastes, approximately 20 percent metals by volume and containing high arsenic concentrations were mixed with lime, and hauled by rail to a local repository (which was lined and capped). Unfortunately, no vegetation will grow on the cap. [3]

--remediation of soils surrounding community homes = $US 5M.

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[3] The main smelter source for this waste once produced 75 tons per day of arsenic (Montana Department of Justice, January 1995, Terrestrial Resources Injury Assessment Report, Upper Clark Fork River NPL Sites: Montana Natural Resource Damage Program). The county where this smelter was located had reported cancer rates among the highest in the USA for many decades. The death rate in Butte, Montana from disease (all disease types) was the highest, or among the highest of any city in the USA between 1949 and 1971, when adjusted for population (Moore, Johnnie, and Luoma, S.N., 1990, Hazardous Wastes From Large-scale Metal Extraction: The Clark Fork Waste Complex, MT, p.163-185: in Proceedings, 1990 Clark Fork River Symposium, April 20, 1990, University of Montana, Missoula, MT.)

--treatment of bedrock ground water contamination resulting from underground and open pit mining. At present, about 3000 miles of underground workings exist near the pit, which sits within the town of Butte. The pit lake is about 900 feet deep, and is still filling. Once the water level approaches that of the neighboring alluvial sediments, ARCO must begin operation of a water treatment plant, in perpetuity. The plant is estimated to require a treatment capacity of 8 million gallons per day (gpd); plant construction capital costs are estimated to be $US 75M, and Operation and Maintenance (O/M) costs are estimated to be $US 10M per year.

--treatment of contaminated alluvial ground water in the Butte area. The estimated capital cost for construction of this treatment plant is $US20M; O/M costs are estimated to be $500,000 per year.

--repair of existing tailings ponds located upstream of an important regional city. This effort involved construction of an improved dam and dikes to prevent the possible release of these tailings into the town as a result of excessive flooding and / or seismic events. Cost = $US 45M.

III.2. General Costs at Other Mining Sites

--Surface reclamation (dirt-moving, recontouring, revegetation) costs vary greatly from mine to mine, but average from less than $US 1000 to more than $20,000 per acre in the western United States (Kuipers, 2000, see section IV.).

--Many copper mining operations occur in desert regions where water is extremely scarce, and additional sources of water must often be purchased from other users. Some average market prices of water (various categories) in the State of Colorado are presented below. These have been provided by the water rights consulting firm of Bishop-Brogden Associates, Englewood, Colorado, USA. Such prices are routinely published in a monthly publication, the Water Strategist---Analysis of Water Marketing, Finance, Legislation, and Litigation (Stratecon, Inc., Claremont, California: www.waterstrategist.com).

Water Rights---General Costs (Western USA)
[1 acre-foot = 1233.6 M^3]

Absolute Water Right:: $US 200 to $US 20,000 per acre-foot
The lower amount is representative of the cost for rural irrigation uses; the higher amount for domestic municipal uses.

Absolute Ground Water Rights: $US 2500 per acre-foot (e.g., non-tributary water in the Denver Basin, Colorado).

--Replacement of ground or surface waters. Kennecott Utah Copper Corp., Bingham Canyon Utah, was required to pay the State of Utah (USA) $9,000,000 to replace sources of water contaminated by copper leaching activities. (Consent Decree, State of Utah v. Kennecott Utah Copper Corp., August 1995.)

--Treatment of contaminated ground water (from Utah site noted above) to municipal quality. Kennecott was required to pay $US 28M for the construction of a water treatment plant having a capacity to treat 7000 acre-feet per year. This amount was based on a calculated value of $4000 per acre-foot of treated water (under these conditions), in 1995 dollars. Treated water must have sulfates concentrations between 250 to 500 mg /L, and total dissolved solids concentrations between 500 and 1,000 mg / L.

--Comparative costs for constructing and operating water treatment plants at three different mining sites in Colorado are also presented in a paper by R.J. McLaughlin, A.Danzberger, and R. E. McLaughlin,1995, Demonstration of an innovative Heavy Metals Removal Process. These plants have treatment capacities ranging between 60 and 520 m^3/ hour. The construction capital costs range between $ 0.6M and $11M; O/M costs range between $0.64 and $6.48 per kg of solids removed. Based on comments from an engineer involved in the construction of the smallest plant, the lowest capital cost is probably too low by about 50 percent. Also, these costs include sludge dewatering, but do not include sludge disposal costs.

-- Data from Decontamination Plans[4] in Chile show that the health costs can be substantial - in the range of US$100.000,- to US$600.000,- for each 100.000tons of SO2 per year. However, these values depend to a great extent on the value of life assumed for the calculations - in these cases a high value of life, based on Willingness to pay for example can be expected to triple or quadruple the cost figures.

--Costs of environmental monitoring and analysis should also be considered---staffs employed, equipment, sampling, lab analyses (water, geochemical sampling and analysis), analysis of data (modeling, interpreting), publishing data, interaction with regulators and the public, etc. Such costs frequently range from a few thousand dollars to hundreds of thousands of dollars US per year.

IV. Financial Assurance / Bonding

Until recently in most countries, regulators failed to require mining companies to pay costs associated with many of the post-operational impacts. Many of these external costs could only be internalized through litigation and the assessment of clean-up costs.

Many new mines in the USA and Canada are now required to guarantee that future environmental costs will be paid for (both during operation and after mine closure), even if the company goes bankrupt. In the words of an economist: regulators have taken such actions to ensure that medium and long-term environmental costs are internalized within the operating costs of the companies. This most often requires the mining company to purchase a bond from an insurance company, which is then held by an independent trustee.

Such bonds are being required because numerous mines have gone bankrupt, leaving the environmental damages and costs to the taxpayers. Several such bankrupt companies have been foreign-based, having many of their assets outside the country where their mines were operated. [5]

It is presently common in the USA and Canada for bonds to cover all anticipated costs of post-closure earth moving and revegetation. However, programs requiring mining companies to post bonds covering long-term water quality problems are in an early stage of development and application. Regulators have usually required companies to supply adequate financial assurance only for impacts they can reasonably *predict* will occur. The predictions/ simulations have usually been made by consultants paid by the mining companies---and results have often been too optimistic. As a result, post-operational impacts, especially the very expensive impacts involving long-term water quality problems, were often unforeseen, leaving the governments with inadequate funds to complete (or often begin) a clean-up. Thus, high-quality, independent predictions are required to develop a reasonable bond estimate.

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[4] Decontamination Plans are a policy tool to confront the problem of saturated areas, that is areas in which the air quality standards are surpassed. The Plans are elaborated by the National Commission on Environment and the implied companies in general participate in a consultative process.

[5] The recent (January 30, 2000) cyanide and metals-laden tailings spill in Romania caused damages to water quality and aquatic life that have been estimated to be in the hundreds of millions of U.S. dollars. The Australian-based operating company (in partnership with the Romanian state mining company) has declared bankruptcy. Neither the government nor the citizens of Romania or any of the impacted downstream countries will be able to pay for the required clean-up and remediation.

As mentioned previously, costs associated with the operation of a water treatment plant often represent the most significant long-term remediation costs. (examples: Summitville, Colorado; Zortman-Landusky, Montana; Golden Sunlight, Montana). Thus, bonding for anticipated, post-closure water quality problems is becoming quite common in the USA and Canada. For example, the RTZ corporation recently agreed to consider providing a bond of about $Can 185 million to obtain governmental approval for development of a diamond mine in northern Canada (see Transcript of Northwest Territories Water Board Hearings, Diavik Diamond Mines, December 13-15, 1999).

Insurance is another form of financial assurance that is being evaluated by regulators. They are considering requiring operators of new mines to purchase enhanced forms of environmental liability insurance prior to permit approval. It is important to note that insurance companies normally set insurance coverage charges on the basis of the risks associated with accidents occurring at a *population* of similar sites---not on predictions for the future any one site.

The main categories of environmental financial assurance options are discussed in: Anderson, Kathleen, 1999, Using Financial Assurances to Manage the Environmental Risks of Mining Projects, pages 283-293 : *in* Environmental Policy in Mining, Alyson Warhurst and L. Noronha, editors, Lewis Publishers, Wash.,D.C. Another pertinent document is: Kuipers, J.R., February 2000, Hardrock Reclamation Bonding Practices in the Western United States: National Wildlife Federation, Boulder, Colorado, USA. This document summarizes the bonding programs of the various state agencies, provides case studies, and summarizes the potential unfunded reclamation liabilities for each state. The authors claim the total, potentially unfunded reclamation liability for all the western states is more than one billion dollars (US).