

International Assessment of Marine and Riverine Disposal of Mine Tailings¹

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This paper summarizes a report of a world-wide inventory of operating mines that dispose of mine tailings to marine and riverine waters and a review of what is known about the environmental impacts of those discharges. The report was commissioned by the International Maritime Organization, specifically the IMO Secretariat for the London Convention 1972 and the 1996 London Protocol (LC/LP), in collaboration with the United Nations Environment Programme (UNEP)-Global Programme of Action. These are the primary international instruments to protect the world's oceans from pollution. The objectives of the LC/LP 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 (LC/LP 2003).

Background

Mining is essential to living as we know it. Mining is not an environmentally friendly activity. Extensive efforts have been made world-wide to minimize environmental damage from mining activities, but the job is not done. The biggest environmental challenge in mining is the management of mine tailings.

Mine tailings are what is left over from the mined ore after the target mineral (e.g., copper or gold) has been separated from the ore. Separation is achieved by an industrial process using physical grinding and crushing to break the ore into small particles. For iron ore, this is followed by magnetic separation without chemical processing. For copper and gold mining, chemical extraction and flotation methods follows physical processing. Tailings from copper and gold mining are known to contain heavy metals, chemical reagents used in the separation process (e.g., cyanide), and sulfide-bearing materials.

What is Mining?

Mining is the process of extracting minerals from the earth's crust. The mining considered in this report occurs in open-pit surface mines or underground mines. Two types of wastes are generated, overburden/waste rock and mine tailings (Australia 2007).

- The overburden is the top layer of soil and rock that must be removed to access the ore. The waste rock often contains the target minerals but at too low concentrations to be economically extracted from the rock. Overburden and waste rock are disposed on-land near the mine site, with three known exceptions, one of which places overburden and waste rock on barges to dump at sea and the other two use indirect riverine disposal (erosion on the banks of rivers).
- Mine tailings contain the fine grained materials from the ore and, for copper and gold mining, the residues of chemical reagents used in the separation process, all part of a slurry. Mine

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tailings contain some of the metal bearing minerals, such as copper. The share of ore that becomes waste is about 20-60% for iron, 99% for copper, and 99.99% for gold (Environment Canada 2009).

What Disposal Techniques are used for Mine Tailings?

There are approximately 2,500 industrial-sized mines world-wide. Nearly all of these mines, 99.3%, dispose of their mine tailings on-land, placing the mine tailings under water in impoundments or behind

In 2013, marine or riverine disposal of mine tailings is used by 18 mines, four of which use riverine disposal and 14 use marine disposal (Vogt 2013). The locations:

- Norway: 5 marine dischargers (3 additional in permit application review process)
- Turkey: 1 marine discharger
- England: 1 marine discharger
- Greece: 1 marine discharger
- France: 1 marine discharger
- Chile: 1 marine discharger
- Indonesia: 1 marine discharger and 1 riverine discharger
- Papua New Guinea: 3 marine dischargers and 3 riverine dischargers

dams, or they are backfilled into closed sections of open-pit or underground mines. Mine tailing storage facilities are engineered impoundments that are created from embankments or dams across valleys in areas of hilly or mountainous terrain.

- At least 3,500 mine tailing dams/impoundments exist world-wide (Vogt 2013). These exist but are not without environmental and public safety issues. Issues include (1) the size of the footprint and loss of habitat and land used for such activities as agriculture, (2) potential contamination to surface waters and groundwater, (3) aesthetics, and (4) short and long term safety and integrity of the engineered facilities.
- There have been 138 significant recorded failures of mine tailing storage dams since the first storage dam was created, continuing in current times with great loss of life and property (Vogt 2013).

Riverine disposal is a very simple concept: pipe the mine tailings to the river and discharge. This technique has been practiced throughout mining history. Because of the catastrophic environmental consequences experienced by the discharge of mine tailings to rivers, riverine disposal is no longer practiced, except at four mines in Indonesia and Papua New Guinea.

Marine disposal of mine tailings is disposal into marine waters via a pipeline. Marine disposal is no longer practiced along shorelines in shallow water. Today's marine disposal discharges are in deep water at final deposition in depths of 30 meters to 300 meters in Norway and over 1,000 meters in Turkey, Indonesia, and Papua New Guinea. The intent is to discharge the mine tailings in deep stratified waters below the pycnocline (and the euphotic zone), such that the mine tailings flow as a dense coherent slurry to a deposition site on the bottom, essentially trapped below the relatively more biologically productive, oxygenated zone (i.e., not mixing with the surface layer).

After release into marine waters from the pipeline, plumes of finer material including tailings process water and suspended sediment can form at various depths. The intention is for these plumes to remain in the deep waters because of the stratification of the marine waters.

The understanding is that the mine tailings will smother everything in the intended footprint on the sea bottom, destroying habitat, and impacting species abundance and diversity. In some cases, result in increased risks of bioaccumulation of heavy metals in aquatic organisms with potential human health risks from fish consumption. The intent is to limit these impacts to the intended footprint.

What is the Rationale for Marine or Riverine Disposal of Mine Tailings?

The rationale for choosing marine disposal or riverine disposal is based upon economics and technical feasibility factors (e.g., mountainous terrain, earthquake prone, extreme rainfall) and will differ depending upon mine location (e.g., topography), distance to potential disposal/storage areas, properties of the mine tailings, and economics.

One of the key issues in assessment of disposal alternatives is the need after mine closure to ensure that a long-term maintenance plan for on-land tailings storage facilities can be sustained in perpetuity.

What are the Environmental Impacts of Marine and Riverine Disposal of Mine Tailings?

Potentially harmful constituents in mine tailings include:

- Heavy metals
- Cyanide and chemical processing agents
- Sulfide compounds
- Suspended and settleable solids

The potential impacts of marine disposal are widely discussed in the literature. The potential impacts of copper and gold mining are shown in the text box (Shimmield 2010; Apte & Kwong 2004).

Potential Environmental Impacts of Marine Disposal of Mine Tailings:

1. Smothering benthic organisms and physical alteration of bottom habitat
2. Reduction in species composition/abundance and biodiversity of marine communities
3. Direct toxicity of trace metals mobilized from mine tailings
4. Bioaccumulation of metals through food webs and ultimately into human fish-consuming communities, and corresponding increases in risk to human health

Mine tailings are distinctive among other industrial wastes. The quantities are enormous. Mine tailings are not normally treated prior to discharge, except for some mines that reduce the levels of cyanide before discharge and some that add coagulants or flocculants before discharge (Skei 2009).

Mine tailings often contain sulfide compounds which can generate sulfuric acid when exposed to air and water. Therefore, mine tailings must be placed under water to avoid exposure to air. This objective is achieved by marine disposal, while at the same time accepting that the non-mobile marine life in the disposal site will be smothered by the mine tailings.

- Known effects are the loss of healthy habitat in the disposal site for in-situ benthic organisms and those in the ecosystem that depend on them as a food source, the potential for direct toxicity and bioaccumulation of heavy metals in local marine life, and changes in species composition and abundance, as noted earlier.
- What is not well known is the extent of these effects outside of the intended deposition site, given the possible shearing off of plumes of turbid materials from the discharged slurry of mine tailings as they settle to the sea bottom, events of up-welling that can bring discharged mine tailings into the upper surface waters impacting shallow water marine life, and currents that may move the mine tailings out of their intended deposition zone.

Monitoring programmes to assess the environmental effects of the marine discharges are being conducted at each of the mines, as required by their government-issued discharge permits. Information that is available shows that each of the mine discharges is meeting their permit conditions, which is a direct function of the stringency of the permit requirements.

The overall impact of riverine disposal on biological resources is not difficult to predict at mines currently discharging mine tailings into rivers. Increased sediment loads and smothering of river bottoms and riverbanks causes the loss of benthic organisms, loss of flora, and changes to the abundance and diversity of aquatic species of fish. Bioaccumulation is also possible with potential direct impacts on fish as well as posing risks to human health. Terrestrial species can also be impacted as riverbank food is no longer available; in dieback areas, flora is eradicated as well as fauna that cannot move to new areas. Tailings can also be transported to coastal waters.

Recovery of damaged and contaminated marine and riverine environments upon closure of the mine and ceasing of mine tailings disposal is an issue. The question is really one of how long (i.e., years, decades, centuries) and what is considered to be recovery of the marine living resources that is equivalent to the time prior to mine waste disposal.

- Studies indicate that recolonization will occur but not necessarily with the same species that were originally present at the sites. *Recolonization is not the same as recovery.* 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. Species that colonize mine tailings on the sea bottom will vary depending upon the physical, chemical, and toxicological characteristics of the mine tailings which are certainly different than in-situ conditions prior to disposal (IIED 2002) (Jensen 2009).
- Sites with higher natural sedimentation are likely to naturally bury the mine tailings more rapidly.

No specific regulatory and assessment guidance for marine disposal of mine tailings is yet available from a country or from an internationally recognized regulatory or scientific body. The London Protocol's Waste Assessment Procedures are applicable. However, development of specific London Protocol guidelines for mine tailings would help government agencies make appropriate choices among disposal choices. See text box.

London Protocol Waste Assessment Guidance

- Characterize waste
- Consider waste prevention and waste management options
 - Consider opportunities to re-use, recycle or treat the waste
 - Consider alternatives to ocean dumping
- Action List
- Select and characterize a dump-site
- Assess potential impacts
- Issue permit with appropriate conditions
- Monitoring (compliance and field)

Summary: What are the Findings and Conclusions?

Mining and mine tailings disposal are not environmentally friendly activities. However, mining is essential for people to live, work, and play. Disposal of mine tailings is often a choice between environmentally unattractive alternatives.

Stating that environmental damage results from marine and riverine disposal of mine tailings is indisputable. The question is: is the size of the footprint acceptable and do the impacts reach beyond the intended footprint? Are there currents that move plumes of the material to adjacent marine habitats? Does periodic upwelling bring the contaminants to the shallow water fisheries and habitats?

A comprehensive understanding of the risks to the ecological resources of the environment and the real potential for impacts to human health is needed prior to making choices among disposal alternatives, including use of tailings dams. Assessments should include sufficient information from studies, site-specific research, and monitoring programs to support environmental risk assessment and evaluation of alternatives.

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