Sulfide Mining Overview

Friends of the Boundary Waters Wilderness

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Introduction

Despite covering only 0.02 percent of the U.S. land area, metal mining operations result in substantial environmental impacts.[1] For example, in 1994 the EPA has determined that Acid Mine Drainage (AMD) from metal mining operations is the "largest problem facing the US mining industry."[2] In 2000, the EPA Toxic Release Inventory (TRI) reported that the metal mining industry was the largest toxic polluter.[3] Increasing use and ongoing depletion of worldwide deposits of metal resources, such as copper, nickel, and platinum have encouraged increased exploration and development attempts. [4]

In Minnesota the Duluth Complex, a sulfur-containing ore body, is thought to be one of the largest known reserves of copper and nickel. Environmental impacts related to this ore body have already been shown at the LTV Dunka mine site, at which the sulfide containing over-burden material produced AMD.[5] Additional concern about AMD and then environmental effects of sulfide mining in our region were raised in 1997 when the state of Wisconsin place a moratorium on sulfide mining until it could be shown that a mine could operate without contamination to ground and surface water (S. 293.5 Wisconsin Statues, described by WI DNR). Nationwide, there is concern over the large financial burden of the perpetual clean-up and reclamation of abandoned mine sites, "with state and/or federal agencies presently potentially responsible for at least some portion of the cleanup costs of 13 mines in Nevada, five in Montana, and additional mines in South Dakota, Alaska, Idaho, Colorado and New Mexico."[6]

Therefore, the proposal for sulfide mining in Minnesota should be taken seriously by Minnesotans who are concerned about the health of our natural environment, the sustainability of our natural resources, and the potential for long-term economic impacts to the state.

What is Sulfide Mining?

Sulfide mining (also known as metallic mining) refers to mining operations which remove metals, such as copper, nickel, platinum and others, from sulfur bearing ores. The

[1] Hudson, T.L., F.D. Fox, and G. S. Plumlee. 1999. Metal Mining and the Environment. American Geological Institute. Accessed at: http://www.agiweb.org/environment/publications/metalsfull.pdf

[2] "Acid Mine Drainage Prediction." U.S. Environmental Protection Agency. December 1994. Website: http://www.epa.gov/epaoswer/other/mining/techdocs/amd.pdf. Retrieved December 30, 2007.

[3] "Evaluation Report: Nationwide Identification of Hardrock Mining Sites" (memorandum to the Office of the Inspector General). US Environmental Protection Agency. 2004.

[4] United States Geological Survey. 1998. Potential for new Nickel-Copper Sulfide Deposits in the Lake Superior Region. Accessed at: http://pubs.usgs.gov/info/mwni_cu/#where

[5] "Acid Mine Drainage Prediction." U.S. Environmental Protection Agency. December 1994.

[6] Kuipers, James. 2000. Hardrock Reclamation Bonding Practices in the Western United States. For the National Wildlife Federation, Boulder, CO.

sulfide mining industry is an important producer of commonly used metals that are necessary for our day-to-day operation and consumption patterns. Copper is used for building materials and electronics and nickel is used to produce stainless steel and nickel batteries (like those being used in electric cars).[7] Sulfide mining is remarkable in its mineral to waste ratio. The USGS reported that the average yield of copper mining was between 0.47 and 0.60 percent[8] and that production of copper[9] reached a high of just under 1.6 million tons (based on data from 1970-1990).[10] This means that the 1.6 million tons represents at most 0.60 percent of the ore that was removed from the earth or about 270 million tons of ore were processed. As demand for materials increases, the economic feasibility of mining ores with even lower concentrations is likely to increase. For example, the proposed Polymet operation has an concentration of 0.28% copper and 0.08% nickel.[11]

Sulfide Mining Process

The sulfide mining process consists of: exploration, site preparation, mining, beneficiation, waste disposal and reclamation:

Exploration. Computer modeling, satellite images and surface research are used to identify potential ore bodies. Then, to determine viability of a mine site, verification of the subsurface character and form of an ore body requires extensive drilling.[12] Currently in Minnesota, exploration near the Kawishiwi Ranger District of the Superior National Forest is proposed to include drilling core samples of hardrock ore at 74 sites requiring 7.5 miles of temporary road construction.[13]

Site Preparation. Mine site requires infrastructure, transportation/roadways, and rail lines.

Mining. Sulfide mining operations can take several forms depending on the ore body and quality. Mines are either open pit mines or underground operations. Open pit mines are most commonly used, 83 percent of copper mines in the US are open pit.[14] This method is used because a greater amount of ore can be processed and the processes offer more safety and access for mine workers.[15] In open pit operations, the fist step is the removal of overburden and waste rock to

[7] United States Geological Survey. 1998. Potential for new Nickel-Copper Sulfide Deposits in the Lake Superior Region. Accessed at: http://pubs.usgs.gov/info/mwni_cu/#where

[8] "Yield of copper is calculated from the recoverable copper content, at the smelter level, of mined copper ore concentrated or leached."

[9] "recoverable copper at the smelter site"

[10] USGS. Table 1: Salient Copper Statistics. *Copper: Statistical Compendium*. 1990. Accessed at: http://minerals.usgs.gov/minerals/pubs/commodity/copper/stat/tbl1.txt

[11] Polyment Projects Webpage: http://www.polymetmining.com/s/Projects.asp

[12] Hudson et. al. 1999.

[13] US Forest Service. 2007. Decision Notice and Finding of No Significant Impact: Kawishiwi Mineral Exploration. Lake County, Minnesota.

[14] US Environmental Protection Agency. 1994. Technical Document: Extraction and Beneficiation of Ore and Minerals, Volume 4: Copper. US Environmental Protection Agency, Office of Solid Waste. Washington D.C.

[15] US Environmental Protection Agency. 1994. Technical Document: Extraction and Beneficiation of Ore and Minerals, Volume 4: Copper. US Environmental Protection Agency, Office of Solid Waste. Washington D.C.

expose mineralized rock – this step creates the largest volume of waste in metals production.[16] Waste rock disposal areas can be hundreds to thousands of acres in size and are often the most visible aspect of the mining operation.[17] The mine shape depends on mineral deposit and is typically a series of benches, terraces, and ramps that enable the machinery to reach the base of the mine. Waste and ore are excavated by drilling 6-12 inch "blast holes" which are filled with explosive. Once removed, the ore is transported for processing.[18]

When underground mining methods are used there is only a small impact at the surface, however these mines tend to produce significantly less metal over their lifetime (on the order of what an open pit mine can produce in a matter of weeks). "Underground mining operations are complex combinations of tunneling, rock support, ventilation, electrical systems, water control, and hoists for the transportation of people, ore, and materials."[19] The three main methods are stoping, room and pillar, and block carving. In stoping, a vertical or horizontal shaft provides access to the ore, which is typically in a vein for this type of extraction. Ore is then removed and hauled to the surface. Generally stoping is used when the copper mining is a by-product.[20] In a room and pillar operation, first large horizontal drifts (called rooms) are excavated parallel to each other and smaller drifts are excavated perpendicular to the rooms. The pillars (which contain 30-60 percent of the ore depending on the site) are the areas between the rooms and give the mine support. In a second phase, after the rooms are mined, ore is removed from the pillars. The process moves from the back of the mine forward and timber is used to support the mine as the pillars are removed. The final step is called "retreating", when timbers are removed and the ground is allowed to collapse.[21] The last method is called "block-caving" and it uses gravity to break the ore down without the being drilled or blasted. The breakdown of ore is basically the result of letting a shaft cave in.[22] One benefit to underground mining is that the ore tends to have a much higher ratio of metal to waste.[23]

Beneficiation. Beneficiation or concentration is the process of separating the minerals from the non-mineralized (valueless) materials. The most common methods are milling and leaching. In milling, the ore is crushed to mineral sized particles using metal balls or rods to pulverize ore to the consistency of sand, silt, or clay.[24] Next, the sand-like substance is mixed with water to create slurry which is run through the floatation process. In floatation ore slurry is run through vats which contain a chemical reagent. Minerals selectively bind to the reagent and float to the

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16 US Environmental Protection Agency. 1994. Technical Document: Extraction and Beneficiation of Ore and Minerals, Volume 4: Copper. US Environmental Protection Agency, Office of Solid Waste. Washington D.C.

17 Hudson et. al. 1999.

18 US Environmental Protection Agency. 1994. Technical Document: Extraction and Beneficiation of Ore and Minerals, Volume 4: Copper. US Environmental Protection Agency, Office of Solid Waste. Washington D.C.

19 US Environmental Protection Agency. 1994. Technical Document: Extraction and Beneficiation of Ore and Minerals, Volume 4: Copper. US Environmental Protection Agency, Office of Solid Waste. Washington D.C.

20 Extraction and Beneficiation or Ore and Minerals, Volume 4: Copper. US Environmental Protection Agency, Office of Solid Waste, 2004.

21 Extraction and Beneficiation or Ore and Minerals, Volume 4: Copper. US Environmental Protection Agency, Office of Solid Waste, 2004.

22 Extraction and Beneficiation or Ore and Minerals, Volume 4: Copper. US Environmental Protection Agency, Office of Solid Waste, 2004.

23 Hudson et. al. 1999

24 Hudson et. al. 1999

surface, the waste produce, non-mineral slurry, is pulled from the bottom of the vat and disposed of as tailings.[25]

Leaching is an alternate beneficiation method. Instead of milling/crushing, ore is placed in heaps over which a water solution containing chemicals like sulfuric acid or cyanide are poured. These chemicals dissolve the desired metals which are collected at the base of the heap. Minerals are removed from the water solution, which is then reused to run through the heap repeatedly until it becomes unproductive. Leaching leaves no tailings, but does leave the heap of spent ore as waste product.[26] Vat leaching uses a series of enclosed tanks rather than an exposed heap. Vat leaching allows for greater recovery of metals, but is more costly than heap leaching.[27]

The most recent technology (and that which will be used at the Polymet site) is hydrometallurgical and electrowinning process (see discussion below).

Smelting. The smelting process may occur on- or off-site. Melting of the beneficiation minerals removes impurities and separates metals. Waste products like iron and silica float to the top and are cooled to a solid glassy waste substance called slag, which requires disposal. Additionally, suspended air particles and gases such as sulfur dioxide must be captured as air rises to the top of smelter furnaces – historically these waste produces entering the environment through the vents and stacks were serious air quality concerns.[28]

"Treatment of sulfide mineral flotation concentrates can also be carried out using *hydrometallurgy*, in which process the metal sulfide is dissolved (leached) into an aqueous solution."[29] Using this process rather than smelting eliminates the sulfur dioxide concerns.[30] "Metals can [then] be recovered from solution by electrolysis, a process that is known in the extractive metallurgy industry as electrowinning. When two electrodes are placed in a solution containing metal ions and an electric current is passed between them, the metal can be deposited on the negative electrode. In the recovery of most metals, oxygen is evolved from water at the positive electrode. An electrolyte, and a current density, is generally chosen that gives a dense, compact electrodeposit, and additives included in the electrolyte to further improve product quality (a practice also used in *electroplating*)."[31] This allows for a purer product.

Waste disposal and reclamation. Waste products are generated at most mining operations, and include: non-mineralized waste rock (overburden or excess un-mineralized rock from the initial open pit mining); tailings (waste from ore processing/mineral beneficiation); and spent ore (from leaching operations). Waste water is an additional by-product depending on the climate of the site.[32] All of these waste products have the potential to contaminate the area surrounding the

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25 Hudson et. al. 1999.

26 Hudson et. al. 1999

27 "Extraction and Beneficiation or Ore and Minerals, Volume 4: Copper. US Environmental Protection Agency, Office of Solid Waste, 2004.

28 Hudson et. al. 1999

29 Woods, Ronald "Extracting Metals from Ores" Electrochemistry Encyclopedia. 2004. http://electrochem.cwru.edu/ed/encycl/art-m02-metals.htm

30 Woods 2004

31 Woods 2004

32 In drier climates or places were mining does not expose the water table, there may not be (as much) waste water. Also, the amount of rainwater received on site impacts the amount of wastewater because it will accumulate in pit or with tailings and therefore need to be prevented from running off into the environment.

mine site. As tailings are disposed of, they are still saturated by water, therefore, seepage must be prevented. Also the surface, if tailings are fine grail or clay-like they may be impermeable to water which can cause ponding (collection of water on the surface of the tailings dump) therefore keeping the tailings constantly saturated and allowing seepage to occur indefinitely[33] Therefore, the use of an impermeable barrier is required to prevent seepage. If the tailings are dry, erosion and sedimentation may pose problems - metal bearing sediments that are blown from the site and reach the environment may become toxic to organisms.[34] In waste disposal and reclamation, metal bearing sediments must remain un-oxidized and remote from wildlife to prevent harm.[35] Similarly, the waste leaching solutions used in heap leaching have the potential to seep into the surrounding environment – the use of liners and leach pads is intended to prevent this.[36]

There are opportunities to recycle some waste products or even market by-products. For example, the waste water pumped from a mine pit site can be re-used in the leaching and hydrometallurgy processes. Also, sulfuric acid waste, when mixed with limestone, can be used to produce gypsum. The result is a marketable product used for agricultural purposes and drywall.[37]

Reclamation includes establishing methods for controlling waste substances and finally re-establishment viable soils and re-vegetating the mine and waste sites. Often, reclamation consists of: modifying slopes and surfaces, adding lime to neutralize acidity, and using vegetation to stabilize material and prevent erosion.[38]

Environmental Effects

The EPA reports that half of the 63 National Priorities List (NPL) sulfide mining sites pose high or medium ecological/environmental risk.[39] Almost one-quarter of the NPL sites have an unknown ecological/environmental risk.[40]

Water

In 1985, the EPA concluded that "contaminants from waste storage impoundments (including tailings impoundment) were being released to underlying aquifers at most copper

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[33] Hudson et. al. 1999

[34] Hudson et. al. 1999

[35] Hudson et. al. 1999

[36] Hudson et. al. 1999

[37] Gypsum for Agricultural Uses in Ohio-Sources and Quality of Available Products. Ohio State Extension University Fact Sheet. .http://ohioline.osu.edu/anr-fact/0020.html

[38] Hudson et. al. 1999

[39] "There are three mechanisms for placing sites on the NPL: The first mechanism is EPA's Hazard Ranking System. Generally, sites with overall scores of 28.50 and above are eligible for the NPL. The second mechanism for placing sites on the NPL allows States or Territories to designate one top-priority site regardless of score. The third mechanism allows listing a site if it meets all three of these requirements:the Agency for Toxic Substances and Disease Registry (ATSDR) of the U.S. Public Health Service has issued a health advisory that recommends removing people from the site;EPA determines the site poses a significant threat to public health; and EPA anticipates it will be more cost-effective to use its remedial authority (available only at NPL sites) than to use its emergency removal authority to respond to the site." http://www.scorecard.org/env-releases/def/land_npl.html

[40] "Evaluation Report: Nationwide Identification of Hardrock Mining Sites" (memorandum to the Office of the Inspector General). US Environmental Protection Agency. 2004.

facilities," probably because outdated methods were being implemented. [41] Modern practices, with additional environmental standards, may be improving. Still, many mines exceed predicted contamination levels.[42] In a recent study of 25 mines, most mines that were predicted to have no exceedences of surface and groundwater standards in EIS documents, actually did exceed those standards.[43] This shows clearly that there either needs to be greater emphasis placed on planning and pre-mining studies, or that we do not have sufficient methods for predicting such contamination.

Water contamination can come from several sources. First, removal of earth and vegetation at the mining site causes erosion and sedimentation.[44] Erosion or blowing of tailings can also be a source of toxic sedimentation. Other waste materials such as leaching chemicals (which are toxic) and other processing chemicals are potential sources of contamination if not contained.[45]

Acid Mine Drainage

Acid Rock Drainage (ARD), is a natural process which occurs when sulfides in rocks become exposed to oxygen and water through weathering. The result is the production of sulfuric acid. Acid Mine Drainage (AMD) is the same process; however, it occurs on a much larger scale because excavation from a mining site produces a tremendous increase in the rate of sulfide exposure to air and water. In both scenarios, acid leaches from the rock until it is no longer exposed to air and water, or until the sulfides have been removed[46]. AMD may or may not occur during the active life of the mine, and may also only being to occur years or decades after closure.[47] Additionally, as the environment approaches specific acidity levels, natural bacteria (*Thiobacillus* iron oxidizing bacteria) may begin to catalyze the oxidation reaction and increase the rate of acidification.[48] Sulfuric acid drains from the site and can be spread by rain water to surface water or can percolate into ground water and can severely degrade water quality.[49] As stated above, the EPA has identified AMD as one of the largest issues facing the mining industry.[50]

AMD drainage is highly site-specific and is controlled primarily by: the type/presence of sulfide minerals; presence of water and the hydrology of the surrounding area; oxygen

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41 "Extraction and Beneficiation or Ore and Minerals, Volume 4: Copper. US Environmental Protection Agency, Office of Solid Waste, 2004.

42 i.e. those reported in Environmental Impact Statements

43 Kuipers, J.R., Maest, A.S., MacHardy, K.A., and Lawson, G. 2006. *Comparison of Predicted and Actual Water Quality at Hardrock Mines: The reliability of predictions in Environmental Impact Statements.*(As high as 92% exceedences of water standards for sites near surface water.)

44 "Extraction and Beneficiation or Ore and Minerals, Volume 4: Copper. US Environmental Protection Agency, Office of Solid Waste, 2004.

45 "Extraction and Beneficiation or Ore and Minerals, Volume 4: Copper. US Environmental Protection Agency, Office of Solid Waste, 2004.

46 "Acid Mine Drainage Prediction." U.S. Environmental Protection Agency. December 1994.

47 "Acid Mine Drainage Prediction." U.S. Environmental Protection Agency. December 1994

48 "Acid Mine Drainage Prediction." U.S. Environmental Protection Agency. December 1994

49 Acid Mining Drainage Prediction. US Environmental Protection Agency, Office of Solid Waste. Washington D.C.

50 "Evaluation Report: Nationwide Identification of Hardrock Mining Sites" (memorandum to the Office of the Inspector General). US Environmental Protection Agency. 2004.

availability; ferric iron; bacteria to catalyze the oxidation reaction; and generated heat.[51] The water serves as a reactant and host for catalyst bacteria and oxygen is a necessary component of the oxidation process, therefore, acidification cannot happen without available water and oxygen. AMD can come from mining wastes such as spent ore, tailings, and waste rock, such as overburden, but can also come from open pit walls and underground mining sites.[52] It is important to note that the time frame is variable, AMD may occur during mining or may be inactive until mining ceases, and acids may not be a source of contamination for years or decades after mine closes.[53] Drainage from waste rock sites have been shown to vary greatly showing seasonal fluctuations as well as variation dependent on mineralogy and the size of the rock pieces/particles. Tailings are likely to produce more uniform drainage.[54] "Efforts by both the mining industry and state regulatory agencies to develop the best protocols for sampling and/or analytical methods to predict acid generation potential have demonstrated that site specific conditions (e.g., climate and geology) dictate a case-by-case approach when evaluating acid potential."[55]

AMD has been shown to be a widespread problem and once it occurs it may be extremely difficult to control.[56] "In the western U.S., the Forest Service estimates that between 20,000 and 50,000 mines are currently generating acid on Forest Service lands, and that drainage from these mines is impacting between 8,000 and 16,000 kilometers of streams".[57] "Both the acids and dissolved metals contained in AMD may be detrimental to aquatic life. Most sites generating large amounts of AMD also experience permanent elimination of, or damage to, aquatic life. This is typically confined to roughly 10 miles downstream from the point of discharge, although there are often more widespread fish kills during periods of high runoff….In ground water, AMD is diluted, attenuated by neutralization, and, possibly, chemically reduced as it moves from the site"[58] However, in some cases there is a risk of drinking water contamination, which would be detrimental to human health.[59]

Heavy Metal Contamination

In addition to AMD, sulfide mining leads to heavy metal contamination of local soil and water. This occurs when heavy metals like arsenic, copper, silver, cobalt, cadmium, and lead, come into contact with water in the mine pit or waste produces and metals are leached out in runoff. For example, Sulfide mining in the Madneuli Copper-Gold open-pit mine in Georgia has caused heavy metal pollution of groundwater and three nearby rivers.[60] The contamination has

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[51] "Acid Mine Drainage Prediction." U.S. Environmental Protection Agency. December 1994.

[52] "Acid Mine Drainage Prediction." U.S. Environmental Protection Agency. December 1994.

[53] "Extraction and Beneficiation or Ore and Minerals, Volume 4: Copper. US Environmental Protection Agency, Office of Solid Waste, 2004.

[54] "Acid Mine Drainage Prediction." U.S. Environmental Protection Agency. December 1994.

[55] "Acid Mine Drainage Prediction." U.S. Environmental Protection Agency. December 1994.

[56] "Evaluation Report: Nationwide Identification of Hardrock Mining Sites" (memorandum to the Office of the Inspector General). US Environmental Protection Agency. 2004.

[57] "Acid Mine Drainage Prediction." U.S. Environmental Protection Agency. December 1994.

[58] Acid Mine Drainage Prediction." U.S. Environmental Protection Agency. December 1994.

[59] Acid Mine Drainage Prediction." U.S. Environmental Protection Agency. December 1994.

[60] Tchelidz, T., Melikadze, G, Levein, J., Kaija, J.& Kumpalaimen, S. (2003). "Assessment and modeling of heavy metal contamination from Madneuli open-pit mine, Georgia." *EGS - AGU - EUG Joint Assembly, Abstracts from the meeting held in Nice, France, 6 - 11 April 2003.* Website: http://adsabs.harvard.edu/abs/2003EAEJA....14256T.

caused the water to be unsafe for drinking.[61] Additionally, "Because the spread of contamination is a slow process, the adverse health effects may not yet have emerged in the investigation area."[62] Without preventive remediation, such as redirecting the extraction of drinking water to an area further from the mining site, the situation can be expected only to get worse.[63]

The heavy metal problem compounds, as this process occurs more rapidly under the acidic conditions associated with acid mine drainage.[64] Though associated with AMD, the heavy metal contamination is often more environmentally harmful when leached into surface waters.[65] Impacts include harm to fish and wildlife (see more in discussion below), impacts to local drinking water (above) and retention of heavy metals in soils (see discussion below). The effects of heavy metals can be long-lasting. For example, in some areas known to be former Roman copper mines, animals today still contain traces of copper in their tissues.[66]

It should be noted that this type of heavy metal contamination is not often associated with iron mining (the historically prevalent mining industry in Minnesota) because AMD is not produced by the oxide ores which contain iron and therefore, heavy metals are not mobilized. [67]

Soil

As stated above, erosion and sedimentation can occur in areas of physical disturbance at the mine site.[68] AMD drainage may cause soils near mine site or within the mine pit to become acidic. Additionally, sediments downstream of mine sites often contain high levels of heavy metals.[69] Accidents at mine sites can increase these chances for contamination, for example: in 1985, a tailings dam collapsed in Hunan province (southern China) leading to soil contamination by heavy metals from the tailings waste.[70] Research conducted on the soil shows that contamination affected the pH, and researchers "could expect serious environmental contamination . . . if mining activities and acid deposition are not under control in the future."[71]

Air

Primary air quality issues resulting from sulfide mining include dust emissions from mine pits, dried tailings, and haul roads.[72] Historically sulfur dioxide emissions from stacks at smelters was a serious environmental concern causing acid rain, however, this has been largely regulated.[73]

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[61] Tchelidz et. al, 2003.
[62] Tchelidz et. al, 2003.
[63] Tchelidz et. al, 2003.
[64] "Acid Mine Drainage Prediction." U.S. Environmental Protection Agency. December 1994.
[65] "Acid Mine Drainage Prediction." U.S. Environmental Protection Agency. December 1994.
[66] http://www.dartmouth.edu/~toxmetal/outkev.shtml
[67] Metallic Sulfide Mining: Impacts on Michigan's Wildlife. National Wildlife Federation. Ann Arbor, MI.
[68] Hudson et. al. 1999.
[69] "Extraction and Beneficiation or Ore and Minerals, Volume 4: Copper. US Environmental Protection Agency, Office of Solid Waste, 2004.
[70] Liao, Bohan, Zhaohui Guo, Anne Probst, & Jean-Luc Probst. (2005). "Soil heavy metal contamination and acid deposition: experimental approach on two forest soils in Hunan, Southern China." *Geoderma*, 127(1-2), pp. 91-103. Retrieved online: www.ScienceDirect.com (doi:10.1016/j.geoderma.2004.11.019).

[71] Liao et. al, 2004.
[72] "Extraction and Beneficiation or Ore and Minerals, Volume 4: Copper. US Environmental Protection Agency, Office of Solid Waste, 2004.
[73] Hudson et. al. 1999.

Fish and Wildlife

Wildlife impacts begin as soon as digging begins, especially large amounts of habitat destruction occur with open pit mining due to the immense size of some of the mines. Erosion and sedimentation resulting from disturbance of soil and waste can produce direct effects on fish (respiration and reproduction) and on photosynthesis in aquatic vegetation.[74] AMD and heavy metals "may be detrimental" to wildlife, impacts typically are confined to 10 miles downstream, but widespread fish kill can occur with periods of high levels of runoff.[75] Heavy metals may impact the physiology, growth, reproduction, and mortality of species.[76] Heavy metals contamination is also present in the cells of plants growing over former mining sites and it has been shown that the concentration of heavy metals in the plants is dependent on the contamination level of the soil.[77]

Heavy metal contamination has been shown to have especially detrimental impacts on fish. Several studies of whitefish, brown trout and artic char health near a copper-nickel smelter in Norway and Russia have revealed that "the prevalence of fish diseases and abnormalities in organs, particularly in the kidney and liver, has been very high (around 90%) in waters with high nickel and copper concentrations.[78] A recent study in the same area concludes that high heavy metal concentrations are likely to blame for the lack of fish in several lakes near the same smelter.[79] Although most of these major impacts were reported in close proximity to the smelter, a small amount of impact on fish populations was seen as far as 15 km from the smelter site due to airborne heavy metals reaching distant lakes.[80]

High concentrations of heavy metals are less likely today due to air quality control measures and advanced smelting methods like hydrometallurgical techniques discussed above. However, impacts are still possible with low concentrations. One study has indicated that several species of fish and aquatic organisms lose their sense of smell (which is necessary to avoid predators, find food sources, or recognize their own eggs) even with very low levels of copper in the water. It shows that, though it was believed heavy metals such as copper and zinc were too low to affect organisms, they can have a detrimental effect.[81] Even in low concentrations, bio-accumulation of mercury and other heavy metals becomes a concern.[82]

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[74] "Extraction and Beneficiation or Ore and Minerals, Volume 4: Copper. US Environmental Protection Agency, Office of Solid Waste, 2004.

[75] "Acid Mine Drainage Prediction." U.S. Environmental Protection Agency. December 1994.

[76] Antti Lappalainen, Jouni Tammi and Annukka Puro-Tahvanainen. 2007. The effects of nickel smelters on water quality and littoral fish species composition in small watercourses in the border area of Finland, Norway and Russia. Boreal Environment Research 12: 455-466

[77] Hobbs and Streit. 1986. Heavy Metal Concentrations in Plants Growing on Copper mine spoil in t he Grand Canyon, AZ. American Midland Naturalist 115(2): 277-281.

[78] Moiseenko *et al*. (1995), Amundsen *et al*. (1997), Moiseenko and Kudryatseva (2001) and Lukin *et al*. (2003) referenced in Lappalainen et all 2007. (Nickel and Copper concentrations in these waters are a result of air pollution from smelting operations that operated from the 1930's to present. It should be noted that heavy metal contamination resulting from this plant has decreased substantially from the 1970s to 2000s)

[79] Lappalainen et. al. 2007

[80] Lappalainen et, al. 2007

[81] Heavy Metals Affect Fish Senses. Oryx 41(3): 277.

[82] Higgins, D.K. and S.N. Wiemeyer. 2001. Interim Report: Assessment of Wildlife Impacts Associated with Mine Pits. Nevada Fish and Wildlife Office. Reno, NV.

Numerous examples of these impacts on wildlife can be documented, and several extreme cases can be cited. Over 300 snow geese were killed by consumption of contaminated water at the Berkley Pit superfund site (a former copper mine in Butte, MT).[83] Also, 17 miles of the Alamosa River rendered lifeless due to cyanide leaching and AMD at the Summitville Gold Mine in CO.[84]

Though ecological health of is reason enough to protect fish and wildlife, it should also be noted that fish, big game and migratory birds require clean water in order to provide recreation opportunities to millions of people each year, and economic sustenance to tourism areas. [85]

Human Health

The US EPA "Toxics Release Inventory (TRI) program collects information on the disposal or other releases and other waste management activities for over 650 chemicals from industrial sources in all 50 states and the U.S. territories."**[86]** Though exact proportions have varied over recent years, metal mining is consistently the top producer of toxic releases of all US industry, accounting for 47% in 2000 (3.4 billion) and 27% (1.17 billion pounds) in 2005 TRI reports. The metal mining industry had the greatest increase between 2005 and 2004 (96 billion) when compared to other industries. The top 7 TRI sites in 2005 were all metal mining sites.

More specifically, AMD and heavy metal contamination can be hazardous to human health if they reach drinking water sources.[87] A study of historical mining sites in the Upper Peninsula of Michigan by the Agency for Toxic Substances and Disesase Registry (ATSDR) concluded that heavy metals in the soil pose long term health risks for those with continued exposure.[88] Specific concerns included arsenic and lead[89] levels, especially for children who may be more likely to be exposed to soils or ingest soils. Children or those who ingest high levels of arsenic may experience "impairments of the circulatory system, gastrointestinal distress, changes in the liver, neurological effects, and changes in the skin on long-term exposure." and "people who spend their lifetime near soils containing the arsenic concentration found in the areas mentioned above might incidentally ingest enough arsenic to incur some increased risk of contracting skin cancer."[90] "Lead is a cumulative poison, causing damage to the nervous system, kidneys, and blood."[91] Even perceived threats of contamination can be detrimental to the mental and emotional health of a community.[92]

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[83] Higgins and Wiemeyer 2001

[84] Westerner's for Responsible Mining

[85] U.S. Environmental Protection Agency. 2000. *Liquid Assets 2000: America's Water Resources at a Turning Point*. EPA-840-B-00-001. Office of Water (4101), United States Environmental Protection Agency, Washington, DC

[86] US EPA. 2007. "Summary of Key Findings." US EPA Toxic Releases Inventory Reporting Year 2005 Public Data Release. Accessed at: http://www.epa.gov/tri/tridata/tri05/pdfs/Key_Findings.pdf

[87] "Extraction and Beneficiation or Ore and Minerals, Volume 4: Copper. US Environmental Protection Agency, Office of Solid Waste, 2004.

[88] Health Consultation: TORCH LAKE AREA BROWNFIELDS HOUGHTON COUNTY, MICHIGAN. 1997. Agency for Toxic Substances and Disease Registry. http://www.atsdr.cdc.gov/HAC/PHA/torch/tol_p1.html

[89] Lead levels at these sites were similar to those at urban areas.

[90] ATSDR 1997

[91] ATSDR 1997

[92] Boulanger, Amy and Alexandra Gorman. 2004. Hardrock Mining: Risks to Community Health. http://www.earthworksaction.org/pubs/MiningHealthReport_WVE.pdf

Social and Economic Costs of Sulfide Mining

Mining is an economic activity and mining companies exist to earn profits; they should be assessed in terms of both profit and sustainability. The UN Commission of 1987 describes "sustainability" as "development that meets the needs of the present without compromising the ability of future generations to meet their needs."[93] Using this definition, a report written for the UNEP/World Bank conference on Sustainability and Global Mining Finance, stated that mining has "*not been economically sustainable.*"[94] One reason for this is that mining companies are not recognizing the "full costs incurred in mining," which include the costs of "meeting their environmental responsibilities, and the needs of the future."[95]

These costs can be quite high. In fact, more than 7,000 kilometers of streams in the eastern United States are affected by acid drainage from mining.[96] In the western U.S., it is estimated that between 20,000 and 50,000 mines are currently generating acid, and that drainage from these mines impacts between 8,000 and 16,000 kilometers of streams.[97] Unfortunately, "many millions of dollars have been invested by the mining industry into the science of how to extract ever smaller concentrations of gold from rock, but very little has gone into determining how to put the earth back together once it has been blasted, crushed and saturated with chemicals."[98]

In Canada, the Mine Environmental Neutral Drainage (MEND) program estimates Canada's total liability for acid rock drainage is between $2 billion and $5 billion.[99] In the United States it is estimated that in 1988 alone, overall cleanup costs of AMD was estimated to be around 30 billion dollars.[100] Unfortunately, lack of foresight and insufficient bonds to cover cleanup costs leads to taxpayers paying the price of reclamation and toxic cleanup after a mine is abandoned.[101] "The tremendous financial costs have created frustration in the EPA, inciting debate about whether the mining cleanups should be exempt from Superfund—not because they are less toxic or hazardous to health but rather because one cleanup alone could cost the entire program's budget."[102]

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93 Crowson, Phillip. 2002. "Sustainability and the Economics of Mining—What Future?" *Minerals & Energy* 17(2) p. 15.
94 Crowson, 2002 at 17.
95 Crowson, 2002 at 19.
96 Kim, A.G., B. Heisey, R. Kleinmann, and M.Duel, 1982. Acid Mine Drainage: Control and Abatement Research. U.S.DOI, Bureau of Mines IC 9805, p.22. (cited in "Acid Mine Drainage Prediction." U.S. EPA. 1994).
97 USDA Forest Service 1993. Acid Mine Drainage From Mines on the National Forests, A Management Challenge. Program Aid 1505, p.12. (cited in "Acid Mine Drainage Prediction." U.S. EPA. 1994).
98 Boulanger & Gorman, 2004. p. 29.
99 Natural Resources Canada. http://www.nrcan.gc.ca/mms/canmet-mtb/mmsl-msm/enviro/effluents/effspecserv-e.htm. Retrieved December 26, 2007.
100 Sturgill, B.J., Poland, K.B. "Acid Mine Drainage: Balancing Environmental Protection and Mining Realities." 10 J. Nat. Resources & Envtl. L. 217. (citing: "Appalachian Clean Streams Initiative: A Proposal to Clean Up Streams Polluted by Acid Mine Drainage from Coal Mines." (Draft Aug. 10, 1994)).
101 Boulanger, Amy and Alexandra Gorman. 2004. Hardrock Mining: Risks to Community Health. http://www.earthworksaction.org/pubs/MiningHealthReport_WVE.pdf
102 Boulanger & Gorman, 2004. p.29.

In addition to financial burden on the community, there are also costs to the social welfare of the community. In the early 1990s, the Formosa Mine in southwest Oregon caused AMD to flow into the headwaters of nearby creeks, reducing fish populations by 90 percent.[103] In Minnesota, it is estimated that somewhere between $1.5 and $3 billion a year is spent on recreational fishing, and about 50,000 jobs in Minnesota are supported by the fishing industry.[104]

Mining Technology

Many people in the mining community purport to use environmentally safe technology.[105] To work with Sulfide Mining, this technology must completely remove at least one of the factors that lead to acid mine drainage, water or oxygen, from the acid-producing rock.[106] Typical strategies miners might use include: flooding the pit, waste, and tailings with water; constructing wetlands or treatment ponds from which sulfide-reducing bacteria will react with metals; using vegetation to take up the metals from soil or sediment; or using concrete or cement to solidify the acid-producing material into an inert block underground.[107] These technologies, and more, have been researched by the Acid Drainage Technology Initiative ("ADTI"), of West Virginia Water Research Institute, at West Virginia University.[108]

ADTI is supported by the U.S. Department of Interior, Office of Surface Mining and Bureau of Land Management; the U.S. Environmental Protection Agency; the National Mining Association; the interstate Mining Compact Commission; the National Mine Land Reclamation Center; and the Eastern Mine Drainage Federal Consortium.[109] ADTI has concluded that "Due to the inherent variability between mines and environmental conditions, no one abatement or treatment technique is effective on all sites."[110] It is important to consider the efficacy of a given method, using the particular environmental circumstances of the proposed mining site. In addition, predicting acid mine drainage is also unreliable. "AMD models to date have not found extensive applications in predicting oxidation rates and effluent quality at operating or proposed sites . . . to date, the availability of field data for validation is very limited."[111] The following are a few methods used to attempt to prevent AMD from occurring in the first place:

Water management. Completely removing water from the mining site is one way to theoretically stop acid mine drainage. While removing water "can be done in a laboratory setting, the total and complete removal of water in nature is nearly impossible and therefore the complete control of AMD, even in dry situations or climates does not occur." [112] One technique that is

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103 "Acid Mine Drainage." Water Encyclopedia. www.waterencyclopedia.com/A-Bi/Acid-Mine-Drainage.html.
104 "Fishing Economic Impact: RadioByte Script." Minnesota Department of Natural Resources. http://preview.dnr.state.mn.us/radiobite/script_067.html. May 12, 2005. Retrieved December 26, 2007.
105 *See e.g.,* "Position Statement." *Citizens for Responsible Mining.* www.citizensforrespnsiblemining.org. Retrieved 12/19/2007.
106 *See e.g.* Nehdi, Moncef & Tariq, Amjad. (2007) "Stabilization of sulphidic mine tailings for prevention of metal release and acid drainage using cementitious materials: a review. *J. Environ. Eng. Sci.* 6: 423-436.
107 *See e.g.,* Nehdi & Tariq, 2007.
108 Skousen, J., Rose, A., Geidel, G., Foreman, J., Evans, R., and Heillier, W. (1998). *Handbook of Technologies for Avoidance and Remediation of Acid Mine Drainage.* The National Mine Land Reclamation Center. West Virginia University.
109 Skousen et. al, 1998
110 Skousen et. al, 1998, at 5.
111 "Acid Mine Drainage Prediction." U.S. Environmental Protection Agency. December 1994. p. 28.
112 Skousen, J. et. al. (1998). p. 44.

highly recommended by ADTI is diverting surface water from the spoil above the site by constructing drainage ditches that move surface water to limit its movement onto the backfill.[113]

Alternatively, acid-producing rock can be flooded with water, thereby minimizing oxidation of acid-forming materials.[114] Inundation of water is a viable option only where mining is conducted under a previously established water table, and is not recommended for surface mines.[115]

Impervious soil cover or membrane

Dry barriers can be constructed from either natural or man-made materials that hold back the movement of water and oxygen into areas containing acid-producing rock, like tailings and leach heaps.[116] These barriers help reduce water flow, but are no economically viable for large volumes of waste, and generally do not completely control AMD.[117]

Underground mine sealing

Acid-producing rock can be sealed underground to help prevent AMD. Most of these are hydraulic mine seals, which function is to "eliminate potential access to the abandoned mine works following closure, to minimize AMD production by limiting infiltration of air and water into the deep mine, and to minimize AMD production by limiting exfiltration of water and maximize inundation."[118] Another method of underground mine sealing is injection, which is the practice of drilling a well down to the porous rock strata and then injecting fluids into the underground formation. [119] This technique is "significantly limited by factors that would either allow the injected waste to escape from the containing strata and polluting ground waters or cause other secondary effects.[120] Additionally, the underground space for storing such fluids is space is limited. [121]

Another method for underground mine sealing is an inert gas blanket. [122] This would involve the placement of an inert gas (that is not reactive in AMD formation) to blanket the acid producing rock.[123] In order for this process to work, the mine must be sealed completely. If it is partially sealed, considerable amounts of gas would have to be continuously injected, and will only work so long as oxygen is never admitted. This is a process that would have to continue into perpetuity.

When prevention of AMD does not occur, mining companies can still try to minimize the environmental impact by purifying the acidic water before it re-enters the environment by use of a water treatment facility.[124] Treatment "involves chemical neutralization of the acidity followed by precipitation of iron and other suspended solids."[125] The factors that dictate the sophistication of the treatment system are the chemical characteristics of the AMD, the quantity to be treated,

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[113] Skousen et. al, 1998, p.44.
[114]Skousen et. al, 1998, p. 41. (Note: As described under the AMD section, the presence of oxygen is a necessary piece of the acid-forming process, by flooding with water, you eliminate the opportunity for oxidation.
[115] Skousen et. al, 1998
[116] Skousen et. al, 1998, p. 45.
[117] Skousen et. al, 1998, p. 45.
[118] Skousen et. al, 1998, p. 53.
[119] Skousen et. al, 1998, p. 74.
[120] Skousen et. al, 1998, p. 74.
[121] Skousen et. al, 1998, p. 74.
[122] Skousen et. al, 1998, p. 75.
[123] Skousen et. al, 1998, p. 75.
[124] "What is Sulfide Mining." Citizens for Responsible Mining. www.citizensforresponsiblemining.org/article5.php.
[125] "Acid Mine Drainage treatment techniques and costs." Department of the Interior: Office of Surface Mining. www.osmre.govamdtcst.htm. Retrieved December 27, 2007.

climate, terrain, sludge characteristics, and projected life of the plant.[126] The chemicals usually used are limestone[127], hydrated lime[128], soda ash[129], caustic soda[130], and ammonia.[131]

Additionally, constructed wetland systems may be able to cleanse an area that has been contaminated by utilizing soil- and water-borne microbes that are associated with wetland plants to remove dissolved metals from mine drainage.[132] "Although promising, constructed wetlands take much time to completely cleanse an area, and are simply not enough to deal with extensively polluted discharge."[133] Additionally, there are seasonal variations to the removal efficiency, with lesser amounts removed in cold weather.[134]

Laws and Regulations

"Hardrock minerals are the most loosely regulated natural resources in U.S. mining."[135] There are several possible reasons for this: first, the extraction of such metals are encouraged by the government for the purposes of national security; second, hardrock mining is primarily concentrated in sparsely populated areas so impacts might not be readily apparent; and third, the laws regulating mining are very old and do not account very well for environmental dangers.[136]

Considering the complexity of the science, the history of mining law is relatively simple. In 1848, when gold was first found in California, mining settlements developed and individual mining communities self-regulated their practices.[137] The laws of these California mining districts were the basis for the first national legislation: the Mining Act of 1866; and six years later, the basis for the General Mining Law of 1872. The purpose of the 1872 Act was to "codify private citizens' right of access to mineral deposits, for purposes of exploration, occupation, and purchase. [138] The General Mining Law of 1872 "allows individuals and corporations to 1) freely prospect for hardrock minerals on Federal lands; 2) mine the land, if an economic deposit is found; 3) sell the extracted minerals without reimbursing the Government; and 4)purchase, or

[126] "Acid Mine Drainage treatment techniques and costs." Department of the Interior: Office of Surface Mining. www.osmre.govamdtcst.htm. Retrieved December 27, 2007.
[127]"Advantages of limestone include low cost, ease of use, and formation of a dense, easily handled, sludge. Disadvantages include slow reaction time, los in efficiency of the system because of coating of the limestone particles with iron precipitates, difficulty in treating Acid Mine Drainage with a high ferrous-ferric ratio, and ineffectiveness in removing manganese." *Id.*
[128] Hydrated lime is usually used by coal mining industry; it is easy and safe to use, effective and relatively inexpensive. The disadvantages are the high amount of sludge produced and high initial costs. *Id.*
[129] Soda ash is especially effective for treating small AMD flows. Disadvantages are "higher reagent cost and poor settling properties of the sludge." *Id.*
[130] Caustic Soda is effective for treating low flows in remote locations and AMD with high manganese content. "Major disadvantages are its high cost, the dangers involved with handling the chemical, poor sludge properties, and freezing problems in cold weather." *Id.*
[131] Anhydrous ammonia costs less and is effective in treating AMD having a high ferrous iron and/or manganese content. However, "ammonia is difficult and dangerous to use and can affect biological conditions downstream from the mining operation;" ammonia is not allowed in all States, and always with additional monitoring. *Id.*
[132] *Id.*
[133] "Acid Mine Drainage." Wikipedia. En.wikipedia.org/wiki?Acid_Mine_Drainage. Retreived December 12, 2007.
[134] "Acid Mine Drainage treatment techniques and costs." Department of the Interior: Office of Surface Mining. www.osmre.govamdtcst.htm. Retrieved December 27, 2007.
[135] Boulanger & Gorman, 2004.
[136] Boulanger & Gorman, 2004. p. 9.
[137] Richardson, Ric. (2003). "Governing Western Mineral Resources: The Emergence of Collaboration." *Natural Resources Journal.* 43 Nat. Resources J. 561.
[138] Richardson, 2003, p. 569.

"patent," the land for a nominal sum of $2.50 or $5.00 an acre."[139] The General Mining Law of 1872 remains largely unchanged today, save for the 1920 removal of oil and gas.[140]

The 1969 passage of the National Environmental Policy Act (NEPA)[141] changed the way federal agencies would regulate mining. It was one of the first laws that established a framework for protecting the environment; federal actions would be examined with public participation and full disclosure.[142] NEPA's purpose was to assure that the government gave proper consideration to the environment prior to undertaking any major federal action that significantly affects the environment.[143] Its requirements are typically invoked when airports, buildings, military complexes, highways, parkland purchases, and other federal activities are proposed. "Environmental Assessments (EAs) and Environmental Impact Statements (EISs), which are assessments of the likelihood of impacts from alternative courses of action, are required from all Federal agencies and are the most visible NEPA requirements."[144]

In 1977, the Surface Mining Control and Reclamation Act (SMCRA)[145] was passed in order to combat the environmental problems associated with mining, including acid mine drainage. Along with SMCRA, came the Office of Surface Mining within the Department of the Interior. Five major components regulate mining under SMCRA: 1) certain environmental standards of performance must be met; 2) mining companies must acquire permits prior to mining that includes in the application information about the environmental impact of the mine, a plan for reclamation after the mine is closed, and a plan for what the land will be used for after the mine is closed; 3) the mining company must post a bond prior to commencing mining that will cover reclamation costs in case company goes out of business; 4) SMCRA allows the government to inspect the mining site at any time; and 5) the federal government can prohibit mining on certain protected lands, such as national parks.[146]

Around the same time, the Clean Air Act,[147] the Federal Water Pollution Control Act (Clean Water Act),[148] the Safe Drinking Water Act,[149] and the Toxic Substances Control Act[150] were passed by congress to further protect the environment from pollution by regulating emissions, water pollution, and toxic chemicals.

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[139] "Summary of the General Mining Law of 1872." Appendix A. Found in "Evaluation Report: Nationwide Identification of Hardrock Mining Sites." U.S. Environmental Protection Agency. March 31, 2004.
[140] Richardson, Ric. *Supra.* at 569.
[141] National Environmental Policy Act, 42 U.S.C. § 4321.
[142] Richardson, Ric. *Supra.* at 569.
[143] "Summary of the National Environmental Policy Act." U.S. Environmental Protection Agency. Website: www.epa.gov/lawsregs/laws/nepa.html retrieved December 27, 2007.

[144] "Summary of the National Environmental Policy Act." U.S. Environmental Protection Agency. Website: www.epa.gov/lawsregs/laws/nepa.html retrieved December 27, 2007.
[145] 32 U.S.C. § 1234-1328 (1977).
[146] "Surface Mining Control and Reclamation Act of 1977." Wikipedia. Retrieved December 27, 2007. http://en.wikipedia.org/wiki/Surface_Mining_Control_and_Reclamation_Act_of_1977.
[147] 42 U.S.C. § 7401 (1970)(The Clean Air Act regulates air emissions from area, stationary, and mobile sources).
[148] 33 U.S.C. § 1251 (1972)(The Clean Water Act regulates the discharge of pollutants into "the waters of the United States" and regulates quality standards for surface waters).
[149] 42 U.S.C. § 300f (1974)(The Safe Drinking Water Act is designed to protect the quality of drinking water in the United States).
[150] 15 U.S.C. § 2601 (1976)(The Toxic Substances Control Act was enacted by Congress to give EPA the ability to track the 75,000 industrial chemicals currently produced or imported into the United States and any new chemicals industry develops each year).

In the 1980s and 1990s, several more federal laws or amendments were passed: the Comprehensive Environmental Response Compensation and Liability Act (CERCLA),[151] the Endangered Species Act,[152] and solid waste disposal amendments to the Resource Conservation and Recovery Act (RCRA).[153] These three comprehensive pieces of legislation bolstered the Environmental Protection Agency's power to regulate sulfide mining in the United States. Still, many of these regulations have exemptions and it is all too easy for environmentally dangerous activity to slip through the cracks.

In addition to federal rules and regulations, states (such as Minnesota) have adapted their own requirements and processes for permitting sulfide mining.[154] For example, it is necessary in Minnesota for a potential mining company to obtain all required local, state, and federal permits, and if proposed mine is large enough, obtain an environmental impact statement and approval by the Environmental Quality Board.[155]

Local permits may be required by counties, townships, or municipalities that address areas such as: hours of operation, noise, traffic, dust, reclamation, etc. Local authorities often require a plan for reclamation along with mining plan to obtain permit.[156]

State permits may be required by the Minnesota Department of Natural Resources (e.g., permits relating to water appropriation, protected waters, burning, or work in shorelands, floodplains, or wild and scenic rivers); the Minnesota Board of Water and Soil Resources (e.g., wetland permits); or the Minnesota Pollution Control Agency (e.g., permits relating to fuel and hazardous materials management, liquid storage tanks, air quality, or water quality).[157]

Federal permits, such as a Section 404 Permit (which may include mining activities, the construction of access roads, building sites, storage areas, or water retention ponds) may be required from the U.S. Army Corps of Engineers.[158]

Finally, Environmental Impact Statements are mandatory for mining operations that exceed 160 acres (or if between 40-160 acres—an Environmental Assessment Worksheet is required).[159] When predicting if there will be acid mine drainage in the assessment, Minnesota also regulates how these tests are to be conducted (described in Minn. Stat. § 6132.100).[160]

In order for a sulfide mine to exist in Minnesota, all legal safeguards must be met and be taken seriously; all permits should be given with great caution in order to avoid potentially very serious environmental consequences.

Conclusion

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[151] 42 U.S.C. § 9601 (1980)(CERCLA or "Superfund" gives the federal government the authority to require the cleanup of hazardous-waste sites by known parties, or if unknown parties, the federal government must cleanup abandoned hazardous-waste sites).

[152] 7 U.S.C. § 136 (1973)(The Endangered Species Act allows the government to protect and conserve endangered plants and animals and the habitats in which they are found).

[153] 42 U.S.C. § 6901 (as amended in 1986) (RCRA gave the environmental protection agency the authority to control the generation, transportation, treatment, storage, and disposal of hazardous waste).

[154] *See e.g.,* "Minnesota Mining Laws." 1998. MN Department of Natural Resources. Retrieved December 27, 2007. Website: http://files.dnr.state.mn.us/lands_minerals/mn_mining_laws.pdf.

[155] "Environmental Regulations for Aggregate Mining." Minnesota Department of Natural Resources. January, 2001. Website: http://files.dnr.state.mn.us/lands_minerals/aggregate1_mar01.pdf. Retrieved December 30, 2007.

[156] "Environmental Regulations for Aggregate Mining." *Supra.* 2001.

[157] "Environmental Regulations for Aggregate Mining." *Supra.* 2001.

[158] "Environmental Regulations for Aggregate Mining." *Supra.* 2001.

[159] "Environmental Regulations for Aggregate Mining." *Supra.* 2001.

[160] "Acid Mine Drainage Prediction." U.S. Environmental Protection Agency. December 1994.

While sulfide mining is necessary to extract the metals used in our day-to-day lives, it should only be permitted with great caution. No proven technology prevents Acid Mine Drainage, or eliminates its adverse effects. Sulfide mining has been shown in the past to be dangerous to the environment and have devastating social and economic impacts on the community. With the ever growing ability of the mining industry to extract smaller and smaller percentages of metals, it becomes increasingly important to adhere to all federal, state, and local regulations that are designed to ensure protection of the environment and the people.