International Assessment of Marine and Riverine Disposal of Mine Tailings

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Background

- Greenpeace International in March 2008 at SG 31 raised the issue of discharges of mine tailings into marine and riverine waters.
- Discussion by SG and LC/LP in subsequent meetings
  - Not much response from information collection efforts (LC-LP.1/Circ.35), and additional direct correspondence with some countries with an active mining industry.
  - Concluded that an inventory and assessment should be conducted.
- Assessment commissioned by LC/LP and UNEP-GPA.

- LC/LP objectives are to protect the marine environment from all sources of marine pollution, and, in particular, control and manage the dumping of wastes and other matter at sea.
- The objectives of UNEP’s Global Plan of Action are to control land-based sources of marine pollution.
Objectives of Assessment

• Develop an inventory of key mining operations worldwide that discharge mine tailings into marine or riverine waters via pipelines.

• The inventory should include descriptions of:
  – Location, primary products, and production size
  – Marine or riverine disposal practices
  – Actual or potential damage to the marine or riverine environment
  – In-place environmental controls or best management practices
  – Monitoring activities to assess the environmental risk
  – Regulatory authorities, regulations, and issued permits
Outline of Presentation

- What is mining and what are mine tailings?
- On-land disposal practices for mine tailings
- Marine disposal of mine tailings
- Riverine disposal of mine tailings
- Environmental impacts of marine and riverine disposal
- Rationale for marine and riverine disposal
- Best management practices
- Legislation and regulations
- Findings and conclusions
- What is the appropriate response for the LC/LP?
What is Mining?

• Mining is the process of extracting minerals from the earth’s crust.

• Mining has four basic phases:
  – Exploration and feasibility
  – Planning and construction
  – Operations
  – Closure

• Why Mine?....Simply put, minerals are needed for living.
  – Mobile phones--many metal components, including silver, gold, platinum, cadmium, lead, nickel, mercury, zinc, arsenic, and copper.
  – Gold--dentistry and medicine, in jewelry and arts, in medallions (e.g., Olympic medals) and coins
  – Copper--building construction, electric cables and wires, switches, plumbing
What are Mine Tailings?

• Two types of wastes are generated by mining:
  1. Overburden/waste rock
  2. Mine tailings

• Overburden/waste rock: top layer of soil and rock removed to access the ore

• Mine tailings:
  – Includes what is left after physical and chemical processing to separate the target minerals (e.g., gold, silver, or copper) from the ore.
  – Include the fine grained particles from the ore and the residues of chemical reagents, all as part of a slurry.
  – The share of the mine ore (not including overburden and waste rock) that becomes waste is about 60% for iron, 99% for copper, and 99.99% for gold

• Constituents of concern in mine tailings include:
  – Heavy metals
  – Cyanide and chemical processing agents
  – Sulfide compounds
  – Suspended and settleable solids
Disposal Practices for Mine Tailings

- Mine tailing storage facilities
  - Cross valley or hillside dams
  - Raised embankments/impoundments
  - Natural lakes
- Dry-stacking of thickened tailings on land
- Backfilling into abandoned open pit mines or underground mines
- Riverine disposal
- Marine disposal (submarine tailings disposal or deep sea tailings placement)

Note: Waste rock or overburden is normally placed on-site in storage dumps, but sometimes placed into mine tailings storage facilities or into completed portions of open pit mines.
Mine Tailing Storage Facilities: on-land

- 99.4% of mines dispose mine tailings in on land storage facilities
- Mine tailings storage facilities are engineered impoundments that are created from embankments on more level surfaces or dams across valleys in areas of mountainous or hilly terrain
- Objectives:
  - Place the mine tailings into the impoundments for long term/permanent storage.
  - For mine tailings that can create acid rock drainage, the objective of the impoundments is to ensure that the tailings are under water.
Mine Tailing Storage Facilities—Not without Issues

• Scale of the terrestrial footprint, loss of habitat, and loss of productive land
• Aesthetics and short and long term safety of dams/impoundments
• 138 significant failures of mine tailing storage facilities, and continuing today
• Very significant support industry to ensure that mine tailing storage facilities are built and operated in a safe manner. International Commission on Large Dams dedicated to provide safe and long term facilities.
• 3,500 mine tailings storage dams world-wide
• Example 1: October 4, 2010, in Hungary--embankment of a red mud impoundment failed and released a mixture of 600-700 thousand cubic meters of red mud and water. Ten people were killed, and approximately 120 people were injured.
Example 2:
In 1998, the Los Frailes mine tailings dam in Aznalcóllar, Spain, failed releasing 5-7 million cubic meters of mine tailings into the Rio Agrio; the river bed rose 3 meters and 3,500 hectares of river farmland were covered. Cleanup costs were estimated to be $100-200 million.
Marine and Riverine Discharges of Mine Tailings

- In 2012, marine or riverine disposal of mine tailings is used by 15 mines, four of which use riverine disposal and 11 use marine disposal. The locations:
  - Norway: 5 marine dischargers (3 additional in permit application review process—no decisions made)
  - Turkey: 1 marine discharger
  - England: 1 marine discharger
  - Indonesia: 1 marine discharger and 1 riverine discharger
  - Papua New Guinea: 3 marine dischargers and 3 riverine dischargers

- Of the total of 2,500 industrial-sized mines world-wide, 0.6% use marine or riverine disposal.
Riverine Disposal

- Riverine disposal is uncomplicated. Pipe the slurry of mine tailings to a river and discharge.
- Practiced world-wide throughout mining history.
- Because of the catastrophic environmental impacts experienced across the world, riverine disposal is no longer practiced, except at four mines, one in Indonesia and the other three in PNG.
<table>
<thead>
<tr>
<th>Location</th>
<th>Type of Mine</th>
<th>Mine Tailings tonnes per year</th>
<th>Deposition</th>
<th>Company</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indonesia</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grasberg</td>
<td>Gold/copper</td>
<td>87,000,000</td>
<td>River</td>
<td>Freeport McMoRan</td>
</tr>
<tr>
<td>Papua New Guinea</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ok Tedi</td>
<td>Copper/gold</td>
<td>90,000,000 mine tailings</td>
<td>River</td>
<td>PNGSDPC-PNG government</td>
</tr>
<tr>
<td>Ok Tedi</td>
<td>Copper/gold</td>
<td>44,000,000 waste rock</td>
<td>River</td>
<td>PNGSDPC-PNG government</td>
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<tr>
<td>Porgera</td>
<td>Gold</td>
<td>5,500,000 mine tailings</td>
<td>River</td>
<td>Barrick Gold</td>
</tr>
<tr>
<td>Porgera</td>
<td>Gold</td>
<td>9,900,000 – 15,000,000 waste rock</td>
<td>river</td>
<td>Barrick Gold</td>
</tr>
<tr>
<td>Tolukuma</td>
<td>Gold</td>
<td>200,000</td>
<td>river</td>
<td>Petromin Holdings</td>
</tr>
</tbody>
</table>
Grasberg, Indonesia, Mine---Riverine discharge of mine tailings: spreading out into the lowlands
Riverine discharge of mine tailings from Grasberg Mine
Riverine discharge of mine tailings from Grasberg Mine

Levies to control the spread of mine tailings into the lowlands

Riverine discharge of mine tailings from Grasberg Mine
Marine Disposal of Mine Tailings

- Discharge of mine tailings into marine waters by a pipeline.

- Discharge into shallow surface waters along coastal shorelines—no longer practiced.

- Today’s marine discharges---final deposition depths of 30 meters to hundreds of meters deep in Norway and greater than 1,000 meters in Turkey, Indonesia, and Papua New Guinea.

- General concepts of marine disposal in Indonesia and PNG include:
  - Discharge on the edge of an extended drop-off (e.g., to 1,000 meters or more)
  - Discharge below the euphotic zone into denser stratified waters
  - Discharge in the form of a coherent turbidity current which flows with minimum dispersal until it reaches the base of the drop-off
  - Minimal chance of tailings upwelling back into shallow water
<table>
<thead>
<tr>
<th>Location</th>
<th>Type of Mine</th>
<th>Mine Tailings tons/year</th>
<th>Depth in meters</th>
<th>Company</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indonesia</td>
<td></td>
<td></td>
<td></td>
<td>Newmont Mining</td>
</tr>
<tr>
<td>Batu Hijau</td>
<td>Copper/gold</td>
<td>40,000,000</td>
<td>3,000-4,000</td>
<td>Newmont Mining</td>
</tr>
<tr>
<td>Papua New Guinea</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lihir</td>
<td>Gold</td>
<td>4,000,000</td>
<td>&gt;2,000</td>
<td>Newcrest</td>
</tr>
<tr>
<td>Lihir</td>
<td>Gold</td>
<td>40,000,000 waste rock</td>
<td>By barge 1 km offshore</td>
<td>Newcrest</td>
</tr>
<tr>
<td>Simberi</td>
<td>Gold</td>
<td>3,300,000</td>
<td>not available</td>
<td>Allied Gold</td>
</tr>
<tr>
<td>Ramu Nickel</td>
<td>Nickel/colbalt</td>
<td>5,000,000</td>
<td>1,500</td>
<td>Metallurgical Corp of China/Highlands Pacific</td>
</tr>
<tr>
<td>Marine Discharges of Mine Tailings</td>
<td>2012 (continued)</td>
<td></td>
<td></td>
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<tr>
<td>-----------------------------------</td>
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<tr>
<td><strong>Turkey</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cayeli Bakir</td>
<td>Copper/zinc/lead</td>
<td>11,000,000</td>
<td>&gt;2,000</td>
<td>Inmet Mining</td>
</tr>
<tr>
<td><strong>England</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boulby</td>
<td>Potash</td>
<td>1,800,000</td>
<td>na</td>
<td>Cleveland Potash</td>
</tr>
<tr>
<td><strong>Norway</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bokfjorden Iron</td>
<td>4,000,000</td>
<td>220</td>
<td></td>
<td>Sydvaranger (Northern Iron Ltd)</td>
</tr>
<tr>
<td>Ranafjorden Iron</td>
<td>2,000,000</td>
<td>80</td>
<td></td>
<td>Rana Gruber Minerals</td>
</tr>
<tr>
<td>Stjernoy Nepheline syenite</td>
<td>~ 300,000</td>
<td>not available</td>
<td></td>
<td>Sibelco Nordic</td>
</tr>
<tr>
<td>Elnesvagen Pigments</td>
<td>500,000</td>
<td></td>
<td></td>
<td>Hustadmarmor</td>
</tr>
<tr>
<td>Skaland</td>
<td>Graphite</td>
<td>20,000-40,000</td>
<td>30</td>
<td>Skaland Graphite ASA</td>
</tr>
</tbody>
</table>
Norway: Mine tailings practice no longer allowed
Conceptual Marine Disposal in Norway
Norway: Site of Proposed Nussir Mine and Marine Disposal
<table>
<thead>
<tr>
<th>Location</th>
<th>Name of Mine</th>
<th>Other Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada-British Columbia</td>
<td>Kitsault Molybdenum</td>
<td>Silled fjord</td>
</tr>
<tr>
<td>Canada-Vancouver Island</td>
<td>Island Copper</td>
<td>Sheltered fjord—Rupert Inlet</td>
</tr>
<tr>
<td>Canada-Vancouver Island</td>
<td>Jordan River Mine</td>
<td>Strait of Juan de Fuca</td>
</tr>
<tr>
<td>Canada-British Columbia</td>
<td>Wesfrob</td>
<td>Tasu Sound</td>
</tr>
<tr>
<td>Chile</td>
<td>Huasco Iron</td>
<td>Chapaco Bay</td>
</tr>
<tr>
<td>France</td>
<td>Marseilles Aluminum</td>
<td>Submarine canyon</td>
</tr>
<tr>
<td>Greenland</td>
<td>Black Angel</td>
<td>Shallow fjord—waste rock and tailings</td>
</tr>
<tr>
<td>Greenland</td>
<td>Ivittuut</td>
<td>Fjord—waste rock</td>
</tr>
<tr>
<td>Indonesia</td>
<td>Minahasa</td>
<td>Bayut Bay</td>
</tr>
<tr>
<td>Norway</td>
<td>About 20 closed mines</td>
<td>Fjords</td>
</tr>
<tr>
<td>Papua New Guinea</td>
<td>Misima</td>
<td>Shallow depths in Solomon Sea</td>
</tr>
<tr>
<td>Papua New Guinea</td>
<td>Bougainville</td>
<td>River</td>
</tr>
<tr>
<td>Peru</td>
<td>Toquepola-Cuajone-</td>
<td>Shallow coastal shelf; now operating on-land disposal</td>
</tr>
<tr>
<td></td>
<td>still operating</td>
<td>facilities</td>
</tr>
<tr>
<td>Philippines</td>
<td>Marcopper</td>
<td>Shallow embayment—Cebu Island</td>
</tr>
<tr>
<td>Philippines</td>
<td>Atlas Copper</td>
<td>200 meters from shore; 10 meters depth</td>
</tr>
</tbody>
</table>
Environmental Impacts of Marine Disposal of Mine Tailings

- Potential environmental impacts of marine disposal of mine tailings:
  - Smothering benthic organisms and physical alteration of bottom habitat
  - Reduction in species composition/abundance and biodiversity of marine communities
  - Acute and chronic toxicity from metals in the mine tailings
  - Bioaccumulation of metals through food webs and ultimately into human fish-consuming communities-increases in risk to human health
  - Formation of sulfuric acid from sulfide minerals in the tailings when exposed to air and water—acute toxicity and release of heavy metals
Environmental Impacts of Marine Disposal of Mine Tailings (continued)

- Extent of potential biological impacts depends upon:
  - Chemical and physical characteristics of the mine tailings
  - Levels of turbidity and toxicity
  - Site specific factors—
    - specific locations of the plumes and sensitive marine organisms
    - whether upwelling brings the mine tailing discharge plumes to surface waters.
  - Impacts to local areas can include coral reefs, sea grass communities, pelagic communities, and coastal fisheries.
Unambiguous demonstration that mine tailings have major impacts on the disposal site in abundance and diversity of animals near the footprint.

Sediment dwelling animals very sparse at the impacted site and more abundant at reference sites.

Limited heavy metals in fish tissue.

Some bioaccumulation in lower levels of the food web — less mobile species.
Institute of Marine Research in Bergen, Norway concluded:

- The biodiversity of the fjord is changed--the ecosystem is disrupted in significant parts of a fjord.
- Benthos in significant parts of a fjord will disappear as long as the dumping lasts and recovery will take an unknown number of years.
- Demersal fish (e.g., tusk, flatfish, rays, cod, haddock), and crustaceans (e.g. prawns, crabs, and king crab) lose their habitat
- Phytoplankton, zooplankton, copepods, krill, pelagic prawns may be affected but more study is needed.
- The “eternal cycle” of production, transfer of matter through the food web and regeneration of nutrients is broken.
Environmental Impacts of Riverine Disposal of Mine Tailings

- Sediment deposition in the river channel and along the river banks cause major changes to physical structure of the river.
  - Riverbed levels rise reducing flow capacity
  - Overbank flooding extending the floodplain
  - Riverbank and floodplain vegetation is killed
- Examples:
  - Ok Tedi: river levels raised by 6 meters; dieback 480 square kilometers
  - Porgera: river levels raised by 2-3 meters
  - Grasberg: created 130 square kilometers of flood plain by 2002, and 220 square kilometers expected by mine closure.
Environmental Impacts of Riverine Disposal of Mine Tailings (continued)

- Smothering of river bottoms and riverbanks: loss of benthic organisms, loss of flora
- Changes in the abundance and diversity of aquatic species of fish
- Bioaccumulation of heavy metals and risks to human health
- Creation of sulfuric acid and release of heavy metals
- Impacts to estuarine waters, including coral reefs
Recovery of Marine and Riverine Environmental Resources

• The key questions:
  – How long will it take before new micorfauna will appear?
  – What type of micofauna will be established (recolonization)?

• Studies indicate that recolonization will occur but not necessarily with the same species that were originally present at the sites.
  – Example: Canada—Island Copper
  – Example: Papua New Guinea--Misima

• In general, benthic species that re-colonize mine tailings are different than the original species, both in number and types, which can shift marine species community structures.

• Actual recovery may be decades or centuries before mine tailings footprint is capped by natural sediment.
What is the Rationale for Marine or Riverine Disposal of Mine Tailings?

• The primary factors: economics, lack of available or appropriate land for disposal, to avoid acid runoff and release of heavy metals, and, in general, to minimize potential environmental impacts

• In Indonesia and Papua New Guinea:
  – Creation of a mine tailings storage facility in the mountainous terrain would not be technically feasible.
    • Located in very active earthquake prone areas which could create a safety hazard to downstream communities
    • Long term maintenance and safety after mine closure;
  – The rainfall is up to 3 meters per year--water management in tailings storage facilities extremely difficult
    – The terrain is unstable for construction of safe mine tailing storage dams.

• In Norway, rationale is suitable land for disposal of mine tailings near the fjords is not available.
Exceptions to the Feasibility Argument in PNG

- Hidden Valley Mine in Papua New Guinea
  - Owned by Newcrest Mining and Harmony Gold
  - Built a mine tailings storage dam
- Wafi-Golpu Gold Project
  - In the feasibility and development stage
  - Owned by Newcrest Mining
  - Recent decision was to not consider marine disposal and to build a mine tailings storage dam

Hidden Valley Mine storage tailings facility in PNG
Best Management Practices

• A number of mining companies, federal and local governments, and environmental interest groups—prepared codes/principles/best practices on best environmental practices (BMP).
  – Marine disposal of mine tailings
  – Considerations for selection of disposal sites for marine disposal
  – Management of mine tailings in on-site in tailings dams
  – Sustainable mining, considering the entire mining operation from exploration to mine closure and rehabilitation

• No BMPs for riverine disposal. Riverine disposal is not compatible with concepts of best environmental management.
Legislation and Regulations: Marine and Riverine Disposal of Mine Tailings

- Report lists pertinent legislation and regulations for countries that allow marine or riverine disposal of mine tailings.
- In every case, permits (or their equivalent) have been issued for marine or riverine disposal.
- Report also lists a few examples of legislation or regulations for countries that do not allow marine or riverine disposal.
- Author’s comment on permit compliance
Lihir Mine in Papua New Guinea
Loading of barges with waste rock for dumping at sea
Lihir Mine in Papua New Guinea
Alert to LC/LP: Deep Sea Mining is Coming

• First project approved: Papua New Guinea
  • 1600 meters deep
  • 30 km offshore
  • 59 square kilometers
• Others being considered: Fiji, India
Findings and Conclusions

• 99.4% of the 2,500 industrial-sized mines dispose of their mine tailings on-land.

• World-wide, 15 mines use either marine or riverine disposal.

• Mining and mine tailings disposal are not environmentally friendly activities.

• Riverine mine tailings disposal should not be allowed for new mines.

• Marine disposal may be the best choice between unattractive alternatives, because of local conditions.

• If marine disposal is selected, comprehensive risk assessments should be conducted, mine tailings characterized, careful site selection for deposition, and extensive monitoring requirements established.

• Many new mines being developed are actively considering marine disposal of mine tailings.

• Deep sea mining---a new issue for the LC/LP?
What is the Appropriate Response by the LC/LP?

Possible actions:

1. Regarding riverine disposal of mine tailings: Issue a statement that censures the use of riverine disposal of mine tailings for new mines.

2. Regarding marine disposal of mine tailings:
   1) Take no action;
   2) Offer technical assistance and cooperation—status quo;
   3) Issue a statement of concern—similar to the initial response to the proposal regarding iron fertilization of the oceans for CO2 capture; or
   4) Issue a statement of concern and prepare waste assessment guidance for marine disposal of mine tailings. Emphasize:
      a) Waste characterization
      b) Site selection
      c) Monitoring programs