Environmental Technologies in the Mining Industry

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Some Issues for Evolving Technologies for Reducing Environmental Impacts in the Mining Industry

1. Environmental standards are driven by environmental concerns, often from the public through the regulatory agencies.
2. Research efforts on environmental technology by the industry need to go hand in hand with federal and academic research.
3. Scale is a major complication: What works on 10 gram samples in the laboratory may have different feasibility on a 100 million ton pile of rock.

Some of the Issues

Mercury: Volatilization from heaps and tailings facilities, and worker exposure to mercury during gold recovery

Pits and pit lakes: Can they be made a public good

Closure of heaps and tailings facilities: Long term water quality concerns

Acidic drainage: The tried and true problem that still haunts us

Alternative lixiviants: Selective regents to extract only the desired valuable metal

Gold and Byproduct Mercury Production

The Chemistry

$$Au + O_2 + CN^- \longrightarrow Au(CN)_2^- \quad \text{(water soluble)}$$

$$Hg + O_2 + CN^- \longrightarrow Hg(CN)_2 + Hg(CN)_4^{2-}$$

(water soluble)

Both the gold and mercury cyanide complexes are trapped on carbon and recovered during processing

Mercury is distilled (retorted) from the gold and collected as liquid mercury and sold by the flask (76 lbs). Nevada produces about 100 metric tons of mercury each year over the past 10 years.

Top of a cyanidization heap

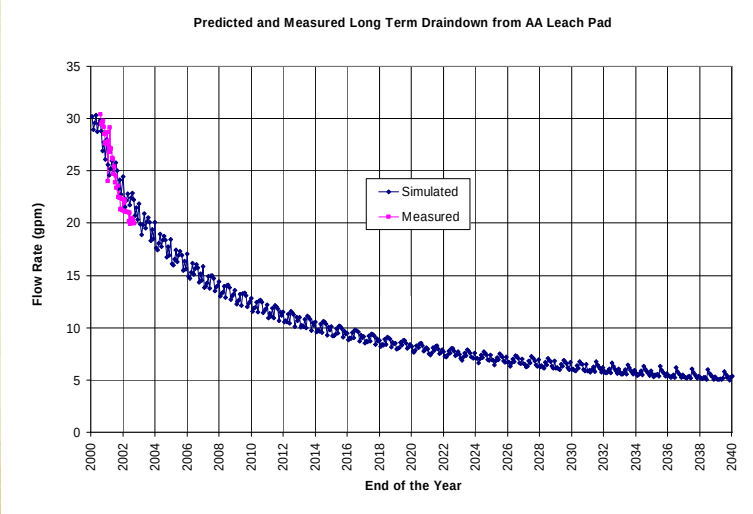
Jerritt Canyon Tailings

Reduction of Fugitive Hg Emmisions

- Certain dithiocarbamate trapping agents added to process fluids have shown distinct promise to trap mercury on tailings or heaps to keep it from volatilizing in sunlight.
- The requirement for, or even testing of the process is determined by regulatory concerns
- Currently the gold mining industry in Nevada has decreased mercury reduction in a dramatic manner, and there is only limited interest in additional reductions.
- Further investigation will be driven by regulatory needs.

Long Term Drainage from Heaps and Tailings

Long Term Draindown



Drainage from heaps and tailings is almost always poor quality water.

- Saline, often containing elevated arsenic, selenium and other contaminants of concern.
- Requires management of that water, sometimes for decades
- Many options available, although long-term
  - Evaporation when climate allows
  - Various membrane processes
  - Salt management

Acid Drainage: Still the Most Difficult Problem

Leviathan Mine lime precipitation and sludge management

Technological Solutions

1. Don't let it form
   - Passivation to limit acid generation
   - Appropriate treatment and waste rock management
2. Treatment
   - Better lime addition/sludge management
   - Use various biological processes
   - Other options based on cost and effectiveness

Pits

- The waste produced can be many times larger than from underground mines
- Are there judgments that can made on a technical basis where open pit mining should not be undertaken? How would an assessment be undertaken to make this decision?
- Planning for a post mine pit use requires an assessment of what options are available: Chemical and physical risks must be considered.

Pinson Mine Pit Backfill

Berkeley Pit Lake, Butte, Montana

Pit Lake Technologies

- The ability to predict pit lake water quality is critical. So far, the geochemical models are largely worthless (my opinion)
- Treatment technologies for acidic pit lake waters needs development: Lime addition; biological processes
- Technologies to understand post mining use of pit lakes are important- Are hard rock mining pit lakes (particularly gold and copper) usable for productive purposed

Aurora Partnership Pit Lake

Florida Canyon Barron Pond

Constitutent	Concentration (mg/L)
Arsenic	0.21 mg/L
Chloride	3200
Copper	0.51
Iron	0.47
Mercury	0.10
Nitrate/nitrite	134
pH	9.8
Selenium	0.11
Sulfate	470
TDS	5670

Relief Canyon Heap

Mercury in Gold Ore

- Concentration varies substantially between mines, from less then 0.1 mg/kg to over 100 mg/kg
- Roasting ore is the largest source of byproduct mercury. If a large roaster processes 4 million metric tons of ore with 10 mg/kg mercury, 40 metric tons of mercury are volatilized and available for capture by air pollution control devices.

Sources of Mercury During Gold Recovery that is Available for Capture

- *Carbon Kilns:* Since, mercury is not completely removed from carbon during stripping, charcoal is heated in carbon kilns to reactivated the carbon and remove the mercury.
- *Roasters:* Heating carbonaceous ore in a roaster will release effectively all of the mercury in that ore.
- *Electrowinning cells* can release mercury during recovery of elemental gold and silver.
- *Retorts* are the primary source of byproduct production in oxide gold mines. The primary use of retorts is for mercury removal from gold and silver.
- *Dore Furnaces:* Residual mercury can be released during dore furnace treatment, where the ore is melted at 1500° C in a refinery furnace to produce dore (gold and silver).

Total Mercury By-Product Recovered for Sale (pounds and metric tons) (provided by each company)

	1999	2000	2001	2002	2004
Jerritt Canyon	4,041	4,313	3,709	5,045	1,540
Placer Dome (Pipeline)	831	814	1,068	903	1,744
Placer Dome (Bald Mtn)	1,203	248		***	825
Barrick (Goldstrike)	13,629	63,701	133,784	204,477	173,538
Newmont (E. Operations)	*N/A*	14,192*	19,484	16,944	7,609
Newmont (W. Operations)	*N/A*		7,986	8,367	26,746
Total pounds		*83,268*	*166,031*	*235,736*	244,160
Total Metric Tons		*37.8*	*75.3*	*106.9*	111

Mercury Byproduct Reports for 2006-2008 to NDEP, (U.S. tons)*

Mine	2006	2007	2008
Gold Quarry (Newmont)	2.94	2.27	6.77
Twin Creeks (Newmont)	8.91	13.22	8.80
Gold Strike (Barrick)	98.55	58.63	67.33
Jerritt Canyon (Queenstake)	2.96	1.02	0.71
Rochester (Coeur)	16.1	15.40	15.60
Bald Mountain (Barrick)	2.94	2.27	2.60
Total (NV) (U.S. tons)	**133.26**	**97.68**	**102.93**
Total (NV) (Metric tons)	**120.89**	**88.61**	**93.38**

*Mines producing less than 1 ton of mercury are not indicated, but the total NV production includes all reported mining sources

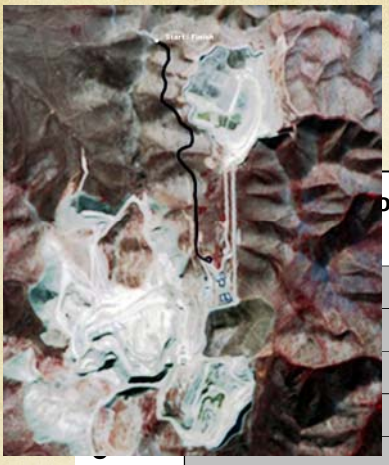
Mercury Air Emissions (lbs) from Precious Metals Mines, 1998-2003 (TRI data)

	1999	2000	2001	2002	2003	2004
Goldstrike	1400	1467	1243	1253	1122	2180
Pipeline		2200	1500	1351	925	1342
Jerritt Canyon	9400	6700	7990	4740	793	310
Newmont Carlin (S)	71	80	490	513	565	227
Twin Creeks	1200	630	570	530	588	588
Total from NV Mines	***12167***	***12505***	***12374***	***8706***	***4828***	***4605***
Total all NV Industries	***12167***	***12912***	***12959***	***9266***	***5025***	***4804***

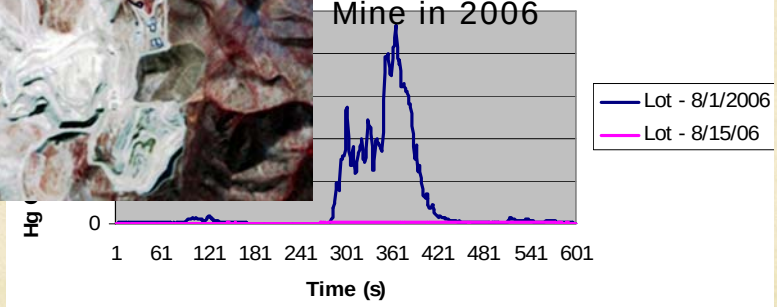
Ranking of States for Atmospheric Mercury Release

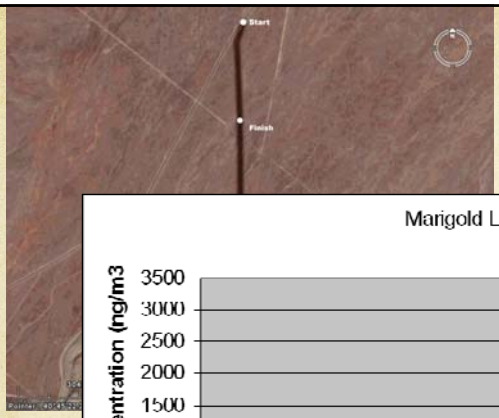
Rank (2002)	State	Pounds released (2001)	Pounds released (2002)
1	Texas	14,766	14,505
2	Ohio	11,405	9,625
3	Pennsylvania	9,089	9,177
4	**Nevada**	**12,959**	**9,069**
5	Indiana	7,168	7,645
6	Illinois	5,963	5,610
7	Alabama	5,903	4,729
8	North Carolina	4,164	4,507
9	California	5,668	4,173
10	West Virginia	6,282	4,051
11	Kentucky	5,256	3,670

NV Mines 2003 4828 lbs

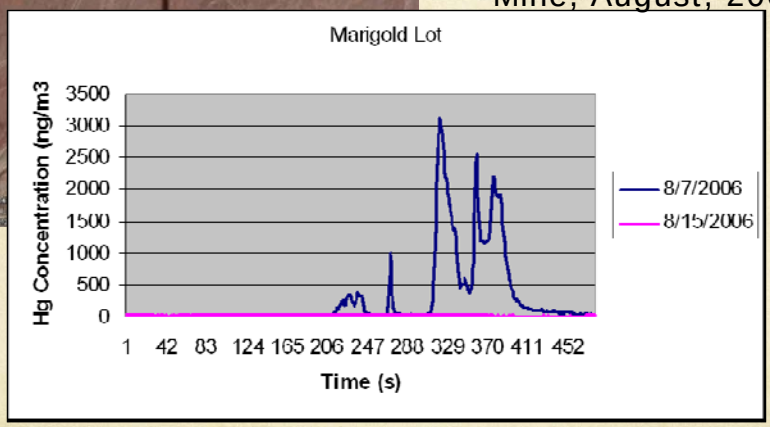


Measurement of ambient mercury at the Coeur Rochester Mine in 2006





Mercury in ambient air at the Marigold Mine, August, 2006



"Green Gold" Criteria

- Climate- Rainfall?
- Geological Setting- Acid Producing?
- Type of Mine- Open Pit vs. Underground
- Company Performance Record
- Regulatory Setting
- Closure Plan with Bonding
- Mercury Plan

Gold Dredging in Siberia

Zakamensk Tungsten Mine

El Tieniente, Chile

Underground Mines

- Impacts are a function of the size of the waste rock dumps, physical plant and water issues.
- Dewatering of underground workings is likely to affect water resources during mining
- The groundwater impacts can be greatest following closure, with very little ability for remediation
- Drainage from rock surfaces is likely to adversely affect groundwater quality until those surfaces are completely rinsed

Community Issues

- What is the record of the mining company?
- Who will regulate the mine?
- What is the record of the regulatory agency
  Does it have sufficient authority, funding, staffing and expertise to protect the public interest?
- What are the benefits and impacts of the mine to the community?
- What financial assurance exists to clean up a mine in the event of bankruptcy?