Environmental Impacts from Modern Mining and Mineral Processing

OSWER
May 2012
Major Environmental Impacts of Hard Rock Mining

- Contamination from Mine Impacted Waters (AKA Acid Rock Drainage or Acid Mine Drainage)
- Waste Rock and Tailings Disposal
- Surface and Ground Water Contamination
- Cyanide Management
- Soils and vegetation contamination
- Impacts on fish and wildlife
- Socio-economic Impacts
Sources from mining
Risk Assessment

- **Source**
  - nature
  - extent

- **Pathway**
  - air
  - water
  - ingestion

- **Receptor**
  - people – children
  - animals – plants – endangered species
The geoavailability of lead

- Trace lead in silicate minerals
- Coarse-grained lead sulfide
- Lead sorbed onto smelter particulates

Lead Concentration:
- Low
- Moderate
- High

Lead Geoavailability:
- Low
- Moderate
- High
Acid Mine Drainage

- AMD flow from mine adit
- Water Table
- Mine Workings
- Original mountain surface
- Pit Lake
- AMD Infiltration
- AMD Infiltration
- Creek
- Ground Water Contamination
- Ground Water Contamination
- [Waste Rock, Waste Ore, Overburden, Landfill]
- AMD
Contaminated Mine Water and Acid Mine Drainage (AMD)

- Generated when metal sulfide minerals are oxidized

- In 1992 the US Bureau of Mines estimated 12,000 miles of western US waterways (about 40 percent) and 180,000 acres of lakes and reservoirs have AMD contamination.

- Tell-tale yellow/orange color of iron deposits
Acid Mine Drainage - Mining Influenced Water

**Typical relation to drainage pH:**

- **Saline Drainage**
- **Neutral Mine Drainage**
- **Acid Rock Drainage**

**pH**

2  3  4  5  6  7  8  9  10

**Typical drainage characteristics:**

<table>
<thead>
<tr>
<th>Acid Rock Drainage:</th>
<th>Neutral Mine Drainage:</th>
<th>Saline Drainage:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• acidic pH</td>
<td>• near neutral to alkaline pH</td>
<td>• neutral to alkaline pH</td>
</tr>
<tr>
<td>• moderate to elevated metals</td>
<td>• low to moderate metals.</td>
<td>• low metals. May have moderate iron.</td>
</tr>
<tr>
<td>• elevated sulphate</td>
<td>• elevated zinc, cadmium, manganese, antimony, arsenic or selenium.</td>
<td>• moderate sulphate, magnesium and calcium</td>
</tr>
<tr>
<td>• treat for acid neutralization and metal and sulphate removal</td>
<td>• low to moderate sulphate</td>
<td>• treat for sulphate and sometimes metal removal</td>
</tr>
<tr>
<td></td>
<td>• treat for metal and sometimes sulphate removal</td>
<td></td>
</tr>
</tbody>
</table>
Metal Hydroxide Solubility

Dissolved Metal (mg/L) vs pH

- Pb
- Ni
- Cu
- Cd
- Ag
- Fe²⁺
- Zn
- Fe³⁺
- Al
Where do you find AMD at mining sites?
Aluminium, Antimony, Arsenic, Barium, Beryllium, Cadmium, Chromium, Cobalt, Copper, Cyanide, Lead, Manganese, Mercury, Nickel, Selenium, Silver, Thallium, Vanadium, Uranium, Zinc
Water Management at Mines

- Biggest environmental issue is the management of mine impacted waters.
- Mine impacted waters include process waste water, open pit water, water contaminated from contact with ore, waste rock or tailings.
- Acid mine drainage and acid rock drainage are essentially the same term.
- Current thinking on water contamination from mines states that metal mobility from mine impacted waters will occur under alkyl, neutral and acid conditions.
- Major challenge is to insure that mine design and operations directly properly addresses mine impacted water throughout the life of the mine.
- There are specific mine waste design and operations approaches which could significantly reduce this risk if properly implemented (lining waste rock piles, lining tailing ponds, proper design of WWTPs at mines).
Surface water - Groundwater interactions

after Gang and Langmuir (1974), coal strip-mining in PA
10 °C, $\Sigma Fe^{10^{3-5}}$, $\Sigma C=10^{+4}$
Research needs

- Water balance and conceptual models
Categories of Discharges from Mines

- **Process wastewater** “…any water which, during manufacturing or processing, comes into direct contact with or results from the production or use of any raw material, intermediate product, finished product, byproduct, or waste product.” (40 CFR 122.22).

- **Mine drainage** “…any water drained, pumped, or siphoned from a mine.” (40 CFR 440.132)

- **Storm water** (associated with industrial activity) “… the discharge from any conveyance which is used for collecting and conveying storm water and which is directly related to manufacturing, processing or raw materials storage areas at an industrial plant. ...[T]he term includes, but is not limited to, storm water discharges from industrial plant yards; immediate access roads and rail lines used or traveled by carriers of raw materials, manufactured products, waste material, or byproducts used or created by the facility; material handling sites; refuse sites; sites used for the application or disposal of process waste waters (as defined at 40 CFR part 401); sites used for the storage and maintenance of material handling equipment; sites used for residual treatment, storage, or disposal; shipping and receiving areas; manufacturing buildings; storage areas (including tank farms) for raw materials, and intermediate and finished products; and areas where industrial activity has taken place in the past and significant materials remain and are exposed to storm water....

- Note that a permit is NOT required for “…discharges of storm water runoff from mining operations … which are not contaminated by contact with or that has not come into contact with, any overburden, raw material, intermediate products, finished product, byproduct or waste products located on the site of such operations.” (40 CFR 126(a)(2))


OVERVIEW OF TYPES OF POLLUTANTS FOUND IN SURFACE WATER DISCHARGES

- **Mine Workings:** mine water is typically pumped from underground and surface operations and often discharged to surface water. After operations cease, mine workings may overflow and uncontrolled mine water/runoff may be discharged.

- **Waste Rock/Overburden Piles:** These units are generally unlined. Potential pollutant loadings in runoff and seepage from waste rock piles include sediment as well as metals, sulfates, and radionuclides. Where sulfur mineralization is present, ARD can occur.
OVERVIEW OF TYPES OF POLLUTANTS FOUND IN SURFACE WATER DISCHARGES

- **Tailings Impoundments**: Impoundment designs frequently include under-drains and controlled discharges (especially in high precipitation/snow melt areas). Tailings impoundments are nearly always accompanied by unavoidable seepage through or beneath the dam structure. Seepage from tailings often include heavy metals, arsenic, and radionuclides. ARD can occur if sulfide mineralization is encountered and may enhance metals mobility.

- **Mill Wastewaters**: If ore concentrates are produced, wastewater from flotation will include heavy metals, cyanide, oils, and soaps. This is often treated in a central WWTP. WWTP discharges may include metals far above existing background levels.
On line Resources

- Framework for Metals Risk Assessment
  - www.epa.gov/osa/metalsframework/raf/metalsframework

- Global Acid Rock Drainage Guide (GARD Guide)
  - www.gardguide.com
Disposal of Liquid Wastes

- Direct discharge to surface water
- Underground injection
- Storm water
Red Dog Mine Outfall 001
Cyanide Management

- Gold is recovered from ore by heap leaching or vat leaching.
- Heap leaching: Place ore in piles with liners. Cyanide solution is collected in surface ponds and gold is recovered by plating gold out of solution. Heaps can leak a metals/cyanide solution into surface or groundwater.
- Vat leaching: ore is placed in tanks and mixed with cyanide. Gold recovery same as heap leaching.
- Cyanide can be treated and recycled.
Three primary pathways exist for soil contamination: air emissions; process and storm water discharges; and waste disposal.

The impacts of tailings piles on soils can include contamination by mixing, leaching, and fugitive dust.

The most serious impact to soils associated with heap and dump leaching is toxic pollutant contamination.

The impacts can include erosion and contamination from leaching solutions.
Surface and ground water releases and discharges may be toxic to fish and animals (Berkley Pit snow geese deaths)
Mining may cause animals to move out of their habitat
Noise/light can adversely impact animals
Air pollution may retard or damage grasses, trees, or wild foods (berries, nuts)
Wetlands can be adversely impact due to restricted inflow or contaminated inflows from mining.
Terrestrial Impacts and Risk

- Air transport of particulate matter and acid emissions
  - Contamination of soils
  - Biological and Vegetation loss and stress

- Massive physical alterations of terrain and erosion
  - Biological /Vegetation loss and degradation
  - Erosion
Solid Waste Products

- Waste Rock

- Tailings
  - Tailings Impoundment disposal
  - Dry stack disposal
  - Disposal in lake impoundment
Both underground and surface mining operations generate waste rock. Consists of non-mineralized and low-grade mineralized rock removed from above or within the ore body during extraction activities. Disposed in large piles or dumps. Most slurry tailings are disposed in impoundments made of local materials. Some are unlined. It is economically advantageous to use natural depressions to contain tailings. New idea of placing tailings in lakes. In some cases, tailings are dewatered or “dried” and disposed in piles. However, except under special circumstances, dry disposal methods can be prohibitively expensive.
Thompson Creek (ID) – waste rock
Teck Red Dog Mine (AK) – impoundment

SOURCE: Teck 1999 annual report
Greens Creek Mine (AK) - tailings dry stack
When Things Go Very Wrong
Mine Sites on the NPL

- There are 63 NPL sites where mining took place after 1990.
- Mining practices which caused a majority of environmental damage have not fundamentally changed over time.
- There is a wide variety of engineering approaches which can reduce environmental liabilities at mines.
Midnite Mine Site (WA)
Blackbird (ID) – Bucktail Creek
Holden Mine (WA) – Tailings Piles
Grouse Creek Mine (ID)
NPL and Superfund Alternative Approach sites which have selected a remedy to address AMD

<table>
<thead>
<tr>
<th>Site Name</th>
<th>State</th>
<th>Remedy</th>
</tr>
</thead>
<tbody>
<tr>
<td>BREWER GOLD MINE</td>
<td>SC</td>
<td>Water treatment lime</td>
</tr>
<tr>
<td>MOLYCORP, INC.</td>
<td>NM</td>
<td>Water Treatment lime</td>
</tr>
<tr>
<td>CALIFORNIA GULCH</td>
<td>CO</td>
<td>Water treatment lime</td>
</tr>
<tr>
<td>CALIFORNIA GULCH</td>
<td>CO</td>
<td>Water treatment lime</td>
</tr>
<tr>
<td>CAPTAIN JACK MILL</td>
<td>CO</td>
<td>Water Treatment bioreactors</td>
</tr>
<tr>
<td>CENTRAL CITY, Clear Creek</td>
<td>CO</td>
<td>Water Treatment created wetlands</td>
</tr>
<tr>
<td>CENTRAL CITY, Clear Creek</td>
<td>CO</td>
<td>Water Treatment bioreactors</td>
</tr>
<tr>
<td>EAGLE MINE</td>
<td>CO</td>
<td>Water treatment lime</td>
</tr>
<tr>
<td>GILT EDGE MINE</td>
<td>SD</td>
<td>Water Treatment lime</td>
</tr>
<tr>
<td>KENNECOTT (SOUTH ZONE)</td>
<td>UT</td>
<td>Water treatment lime</td>
</tr>
<tr>
<td>KENNECOTT (SOUTH ZONE)</td>
<td>UT</td>
<td>Water Treatment created wetlands</td>
</tr>
<tr>
<td>KENNECOTT (NORTH ZONE)</td>
<td>UT</td>
<td>Water Treatment bioreactors</td>
</tr>
<tr>
<td>SILVER BOW CREEK/BUTTE AREA</td>
<td>MT</td>
<td>Water Treatment lime</td>
</tr>
<tr>
<td>SILVER BOW CREEK/BUTTE AREA</td>
<td>MT</td>
<td>Water treatment lime</td>
</tr>
<tr>
<td>SILVER BOW CREEK/BUTTE AREA</td>
<td>MT</td>
<td>Water Treatment lime</td>
</tr>
<tr>
<td>SUMMITVILLE MINE</td>
<td>CO</td>
<td>Water treatment lime</td>
</tr>
<tr>
<td>UPPER TENMILE CREEK</td>
<td>MT</td>
<td>Water Treatment other</td>
</tr>
<tr>
<td>IRON MOUNTAIN MINE</td>
<td>CA</td>
<td>Water Treatment lime</td>
</tr>
<tr>
<td>BLACKBIRD MINE</td>
<td>ID</td>
<td>Water Treatment lime</td>
</tr>
<tr>
<td>BUNKER HILL MINING</td>
<td>ID</td>
<td>Water treatment created wetlands</td>
</tr>
</tbody>
</table>
## Major Superfund Expenditures at Mines and Mineral Processing Sites > $100 Million

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>1000195</td>
<td>IDD048340921</td>
<td>BUNKER HILL MINING &amp; METALLURGICAL COMPLEX</td>
<td>$566,824,690</td>
</tr>
<tr>
<td>08</td>
<td>0801744</td>
<td>MT0009083840</td>
<td>LIBBY ASBESTOS SITE</td>
<td>$324,069,153</td>
</tr>
<tr>
<td>08</td>
<td>0801194</td>
<td>COD983778432</td>
<td>SUMMITVILLE MINE</td>
<td>$290,698,794</td>
</tr>
<tr>
<td>06</td>
<td>0601269</td>
<td>OKD980629844</td>
<td>TAR CREEK (OTTAWA COUNTY)</td>
<td>$223,170,485</td>
</tr>
<tr>
<td>08</td>
<td>0800247</td>
<td>COD980716955</td>
<td>DENVER RADIUM SITE</td>
<td>$220,991,821</td>
</tr>
<tr>
<td>02</td>
<td>0200996</td>
<td>NJD980785646</td>
<td>GLEN RIDGE RADIUM SITE</td>
<td>$181,145,188</td>
</tr>
<tr>
<td>07</td>
<td>0703481</td>
<td>NESFN0703481</td>
<td>OMAHA LEAD</td>
<td>$180,605,255</td>
</tr>
<tr>
<td>02</td>
<td>0200997</td>
<td>NJD980785653</td>
<td>MONTCLAIR/WEST ORANGE RADIUM SITE</td>
<td>$170,096,019</td>
</tr>
<tr>
<td>09</td>
<td>0901755</td>
<td>CAD980498612</td>
<td>IRON MOUNTAIN MINE</td>
<td>$167,963,280</td>
</tr>
<tr>
<td>02</td>
<td>0200772</td>
<td>NJD980654172</td>
<td>U.S. RADIUM CORP.</td>
<td>$161,276,903</td>
</tr>
<tr>
<td>07</td>
<td>0701290</td>
<td>MOD980686281</td>
<td>ORONOGO-DUENWEG MINING BELT</td>
<td>$110,955,934</td>
</tr>
<tr>
<td>08</td>
<td>0800694</td>
<td>UTD980951388</td>
<td>SHARON STEEL CORP. (MIDVALE TAILINGS)</td>
<td>$105,320,041</td>
</tr>
<tr>
<td>08</td>
<td>0801644</td>
<td>UTD002240158</td>
<td>EUREKA MILLS</td>
<td>$104,169,703</td>
</tr>
<tr>
<td>08</td>
<td>0801478</td>
<td>COD980717938</td>
<td>CALIFORNIA GULCH</td>
<td>$101,693,300</td>
</tr>
</tbody>
</table>
## Major Superfund Expenditures at Mines and Mineral Processing Sites $50–$100 Million

<table>
<thead>
<tr>
<th>Year</th>
<th>Code</th>
<th>Identifier</th>
<th>Location</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>08</td>
<td>0801668</td>
<td>SDD987673985</td>
<td>GILT EDGE MINE</td>
<td>$85,856,427</td>
</tr>
<tr>
<td>07</td>
<td>0700667</td>
<td>KSD980741862</td>
<td>CHEROKEE COUNTY</td>
<td>$83,730,173</td>
</tr>
<tr>
<td>08</td>
<td>0800445</td>
<td>MTD980717565</td>
<td>MILLTOWN RESERVOIR SEDIMENTS</td>
<td>$69,059,410</td>
</tr>
<tr>
<td>08</td>
<td>0800416</td>
<td>MTD980502777</td>
<td>SILVER BOW CREEK/BUTTE AREA</td>
<td>$65,201,232</td>
</tr>
<tr>
<td>02</td>
<td>0202972</td>
<td>NYD986882660</td>
<td>LI TUNGSTEN CORP.</td>
<td>$64,792,330</td>
</tr>
<tr>
<td>08</td>
<td>0801699</td>
<td>MTSFN7578012</td>
<td>UPPER TENMILE CREEK MINING AREA</td>
<td>$61,893,798</td>
</tr>
<tr>
<td>08</td>
<td>0800257</td>
<td>COD980717557</td>
<td>CENTRAL CITY, CLEAR CREEK</td>
<td>$61,480,743</td>
</tr>
<tr>
<td>01</td>
<td>0102071</td>
<td>VTD988366621</td>
<td>ELIZABETH MINE</td>
<td>$56,678,197</td>
</tr>
<tr>
<td>10</td>
<td>1000981</td>
<td>WAD980726368</td>
<td>COMMENCEMENT BAY, NEAR SHORE/TIDE FLATS</td>
<td>$54,896,190</td>
</tr>
<tr>
<td>08</td>
<td>0800403</td>
<td>MTD093291656</td>
<td>ANACONDA CO. SMELTER</td>
<td>$53,692,643</td>
</tr>
</tbody>
</table>