



Copper smelter site near Butte, Montana

Ruined Lands, Poisoned Waters

The first step in mining is to locate a subterranean ore deposit and bring it to the surface. Increasingly, mining operations find that it's cheaper to do this by blasting away the soil and surface rock, called “overburden,” rather than by digging underground shafts. The resulting open-pit mines essentially obliterate the surrounding landscape and open up vast craters. The world's largest open pit, the Bingham Canyon mine in Utah, measures 1.5 kilometers (1 mile) deep and 4 kilometers (2.5 miles) wide. Open-pit mines produce 8 to 10 times as much waste rubble as underground mines. This rubble is generally piled into enormous mounds, some of them reaching heights of 100 meters, which is nearly as tall as a 30-story building. In the United States, 97 percent of all metals are now mined in open pits. Globally, that figure is two-thirds and it's rising.³

Once the ore is brought to the surface it must be processed to extract the mineral. The processing varies depending on the metal being mined, but it too generates immense quantities of waste. That's because the amount of recoverable metal in even high grade ores is generally just a small fraction of their total mass. The amount of waste created per unit of recovered metal has tended to increase as more and more high-grade deposits are exhausted and the industry turns increasingly to lower grade ores. In the United States, for example, the copper ore mined at the beginning of the 20th century consisted of about 2.5 percent usable metal by weight; today that proportion has dropped to 0.51 percent. In gold mining, it is estimated that only 0.00001 percent (that's one-hundred thousandth of 1 percent) of the ore is actually refined into gold. Everything else is waste.⁴

The cumulative amounts of solid waste produced by these processes are so large as to be almost incomprehensible. As a global average, the production of 1 ton of copper results in 110 tons of waste ore and 200 tons of overburden. Every

year, mines in the United States generate an amount of solid waste equivalent in weight to nearly nine times the trash produced by all US cities and towns combined. The total amount of waste ore (not including overburden) that has been generated to date by the US metals mining industry probably exceeds 90 billion tons.⁵

But to understand why the waste is so dangerous, you have to look at more than just the amount of it. You have to look at what the waste contains—and a lot of the contents are toxic. When it comes to toxic emissions, metals mining is one of the leading industries. In the United States, where companies are required to report such emissions, the industry's own data have earned it the dubious distinction of being the country's top polluter. In 2001, the most recent year for which data were available, metals mines produced 1,300 tons of toxic waste—46 percent of the total for all US industry combined—including 96 percent of all reported arsenic emissions, and 76 percent of all lead emissions.⁶

Some of these toxics are contaminants of the ore itself—for example, heavy metals such as mercury, arsenic, selenium, and lead often drain out of the piles of waste rock. But other toxics are introduced intentionally during the extraction process. Gold, for instance, is commonly extracted through a technique called “heap leaching.” The ore containing the gold is crushed, piled into heaps, and sprayed with cyanide, which trickles down through the ore, bonding with the gold. The resulting gold-cyanide solution is collected at the base of the heap and pumped to a mill, where the gold and cyanide are chemically separated. The cyanide is then stored in artificial ponds for reuse. Each bout of leaching takes a few months, after which the heaps receive a layer of fresh ore. Given the scale and duration of these operations (usually decades), contamination of the surrounding environment with cyanide is almost inevitable. A rice-grain sized dose of cyanide can be fatal to humans; cyanide concentrations of 1 microgram (one-millionth of a gram) per liter of water can be fatal to fish.⁷

Wasting Rivers and Seas

Toxic emissions can be insidious—largely invisible until their effects are widespread. But there’s another kind of mining pollution that’s impossible to miss: tailings dam failures. A by-product of extraction, tailings are usually a soupy to semi-solid suspension of pulverized rock in water, generally

laden with toxics. On-site tailings disposal generally consists of bulldozing some of the dried tailings into a dam which can then retain the more fluid material. The dam is periodically enlarged as the level of the tailings reservoir rises.

Despite its name, a tailings dam bears little structural similarity to an ordinary river dam. A conventional dam is generally constructed as a single project, to a single set of predetermined standards. On the other hand, the “construction” of a tailings dam usually occurs over the life of the mine, which makes it much more difficult to maintain structural integrity. Over the past quarter century or so, tailings dam failures have accounted for three-quarters of all major mining accidents.⁸

Consider, for example, the failure at the Omai gold mine in Guyana. A project of the Canadian mining corporation Cambior, the Omai is one of the largest open-pit mines in the world. Its tailings dam failed in 1995, releasing some 3 billion cubic liters of cyanide-laden tailings into the Omai River, a tributary of Guyana’s largest river, the Essequibo. Following the spill, the President of Guyana declared all 51 kilometers (32 miles) of river drainage from the mine to the Atlantic Ocean—home to 23,000 people—an official “Environmental Disaster Zone.” Initial government reports estimated the cyanide concentration in the Omai to be 28 parts per million, which is 140 times the level that the US Environmental Protection Agency (EPA) considers lethal.⁹

Photo: Tibor Kocsis

Fish kill at Baia Mare, Romania



To get around the problems of managing tailings on site, some mines pump them directly into nearby bodies of water. “Riverine tailings disposal”—a euphemism for dumping mine waste into rivers—poisons aquatic ecosystems, clogs rivers, and can disrupt the hydrology of entire watersheds. Once a common practice around the world, it has now been effectively banned by most developed countries, including the United States and Canada. Elsewhere, the practice is not common, at least officially. Today, only three mines in the world, all located on the giant Pacific island of New Guinea, openly use this disposal method: the Ok Tedi, Grasberg, and Porgera mines. (For more on Ok Tedi, see page 7; for Grasberg, see pages 14, 19, and 24. Porgera is a gold mine run by Placer Dome, a Canadian corporation; it has been dumping all its tailings directly into the Porgera River since 1992.) To date, only three companies (the Canadian firm Falconbridge and Australian firms Western Mining Corporation and BHP Billiton) have publicly pledged not to dump waste into rivers.¹⁰

Riverine disposal is, however, practiced illegally at many other mines. In Ilo, Peru, for example, two mines and a smelter operated by the Southern Peru Copper Corporation (controlled by the Mexican firm Grupo Mexico) have caused severe environmental degradation through this kind of dumping, which the company practiced for decades, in violation of Peruvian law. Between 1960 and 1992, the company dumped an average of 2,100 tons of smelter slag per day onto beaches north of Ilo; until 1995, it pumped an average of 107,000 tons of tailings per day into nearby Ite Bay. Between 8 and 9 million tons of accumulated slag now form artificial beaches along the coast. The mine tailings are now pumped into inland tailings ponds, but these are still contaminating the Locumba River, which flows into the bay.¹¹

Ocean dumping is a form of water disposal that is less conspicuous than the river option, and the Ilo mines are hardly the only coastal mines to have used the sea as a waste disposal site. Coastal dumping is a grave ecological concern because coastal waters are biologically the richest parts of the oceans, and because they support ocean life elsewhere as well: many open-ocean species depend on coastal habitat for part of their life cycle. Coastal dumping is a menace to public health as well. For example, in Northern Sulawesi, Indonesia, the Minahasa Raya gold mine, operated by the US-based Newmont Corporation, dumped over 4 million tons of tailings into Buyat Bay during the mine’s seven-year life, from 1996 to 2003. Local people have reported skin rashes after contact with seawater, and a toxicologist has found heavy metals in fish and plankton.¹²

It’s especially unfortunate that coastal dumping is practiced in parts of the Pacific that are home to some of the world’s richest coral reef communities—places like the coastal waters of Marinduque island in the Philippines. Those are the waters where the Marcopper copper mine pumped 200 million tons of toxic waste rock over a period of 16 years, carpeting 80 square kilometers of seabed, suffocating coral reefs, and poisoning reef fish. In the island’s fishing communities, children have tested dangerously high for lead and cyanide.¹³

In response to public health and ecological concerns over shallow sea disposal, the industry is turning increasingly to deep-water disposal, a practice in which a pipe conducts the tailings to a depth of at least 100 meters before releasing them into waters considerably deeper than 500 meters. The industry argues that this is a “best practice” because deep seawater has low levels of dissolved oxygen—a necessary ingredient for the chemical reactions that release heavy metals from the rock. (See page 9.) But deep-water disposal remains highly controversial because so little is known about the ecology of the ocean floors, and because of the possibility that broken pipes, deep-water currents, or geologic activity could disperse the waste into shallower waters.¹⁴

A growing awareness of the risks of marine tailings disposal has led the United States and Canada to effectively ban the practice. And in December 2003, the World Bank’s Extractive Industries Review recommended that the Bank not finance mines that dump their tailings at sea. But it remains to be seen whether such moves are the beginnings of a broader ban, since other mines that use marine disposal continue to be developed. For example, BHP-Billiton has proposed a nickel mine on Indonesia’s Gag Island, which contains the third-largest nickel deposit in the world. If the project is approved in its present form, all waste would be dumped at sea—even though the coral reefs off the island are among the most biologically diverse in the world.¹⁵

Metal Smoke, Acid Air

The ore processing at the mine does not yield a metal that is pure enough to use. Further refining is necessary. For some metals, such as aluminum, nickel, and copper, this takes place at a smelter, a kind of furnace in which very high temperatures release the metal from other materials in the ore. Smelting technology has improved considerably over the past half century, but smelters still produce a great deal of air pollution, especially oxides of nitrogen and sulfur, components of smog and acid rain.

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Facts on the Ground: The Ok Tedi Mine

The Ok Tedi mine, on the banks of the Ok Tedi river in western Papua New Guinea, began producing copper and gold for the giant Australian mining corporation BHP (Broken Hill Properties Ltd.) in 1984. Because the mine's tailing dam was destroyed during construction by a massive landslide, the company convinced the government to allow it to dump waste directly into the river.

Currently the mine discharges, on a daily basis, 80,000 tons of ore and 120,000 tons of waste rock into the Ok Tedi river. One industry-funded study predicts that if the dumping continues at that rate until the mine is scheduled to close in 2010, the total amount of sediment in the river would be 1.72 billion tons, or the weight of 4,712 Empire State Buildings.

The dumping has contaminated the river with toxic metals and caused an enormous, permanent flood. Nearly all the fish in the river have been poisoned, and some fish species appear to have gone extinct. Vast tracts of forest

have been drowned. A 1999 estimate put the amount of forest damaged in that year alone at 176 square kilometers, an area nearly three times the size of Manhattan. Most of the wildlife has disappeared from the region. Plantings of sago palm and other staple crops have died, and some 30,000 to 50,000 people have been displaced. One anthropologist studying the situation coined a new term to describe it: "ecocide."

The people affected were unable to negotiate a settlement with BHP directly, so a delegation of them addressed their concerns to the International Water Tribunal in The Hague. Although the tribunal had little power to enforce change, its involvement drew international attention. In 1996, an out-of-court settlement was reached: BHP was required to pay compensation and reform its waste disposal practices. But even the industry and its funders were beginning to wonder whether the mine was worth the damage it was doing. In 2000, the World Bank publicly suggested

that the mine be closed. In 2002, the CEO of BHP Billiton (the successor company to BHP) called the project "an environmental abyss" and said it should never have been built.

In the same year, BHP Billiton handed over its 52 percent share of the project to a government-controlled local corporation, in exchange for indemnity from future legal claims. In an effort at remediation, the government has begun dredging the river to remove about 20 million tons of sediment per year. The dredging has begun to reverse the flooding, and vegetation is slowly returning to some areas. Ultimately, however, up to 6,600 square kilometers of vegetation may be destroyed during the life of the mine.¹⁹

Discharge from the
Ok Tedi mine, Papua
New Guinea



Close-Up: Your Computer

Your personal computer contains a medley of metals, including gold, silver, aluminum, lead, copper, iron, zinc, and tin. Many of these materials could be salvaged at the end of the computer's life and recycled. But currently, most discarded computers are dumped in landfills or incinerated. Incineration of electronic waste, or e-waste, releases heavy metals and dioxin into the atmosphere. The landfill option is also polluting. In the United States, about 70 percent of the heavy metals in landfills come from e-waste. These metals can leach into the soil and groundwater. Exposure to them

has been shown to cause a range of injuries, including abnormal brain development in children, nerve damage, disruption of the endocrine system, and damage to various organs.

Because it contains substantial quantities of valuable metals, e-waste is an internationally traded commodity. Many junked computers make their way to developing countries, mostly in Asia, where some of the metal is salvaged. These salvaging operations are usually very crude and operate outside any environmental or labor regulations. An investigation

of one such operation, in Guiyu, a village in China's Guangdong Province, found workers dismantling computer equipment with hammers, chisels, screw drivers, and their bare hands. Only the most readily extracted metal components were recovered. For example, workers would crack open monitors, extract the copper "yoke," then dump the smashed equipment in a field or push it into a river. Area residents say the local water is now too foul-tasting to drink; drinking water is now trucked into the area from 30 kilometers away.²⁰

Sketch: Chris Engnoth

Some of the larger and older smelters have done extensive ecological damage, primarily from heavy sulfur dioxide emissions. For example, nickel and copper smelters near Sudbury in Ontario, Canada, rendered the soil practically lifeless within 3 kilometers and badly damaged forests, lakes, and wetlands up to 30 kilometers away. Although the original Sudbury operation shut down in the 1970s, other smelters in the region continue to number among the top air polluters in Canada. Close by Sudbury, for example, is Inco's Central Mills smelter. By far the worst air polluter in the Canadian metals mining sector, Central Mills released nearly 622 tons of sulfur dioxide and other toxic pollutants in 2001. A more extreme but less studied case involves the nickel smelters at Norilsk, in northeastern Russia. Acid emissions from these smelters, which are still operating, have destroyed an estimated 3,500 square kilometers of forest and injured the respiratory health of thousands of people. Worldwide, smelting adds about 142 million tons of sulfur dioxide to the atmosphere every year. That's 13 percent of total global emissions.¹⁶

Smelting releases a range of other pollutants as well. Emissions of metals such as lead, arsenic, cadmium, and zinc are common and can pose serious health risks. In the town of Herculaneum, Missouri, emissions from the 110-

year-old lead smelter operated by the Doe Run lead company have caused lead poisoning in 30 percent of the town's children. In the Peruvian town of La Oroya, where another Doe Run smelter operates, a study by the Peruvian Ministry of Health revealed that 99 percent of the children have severe lead poisoning, and 20 percent of these children needed hospitalization. Yet another type of pollutant detected in the emissions of some smelters, such as Noranda's Horne copper smelter in Quebec, Canada, is "persistent organic pollutants," or POPs. These compounds do not break down readily and they tend to bioaccumulate—that is, they build up in the fat of animals in increasing concentrations at higher links of the food chain. ("Organic" means they're carbon-based.) POPs can disrupt a broad range of physiological processes in animals and people.¹⁷

And since smelters burn huge amounts of fuel (see page 12), they also release substantial quantities of greenhouse gases, such as carbon dioxide and perfluorocarbons (PFCs). Aluminum smelters, for example, release 2 tons of carbon dioxide and 1.4 kilos of PFCs for every ton of aluminum produced. PFCs have up to 9,200 times the heat-trapping potential of carbon and will linger in the atmosphere for tens of thousands of years.¹⁸ ■

Acid Mine Drainage: Pollution on a Millennial Scale

Gold, copper, silver, and other valuable metals are often found in rocks rich in sulfide minerals, such as pyrite, or “fool’s gold,” and pyrrhotite. Mining often exposes these rocks to the elements for the first time since the rocks were formed. Once they are dumped as heaps of waste rock or pumped into impoundments as crushed tailings, their sulfides are exposed to oxygen and water. The result is a chemical reaction that produces sulfuric acid, a component of acid rain. But in comparison to acid rain, the acid in mine waste is 20 to 300 times more concentrated.

As it leaches through the mine waste, the acid liberates various metals from the rock—for example, arsenic, cadmium, mercury, and lead. These metals are not dangerous when embedded in the rock, but once they are freed, they are highly toxic to a broad range of living things. In humans, chronic exposure to arsenic, for example, is associated with skin cancer and tumors. Cadmium has been linked to liver disease, mercury to nerve damage, and lead to growth retardation in children.

Eventually, this toxic, acid leachate finds its way into streams and rivers, where the acid releases still more metals from exposed rock.

As they flow downstream, the acid and toxic metals can kill virtually all aquatic life for several kilometers and badly degrade downstream environments many times farther than that.

This process, known as acid mine drainage, or AMD, is the most widespread and persistent form of water pollution caused by mining. The signature of AMD is a slimy, orange coating that builds up in the beds of affected rivers and streams. This is caused by metals, especially iron, settling out of the water column. For all practical purposes, AMD is irreversible. There is evidence, for example, that some AMD in the Rio Tinto mining district of southern Spain is coming from ancient Roman or even Phoenician mines.

But ancient mines are small compared to those of our own day. Take the 17.8 square kilometer Iron Mountain mine in northern California. During nearly a century of operation, the mine produced iron, silver, gold, copper, and zinc. Iron Mountain was closed in 1963, but 40 years later, AMD continues to poison fish and other aquatic life in the Sacramento River, which drains the region. The Sacramento flows into the immense San Francisco Bay and there too, the AMD is endangering aquatic life.

Groundwater near the mine has registered pH levels as low as minus 3, which is 10,000 times more acidic than battery acid. And experts predict that Iron Mountain will continue to poison its watershed for at least 3,000 years.

Treatment procedures for AMD do exist, but they are costly and difficult to implement. There are basically two options: either preventing water and oxygen from reaching the sulfide-laden waste rock, or applying alkaline materials such as limestone to the leaching runoff to counteract the acidity. The first option generally requires a massive and very difficult revegetation effort; building soil on barren, poisonous rock and then getting plants to grow in that soil is not a simple matter. Treating the acid runoff might seem more feasible, but to produce a stable result, the treatment would have to be maintained as a matter of routine indefinitely—that is, for thousands of years. And the limestone treatments produce a metal-contaminated, toxic sludge that presents additional remediation problems. In many developing countries, a lack of resources and political interest makes treatment through either option an unlikely prospect.²¹

Porgera gold mine, Papua
New Guinea

Facts on the Ground: The Yanacocha Mine

On June 2, 2000, a truck from the Yanacocha gold mine in northern Peru spilled 150 kilograms of mercury out of some poorly sealed containers and onto a 43-kilometer stretch of road running through the towns of Choropampa, Magdalena, and San Juan. (Mercury is a secondary product of the mine.) Many local people, not knowing what the material was or that it was toxic, collected it in the hope that it might be valuable. Other villagers were hired by the mine to clean up the spill—but were not provided with any protective gear. Mercury can damage the lungs, kidneys, and nervous system. It can also cause birth defects.

The spill affected an estimated 925 people; 400 of them were treated for mercury poisoning and over 130 were hospitalized. The Newmont Mining Company, the US-based corporation that co-owns the mine with Buenaventura Mining of Peru and the World Bank's International Finance Corporation (IFC), spent \$12 to 14 million on the clean-up, but was unable to account for nearly 15 percent of the spilled mercury. In exchange for agreeing not to sue the mine, some of the spill victims were offered small cash settlements and medical care. But many residents continue to report health

problems and some have attempted to press their case against Newmont in US courts.

Yanacocha, located high in the Andes, is the most profitable gold mine in South America and the second largest gold mine in the world (after the Grasberg mine in Indonesia). Newmont insists that it has been a good corporate citizen of the Yanacocha region. The communities affected by the mine, the company argues, receive a share of the mining wealth. The company also claims that it has created over 1,600 jobs in the area, and helped build schools and clinics.

But many area residents worry about the mine. Some argue that by causing local inflation and driving people off their land, it has deepened their poverty. They also worry about the condition of their streams. "The water that comes down from the mountains is now brown, full of sediments," says one resident. "The trout are dying." They worry about the cyanide used to leach the gold out of the ore; they fear it has contaminated the water and is sickening their livestock. And they worry about what's in the dust that blows off the tailing piles and into their homes.

They have reason to worry. According to

tests done by both the government and the mine, many local river and stream sites exceed the World Health Organization (WHO) limits for acidity and concentrations of various metals, such as mercury and arsenic. One site had an aluminum concentration 20 times the WHO limit. (Free aluminum is toxic to a wide range of plants and animals, including people.) The tailings dust is also contaminated with toxic metals. And a study recently commissioned by the IFC found that acid leaching from the mine could further degrade local waters.

Since the mercury spill, Newmont has proposed expanding the mine to Quilish Mountain, the sixth mountain in the area the company would be leveling for gold. Quilish is a critical source of water for over 100,000 people in and around the nearby city of Cajamarca. Many local residents, concerned about the risks of water pollution, oppose the plan. There have been mass protests, including one in April 2003 that drew thousands of people to Cajamarca's main square. "I'm aware that Peru is a country that relies on mining," Jorge Hoyos, the Mayor of Cajamarca, told a Reuters reporter in 2002. "But we can't sit by and wait for our water supply to be ruined. We can't swap gold for lives."²²



Photo: Payal Sampat/Earthworks



Protest in Esquel, Argentina

Tambogrande and Esquel: Two Communities Stand Up to the Companies

Two rural Latin American communities, each faced with a large-scale mining project, are demonstrating the power of direct, peaceful opposition.

The small farming community of Tambogrande, located in Peru's sub-tropical San Lorenzo Valley, is sitting on deposits of gold and copper worth millions of dollars. It's also sitting in the midst of prime orchard country: the San Lorenzo Valley is Peru's top fruit-growing region. Tambogrande produces close to half of Peru's citrus crop.

In 1999, the Canadian mining company Manhattan Minerals proposed to relocate half of the town's 16,000 residents, demolish most of the town itself, and create an open-pit mine in its place. The proposal included a promise of new jobs and housing. But the people of Tambogrande, fearing that the mine would poison streams and farmland, said no deal.

That message was delivered in a referendum held in June 2002, in which 93 percent of the voters opposed the mine. (About 75 percent of the town's residents participated in the referendum.) The referendum was not legally binding—the mine proposal was put to

the Peruvian government not the local community—but the vote attracted considerable international attention. It was followed by frequent protests against the mine, and a peaceful, three-day general strike in November 2002. Local activists also began working with their counterparts in other countries to keep Tambogrande in the public eye. Finally, in December 2003, the Peruvian government turned down Manhattan's proposal. The official reasons for the rejection included an inadequately researched environmental impact assessment, as well as insufficient proof of assets and processing capacity. Citizen activism, however, had created a political context in which the proposal's social and environmental deficiencies could count against it.²³

A similar scenario has emerged in Esquel, a town of about 30,000 in the still largely unspoiled Patagonian region of Argentina. Meridian Gold, a mining company based in the United States and Canada, is proposing to mine a silver and gold deposit about 7 kilometers outside the town. The mine would be an open-pit operation using 2.7 tons of cyanide per day. The company proposes to operate

the mine for 8 or 9 years, but it does not propose to guarantee the remediation costs up front.

Esquel is an ecotourist destination; it is located near the Los Alerces National Park, home to gigantic, 2,000-year-old *alerce* trees, a kind of conifer that grows only in that region. Esquel is also a farming and fishing community. So it's not surprising that when the town held its own mining referendum, in March 2003, the response was similar to what it had been in Tambogrande: an overwhelming No. Eighty-one percent of the voters opposed the mine. (Seventy-five percent of Esquel's residents voted.) Esquel's referendum isn't legally binding either—although it was called by the provincial government—but the project has been stalled since the vote.²⁴

In both Esquel and Tambogrande, the message to the mining industry is essentially the same. Increasingly, the communities directly affected by mining proposals are demanding a say in decision-making about their future. That right imposes a basic obligation upon any form of extractive project: the obligation to obtain the free, prior, informed consent of the communities concerned.