Introduction to Mining and Mineral Processing

OSWER
May 2012
Key Messages

- Mining is a complex long term activity.
- The basic elements of environmental risk at mining sites has not changed: mines have large pits and generate large amounts of tailings and waste rock.
- Modern mining often resembles a complex chemical plant rather than a quarry due to the reliance on acids and cyanides.
- Environmental management of mining requires attention from the very beginning of mine design throughout the life of the mine until closure.
- Environmental compliance requires a robust monitoring program which provides data to the public on a regular basis.
Key Messages

- Reclamation and closure planning begin at the start of mining and are refined throughout the life of the mine.

- Environmental modeling of mine waters is extremely complex. The reliability of modeling is at best questionable. Modeling must be confirmed with life of mine monitoring.

- Environmental impacts may not become apparent until years after closure and may occur despite the best designs.

- Mines should be required to obtain financial assurance to cover the costs of remediation by a third party.
The industry includes exploration, extraction, and beneficiation.

Typically located in rural areas and may vary in size exceeding 10,000 acres.

About 25 large mining companies dominate the industry. Ownership structures are complex, with individual mining operations separately incorporated, potentially shielding parent corporations from future liabilities.

Many of the mines are sited on a mix of public and private lands that often involve multiple ownerships including BLM, FS, National Park Service, Tribal, State, and private lands.
Coal Basins in the US
Uranium Deposits in the US

Major U.S. Uranium Reserves

Sources: Based on U.S. Department of Energy, Grand Junction Project Office (GJPO), National Uranium Resources Evaluation, Interim Report (June 1979) Figure 3.2, and GJPO data files.
Active Precious Metal Mines in US
Mining Background

- Approximately 1200 active extraction and beneficiation hardrock mining sites operating

- Gold mines in NV, CO, AK, with prospects in SC
- Copper mines in AZ & NM, w/new copper/gold mines potential in MI, MN and WI
- Lead mining takes place in MO
- Zinc mining occurs in TN
- Phosphate mining takes place in FL and ID
- Iron ore mining occurs in MN and MI
- Uranium mining is taking place in NM & Colorado w/new exploration throughout the US.
- Approximately 500 mineral processing facilities located throughout the US.

- Chemical use in mining has changed dramatically over the last 20 years (e.g., cyanide “heap leaching” of gold has become widespread), creating new environmental and human health challenges and leading to a resurgence of mining activities in many areas of the country.

- Copper and gold mines comprise 80% of the facilities in the United States.

- Nevada is the most active with approximately 150 gold mines.
Steps in the Mining Process

- **Mine**
  - Ore
  - Waste Rock

- **Crushing**

- **Grinding**
  - Recycle Water

- **Ore Separation**
  - Tailings

- **Concentrate Dewatering**
  - Waste Water

- **Waste Rock Pile**
  - Waste Water
What is Mining?
Extraction—removal of overburden and ore from the ground
Underground and surface mining methods
In-situ mining—pump solution into ore from surface wells

Underground Mining
Use of shafts and tunnels to access ore
Pumping out mine water
Bring ore to the surface for additional handling

Surface Mining
Open pit—Cheapest method to access ore
Causes greatest potential environmental impacts
Diagram of a Typical Underground Mine
Mining Background (cont.)

- **Ore Concentration**
  Crushing, grinding in ball mills, then froth floatation
  Final product looks like dark sand which goes to smelting

- **Cyanide Heap/Tank Leaching**
  Concern about leakage into ground and surface water
  Concern about releases of mercury

- **Hydrometallurgical Processing**
  Ore is leached with chemicals and then a liquid/liquid chemistry to create a metal rich solution which is then electrowinning produces solid metal plates with out smelting
In a general sense, **Extraction** is the initial removal of ore from the earth.

In a general sense, **Beneficiation** is the initial attempt at liberating and concentrating the valuable mineral from the extracted ore. This is typically performed by employing various crushing, grinding and froth flotation techniques. The remaining material is often physically and chemically similar to the material (ore or mineral) that entered the operation, except that particle size reduction has often occurred.

**Mineral processing** is generally viewed as smelting but the term encompasses a wide variety of processes. Primary smelters covered under this Rule.
Extraction Methods

- Open Pit
- Underground
- Strip/Ridge Top
- Placer
- In-Situ Leaching (uranium)
Surface mining
Haulage
BERKELEY PIT

1.5 mi

1 mi
Underground mining

- Shaft – vertical opening to the surface
- Adit – horizontal opening to the surface
- Stope – opening along the vein or ore deposit
AK Placer Mining
In-Situ Leaching of Uranium

Diagram showing the process of in-situ leaching, including:
- Injection well
- Extraction well
- Monitor well
- Screened interval
- Injected solution
- Uranium enriched solution

Layers and components:
- Willawong Formation
- Shoestring sands, clays and gravels
- Beverley Clay
- Beverley Sands
- Uranium
- Alpha Mudstone

Facilities:
- Laboratory
- Uranium extraction columns
- Uranium recovery columns
- Thickeners
- Yellowcake drying and packaging
- Shipping containers
- Workshop
- Power station
- Evaporation ponds
- Control room
- Trunk lines
- Well house
- Production monitor well
Beneficiation

- Crushing/Grinding in Ball mills
- Froth floatation
- Cyanide Heap Leach
- Copper (SX/EW) solvent extraction/electro-winning
Milling

- Large rotating mills use metal balls or rods to grind the ore
A concentration process commonly used for sulfide ores of copper, lead, and zinc is flotation.
Heap leach pad
Copper (SX/EW) electro-winning/solvent extraction
Solid Waste Products

- Waste Rock
- Tailings
  - Tailings Impoundment disposal
  - Dry stack disposal
  - Disposal in lake impoundment
- Heap Leach/Dump Leach
Teck Red Dog Mine (AK) – impoundment

SOURCE: Teck 1999 annual report
Greens Creek Mine (AK) – tailings dry stack
Coeur Alaska Kensington – lake impoundment
References

- ATSDR – Agency for Toxic Substances and Disease
- Cleaning up Abandoned Mines in the West – CU
- EPA and Hardrock Mining: A Source Book for Industry in the Northwest and Alaska
  http://yosemite.epa.gov/r10/water.nsf/59f3b8c4fc8c923988256b5800
  60f5d9/e4ba15715e97ef2188256d2c00783a8e?OpenDocument
- EPA National Hardrock Mining Framework (EPA 1997)
- EPA Mining Waste http://www.epa.gov/epaoswer/other/mining/index.htm
- Inactive Mine Site Characterization and Cleanup Handbook (EPA 2000)
- Mining 101 Training: Introduction to Non-Coal Mining Operations
- Mining Engineering Handbook – SME
- USEPA R10 Mining Financial Assurance Strategy (PDF)
- The Process and Requirements for Large Mine Permit Applications in Alaska. State of Alaska Large Mine Team presentation.
  (See pages 5–8 for Mining 101 information.)
- http://www.dnr.state.ak.us/mlw/mining/largemine/lmpt.pdf