International Assessment of Marine and Riverine Disposal of Mine Tailings

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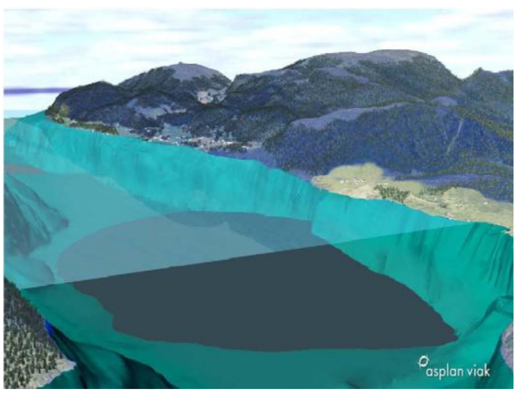

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Front Cover Photos

Upper left: Grasberg mine in Indonesia. The mined out Ertsberg pit, filled with copper-impregnated acid rock drainage is dwarfed by comparison with the Grasberg mine above it. Source: WALHI 2006

Upper right: Lihir mine dump site and tailings discharge location in Papua New Guinea. Source: McKinnon 2002

Bottom left: Engebro mine tailings discharge concept in Norway fjord. Source: Gunnar Skotte 2011

Bottom right: Grasberg mine and Mine Tailings in the Ajkwa River Deposition Area. Source: WALHI 2006

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Preface

This report presents 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, in collaboration with the United Nations Environment Programme (UNEP)-Global Programme of Action.

The Convention on the Prevention of Marine Pollution by Dumping of Waste and Other Matter, *1972 (London Convention)* and its update and more modern version, the *1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Waste and Other Matter*, *1972* (London Protocol) are the primary international instruments to protect the world's oceans from pollution. The 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.

Figure 1 Meeting of the Parties at IMO Building in London. Courtesy IMO

Significant progress has been made since the London Convention was established in 1972, but disposal of wastes and other matter into the oceans continues to contribute to the degradation of the health of the marine environment in various regions of the world. Over the last several years, a number of reports have been provided to the Meetings of the Parties to the London Convention and the London Protocol regarding marine and riverine disposal of mine tailings around the world. Concern was expressed about the impact upon coastal and ocean waters, concluding with recommendations to learn more about the disposal of mine tailings into marine waters and into riverine waters.

The UNEP Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA) was adopted by the international community in 1995 and "aims at preventing the degradation of the marine environment from land-based activities by facilitating the realization of the duty of States to preserve and protect the marine environment." It is unique in that it is the only global initiative directly addressing the connectivity between terrestrial, freshwater, coastal and marine ecosystems. The GPA targets major threats to the health, productivity and biodiversity of the marine and coastal environment resulting from human activities on land and proposes an integrated, multi-sectoral approach based on commitment to action at local, national, regional and global levels.

The objective in commissioning this report is to provide a baseline of information about the mines that are discharging mine tailings into marine and riverine waters and the potential impact upon marine waters. The Parties to the London Convention and London Protocol will consider this information in their deliberations regarding policy and scientific/technical considerations, which may include the preparation of waste assessment guidance for mine tailings disposal into marine waters.

The author notes that this assessment is not intended to answer the question whether mine tailings should be disposed in marine or riverine waters. That question is well beyond the scope of this assessment and best left to government permitting authorities. There is a huge amount of information available on the topic of marine and riverine disposal of mine tailings, and a great deal of controversy about the technical and scientific aspects, the social aspects, and the policies for economic development and environmental protection in the countries where these disposal practices are occurring.

- This author has not attempted to distill all of the information from the mining companies, from government reports, or from environmental and public interest groups as the information is too voluminous and is not always consistent in its conclusions between the sources.
- The author has attempted to identify marine and riverine dischargers and summarize their disposal practices and potential environmental impacts, as reported in the available information, which, as noted above, is sometimes conflicting.
- An assessment of environmental impacts of disposal of mine tailings for each mine is well beyond the scope of this report; most studies and research have been undertaken or sponsored by the mining companies without the benefit of additional studies sponsored by other interest groups. This author does not question the professionalism of those studies, merely an observation, and notes that many of those studies appear to be first class in design and intensity. There have been several independent studies conducted that provided excellent information.
- For some mines that use marine and riverine disposal for mine tailings, a paucity of information was available which is reflected in the case studies.

The author recognizes the kind guidance of the IMO's London Convention/London Protocol Secretariat, Mr. Edward Kleverlaan, and the support by the UNEP-GPA for their interest in mine tailing disposal methods and possible impacts to the marine and riverine environments. In addition, it is important to recognize Canada and the United Kingdom as the primary funders of this effort, acknowledging their foresight in addressing these issues.

This study found that marine and riverine discharges of mine tailings were from a limited number of mines and a limited type of mining operations:

- Metals, such as copper, gold, and silver;
- Iron
- Rutile (TiO2)
- Graphite
- Pigments

Other types of mining do not discharge mine tailings to marine or riverine waters, such as coal mines, uranium mines, or diamond mines.

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Executive Summary

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 metal (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 followed by chemical extraction and flotation methods. Mine tailings are known to contain heavy metals, chemical reagents used in the separation process (e.g., cyanide from gold processing), and sulfide-bearing materials.

There are about 2,500 industrial-sized mines operating around the world. Except for a very few, these mines dispose of their mine tailings on-land, usually under water in impoundments or behind dams. In a very few countries, mines are allowed to dispose of mine tailings into rivers and into marine waters.

This report was commissioned by the London Convention and London Protocol, in cooperation with the United Nations Environment Programme-Global Program of Action (UNEP-GPA), to assemble what is known about the discharge of mine tailings to marine and riverine waters that may result in adverse impacts to marine waters. Concern has been expressed by Parties to the Conventions and by UNEP-GPA regarding the adverse impacts upon marine waters from marine and riverine disposal of mine tailings. The emphasis of the two conventions is control of wastes and other matter that is dumped from vessels into marine waters; the overall objective of the London Convention and the London Protocol is to protect and preserve the marine environment from all sources of pollution. The objectives of UNEP Global Programme of Action are for the protection of the marine environment from land-based activities.

What is Mining?

Mining is the process of extracting minerals from the earth's crust. For mining considered in this report, mining is accomplished by either open-pit surface mines or underground mines. Whether surface mines or underground mines are used depends on a number of on-site factors; surface mines can extend to about 200 meters deep at which point underground mines become the more efficient mechanism for removal of the ore. Two types of wastes are generated from mining, overburden/waste rock and mine tailings.

- 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 of concentrations to be economically separated from the rock. Overburden and waste rock are disposed on-land at 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 riverine disposal, although not directly in that the waste is stored on land in areas subject to serious erosion.

- Mine tailings contain the fine grained materials from the ore and the residues of chemical reagents used in the separation process, all part of a slurry. Mine tailings contain some of the metal bearing minerals, such as copper, because the separation process does not recover all of the minerals. The share of ore that becomes waste is about 60% for iron, 99% for copper, and 99.99% for gold.

What Potentially Harmful Contaminants are in Mine Tailings?

Constituents of concern in mine tailings include:

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

What Disposal Techniques are used for Mine Tailings?

Of the approximately 2,500 industrial-sized mines world-wide, 99.3% dispose of their mine tailings on-land placing the mine tailings under water in impoundments or behind dams, or backfilling into closed sections of open-pit or underground mines (dry stacking of dewatered mine tailings is also practiced in a few places). Mine tailing storage facilities are engineered impoundments that are created from embankments or dams across valleys in areas of hilly or mountainous terrain.

- The fundamental objective of mine tailings storage facilities is to provide safe, stable, and economical storage of tailings presenting negligible public health and safety risks and acceptably low social and environmental impacts during operation and post closure.
- At least 3,500 mine tailing dams/impoundments exist world-wide. 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 and continuing in current times. Recent examples include the failure of the embankment in Hungary in 2010 releasing 600-700 thousand cubic meters of red mud and water causing huge devastation and 10 deaths. 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. In 1985, 268 people died from the failure of a mine tailings storage dam in Stava, Italy.
- There is a very significant support industry to make certain that mine tailings storage facilities are built and operated in a safe manner, and to ensure that they are safe in perpetuity following

mine closure. Best available designs, operating principles and factors, websites, engineering consulting firms, and non-government organizations, such as the International Commission on Large Dams, provide the basis for ensuring safe short- and long-term facilities.

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. The locations:

- Norway: 5 marine dischargers (3 additional in permit application review process—no decisions made)
- 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

The reader is referred to Appendix 3 for a description (i.e., a case study) of each mine, its use of marine or riverine disposal, and what is known about the environmental impacts of its discharge.

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 (also termed submarine tailings disposal or deep sea tailings placement) is disposal of mine tailings 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 pynocline (and the eutrophic zone) such that the mine tailings flow as a dense coherent slurry to a deposition site on the bottom, essentially trapped below the 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 and intention is that the mine tailings will smother everything in the intended footprint on the sea bottom, destroying habitat, impacting species abundance and diversity, and resulting in increased risks of bioaccumulation of heavy metals in aquatic organisms with potential human health risks from fish consumption.

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 and will differ depending upon mine location (e.g., topography), distance to potential disposal/storage areas, properties of the mine tailings, and economics.

In Indonesia and Papua New Guinea, it is argued that:

- Creation of a mine tailings storage facility in the mountainous terrain is not technically feasible because they are located in very active earthquake prone areas which could create a safety hazard to downstream communities; long term maintenance is an issue especially after mine closure;
- The rainfall is up to 3 meters per year making water management in tailings storage facilities extremely difficult, and
- The terrain is unstable for construction of safe mine tailing storage dams.

In Norway, the argument is that suitable land for disposal of mine tailings near the fjords is not available.

One of the key issues, as noted above, in assessment of disposal alternatives, is the perceived risk after mine closure to ensure that a long-term maintenance plan for on-land tailings storage facilities can be sustained in perpetuity. This is particularly an issue in Indonesia and Papua New Guinea, given the challenging conditions of high rainfall and earthquake events, topography, and valley wall instability; combined with social demands on the customary lands, it is argued that these conditions often preclude tailings storage facility development.

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

The potential impacts of marine disposal are widely discussed in the literature. The potential impacts are shown in the text box.

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 somewhat unique compared to 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. For example, under the London Convention and London Protocol, dredged material can be disposed in marine waters, and it is expected that the dredged material will smother existing habitat and benthic organisms similar to depositing mine tailings on the sea floor. The distinct difference is that dredged material cannot be disposed in marine waters without passing stringent toxicity testing including limits on heavy metals and toxic organic compounds. Thus, direct toxicity and bioaccumulation is not an issue for dredged material. In addition, after the disposal ceases, a healthy community similar to pre-disposal is expected to rapidly re-colonize the dredged materials, whereas mine tailings will be re-colonized but not by the same flora and fauna that existed prior to placement, with serious implications for long term issues of abundance and diversity of marine life.

Mine tailings usually contain sulfide compounds which can generate sulfuric acid when exposed to air and water, and 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 marine tailings.

- Known effects are the complete 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 real potential for direct toxicity and bioaccumulation of heavy metals in local marine life, and changes in species composition and abundance.
- 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. In certain cases, monitoring programs are extensive, including efforts such as water and sediment quality and bioaccumulation studies in fish tissues. To state the obvious, compliance with permit conditions and protection of the marine and riverine environments is a direct function of the stringency of the permit requirements. Information that is available shows that each of the mine discharges is meeting their permit conditions; it appears that each of the mines provides an annual report of monitoring data to the permit issuance authority; access and evaluation of that data are beyond the scope of this assessment. In a number of cases, it seemed like the only information publically available was a comparison to the conditions specified in the original environmental impact assessment (e.g., "the monitoring data are consistent with what was predicted in the environmental impact assessment"), which is generally not particularly helpful in evaluation of specific on-site impacts.

Major studies have been conducted at several mines, some by independent outside scientific institutions. These studies are noted in the case studies; for example:

- At the Lihir mine in Papua New Guinea, an independent oceanographic assessment showed that the extent of the mine tailings footprint was 60 square kilometers. By comparing reference sample locations to the east and to the west of the footprint, the study found that the larger sediment-dwelling animals (macrofauna) were very sparse at all of the impacted sampling stations but much more abundant and diverse at the reference stations. The study reached the conclusion that the discharge of mine tailings had major impacts on the abundance and diversity of animals in the area of the mine tailings footprint, extending to depths of 2,020 meters.

- At the Ramu Nickel mine in Papua New Guinea which has just initiated operations in 2012, the potential environmental impact of mine tailings disposal in marine waters was subject to an extensive court case. In April 2012, the court made the following findings:
    - *it was likely that the tailings would smother benthic organisms over a wide area of the ocean floor (at least 150 km^2), which would inevitably alter the ecology of that part of the ocean;*
    - *it was very likely that the tailings would be toxic to marine organisms; and*
    - *there was a real danger that the tailings would not settle on the ocean floor but be subject to significant upwelling, which meant that substantial quantities of tailings would be transported towards the PNG mainland.*

  The court did not grant the injunction to stop the marine discharge as it weighed a number of factors in that decision. A major oceanographic study of the proposed site of deposition for the mine tailings on the seafloor was conducted in the mid to late 2000s. That study established a quantitative baseline for assessment of the effects of the Ramu Nickel disposal of mine tailings.

- For the mine at Batu Hajiu, Indonesia, the government of Indonesia approved deep sea tailings placement in 1996 based upon an environmental impact assessment study completed in 1996. The permit was issued in 2003, and reissued in 2005, 2007, and 2011. The permit allows 140,000 tons per day of mine tailings to be disposed by pipeline into Senunu Bay.

  Marine water quality standards are being achieved as specified in the permit. The water quality standards do not apply in the depositional zone. The mine tailings are not causing a turbidity plume that reaches the surface and the mine tailings flow down the steep walls of the Senunu Canyon to greater than 3,000 meters depth. The tailings are confined to that canyon and have not been identified in other nearby areas. Supported by a survey by the Fishery Agency of West Sumbawa in 2011, it was informally reported by an Indonesian environmental interest group that fishery folk living nearby Sununu Bay were experiencing decreasing fish catchments since the initiation of marine disposal of mine tailings and that species such as squid, which were abundant before mine tailings disposal, were now nearly extinct.

  Reissuance of the permit in 2011 was the subject of court litigation. On 3 April 2012, the State Administrative Court affirmed that the permit had been properly issued. The findings were corroborated during the trial by a number of experts from reputable universities and factual witnesses from the communities living around Batu Hijau's copper and gold mine. During testimonies under oath, these witnesses affirmed that Batu Hijau's submarine tailing placement system has operated as designed and has not negatively impacted fisheries in West Sumbawa.

The Deputy Minister of Environment testified that the issuance of the permit is based on comprehensive environmental and social review of assessments prepared before the operation commenced 10 years ago as well as further environmental studies carried out during the mining operation. It was stated that the submarine tailings placement appears to be the best method and the most appropriate for tailings produced from the Batu Hijau operation.

- At the Cayeli Bakir Copper-Zinc mine in Turkey, mine tailings are discharged though a 350 meter long outfall at a depth of 275 meters into the anoxic zone. The Black Sea had been subjected to many years of oceanographic and marine biological assessments, which served as the basis for the design of the outfall pipe and the discharge location. The discharge into the Black Sea takes advantage of the natural anoxic conditions below about 150 meters depth with hydrogen sulfide concentrations greater than 3 mg/l. The depths are thus devoid of marine life other than sulfide metabolizing bacteria, and the hydrogen sulfide serves to precipitate heavy metals in the mine tailings. A government institute in Turkey monitors water quality in the area surrounding the submarine tailings outfall; up to 2010, 65 surveys have been completed and indicate no change in water quality. Studies have shown that upwelling is not occurring to any extent such that the plume of the mine tailings reaches surface waters.

- In a review of the effects of mine tailings on the ecosystem and biodiversity in Norway's fjords, the conclusion was that the biodiversity of the fjord is changed. The authors from the Institute of Marine Research in Bergen, Norway, stated that:
    - *The ecosystem is disrupted in significant parts of a fjord and possibly poisoned.*
    - *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, such as tusk, flatfish, rays, cod, haddock, lose their habitat.*
    - *Crustaceans, e.g, prawns, crabs, and king crab, on and close to the bottom loose habitat, or it becomes strongly modified, possibly also poisoned depending upon the chemicals used in the ore separation process.*

- Another example is the closed Island Copper Mine on Vancouver Island in Canada, which was allowed to discharge mine tailings into the marine waters of Rupert Inlet until the 1980s. In its two decades of operation, a total of 400 million tonnes of mine tailings were deposited at 50 meters depth, expecting the tailings to flow as a density current into the deep sea placement zone.

  Physical impacts associated with the deposition of the tailings solids were predicted to be a temporary effect of limited impact followed by rapid recolonization. This prediction was subsequently initially confirmed by benthic studies conducted in the years following the suspension of the operations. Annual biodiversity surveys of deposited tailings demonstrated that they can be re-colonized rapidly, within several years of the deposits stabilizing.

  However, in May 1996, the Canadian Department of the Environment released a report that examined decades of environmental monitoring data at the Island Copper mine site and concluded that the sea floor showed widespread and permanent alteration by tailings. In view of this, the Canadian site specific regulations were repealed when the *Metal Mining Effluent Regulations* were promulgated in 2002, the effects of which were to ban marine disposal of mine tailings.

The overall impact of riverine disposal on biological resources is not difficult to predict. 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, impacting sensitive ecosystems in estuaries and in ocean waters, such as coral reefs. Similar to river waters, sedimentation in estuaries causes smothering and loss of habitat, reduced water quality and reductions in abundance and diversity of fish populations. Elevated levels of metals, such as copper, lead, and arsenic can cause direct acute and chronic toxicity and bioaccumulation in fish tissues may pose risks to human health.

In the Ajkwa River downstream of the Grasberg mine, 130 square kilometers of new flood plain had been created by 2002 and it is expected to increase to 220 square kilometers before the targeted time for mine closure. This resulted in dieback and a long term problem of acid rock drainage. In 2002, the mine at Ok Tedi was reported to have caused dieback from riverine disposal of mine tailings impacting approximately 480 square kilometers of rainforest along the Ok Tedi.

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. 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.
- Sites with higher natural sedimentation are likely to naturally bury the mine tailings more rapidly. For example, scientific studies in Norway showed that re-colonization began immediately as disposal of mine tailings ceased. In Jossinfjord, recolonization took place in 5-10 years whereas in Franfjorden, a biological community was established in one year. Average sedimentation rates in the ocean are very low in the deep ocean, and depending upon the location of the disposal site, it may take tens to hundreds of years before the footprint of the disposal site is capped by an appreciable layer of natural sediment. Sedimentation rates in

places such as the fjords of Norway are likely to be higher than ocean sites in Indonesia and Papua New Guinea.

What are Best Management Practices?

Much has been written about how best to manage mine tailings and promotion of sustainable mining. Mining is not an environmentally friendly operation, but mining is absolutely critical to supply needed metals and minerals for living, and thus, many mining companies, federal and local governments, and environmental interest groups have prepared codes/principles/best practices on best environmental practices (BMP). These BMPs suggest the best and feasible approaches and factors to consider for:

1. Marine disposal of mine tailings,
2. Considerations for selection of disposal sites for marine disposal,
3. Management of mine tailings in on-site in tailings dams, and
4. Sustainable mining, considering the entire mining operation from exploration to mine closure and rehabilitation.

Note: there are no BMPs for riverine disposal, given that riverine disposal is not compatible with concepts of best environmental management.

What Government Controls are in Place to Manage Marine and Riverine Disposal?

In every case of marine or riverine disposal of mine tailings, government authorities have been involved in evaluation of the alternatives and in reaching decisions regarding disposal and issuing permits to discharge. Each country has environmental legislation, regulations, and permit processes which vary from country to country, such that government involvement and evaluation means different decision-making processes with different levels of evidence considered in issuing permits. This report provides a brief summary of legislation and regulations for each country as well as for several countries that do not allow marine or riverine disposal of mine tailings.

Summary: What are the Findings and Conclusions?

Mining is not an environmentally friendly activity. However, mining is essential for people to live, work, and play. Management and disposal of mine tailings is the biggest environmental challenge for mining operations. Disposal of mine tailings is often a choice between environmentally damaging alternatives. On-land disposal alternatives are used by 99.3% of industrial-sized mines.

For those few mines that have selected marine or riverine disposal of mine tailings, it is an economic choice but in certain cases also one of technical feasibility. The feasibility factors include such arguments as topography, high seismic activity, and the inability to build structurally sound dams due to instability of local geology and high rainfall, thereby unable to ensure public safety of communities downstream of tailings storage facilities in perpetuity, after mines are closed.

Stating that environmental damage results from marine and riverine disposal of mine tailings is indisputable.

- Riverine disposal overwhelms natural sedimentation systems and results in raising the levels of riverbeds, expanding floodplains and associated dieback, and exposes ecological and human populations to heavy metals in river water and to the fishery. Riverine disposal also results in significant long term issues of acid rock drainage from the sulfur compounds in the mine tailings along the river banks, in the flood plain, and in estuarine waters where deltas have formed.

- Marine disposal smothers everything in its footprint, with associated loss of habitat and benthic life in that footprint. This reduces the species composition/abundance and biodiversity. In addition, risks to humans can be increased from bioaccumulation of metals through food webs and ultimately to fish-consuming communities. 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?

After mining ceases, recolonization of mine tailings deposits on the ocean floor is known to happen in relatively short times, such as one to ten years, depending upon local conditions. However, studies are showing *that recolonization is not the same as recovery*, because the benthic species that re-colonize mine tailings are different than the original species, which can shift marine species community structures. The question is one of time, as sedimentation rates vary among discharge locations, such that it may take tens to hundreds of years before an appreciable layer of natural sediment covers the mine tailings, which would then lead to actual recovery of the ecosystem.

In every case of marine or riverine disposal, governments have issued permits to the mining operations after considering the alternatives through an environmental impact assessment (or an equivalent). These permit decisions, and the permit renewals have not been without controversy, as interest groups, such as local landowners, downstream communities, fisherfolks, and environmental interest groups, have argued against marine and riverine disposal. A number of companies have declared that riverine disposal is not consistent with their company policies on environmentally sustainable mining.

The decisions by the government authorities have been based upon a weighing of economic, technical, environmental, and social policy considerations. This report makes no judgment regarding those decisions. What is clear from the overall consideration of discharges of mine tailings in this report, however, is that a comprehensive understanding of the risks to the ecological resources of the marine and riverine environments and the real potential for impacts to human health is needed prior to making choices among disposal alternatives. New applications proposing to use marine or riverine disposal, as well as renewal of existing permits, should include sufficient information from studies, site-specific research, and monitoring programmes to support comprehensive environmental risk assessment and evaluation of alternatives prior to government permit decisions. In some cases after weighing all of the factors in the decision-making process, it might be determined that a mine in that particular location is inappropriate.

Introduction

Background

Mining is essential to support life on earth as we know it. Mining is a huge industry with over 2,500 industrial-sized mines around the world, and thousands more, smaller mining operations. The biggest environmental challenge of mining operations is the safe and environmentally sound disposal of mine tailings. Mine tailings are what is left after the target metal (e.g., copper) is removed from the ore. Mine tailings contain heavy metals, mill processing chemicals and reagents, and commonly include sulfide bearing materials. Potential environmental issues include:

(1) toxic impacts of heavy metals,
(2) generation of acid rock drainage (i.e., sulfuric acid), and
(3) habitat destruction.

In the vast majority of operating mines around the world, on-land disposal of mine tailings is conducted using impoundments or dams to store mine tailings under water to avoid generation of sulfuric acid and control the potential impacts of exposure to heavy metals. However, a number of major mining operations are known to dispose of their mine tailings into marine waters or into rivers. These disposal mechanisms have become increasingly the disposal alternative of choice for certain areas of the world since the early 1990s. With the extensive amount of exploration for minerals and new mines being considered, more mines may choose to place mine tailings in marine or riverine waters in the future.

The objective of this report is to provide an inventory of those mining operations that use marine or riverine disposal, and to provide an assessment of the potential or actual environmental impacts of those disposal practices. The inventory and assessment are intended to be used by the Parties to the London Convention and the London Protocol (see Box 1) as a basis for policy decisions on needed actions, including international guidelines, to address the potential or actual damage to marine waters resulting from these disposal practices.

Box 1 Objectives of the London Convention and the London Protocol

Parties to the London Convention/Protocol are to take effective measures, according to their scientific, technical, and economic capabilities, to prevent, reduce and where practicable eliminate marine pollution caused by dumping of wastes into the sea.

While discharge of mine tailings to marine waters via pipeline or to rivers via pipeline is not considered dumping, *the overall objective of the London Convention/Protocol is to protect and preserve the marine environment from all sources of pollution.* (London Protocol 2003)

This report first addresses the basics of mining to provide a fundamental understanding of the mining process, the reasons for mining, and the generation of wastes, including the overburden and waste rock from open pit and underground mines and the mine tailings from the ore milling and separation processes. Next, the practices of marine and riverine disposal are described, followed by a brief discussion of the rationale for allowing these discharges. The assessment of the environmental impacts is then presented. This discussion is then followed by a discussion of best management practices for (1) mines that conduct marine disposal (see box 2) and (2) mines that use on-land disposal techniques for mine tailings. Finally, examples of environmental legislation, regulations, and guidance for disposal of mine tailings are provided both for countries that allow and that do not allow marine and riverine disposal.

In the Appendices, detailed case studies are provided for each mine that is currently disposing of mine tailings via marine or riverine disposal. The reader is cautioned not to skip the reading of the case studies as important lessons are provided in the case studies.

In every case of marine or riverine disposal around the world, the dischargers have received government issued permits (or an equivalent) to discharge with specific conditions to meet water quality standards as well as monitoring requirements. Federal and local governments are involved in overseeing the mines that discharge mine tailings into marine or riverine waters.

<ins>Box 2 What's the difference?</ins>
<ins>Marine discharge vs submarine tailings disposal (STD) vs deep sea tailings placement (DSTP)</ins>

In the context of this report, these terms mean the same thing---disposal of mine tailings in the sea. The practice of disposal of mine tailings along the shoreline in shallow waters is no longer practiced. Discharges in marine waters are intended to be placed into deep waters below the mixing zone. Some say the discharge should be below the eutrophic zone, some say thermocline, some say pynocline, but they are all intending to deposit mine tailings in deep water where it is not in the biologically productive zone and does not mix with the upper surface waters.

The notion of deep water is different in Norway from other marine dischargers in Turkey, Indonesia, and PNG. Norway's fjords can be at 30 to 300 meters in depth whereas placement in Turkey, Indonesia, and PNG is intended for the mine tailings to reach the bottom at 1,000 to 4,000 meters depth.

The term deep sea tailings placement has been in use since the 1990s as a more descriptive phrase.

The conclusions reached in this report are not in black and white. Marine or riverine disposal of mine tailings cause major damage to ecosystems and pose serious risks to human health. Inappropriate on-land disposal (e.g., failure of a mine tailings storage facility) is known to cause great losses of human life as well as major damage to aquatic and terrestrial ecosystems. Well conceived scientifically and managed disposal mechanisms on-land or in the sea can minimize the extent of those adverse impacts; site-specific considerations, including comprehensive environmental impact assessments and risk assessments of disposal alternatives, are essential prior to determining an appropriate disposal alternative.

What Mines are Discharging Mine Tailings into Marine or Riverine Waters?

World-wide, a total of 18 mines in 2012 are conducting marine or riverine disposal of mine tailings (i.e., 99.4% are using on-land disposal), 4 using riverine disposal and 14 disposing of mine tailings in marine waters.

The locations are shown in Figures 2 and 3 for mines in Norway and Papua New Guinea/Indonesia, respectively. In summary:

- Norway: 5 marine dischargers (plus 3 applications for marine disposal are in the permit 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

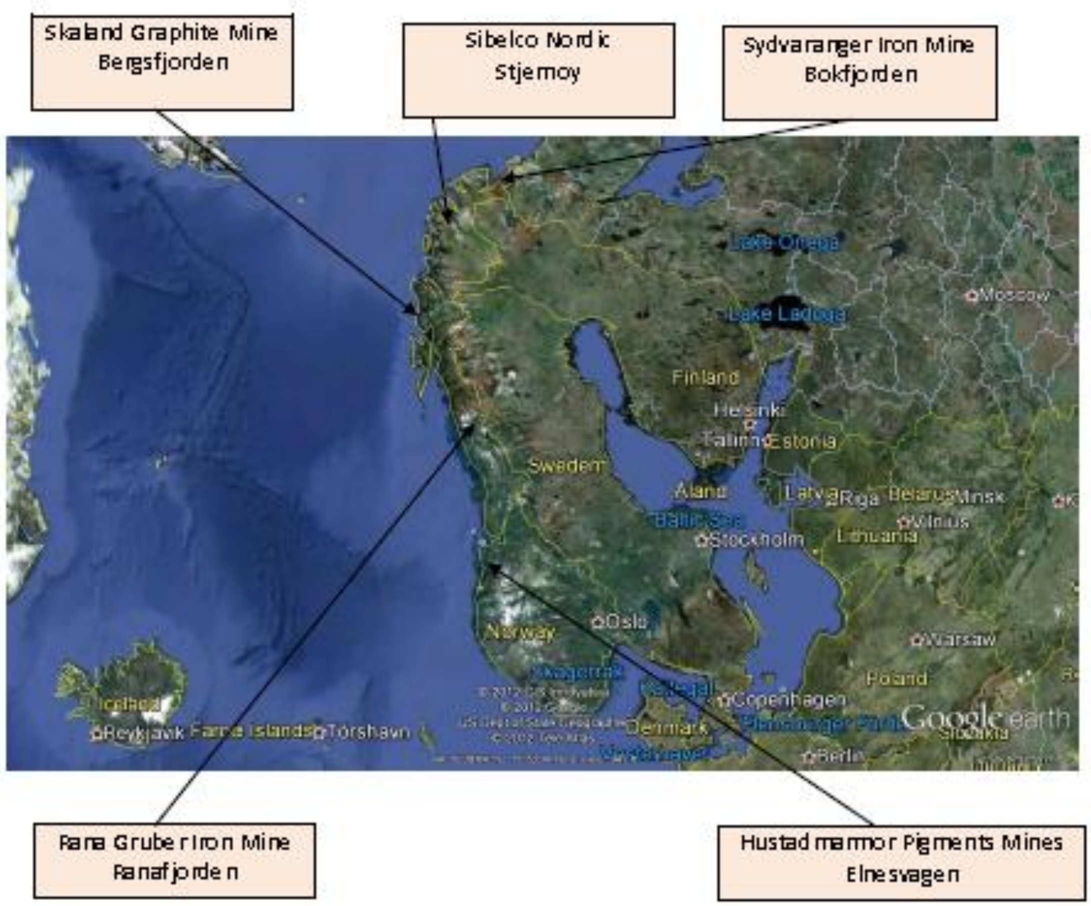


Figure 2 Marine Disposal of Mine Tailings in Norway

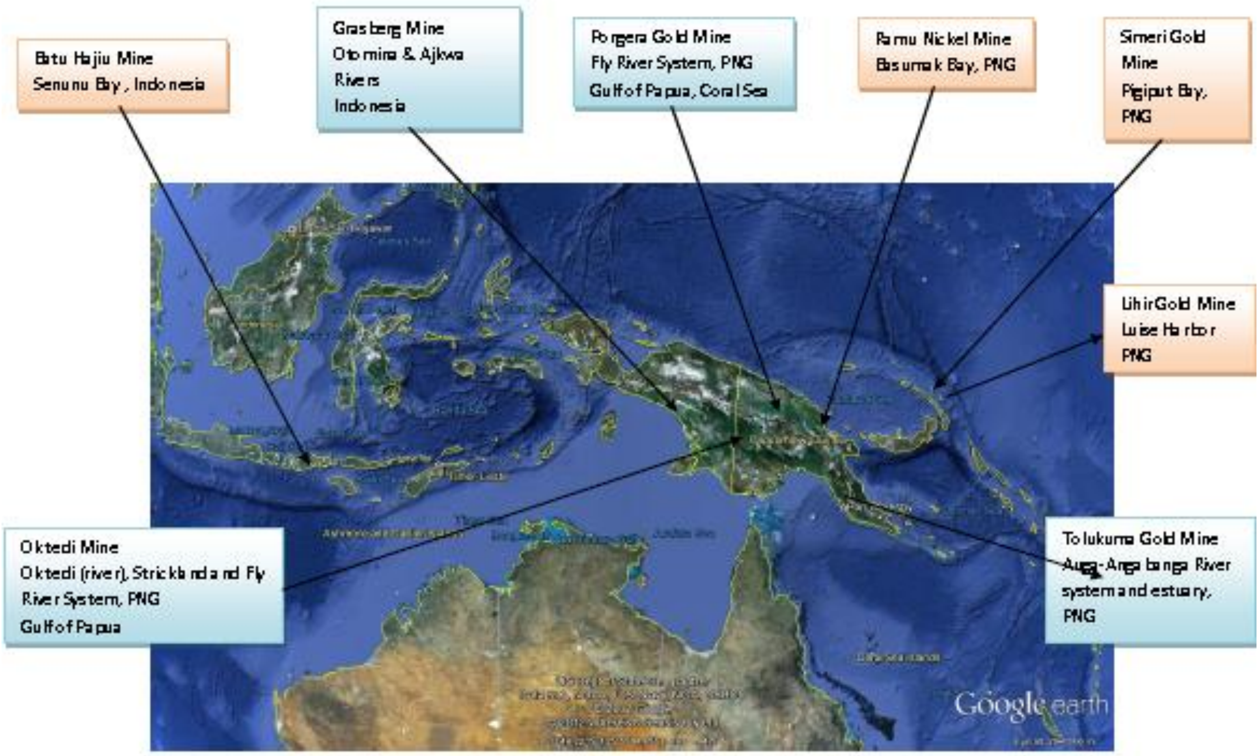


Figure 3 Marine and Riverine Disposal of Mine Tailings in Indonesia and Papua New Guinea

Table 1 presents an array of locations showing the depths of waters where mine tailings are intended to deposit after discharge. In this table, the term storage is used instead of disposal. These depths are provided for comparison only, as marine disposal is not occurring in many of these locations, but have in the past. Table 2 summarizes mines that are discharging mine tailings into marine or riverine waters.

Table 1 Storage Depths and Current Regimes

Note: these depths are provided for comparison only, as marine disposal is not occurring in many of these locations, but have in the past. Source: Greisman 2009

Location	~ Storage Depth in meters	Currents
PNG atoll	>1000 m	Basin wide
BC fjord (Canada)	40 -100 m	Local tidal
Chilean coast	35 - 50 m	Basin wide, wave transport
Turkish Black Sea	2000 m	Slow, deep
Indonesian Bay	80 m	Locally wind-driven
Indonesian subsea canyon	> 3000 m	Weak?
Greenlandic fjord	200 m	Wind driven, ocean intrusions
Norwegian fjord	30 -300 m	Estuarine

Table 2 Marine and Riverine Discharges of Mine Tailings 2013				
Location	*Type of Mine*	*Mine Tailings tonnes per year*	*Depth of Deposition in meters*	*Company*
Indonesia				
Grasberg	Gold/copper	87,000,000	river	Freeport McMoRan
Batu Hijau	Copper/gold	40,000,000	3,000-4,000	Newmont Mining
Ok Tedi	Copper/gold	90,000,000	river	PNGSDPC/PNG govt
Porgera	Gold	5,500,000	river	Barrick Gold
Tolukuma	Gold	200,000	river	Petromin Holdings
Lihir	Gold	4,000,000	>2,000	Newcrest
Lihir	Gold	40,000,000 waste rock	By barge 1 km offshore	Newcrest
Simberi	Gold	3,300,000	not available	Allied Gold
Ramu Nickel	Nickel/colbalt	5,000,000	1,500	Metallurgical Corp of China/Highlands Pacific
Turkey				
Cayeli Bakir	Copper/zinc/lead	11,000,000	>2,000	Inmet Mining
En gland				
Boulby	Potash	1,800,000	NA	Cleveland Potash
France				
Gardanne	Alumina/aluminum	NA-bauxite	330	Rio Tinto Alcan
Greece				
Agios Nikolaos	Aluminum	N-bauxite	800	Aluminum of Greece
Chile				
Husaco	Iron ore	1,200,000	35	CAP Minería
Norway				
Bokfjorden	Iron	4,000,000	220	Sydvaranger (Northern Iron Ltd)
Ranafjorden	Iron	2,000,000	80	Rana Gruber Minerals
Stjernoy	Nepheline syenite - pigments, glass making	~ 300,000	not availaable	Sibelco Nordic
Elnesvagen	Pigments	500,000		Hustadmarmor
Skaland	Graphite	20,000-40,000	30	Skaland Graphite ASA

The reader is referred to Appendix 3 for a description (i.e., a case study) of each mine, its use of marine or riverine disposal, and what is known about the environmental impacts of its discharge.
A number of mines are in various stages of development from feasibility stages to design to permitting. Several are considering marine disposal of mine tailings. While not considered to be a complete list, which was beyond the scope of this project, Table 3 provides a list mines that were identified during this study that are considering marine disposal.

Table 3 Proposed Mines that are Considering Marine Disposal of Mine Tailings[1]

Location	*Mine*	*Type of Mine*	*Other Information*
Greenland	Skaegaard Gold Project	Gold	Ore offsite for processing or on-site storage--leading options
Greenland	Saaqqa Fjord		
Greenland	Nalunaq		
Greenland projects near EIA level—no information on mine tailings disposal alternatives	Isua Kvanefjeld Fiskenaesset Citronen fjord Skaergarden Garnet Lake	Iron Rare earth element Ruby Zinc Platinum Diamond	
Norway	Nordic mine at Engebo	Rutile (titanium dioxide)	Fordefjorden—300 meters deep
Norway	Nussir at Kvalsund	Copper, gold, silver	Repparfjord—60-80 meters deep
Norway	Norsk Stein at Jelsa in Rogaland		
Papua New Guinea	Freida River	Gold, copper	Mine tailings storage facility likely
Papua New Guinea	Inwanuna	Gold	
Papua New Guinea	Mt Sinivit	Gold, silver	
Papua New Guinea	Woodlark Island Gold Project	Gold	

Many other mines have used marine and riverine disposal most of which are now closed; a few operating mines have changed to on-land storage of mine tailings. Table 4 provides a list of mines that used marine or riverine disposal that are now closed (except for the mine listed in Peru) (Table 4 is intended to be a sample list and thus should not be considered a comprehensive list of all mines that used marine or riverine disposal.).

[1] Sources: IIED 2002, Egersund 2009, Shimmield 2010, Halkbrekken 2012, Limu 2012

Table 4 Closed Mines that used Marine or Riverine Disposal[2]		
Location	*Name of Mine*	*Other Information*
Canada-British Columbia	Kitsault Molybdenum	Silled fjord
Canada-Vancouver Island	Island Copper	Sheltered fjord-Rupert Inlet
Canada-Vancouver Island	Jordan River Mine	Strait of Juan de Fuca
Canada-British Columbia	Wesfrob	Tasu Sound
Greenland	Black Angel	Shallow fjord—waste rock and tailings
Greenland	Ivittuut	Fjord—waste rock
Indonesia	Minahasa	Bayut Bay[3]
Norway	About 20 closed mines	Fjords
Papua New Guinea	Misima	Shallow depths in Solomon Sea
Papua New Guinea	Bougainville	River
Peru	Toquepola-Cuajone-still operating	Shallow coastal shelf; now operating on-land disposal facilities
Philippines	Marcopper	Shallow embayment—Cebu Island
Philippines	Atlas Copper	200 meters from shore, 10 meters depth

[2] IIED 2002, Egersund 2009, Shimmield 2010,

[3] An excellent case study of the extensive and serious environmental impacts of the marine discharge of mine tailings from the Newmont Minahasa Raya gold mine at 82 meters depth is provided in Edinger, E. 2012. Gold mining and submarine tailings disposal: Review and case study. *Oceanography* 25(2):184–199, http://dx.doi.org/10.5670/oceanog.2012.54.

II The Basics of Mining

In this section, a brief introduction to mining is provided including the fundamental mining process, the benefits of mining, facts about the mining industry such as locations and what is mined around the world, and the types of wastes generated by mining.

What is Mining?

Mining is simply the process of extraction of minerals from the earth's crust. A mineral is a naturally occurring inorganic substance with a definite and predictable chemical composition and physical properties. An ore is a mineral or combination of minerals from which a valuable constituent, such as gold or copper, can be profitably separated.

For mining considered in this report, mines are either surface mining (i.e., open pits) or underground mining.

- Surface (or open pit) mines remove the overburden of soil, rock, and vegetation to access the mineral deposit. Surface mines can extend to about 200 meters deep, at which point underground mining becomes the more efficient mechanism for removal of the ore. Whether surface mining or underground mining is appropriate for a particular site depends upon a number of factors, such as the stripping ratio (the ratio of overburden and waste rock to ore) which is based upon such considerations as ore grades, the geometric shape of the ore body, the topography, and the stability of the wall and bench heights.

  After removal of the overburden and waste rock, surface mining is usually conducted by blasting and then removal of the ore by trucks or placed onto conveyors for transportation to the processing plant.

- Underground mining is via vertical shafts or inclined roadways. Usually, there are two types of access routes: one for miners and materials and the other for the ore. Once at the correct depth, horizontal tunnels are constructed to reach the ore deposits. The ratio of waste rock to ore is much lower in underground mines.

While mining is commonly thought of as the extraction process itself, mining has four basic phases (Environment Canada 2009).

1. Exploration and feasibility. This phase identifies the location, characterizes the mineral deposits, and accesses the technical and economic feasibilities of mining.
2. Planning and construction. This phase includes land purchase, acquiring access rights, detailed mine planning, environmental impact assessments and permits, and construction of the mine and infrastructure.
3. Operations. This phase includes ore extraction, ore processing, disposal of waste rock/overburden and mine tailings, and, in some cases, initiation of reclamation.

4. Closure. This phase includes site cleanup and reclamation and long term environmental monitoring.

Why Mine?

Simply put, minerals are needed for living. For example,

- Mobile phones and accessories have many metal components, including silver, gold, palladium, platinum, cadmium, lead, nickel, mercury, manganese, lithium, zinc, arsenic, antimony, beryllium, and copper.
- Precious, rare earth and base metals - such as lead, mercury, indium, lithium, bismuth, ruthenium, platinum, cadmium, silver, palladium, rhodium, tantalum, nickel and gold - are essential to producing computers and laptops.
- Without boron, copper, gold and quartz, a digital alarm clock would not work.
- Silver's largest market use is for industrial applications, particularly as an electrical connector. Jewelry is the second largest use of silver.
- The Toyota Prius hybrid requires about 50 pounds of rare earth metals for its motor and drive train (Mine Engineer website).
- Gold is used in dentistry and medicine, in jewelry and arts, in medallions (e.g., Olympic medals) and coins, in ingots as a store of value, for scientific and in electronic instruments.
- Copper is used in building construction, electric cables and wires, switches, plumbing, heating, roofing; chemical and pharmaceutical machinery; alloys (brass, bronze and a new alloy with 3 percent beryllium that is particularly vibration resistant); and in paint coatings for bottoms of boats to resist barnacles and other marine growth (National Mining Association website).

The Mining Industry

There are a huge number of mines in the world (for example, it is estimated that there are over 8,000 small scale coal and metals mines in China, and South Africa has a total of 1,100 mines of which 400 are metals and coal mines and 30 diamond mines); if only the industrial scale operations are included, there are a total of about 2,500 metal producing mines in the world. Overall, approximately 2,000 coal, metals, and diamond mines produce about 90% of the world's total mined output (by value).

The total value of annual mined production in recent years has averaged US$450 billion, with US$200 billion of this being attributed to coal/lignite, US$150 billion to metals (and gems), and US$100 billion to industrial minerals and aggregates (see Box 3).

Other interesting points (Mining Journal website):

- Surface mines account for about 80% of all ore and rock extracted.

- The top ten mining companies produce 25% of the mined production (by value).
- Half of the world's mine and exploration expenditure is in the Americas.
- The total mining equipment sector is worth around US$50 billion per annum.
- There are about 3,000 stock exchange-listed exploration and mining companies.

Some 15,000 million tonnes of rock is moved every year, two-thirds of it being waste. Around US$5 billion is spent every year on exploration and mine-feasibility studies, slightly more on mine construction, and up to US$80 billion on the actual cost of mining and processing.

Box 3 The most important metals/gems (ranked by the average annual value of mined production over recent years) are:

US$ billion per year

Aluminum	32
Gold	30 (although US$44 billion at current prices)
Copper	23
Iron Ore	15
Diamonds	10
Zinc	9
Nickel	6

Approximately 100,000 exploration licenses are awarded per year worldwide. At any one time there are about 8,000 drilling projects underway, 1,500 reserve-definition studies, 800 feasibility studies and 400 mines under construction (Mining Journal website).

What Wastes are Produced in Mining?

Two separate categories of solid and liquid waste are generated from mining, overburden/waste rock and mine tailings. The overburden is that the top layer of soil and rock that must be removed to access the ore. After removing the overburden, a layer of waste rock must also be removed from open pit or underground mines to access the ore. The waste rock often contains target minerals but at too low of concentrations to be economically separated from the rock. Ore is the rock that contains the target mineral, such as gold or copper, that can be feasibly processed and separated from the rock. A strip ratio in open pit mines of waste rock to ore of 1:1 is generally considered good but it can be up to 6:1. Overburden/waste rock is generally disposed into large piles in a waste rock storage area. In one case in Papua New Guinea, the waste rock is placed on barges and dumped at sea. Two other mines in Papua New Guinea dispose of their waste rock through riverine disposal, although not directly in that the waste rock is stored in a location subject to serious erosion.

Mine tailings are what is left after physical and chemical processing to separate the target minerals (e.g., gold, silver, or copper) from the ore. Mine tailings include the fine grained particles from the ore and the residues of chemical reagents, all as part of a slurry. Mine ore (i.e., ore extracted from the open pit or underground mine) is normally brought to the processing plant by truck or conveyor belt, where it is crushed and ground to reduce the particles to sizes of sand and silt. Crushing is a dry process and achieves a coarse size reduction, whereas grinding is conducted wet with the addition of chemicals such as lime, soda ash, sodium cyanide, and sulfur dioxide to aid in the separation process.

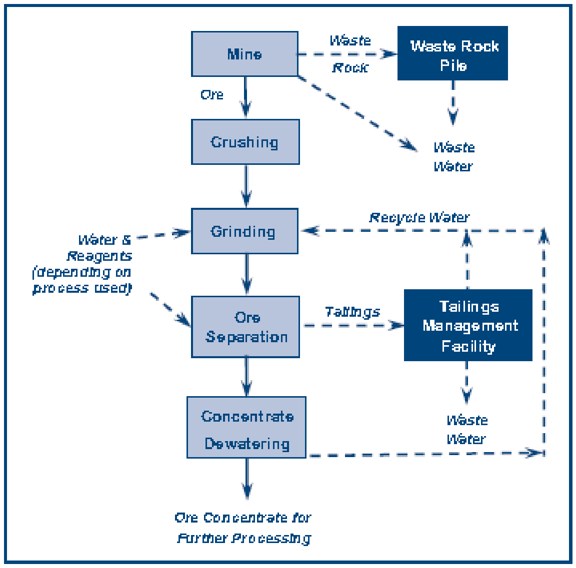


Figure 4 Mining Process (Source: Environment Canada 2009)

The concentration or separation process is conducted by physical and/or chemical methods, the objective of which is to produce an ore concentrate. The ore concentrate is sent to further processing, frequently offsite, to produce a marketable metal.

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 (MMSD 2002) which means that essentially all ore becomes a waste product, i.e., mine tailings. Mine tailings contain some of the metal bearing minerals, such as copper, because the separation process does not recover all of the minerals. The mine tailings also include whatever reagents and chemicals that were used in the process.

- Physical separation processes include gravity, magnetic, and floatation techniques. Chemical reagents are used to assist in the separation process. Floatation is the primary process used in the base metal ores and in gold processing operations. Fine air bubbles are introduced to the ore in water, during which the target minerals float to the top as a froth, which becomes the ore concentrate. The remaining solid and liquid materials are the mine tailings. In the flotation cells, collector reagents and frother reagents are added. These reagents help to form air bubbles allowing the copper and gold minerals to attach to air bubbles. As the air bubbles float to surface, the ascended froth and minerals are collected, as the mineral concentrate.
- Chemical separation processes include leaching with cyanide for gold and silver. Calcium or sodium cyanide is used to dissolve the metal from the finely ground ore, which is then absorbed from the leach slurry onto activated carbon which is captured for the ore concentrate. The remaining solid and liquid materials are the mine tailings.
- Ore concentrates from physical or chemical separation processes are dewatered by thickening (i.e., gravity settling) and vacuum filtration; the process water can be recycled into the separation process.

As noted above, mine tailings are what is left after the recoverable minerals have been separated from the ore. Mine tailings are well known to contain heavy metals such as arsenic, lead, mercury, copper, cadmium, and selenium as well as compounds of cyanide which are used in gold and silver processing. A number of process chemicals are used in the separation process, the most common of which are sodium ethyl xanthate, methyl isobutyl ketone, sulfuric acid, sodium hydroxide, copper sulfate, hydroxyl oxime, and polycarboxylic acid. Most of these chemicals are used in the flotation process to control or accentuate leaching, with residuals discharged in the mine tailings (see Box 4) (MMSD 2002).

Mine tailings and waste rock naturally include sulfide minerals (such as pyrite, pyrrhotite, marcasite), which when exposed to oxygen and water can lead to generation of sulfuric acid (acid rock drainage/acid rock drainage). Acid mine drainage is one of mining's most pressing issues. Sulfuric acid, in addition to being potentially toxic in itself, accelerates the leaching of heavy metals from the mine tailings or waste rock. The potential for acid rock drainage from mine tailings and waste rock can be greatly reduced if they are kept under water, isolating the tailings and waste rock from air and the oxidation process.

<u>Box 4 What Potentially Harmful Contaminants are in Mine Tailings?</u>

Mine tailings consist of crushed and ground rock and process effluents that are generated in a mine processing plant. The unrecoverable and uneconomic metals, minerals, chemicals, organics, and process water are discharged as a slurry (Tailings.Info website). Constituents of environmental concern in mine tailings include (Environment Canada 2009):

<u>Heavy metals</u>. Mine tailings commonly contain metals (that naturally occur in the mined rock) such as copper, mercury, zinc, and arsenic. Most metals are more soluble at lower pH levels.

<u>Alkaline Effluents</u>. Most ore separation processes are most efficient at pH levels of 10 or 11, including flotation separation processes. Process wastewaters are sometimes adjusted to lower pH levels prior to discharge.

<u>Cyanide</u>. Cyanide compounds are used in the gold separation process or other base metals separation flotation processes, and cyanide and cyanide compounds are in the slurry of mine tailings.

<u>Sulfur Compounds</u>. Sulfur oxide compounds occur naturally in ores mined for copper and gold and other metals. During the ore separation process, partial oxidation of sulfur compounds occurs during the crushing, grinding, and flotation processes under alkaline conditions, producing thiosalts (e.g., thiosuphate). Thiosalts can oxidize in water to form sulfuric acid, which can lower pH levels as well as leach metals from the crushed and ground ores as well as in the receiving waters after discharge.

<u>Suspended and Settleable Solids</u>. The crushed and ground rock are discharged as a slurry along with process chemicals after the recoverable metals have been recovered. For copper, 99% of the incoming ore becomes mine tailings whereas, for gold essentially all of the mined ore becomes mine tailings.

III Disposal Practices for Mine Tailings and Overburden/Waste Rock

Mine tailings may be disposed or stored in a variety of ways, depending on their physical and chemical nature, the site topography, climatic conditions, and the socio-economic context in which the mine operations and processing plant are located. Mine tailings include (1) a solid fraction, the fine-grained (typically silt-sized, in the range from 0.001 to 0.6 mm) solid material remaining after the recoverable metals and minerals have been extracted from mined ore, and (2) a liquid fraction, the process water including dissolved metals and ore processing reagents. The physical and chemical characteristics of the tailings vary with the nature of the ore (Australia 2007).

The vast majority of industrial-sized mines (i.e., 99.4%) dispose of their mine tailings in on-site storage facilities, i.e., artificial dams or impoundments or in lakes. Early on, before environmental considerations came into focus, disposal of mine tailings was by whatever was convenient, usually riverine disposal. Riverine disposal is no longer used, except for four mines in Indonesia and Papua New Guinea. Backfilling or in-pit storage into abandoned parts of the mine is used in a number of locations, but this technique is unique to each mine in that operating parts of the mine cannot be backfilled, thereby practically limiting this disposal option. Marine disposal has been used for over 40 years in a number of locations around the world. See Box 5.

Box 5 Disposal Alternatives Used 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
- Submarine tailings disposal (deep sea tailings placement)

Waste rock or overburden is normally placed on-site in storage dumps, but sometimes placed into mine tailings storage facilities; backfilling of the completed portions of open pit mines is also practiced.

Mine Tailings 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. See Figure 5. The objective is to place the mine tailings into the impoundments for long term/permanent storage. The basic requirement of a tailings storage facility is to provide safe, stable, and economical storage of tailings presenting negligible public health and safety risks and acceptably low social and environmental impacts during operation and post-closure. For mine tailings that can create acid rock drainage, the objective of the impoundments is to ensure that the tailings are under water. Mine tailings are delivered to the storage site in a slurry in the range of 25-50% solids, thereby creating a tailings pond with solids settling to the bottom. The ponded water is sometimes reused in the mine processing operation (Australia 2007). At least 3,500 mine tailings dams exist world-wide (Davies and Martin 2000). Dry stacking of mine tailings is also practiced; most of the process water is removed from the mine tailings by vacuum filtration or presses before being placed in an engineered impoundment that is managed carefully for minimizing water intrusion. See Box 6.

Box 6 Issues of on-land Disposal of Mine Tailings

- Acid rock drainage
- Short and long term safety of dams/impoundments
- Scale of the terrestrial footprint, loss of habitat, and loss of productive land
- Aesthetics
- Economics

The primary issue addressed in the engineering design of mine tailings storage facilities is safety and the permanence of the structure, such that the embankments or dams do not fail, causing the spread of mine tailings well beyond the footprint or down the valley. The design factors include such considerations as (Australia 2007):

- Site setting: topography, storage volume needed, stability of terrain, public safety risks (not locating directly above populated areas), and potential social and environmental impacts
- Characteristics of mine tailings: particle size, contaminants
- Potential groundwater and surface water impacts
- Expected footprint (i.e., area of disturbance)
- Closure issues: long term storage, public health and safety, seepage and water quality

Figure 5 Cross valley tailings impoundment at Highland Valley Copper, BC, Canada (Courtesy of Teck) (Tailling.Info.org)

The use of natural lakes as mine tailings storage facilities has long been a practice in many countries, as an alternative to construction of dams. This is not without controversy, as the lakes generally lose their natural character becoming tailings impoundment areas; this means that mining companies do not need to build impoundment facilities for mine tailings, but may have to augment the natural lake's impoundment capacity and provide mitigation measures for loss of natural resources.

There have been at least 138 significant recorded failures of mine tailings storage dams around the world, beginning from the time of the first tailings storage dam and continuing in current times. The average failure rate was 1.3 failures per year between 1998 and 2008 (Spitz and Trudinger 2009). For example, tailings storage facilities failed in several mines in the Philippines which involved Manila Mining in Surigao City, Philex Mines in Baguio City, Maricalum Mining in Sipalay Negros occidental, and Marcopper in Marinduque in 1996; all resulted in mine tailings reaching marine waters. See Boxes 7 and 8.

Box 7 Recent storage dam failures

On October 4, 2010, in Hungary, the embankment of a red mud impoundment failed and released a mixture of 600-700 thousand cubic meters of red mud and water. The slurry flooded the lower sections of the settlements of Kolontár, Devecser and Somlóvásárhely via the Torna creek. Ten people were killed, and approximately 120 people were injured. The spilling red mud flooded 800 hectares of surrounding areas. The most severe devastation was caused in the villages of Devecser and Kolontár, which are located near the reservoir (Wise-uranium website). See Figure 6.

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 (Hoang undated). See Figure 7.

Figure 6 Collapse of Red Mud Impoundment Facility in Hungary. Source: Mines and Communities website

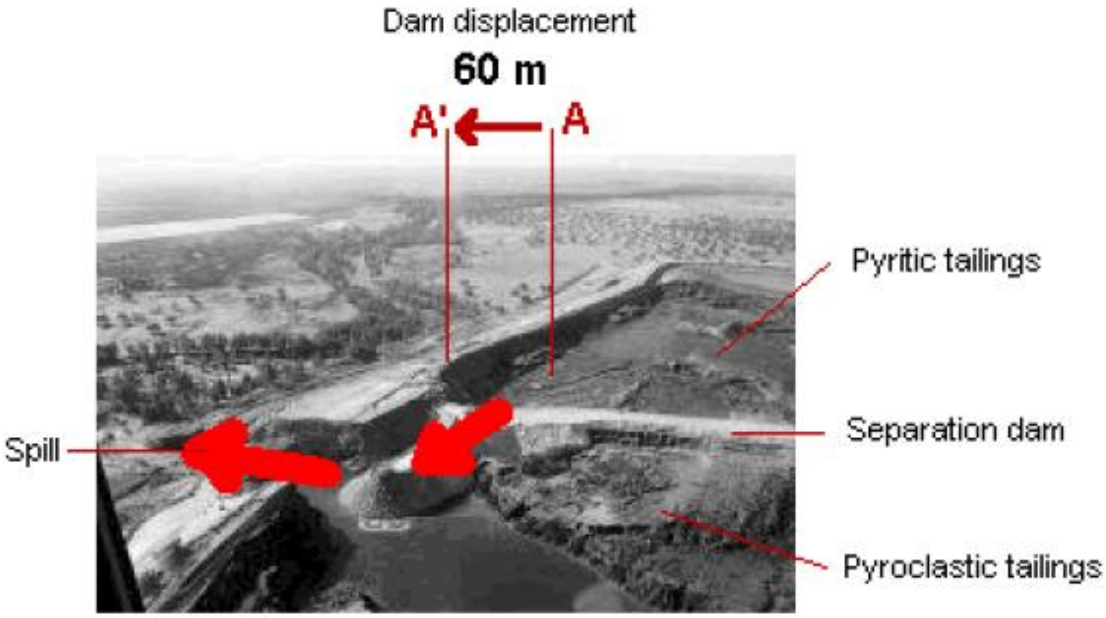


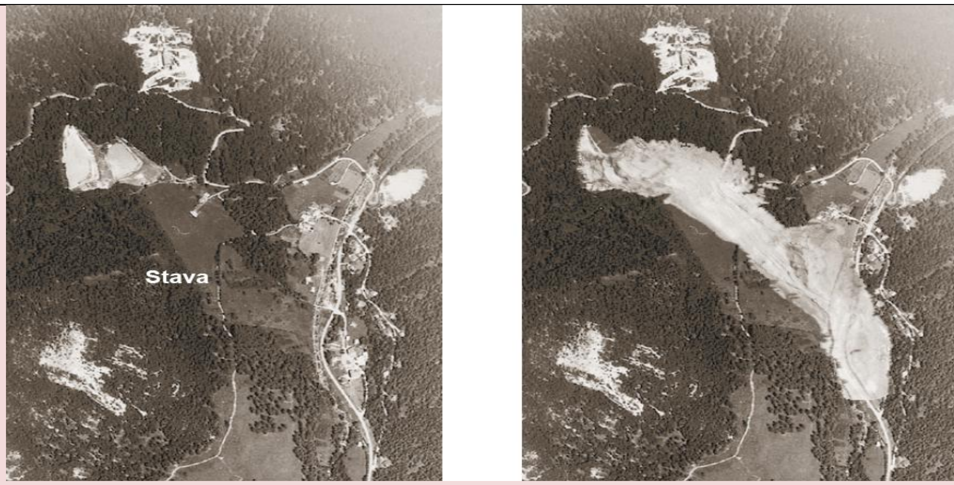
Figure 7 Failure of mine tailings dam in Aznalcollar, Spain (Source: Hoang undated)

Primary causes of mine tailings storage dam failures include (Muller 2009):

- Liquefaction of tailings and dam--from earthquakes;
- Rapid increase in dam wall height—if raised and filled too quickly, high internal pore pressures can lead to dam failure;
- Foundation failure—the base of the dam is too weak to support the weight of the dam;
- Excessive water levels—flood inflow, high rainfall, and improper water management can cause excessive water levels causing dam failure; overtopping can cause erosion and failure of dam walls; and
- Excessive seepage—seepage within or beneath the dam can cause failure of the embankment.

Mine tailing impoundment failures in arid or semi-arid locations are rare.

There is a very significant support industry to ensure that mine tailing storage facilities are built and operated in a safe manner. Best available designs, operating principles and factors, websites, engineering consulting firms, and non-government organizations, such as International Commission on Large Dams (ICOLD) (ICOLD website) dedicated to the topic of mine tailings storage facilities provide the basis for ensuring safe short and long term facilities. See section VI, Best Management Practices.



When a tailings dam fails occurs, some or all of the tailings migrate out of the impoundment and flow downstream. Obstructions in the path of the flow are either swamped or carried downstream. A disastrous dam failure and flow of tailings occurred in 1985 at flourite Prestavel mine in Stava, Italy. The dam breached as a result of inadequate construction and inspections combined with heavy rains which caused overtopping. The flow travelled down the valley at 90 km/hour through the town of Stava, killing 268 and destroying 62 buildings and 8 bridges (Muller 2009), depositing 180,000 cubic meters of mud over 4.2 square kilometers measuring 20-40 centimeters in thickness. The cost: 133 million Euros. Source: Tailings.info and Stava website. See Figure 8.

Box 8 Tailings dam failure – Stava, Italy, 19 July 1985

Figure 8 List of the 268 people who died shown during the court trial of Stava mine tailings dam disaster. Source: Stava website

Backfilling Abandoned Mines with Mine Tailings

Backfilling is the practice of placing mine tailings in open-pits or underground mine shafts in mines or parts of mines that have completed their useful production. The advantage to both is that these mine tailings do not have to be placed into a surface mine tailings storage facility and other disposal technique. The key is the timing of the availability of the open pit or space in the underground mine for placement of mine tailings. One of the key challenges is to avoid contamination of groundwater.

Riverine Disposal

Riverine disposal is uncomplicated. Pipe the slurry of mine tailings to a river and discharge. This technique has been practiced world-wide throughout mining history. See Figure 9. 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. Damages from previous cases of riverine mine tailings disposal are well documented, for example, King River, Tasmania, Australia, Coeur D'Alene, Idaho, USA, and Bougainville, Papua New Guinea. In Papua New Guinea and Indonesia, riverine disposal is used in these areas because it is argued that the construction of mine tailings dams is geotechnically impossible given the topography, potential for earthquakes, and high rainfall. The advantages are economic but huge disadvantages exist in terms of environmental and social/economic damage to local communities (Ethics Council 2011).

Figure 9 Riverine disposal in abandoned gold mine in Nevada, USA. Copyright Jon Engels

One example is Coeur D'Alene river basin in Idaho, USA, where at least 44 ore processing facilities operated between 1886 and 1997 and used riverine disposal for most of that time into the South Fork/Coeur D'Alene Rivers or discharged directly to the floodplain where they eventually eroded into the river system. Sediments from mining have impacted an area extending over 3,885 square kilometers and it is estimated that it will take 20-30 years to reverse the damage and cost over US$1 billion for rehabilitation, which is only part of the overall picture (IIED 2002).

Submarine tailings disposal (deep sea tailings placement)

Submarine tailings discharge or deep sea tailings placement is simply the discharge of mine tailings into marine waters via a pipeline. See Box 9. Submarine tailings disposal is no longer practiced in surface waters or along shorelines, such as the Atlas Copper Mine in the Phillipines where tailings were discharged 200 meters from shore at 10 meters depth. Depending upon the local discharge location, today's marine discharges of mine tailings are at final deposition depths of 30 meters to hundreds of meters deep or in Indonesia, PNG, and Turkey, final deposition is at over 1,000 meters depth. The intent is to discharge the mine tailings into deep stratified waters below the pynocline such that the mine tailings flow as a dense coherent slurry to a deposition site on the bottom, essentially trapped below, preventing tailings from entering the shallow, biologically productive, oxygenated zone (i.e., not mixing with the surface layer) (IIED 2002).

Box 9 The general concepts of submarine tailings disposal in Indonesia include (Shimmield 2010):

- Discharge on the edge of an extended drop-off (e.g., in Indonesia and PNG, to 1000 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

Figure 10 and 11 are simple representations of subsea marine discharge of mine tailings. As shown, the slurry of mine tailings goes though a de-aeration step to substantially remove any air bubbles entrained in the slurry to reduce the buoyancy such that the plume does not mix with surface waters. In some cases, coagulants and flocculants are added to the slurry to help maintain its cohesiveness to form a thicker slurry to prevent wide mixing of the tailings plume in deep waters and not mix with surface waters. The mine tailings are then sometimes mixed with seawater to achieve the correct temperature and density.

After release into marine waters from the pipeline, the mine tailings flow down the sea floor to the bottom depth. Plumes of finer material including tailings process water, suspended sediment can form at various depths but should remain in the deep waters because of the stratification of the marine waters; these plumes contain residual process chemicals, metals, and other contaminants of the ore separation process.

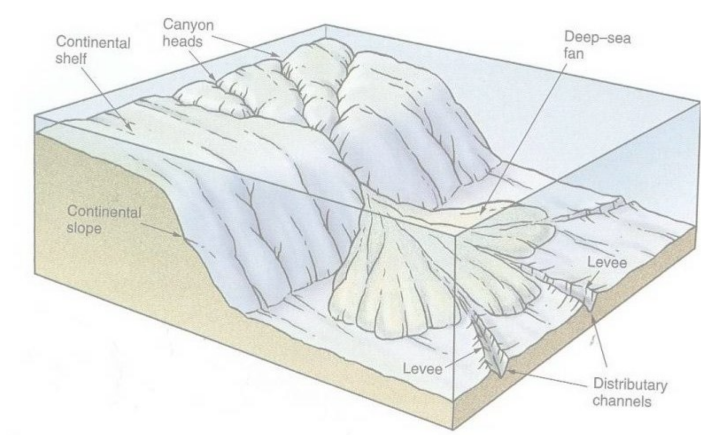
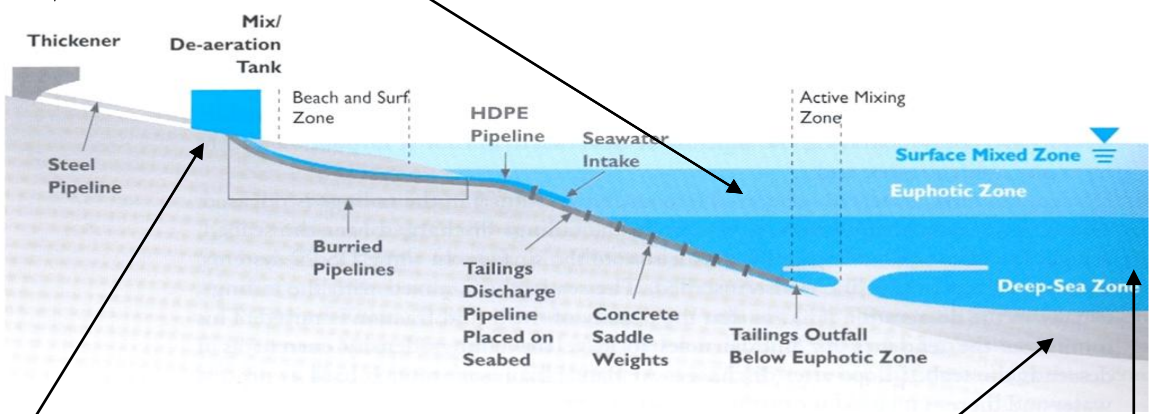


Figure 10 Conceptual drawing of marine disposal in Norway (Gunnar Skotte, 2009).

Coagulants and flocculants used to bind particles together to form a thicker mixture to prevent wide dissemination of the tailings-plume underwater

The euphotic layer is defined as the depth reached by only 1% of photosynthetically active light



Seawater to increase density of slurry
Final resting place of tailings on the sea-floor

Greater than 50 m water depth

Figure from Spitz and Trudinger, 2009

Figure 11 Conceptual Drawing of Submarine Tailings Disposal

The outfall discharge pipes are engineered to meet the conditions of the physical environment at the shoreline and to the depth of discharge. Experience has shown that the pipeline slope must be at least 12 degrees to avoid the risk of tailings build-up at the discharge point. The rate of discharge is also an important factor to minimize the possible blockage of the discharge. Another example of a discharge location is shown in Figure 12 at Batu Hajiu in Indonesia.

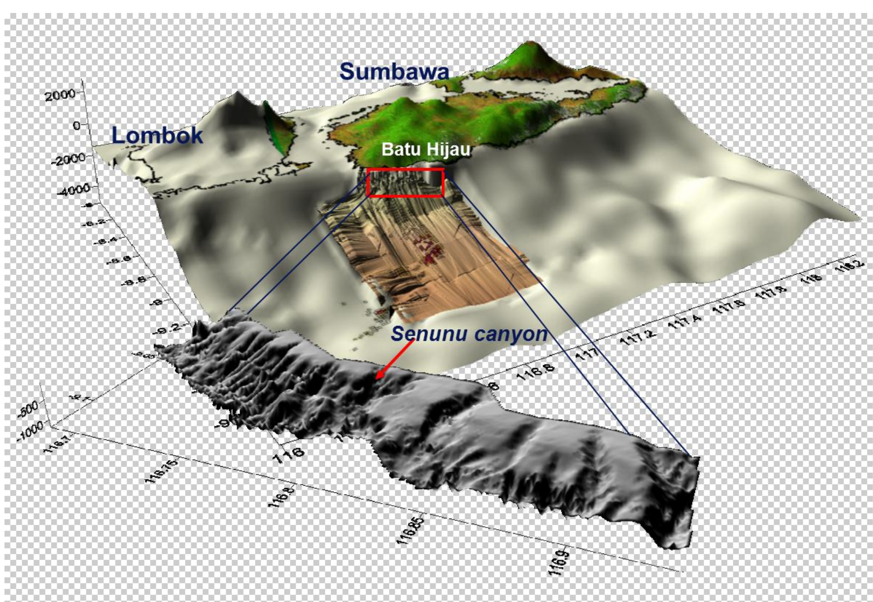


Figure 12 Bathymetry at Batu Hajiu showing location of deep sea tailings placement into Senunu Canyon. Courtesy of Newmont Mining

IV Rationale for Marine Disposal/Submarine Tailings Disposal/Deep Sea Tailings Placement and Riverine Disposal

The rationale for choosing marine disposal/submarine tailings disposal/deep sea tailings placement or riverine disposal is based upon several factors and will differ depending upon topography, distance to potential deposit areas, and the properties of the mine tailings. The primary factors include 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 (Skotte 2011).

- Costs of constructing pipelines for marine disposal and operating them are not small, but the costs of the alternative which would be land-based storage (i.e., construction and maintenance of a mine tailings storage facility) is about 100 times greater in capital cost than constructing a marine discharge pipeline. For example, it was estimated for the Nussir project in Norway to establish a land-based mine tailings storage facility would cost US$650 million compared to US$6.5 million for marine disposal (Kvalsund 2011).

- Land-based tailings disposal involves construction of an impoundment for storage of the mine tailings in water. These tailing storage facilities raise a number of on-site issues, such as aesthetics, recreation, lost fish and wildlife habitat, lost agricultural land, possible surface and ground water contamination, and long term maintenance to avoid catastrophic flooding (Shearman 2001).

- In Indonesia and Papua New Guinea, it is argued that (PT Newmont Brochure):
    - Creation of a mine tailings storage facility in the mountainous terrain would not be technically feasible because they are located in very active earthquake prone areas which could create a safety hazard to downstream communities, and long term maintenance is an issue especially after mine closure;
    - The rainfall is up to 3 meters per year making water management in tailings storage facilities extremely difficult, and
    - The terrain is unstable for construction of safe mine tailing storage dams (McKinnon 2002).

  In Norway, the argument is that suitable land for disposal of mine tailings near the fjords is not available.

- One of the key issues, as noted above, in assessment of disposal alternatives, is the perceived risk after mine closure to ensure that a long-term maintenance plan can be sustained in perpetuity. This is particularly an issue in Indonesia and PNG, given the challenging conditions of high rainfall and earthquake events, topography, and valley wall instability; combined with social demands on the customary lands, it is argued that these conditions preclude tailings storage facility development.

- In some locations, it is argued that disposal in the deep sea is a temporary impact upon marine resources, such as smothering, compared to the permanent location of a tailings dam, which in mountainous terrain means damming up a river or creek and filling the valley with mine tailings. A number of studies have shown that recolonization begins when the mine tailings discharge ceases, but actual recovery could be decades or hundreds of years depending upon site specific conditions. More studies of recovery are needed.

- The rationale for use of riverine disposal of mine tailings is primarily one of economics but also site specific conditions including topography, seismic activity, high rainfall, and long term questions on maintenance in perpetuity of tailings storage dams.
    - Decisions to use riverine disposal do not address acid rock drainage from the mine tailings. Most mine tailings pose serious risks of generating sulfuric acid when exposed to water and air. Sedimentation downstream on riverbanks or from flood events results in a long term issue of acid drainage; storage of mine tailings behind dams or disposal in marine waters lessens this risk.
    - Another side note is the case of the El Teniente mine in Chile where the mine tailings are sent to a location, where the conditions (such as the topography) are appropriate, by pipeline to a tailings storage facility 75 kilometers from the mine (IIED 2002).

<u>An Exception to the Feasibility Argument in PNG?</u>

Hidden Valley Mine owned by Morobe Mining Joint Venture (50% Newcrest Mining and 50% Harmony Gold) is the first major open pit mine in Papua New Guinea to build a tailings storage facility (shown in Figure 13) to contain all tailings, permitted under the new Environment Act 2000. The construction of the tailings dam appears to counter the conventional wisdom in Papua New Guinea regarding site specific factors such as topography, rainfall, and seismic activity that allegedly make tailings dams infeasible.

Another example is the Wafi-Golpu Gold Project in Papua New Guinea which is in the planning stages of evaluating construction of a tailings storage facility, having eliminated marine and riverine disposal as alternatives (Thompson 2012).

Figure 13 Tailings Storage Facility at Hidden Valley Mine--The first of its kind in PNG.

V Environmental Impacts of Marine and Riverine Mine Tailings Disposal

Mine tailings are unique, compared to other industrial wastes. The quantities are enormous. The potential for environmental damage from their disposal is huge. Mine tailings are not treated to remove contaminants (except a few mines treat to reduce cyanide levels) before they are discharged into marine or riverine waters, unlike most other industrial wastewaters. Most mine tailings will cause sulfuric acid to be generated when exposed to air and water, and thus, disposal necessarily involves submerging the tailings under water. The choice of disposal alternatives is often between environmentally damaging options. Acceptance of a huge footprint of destroyed habitat in on-land tailings storage facilities is the state-of-the-practice. In a few locations, a huge footprint of destroyed habitat on the seafloor in combination of an unknown extent of impacts to neighboring habitats and to sealife has been determined to be acceptable. These choices are usually made through some form of risk assessment, comparing the alternatives.

Most of the countries in the world with mining industries have determined that mine tailings belong in engineered and managed on-land tailings storage facilities. In a few countries, local conditions and available on-land disposal alternatives are such that judgments have been made to use marine or riverine disposal. The environmental trade-offs are one piece of these country's decision criteria for determining that marine or riverine disposal is appropriate. This report does not attempt to answer the question regarding the significance of environmental impacts of marine disposal of mine tailings; it does raise fundamental scientific and technical questions through examples and cases studies.

Marine Disposal----i.e., Submarine Tailings Disposal or Deep Sea Tailings Placement

The objective of marine disposal is to dispose of mine tailings into deep waters that rest on the bottom without mixing with surface waters or spread beyond the intended footprint. Adding coagulants and flocculants, adding seawater, de-aerating, using a slope of at least 12 degrees for the discharge pipe, and discharging below the pynocline (depth of density stratification) are all intended to minimize any possible mixing of the mine tailings with upper surface waters and to lessen the creation of plumes that can be carried by ocean currents to areas outside the intended deposition zone. Table 4 provides the inventory of mines that discharge mine tailings into marine waters in 2013.

Table 4 Marine Discharges of Mine Tailings
2013

Location	*Type of Mine*	*Mine Tailings tonnes per year*	*Depth of Deposition in meters*	*Company*
Indonesia				
Batu Hijau	Copper/gold	40,000,000	3,000-4,000	Newmont Mining
Papua New Guinea				
Lihir	Gold	4,000,000	>2,000	Newcrest

Table 4 Marine Discharges of Mine Tailings 2013				
Lihir	Gold	40,000,000 waste rock	By barge 1 km offshore	Newcrest
Simberi	Gold	3,300,000	not available	Allied Gold
Ramu Nickel	Nickel/colbalt	5,000,000	1,500	Metallurgical Corp of China/Highlands Pacific
Turkey				
Cayeli Bakir	Copper/zinc/lead	11,000,000	>2,000	Inmet Mining
En gland				
Boulby	Potash	1,800,000	Na	Cleveland Potash
France				
Gardanne	Alumina/aluminum	NA-bauxite	330	Rio Tinto Alcan
Greece				
Agios Nikolaos	Aluminum	NA-bauxite	800	Aluminum of Greece
Chile				
Husaco	Iron ore	1,200,000	35	CAP Minería
Norway				
Bokfjorden	Iron	4,000,000	220	Sydvaranger (Northern Iron Ltd)
Ranafjorden	Iron	2,000,000	80	Rana Gruber Minerals
Stjernoy	Nepheline syenite	~ 300,000	not available	Sibelco Nordic
Elnesvagen	Pigments	500,000		Hustadmarmor
Skaland	Graphite	20,000-40,000	30	Skaland Graphite ASA

One of the objectives is to place mine tailings under water such that acid is not generated from interactions between oxygen and the sulfide containing tailings. This objective is achieved by marine disposal, while at the same time accepting that the marine life in the disposal site will be smothered by the marine tailings. Known effects are the complete 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 real potential for direct toxicity and bioaccumulation of heavy metals in local marine life, and changes in species composition and abundance. See Box 10 and Figure 14.

Box 10 Potential Environmental Impacts of Marine Disposal of Mine Tailings (Shimmield 2010)(Brewer 2007) :

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-increases in risk to human health

Two issues related to the extent of the potential impacts are up-welling and ocean currents. Up-welling is a phenomenon of movement of deep ocean water to the surface of the sea, usually occurring along the coastline and also in the open ocean. Upwelling is caused by winds pushing water which causes water to rise from the depths to the surface. Upwelling brings nutrients from deeper ocean waters to surface waters, enhancing biological productivity of the surface waters. Upwelling can also bring constituents of mine tailings to the surface waters. Deep ocean currents can also spread plumes of the finer materials from mine tailings to surrounding areas (McKinnon 2002). In an assessment by the Scottish Association for Marine Science of the impacts of deep sea tailings placement upon the PNG coastal waters, they found that along the coasts of Lihir and the closed mine Misima, there was no evidence and little likelihood of up-welling to occur due to the shortness of the coasts to allow up-welling divergence to occur. They pointed out that upwelling in intense areas, such as the west coast of South America, results in up-welled waters coming from relatively shallow depths (i.e., less than 150 meters (Shimmield 2010). Up-welling for other areas where mine tailings are disposed in marine waters is a site-specific consideration.

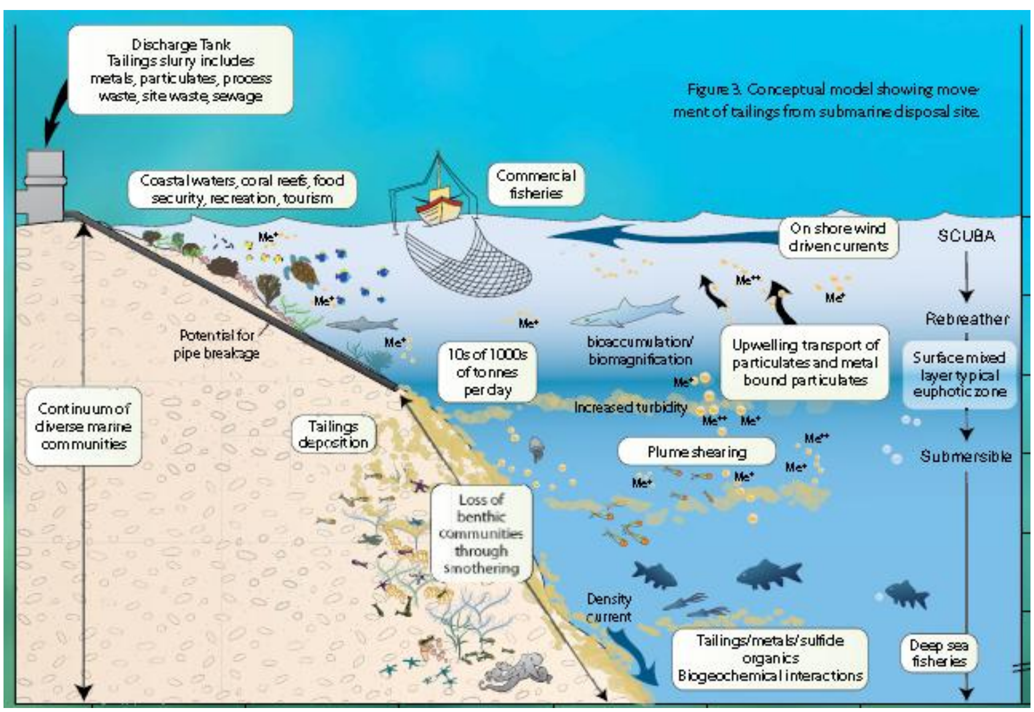


Figure 14 Potential impacts of marine disposal. Source: Reichelt-Brushett, Oceanography 2012

In 2003, the World Bank Extractive Industries Review stated that the area of the Southeast Asia and the Pacific are critical regions of maximum marine biodiversity and of global marine conservation significance. The review concluded that the effects of marine disposal of mine tailings on tropical life, marine resource use, and ecosystem functions were not well understood, and that there was an urgent need to address these issues with respect to marine disposal of mine tailings. The Review went on to recommend that where the effects of marine disposal of mine tailings are not well understood, the precautionary principle would be applicable, i.e., marine disposal should be avoided, especially in island regions. The Review recognized that almost all marine disposal operations world-wide disposing in shallow depths or in deep water have had problems, including the predicted smothering, loss of biodiversity, increased turbidity, and introduction into the sea of metals and ore separation chemicals, such as cyanide and frothing agents (World 2003).

The extent of potential biological impacts in the water column is a result of such factors as the levels of turbidity, levels of toxicity, and the specific locations of the plumes and sensitive marine organisms, and 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.

Box 11 The potential impacts on shallow water organisms after accident or upwelling are (Apte and Kwong 2004):

- Local decreases in primary productivity as a result of increased turbidity
- Local acute toxicity of dissolved metals, particulate metals, process chemicals
- Chronic/sublethal effects of metals on organisms
- Metal bioaccumulation leading to increased trophic transfer of metals
- Habitat alteration (e.g. increased turbidity, smothering of coral reefs)
- Changes in species composition/abundance
- Changes in biodiversity
- Reduction in food availability
- Effect of fine particles on organisms: e.g. clogging of gills and feeding mechanisms
- Local effects of increased turbidity on organisms that utilise bioluminescence
- Increased productivity due to iron or other nutrient availability.

While the recovery of pelagic environments following cessation of mining is likely to be rapid, more long lasting impacts are expected for benthic organisms.

Source: Shimmield 2010

In the 2011 annual report, Norway's Council on Ethics for the Government Pension Fund Global[4] stated that:

> *Experience shows that the disposal of millions of tons of tailings destroys the natural seabed in substantial areas during operation and for periods following the closing down of operations. Most of the tailings will settle in thick layers relatively shortly after disposal. Fine particles, chemicals, heavy metals and other pollution may spread with currents and impact larger areas, causing reduced biological production and toxic effects. It is difficult to limit the extent of impacted areas. Often, impacted areas are larger than originally predicted and the environmental impacts have often been underestimated* (Ethics Council 2011).

In a paper presented to the Egersund Conference in Norway in 2009, "Effects of mine tailings disposal on the ecosystem and biodiversity in the marine environment – a critical view" by the Institute of Marine Research in Bergen, Norway (Fosså et al 2009), the conclusion was that the biodiversity of the fjord is changed. The authors stated that:

- *The ecosystem is disrupted in significant parts of a fjord and possibly poisoned.*
- *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, such as tusk, flatfish, rays, cod, haddock, lose their habitat:*
- *Crustaceans, including prawns, crabs, and king crab, on and close to the bottom loose the habitat, or it becomes strongly modified, possibly also poisoned depending upon the chemicals used in the ore separation process.*
- *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.*

Case studies, summaries of each mine that is using marine or riverine disposal of mine tailings, are included in Appendix 3. The reader is advised to not skip those case studies, in that they include specific information on each mine, the disposal techniques, and the environmental impacts of disposal. Several examples are provided below.

Lihir Gold Mine

In the mid to late 2000s, the Scottish Association for Marine Sciences conducted an oceanographic study of the possible impacts of the deep sea tailings placement from the Lihir mine. The efforts were funded by the European Commission and thereby are considered an independent review. The extent of the

[4] The Council on Ethics for the Government Pension Fund Global (GPFG) is an independent council that makes recommendations to Norway's Ministry of Finance on possible exclusion of companies from the Fund. The Council issues its recommendations following an assessment of whether a company's actions or omissions are in contravention of the criteria in the guidelines laid down by the Ministry.

mine tailings footprint on the seafloor was estimated to be 60 square kilometers in 2005. By comparing reference sample locations to the east and to the west of the footprint, they found that the larger sediment-dwelling animals (macrofauna) were very sparse at all of the impacted sites but much more abundant and diverse at the reference stations. They reached the conclusion that the studies showed an unambiguous demonstration that the ongoing Lihir deep sea tailings placement has major impacts on the abundance and diversity of animals in area of the mine tailings footprint in deep sea sediment, extending to water depths of at least 2,020 meters (Shimmield 2010).

Ramu Nickel Mine

The potential environmental impact of the proposed Ramu Nickel marine disposal of mine tailings was subject to an extensive court case. The decision in April 2012 was that the Ramu Nickel mine could discharge marine tailings in marine waters. One basis for the decision was weighing the economic benefits of the mine verses the potential environmental damage. It appears that one of the primary factors in the decision was that over a US$1 billion had already been invested in developing the mine. The court found there was a reasonable probability that the proposed deep sea tailings placement processes would cause environmental harm that may have catastrophic consequences, cause irreparable damage to the ecology of coastal waters, and seriously harm the lives and futures of the plaintiffs, and of thousands of other people in Madang Province. In particular, the court made the following findings (Allens website):

- It was likely that the tailings would smother benthic organisms over a wide area of the ocean floor (at least 150 km^2), which would inevitably alter the ecology of that part of the ocean;
- It was very likely that the tailings would be toxic to marine organisms; and

  There was a real danger that the tailings would not settle on the ocean floor but be subject to significant upwelling, which meant that substantial quantities of tailings would be transported towards the PNG mainland.

While Judge Cannings did not grant the injunction sought, he made it clear what he thought of marine disposal of mine tailings, as noted in Box 12.

Box 12 Judge Canning Opinion on Marine Disposal of Mine Tailings

"I therefore feel obliged to state that my considered opinion as a Judge, having heard extensive evidence on the likely environmental effect of the DSTP and made findings of fact on that subject, is that the approval of the DSTP and its operation has been and will be contrary to National Goal No 4. It amounts to an abuse and depletion of Papua New Guinea's natural resources and environment – not their conservation – for the collective benefit of the People of Papua New Guinea and for the benefit of future generations, to discharge into a near-pristine sea (a widely recognized hotspot of biodiversity), mine tailings at a rate of 5 million tonnes of solids and 58.9 million cubic metres of tailings liquor per year. It constitutes unwise use of our natural resources and environment, particularly in and on the seabed and in the sea. It amounts to a breach of our duty of trust for future generations for this to happen. It is a course of action that shows deafness to the call of the People through Directive Principle 4(2) to conserve and replenish our sacred and scenic marine environment in Astrolabe Bay. It puts other coastal waters of Madang Province at risk. Inadequate protection has been given to our valued fish and other marine organisms."

While the injunction was not granted and opinions have been provided, an extensive benchmark survey of baseline conditions prior to the commissioning of the mine was conducted by the Scottish Association for Marine Sciences. Benthic environments, meio- and macrofaunal communities, were characterized at stations along the projected tailings "footprint", and at control stations to the east and west of the outfall. This established a quantitative baseline for monitoring to assess potential future impacts of the Ramu Nickel's Basamuk Bay deep sea tailings placement outfall and tailings dispersal and environmental impacts along the Rai Coast (Shimmield 2010).

Batu Hajiu

The government of Indonesia approved the deep sea tailings placement in 1996 based upon an environmental impact assessment study completed in 1996. The permit was issued in 2003, and reissued in 2005, 2007, and 2011 (Batterham and Waworuntu 2009). The permit allows 140,000 tons per day of mine tailings to be disposed by pipeline into Senunu Bay (Jarkarta Post 2012). Actual disposal over 2000-2012 averaged 112,000 tons per day (Waworuntu 2012).

Marine water quality standards are being achieved as specified in the permit. The water quality standards do not apply in the depositional zone. The mine tailings are not causing a turbidity plume that reaches the surface and the mine tailings flow down the steep walls of the Senunu Canyon to greater than 3,000 meters depth. The tailings are confined to that canyon and have not been identified in other nearby areas (Shiemmield 2010). Based upon a survey by the Fishery Agency of West Sumbawa in 2011, it was informally reported by WALHI (Indonesian environmental interest group) that fishery folk living nearby Sununu Bay were experiencing decreasing fish catchments since the initiation of marine disposal of mine tailings and that species such as squid, which were abundant before mine tailings disposal, were now nearly extinct (Ginting 2012).

Reissuance of the permit in 2011 was the subject of court litigation. On 3 April 2012, the State Administrative Court affirmed that the permit had been properly issued. The findings were corroborated during the trial by a number of experts from reputable universities and factual witnesses from the communities living around Batu Hijau's copper and gold mine. During testimonies under oath, these witnesses affirmed that Batu Hijau's submarine tailing placement system has operated as designed and has not negatively impacted fisheries in West Sumbawa.

The Deputy Minister of Environment testified that the issuance of submarine tailings placement permit is based on (1) comprehensive environmental and social review of assessments prepared before the operation commenced 10 years ago, and (2) further environmental studies carried out during the mining operation. The Deputy Minister stated that the submarine tailings placement appears to be the best method and the most appropriate for tailings produced from the Batu Hijau operation.

Cayeli Bakir Copper-Zinc Mine in Turkey

Mine tailings are discharged though a 350 meter long outfall at a depth of 275 meters into the anoxic zone. The Black Sea had been subjected to many years of oceanographic and marine biological assessments, which served as the basis for the design of the outfall pipe and the discharge location. The tailings are de-aerated and diluted with seawater taken from a depth of 15 meters prior to discharge The final tailings deposition zone is in anoxic water at a depth of greater than 2,000 meters. The Black Sea is a highly stratified inland sea with a large anoxic zone (90% of the water column), and a permanent pycnocline at depths of 35 to 150 meters which limits exchanges between surface and deep water (Berkun 2005).

The discharge into the Black Sea takes advantage of the anoxic conditions below about 150 meters depth with hydrogen sulfide concentrations greater than 3 mg/l. The depths are thus devoid of marine life other than sulfide metabolizing bacteria, and the hydrogen sulfide serves to precipitate heavy metals in the mine tailings. Studies have shown that upwelling is not occurring to any extent such that the plume of the mine tailings reaches surface waters (Interior 1994). The system appears to be working.

Studies/Research/Information needed to Assess Environmental Impacts of Marine Disposal of Mine Tailings

The United States Geological Survey conducted an assessment of a mine tailings spill into marine waters at Marinduque Island, Philippines, in 2000. As a result of that assessment, the investigators prepared a report in which they listed key information that is necessary in the determination of the environmental impacts of submarine disposal of mine tailings. This is shown in the Box 13.

This list of questions is relevant to this report. A number of studies have been conducted at mines that are proposing to conduct (or are already in the process of marine disposal) of mine tailings; questions are commonly raised regarding the sufficiency of those studies, and these questions can help in review of disposal alternatives.

Box 13 What information is needed about submarine tailings disposal to judge its suitability for the mine tailings? (Plumlee 2000)

In order to assess as completely as possible the potential environmental impacts of submarine tailings disposal, there is an extensive set of information that must be gathered. For example, the following questions regarding physical processes must be considered:

- What are the sea-floor conditions and oceanographic conditions? How do these conditions vary spatially across the ocean bottom and within the sea water column? How do these conditions vary with time (seasonally, and during storms or typhoons)?
- What are the directions of sediment transport in the water column and on the sea floor? How do these directions vary with time, both seasonally and during storms or typhoons?
- What are the forces that drive the primary physical processes (local wind, swell, tides, fluvial discharge)?
- What are the high-energy events that affect the physical setting (riverine flooding, typhoons, earthquakes, tsunamis)?
- What are the sea-floor conditions in the directions of sediment transport and at the anticipated site of tailings deposition?
- What is the composition and size distribution of the waste material?
- What are the proposed method, rates, and duration of waste emplacement?
- Are offshore slopes sufficiently steep to maintain density flow to the basin floor?
- Can the tailings discharge system be designed to withstand the impacts of storms? Storm induced failure of the piping discharge system could lead to catastrophic release of tailings in the near-shore environment.
- The following questions regarding the geochemical impacts of the disposal must be considered:
- What are the minerals in which heavy metals occur in the tailings materials? How soluble are these minerals in sea water and in the digestive tracts of marine organisms? Heavy metals residing in more soluble or reactive phases will be more readily taken up by marine organisms.
- How readily will sulfides in the tailings oxidize in sea water?
- What processing chemicals are present in the tailings fluids?
- What chemical reactions will occur between the tailings solids, tailings fluids, and sea water?
- If metals are dissolved from the tailings by sea water, what geochemical attenuation reactions with sea water will occur, and how far away from the tailings discharge outfall will these metals affect sea water quality?

The following questions regarding ecological impacts of the tailings disposal must also be answered.

- What are all of the marine organism communities that could be affected by the tailings disposal, given the predicted area of impact?
- What is the economic and ecological value of each of the marine biological communities identified in the disposal area?
- How will physical processes (such as sedimentation) and geochemical processes (such as dissolution of metals from the tailings) affect each of the different aquatic marine communities?
- What are the maximum chronic and acute toxicity concentrations of heavy metals in sediments and sea water for each type of marine organisms found in the areas affected by the tailings discharge, and will these levels be exceeded?

Only by satisfactorily answering each of these many questions can a scientifically sound decision be made regarding the potential suitability of each site proposed for submarine tailings disposal.

Riverine Disposal of Mine Tailings

Riverine disposal has historically been selected because it is the most economical approach to disposal of mine tailings, and, in some cases, the overburden and waste rock. In more recent times and certain locations, riverine disposal has been selected because other alternatives are judged to be technically and economically infeasible; in each of these cases, it is said that the mine is located too far from the coast for marine disposal, and that construction of mine tailings dams/impoundments is not feasible, being located in unstable mountainous terrain, with high rainfall and in areas of seismic activity. As shown in Table 6, four mines continue to use riverine disposal: Grasberg in Indonesia, and Porgera, Tolukuma, and Ok Tedi in PNG (IIED 2002, Ginting 2012).

Table 6 Riverine Discharges of Mine Tailings
2013

Location	*Type of Mine*	*Mine Tailings tonnes per year*	*Deposition*	*Company*
Indonesia				
Grasberg	Gold/copper	87,000,000	River	Freeport McMoRan
Papua New Guinea				
Ok Tedi	Copper/gold	90,000,000 mine tailings	River	PNGSDPC/PNG govt
Ok Tedi	Copper/gold	44,000,000 waste rock	River	PNGSDPC/PNG govt
Porgera	Gold	5,500,000 mine tailings	River	Barrick Gold
Porgera	Gold	9,900.000 – 15,000,000 waste rock	River	Barrick Gold
Tolukuma	Gold	200,000	River	Petromin Holdings

The concerns and known impacts of riverine disposal are directly from the increased sediment placed in the river system. The river morphology developed over millions of years carrying natural loads of sediment to lower reaches of the rivers and eventually into estuarine and coastal waters. The river channels, flood plains, and ecosystems were built by natural forces (see Boxx 14). The addition of mine tailings to that natural system creates major changes to the river physical structure, due to sedimentation along the river which raises streambed levels, causing flooding, and changing the floodplains. Riverine and floodplain forests and agricultural croplands have been destroyed, as well as towns and villages along the rivers.

Box 14 River Morphology

The term river morphology is used to describe the shapes of river channels and how they change over time. The morphology of a river channel is a function of a number of processes and environmental conditions, including the composition and erodibility of the bed and banks; vegetation and the rate of plant growth; the availability of sediment; the size and composition of the sediment moving through the channel; the rate of sediment transport through the channel and the rate of deposition on the floodplain, banks, bars, and bed (Wikipedia.org).

Sediment deposition downstream of the mine tailings disposal point is dependent upon the size of the sediment particles and the characteristics of the river flow. Larger particles in the mine tailings and the waste rock are likely to deposit closer to the discharge point and the finer mine tailings are transported further downstream. Sediment deposition causes riverbed levels to rise and results in over-riverbank deposition. In 2002, it was reported that riverbed levels had risen in certain sections by 2-3 meters in the Porgera River and by 6 meters in the Ok Tedi (IIED 2002).

Sediment deposition in the riverbank reduces flow capacity, increases the likelihood and severity of overbank flooding, and increases the extent of the floodplain and the footprint of the mine tailings. Much of the riverbank vegetation is killed off from the sedimentation because of a lack of oxygen and inundation with river water due to raised river beds (a phenomenon termed dieback). In the Ajkwa River downstream of the Grasberg mine, 130 square kilometers of flood plain had been created by 2002 and it is expected to increase to 220 square kilometers before the targeted time for mine closure. In 2002, it was reported that dieback had impacted approximately 480 square kilometers of rainforest along the Ok Tedi (IIED 2002).

Two additional direct issues of riverine disposal include:

- Disposal of mine tailings into rivers introduces heavy metals into the ecosystems and ore processing separation chemicals such as cyanide or frothing agents (cyanide treatment is employed by two mines prior to discharge to reduce levels of cyanide in the mine tailings); and
- Acid drainage from mine tailings created from exposure to water and air is an issue in overbank deposition of mine tailings in the floodplains. At the Ok Tedi mine, the natural ore body includes limestone which has a buffering effect, and at Grasberg, ore and limestone are blended to ensure a buffering capacity above the natural river capacity. Impact of acid drainage from the footprint of the mine tailings is a long term issue.

The overall impact of riverine disposal on biological resources is not difficult to predict. 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 (IIED 2002).

Tailings can also be transported to coastal waters, impacting sensitive ecosystems in estuaries and in ocean waters, such as coral reefs. Similar to river waters, sedimentation causes smothering and loss of habitat, reduced water quality, and reductions in abundance and diversity of fish populations. Elevated levels of metals, such as copper, lead, and arsenic, can cause direct acute and chronic toxicity and bioaccumulation in fish tissues may pose risks to human health (Ethics Council 2011).

The World Bank's Extractive Industries Review (EIR) in 2003 (World Bank 2003) stated:

Riverine tailing disposal is considered by some companies to be a practice of the past that is no longer acceptable. Scientific evidence clearly demonstrates that this method of waste disposal causes severe damage to water bodies and surrounding environments, and at least three major mining companies .Falconbridge, WMC, and BHP have made public statements that they will not use riverine tailings disposal in future projects. In practice, this technology is being phased out due to recognition of its negative consequences: today only three mines in the world, all on the island of New Guinea, still use this method to dispose of mine wastes. The EIR agrees with the call for a ban on riverine tailings disposal.

Issues of riverine disposal are environmental but also impact the community and people's way of life. See Box 15.

Box 15 Riverine Disposal of Mine Tailings Leads to Civil War

Bougainville copper mine closed in 1989, primarily due to social unrest resulting from massive environmental damage from riverine discharge of mine tailings and due to unmet claims from landowners. Bougainville mine is located in PNG on Bougainville Island at 670 meters elevation. The mine is in steep, rugged highlands in tropical forest with rainfall about 4.4 meters per year.

Mine tailings of about 130,000 tonnes per day were discharged to the Kawerong River which then flowed into the Jaba River and into the coastal plain. The tailings that did not settle in the coastal plains reached the sea in the Empress Augusta Bay, forming an extensive delta. One researcher stated that the rivers had been converted into a "tailings flume" resulting in unconfined and uncontrolled flooding

The riverine disposal of mine tailings destroyed most marine life in the estuary where freshwater fish also breed. The entire 480 square kilometers tributary system is essentially devoid of fish. The mine tailings have raised the river bed by 40 meters in some places, causing contaminated groundwater to spread into surrounding lands.

In 1987, Francis Ona won election to the Panguan Landowners Association, giving a new voice to the frustrations of the poor communities living in mountainous areas around the mining operation that faced land shortages, lack of income generating opportunities, and an environmental catastrophe.

Ona declared outright guerrilla war proclaiming, "*Our land is being polluted, our water is being polluted, the air we breathe is being polluted with dangerous chemicals that are slowly killing us and destroying our land for future generations. Better that we die fighting than to be slowly poisoned.*" (McIntosh 1990).

In 1988, Ona and other disenfranchised landowners began a campaign of industrial sabotage. This campaign started a civil war, a succession movement, and the PNG defense force assaulted villages using mortars, attack helicopters and automatic rifles. A blockade was placed around the island. The civil conflict lasted 8 years until a cease-fire was put in place. Some 20,000 Papua New Guineans lost their lives. The mine closed in 1989. Additional information is in the case study in Appendix 3.

Recovery of Marine and Riverine Environmental Resources

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 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. 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). See Box 16.

<u>Box 16 Recovery after Mine Closure (i.e., Stopping Marine Disposal of Mine Tailings)</u>

- How long will it take before new micorfauna will appear?
- What type of micofauna will be established (recolonization)?

A number of studies have been conducted on recovery, including such closed mines as Island Copper in Canada, Black Angel in Greenland, and a number of closed mines in Norway. These studies indicate that recolonization will occur but not necessarily with the same species that were originally present at the sites; sites with higher natural sedimentation were likely to bury the mine tailings more rapidly.

Norway

Scientific studies in Norway showed that re-colonization begins immediately as disposal of mine tailings ceases. In Jossinfjord, recolonization took place in 5-10 years whereas in Franfjorden, a community was established in one year (Jensen 2009). Average sedimentation rates in the ocean are very low in the deep ocean, and depending upon the location of the disposal site, it may take tens to hundreds of years before the footprint of the disposal site is capped by an appreciable layer of natural sediment (Shimmield 2010). Sedimentation rates in places such as the fjords of Norway are likely to be higher than ocean sites reported in the Shimmield report.

In Norway, the Norwegian Institute for Water Research (NIVA) is mounting a series of studies to assess the short and long term consequences of disposal of mine tailings in fjords. The project*, Improved Submarine Tailings Placement in Norwegian Fjords*, is financed 50 percent with funding from the Norwegian government, the Norwegian Research Council, and 50 percent from mining companies (Nordic Mining, Rana Gruber, Sydvaranger Mining, and Titania). The work is to be carried out over the next several years (NIVA website).

Papa New Guinea

Misima Mine was a large scale, open pit, gold and silver mine, located at the eastern end of Misima Island, within Papua New Guinea. Misima Island is a large mountain jutting out of the sea with fringing coral reefs very close to the shore, and steep submarine slopes to the south that extend down to a depth of 1,500 meters in the Bwagaoia Basin.

In the context of deep sea tailings placement, Misima was the first case outside of Canada in which deep sea tailings placement was publicly documented from conception, through construction, to operations. The mine at Misima was the first waste disposal system to use 'very deep' tailings disposal, with the bathyal plain (1,000-1,500 meters) in Bwagaioa Basin as the target area for its final tailings deposition zone (Jones and Ellis 1995). See Figure 15.

Government approval for the mine was granted in 1987 under the terms of the *Environmental Planning Act* 1978, and a Water Use Permit for deep sea tailings placement under the *Water Resources Act* 1982 was obtained. Construction of Misima mine began in 1988 and mining operations commenced in 1989. The mine closed in May 2004 following depletion of the mineable reserves.

The decision to allow deep sea tailings placement was made after a comprehensive evaluation of alternative waste disposal options. Factors considered in the selection of deep ocean disposal as the preferred waste disposal option included:

- Flat and gentle sloping land suitable for waste impoundment structures was in productive agricultural use, supporting the island's subsistence gardeners.
- Waste impoundment structures had to be located in the forested and mountainous hinterland to avoid use of agricultural land.
- Impoundment structures in mountainous terrain had to withstand severe seismic activity and cyclonic rainfall events.
- Impoundment structures in the mountainous hinterland posed a safety risk to the coastal villages below.
- The steep drop-off near shore on the south coast of Misima allowed discharge of tailings to the deep ocean floor.
- Fishing was only practiced in the shallow-water reef area, with no deep-water fishery.
- The risk of tailings upwelling to the surface waters could be minimized by locating the tailing outfall terminus below the mixed layer depth.

The outfall pipeline terminated at a depth of 112 meters on the steep submarine slope (>45degrees), approximately 200 meters offshore. The outfall terminus was located below the euphotic zone (80 meters) and deepest mixed layer depth (95 meters) to minimize the risk of tailings upwelling to the surface.

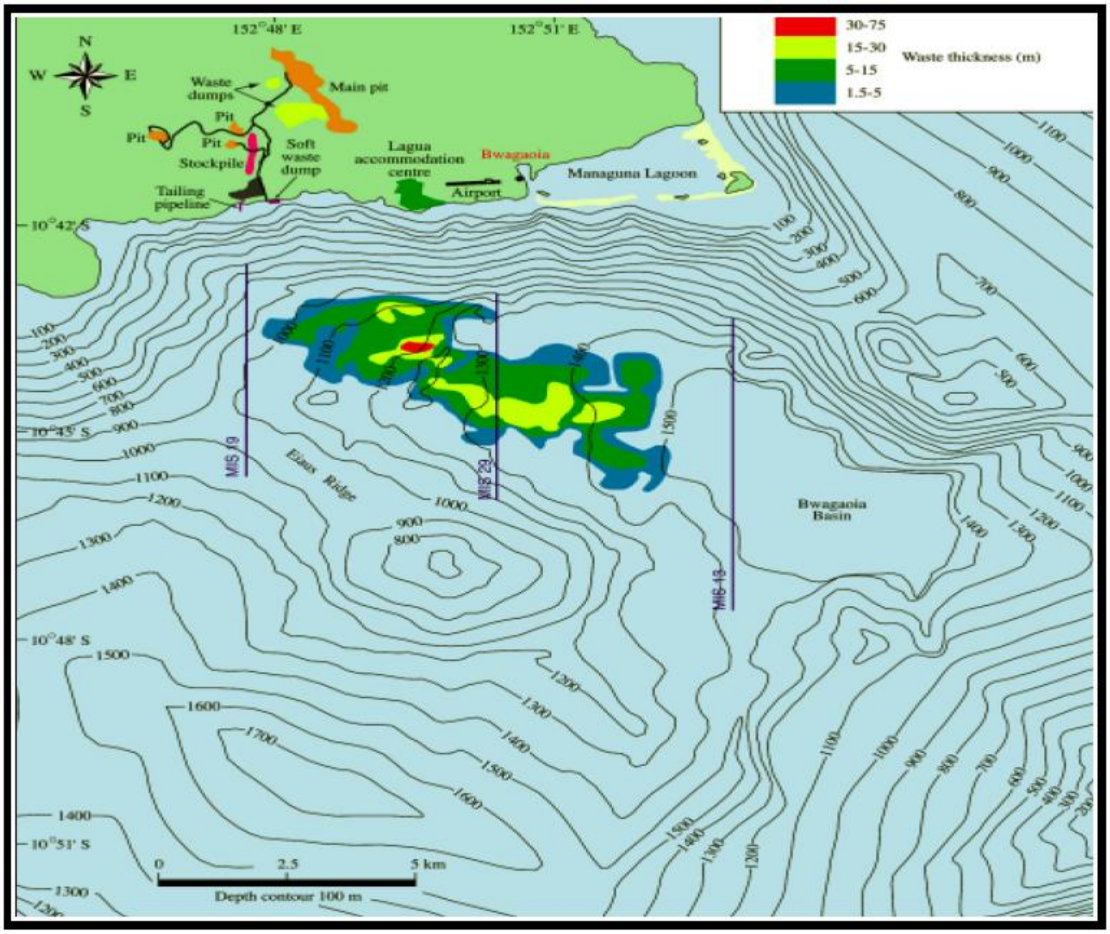


Figure 15 Bathymetry of the Bwagaoia basin showing the area and thickness of tailings and soft waste deposition from Misima Mine (source: Shimmield 2010).

After the Misima mine closed, the Scottish Association for Marine Science, sponsored by the government of PNG, conducted extensive work to assess recovery of the footprint (see Figure 15) where the mine tailings had been deposited. Results demonstrated that the benthic community at three sampling stations where mine tailings were deposited were significantly different in benthic abundance and community structure in comparison with three stations outside the Bwawaoia Basin. It was therefore inferred that significant tailings impacts on seabed animal communities were still apparent 3 years after the cessation of deep sea tailings placement at Misima (Shimmield 2010). Tailings had not spread to any extent outside of the targeted footprint.

Canada

Another example is the closed Island Copper Mine on Vancouver Island in Canada, which was allowed to discharge mine tailings into the marine waters of Rupert Inlet until the 1980s. In its two decades of operation, a total of 400 million tonnes of mine tailings were deposited at 50 meters depth, expecting the tailings to flow as a density current into the deep sea placement zone. When the government mining project was approved to practice sub-sea tailings disposal in the early 1980's, no formal environmental assessment process was required. The Scientific Review Panel established by the Canadian Minister of Fisheries and Oceans in the early 1980's concluded in its report dated July 31, 1983, that the tailings discharge from the mine had "no demonstrated effect on fishery resources of the water body". In reaching this conclusion, the Panel noted that toxicity tests showing "consistent survival at 100% level demonstrated that the tailings were not acutely toxic to fish".

Chemical and biological effects of the tailings in the water body were found to be negligible. Physical impacts associated with the deposition of the tailings solids were predicted to be a temporary effect of limited impact followed by rapid recolonization. This prediction was subsequently confirmed by benthic studies conducted in the years following the suspension of the operations. Annual biodiversity surveys of deposited tailings demonstrated that they can be re-colonized rapidly, within several years of the deposits stabilizing (IIED 2002). Studies showed that primary opportunists settle first, and within 1-2 years form a sustaining ecological succession.

However, in May 1996, the Canadian Department of the Environment released a consultant's report on the effect of unconfined tailings disposal in Canada's marine environment. The report examined decades of environmental monitoring data at the Island Copper mine site and concluded that the sea floor showed widespread and permanent alteration by tailings. In view of this and the very strong opposition to the disposal practice by local communities, the Canadian site specific regulations were repealed when the *Metal Mining Effluent Regulations* were promulgated in 2002 (Dioron 2012), the effects of which were to ban marine disposal of mine tailings.

VI Best Management Practices

Much has been written about how best to manage mine tailings and to promote sustainable mining. Mining is not an environmentally friendly operation, but mining is absolutely critical to supply needed metals and minerals for living; thus, many mining companies, federal and local governments, and environmental interest groups have prepared codes/principles/best practices on best environmental practices (BMP). These BMPs suggest the best and feasible approaches and factors to consider for:

1. Marine disposal of mine tailings,
2. Considerations for selection of disposal sites for marine disposal,
3. Management of mine tailings in on-site in tailings dams, and
4. Sustainable mining, considering the entire mining operation from exploration to mine closure and rehabilitation.

Note: there are no BMPs for riverine disposal, given that riverine disposal is not compatible with concepts of best environmental management.

Best Management Practices for Marine Disposal of Mine Tailings

For mining companies and the government permitting authorities that determine that marine disposal is the appropriate approach for their particular mine and local conditions, advice on best management practice has been prepared by several institutions and government agencies (Skotte 2011, Shimmield 2010, Australia Cyanide 2008, Skei et al 2009, Skei et al 2010, Interior 1994).

The advice on best management practice for marine disposal includes:

Technical and Engineering Considerations

- Tailings should not contain soluble toxic compounds. The flotation agents and flocculation compounds should be easily degradable. Effort should be expended into minimizing use of chemicals in the ore separation process.
- Cyanide management plans should be developed and implemented such that minimum levels of cyanide are used to achieve acceptable levels of separation, and specific treatment processes should be applied to reduce cyanide compounds resulting from the ore separation process prior to discharge.
- The mine tailings slurry should not contain air bubbles. A system to reduce entrainment of air into the tailings discharge pipe should be installed to avoid air bubbles bringing fine particles to surface waters.
- The tailings slurry should be a minimum of 30% solids.
- The tailings should be mixed with seawater to achieve a density of the suspension exceeding the density of the seawater where the tailings will be disposed. The intent is for the tailings plume to sink towards the bottom, with the finer particles moving as a density current to the seafloor instead of dispersing higher up in the water column.
- To help control fine particles, flocculants can be added to the mine tailings slurry.

- The outfall discharge pipes should be engineered to meet the conditions of the physical environment at the shoreline and to the depth of discharge.
    - A low energy environment is needed to reduce the potential for pipe breaks.
    - Experience has shown that the pipeline slope must be at least 12 degrees to avoid the risk of tailings build-up at the discharge point. The rate of discharge is also an important factor to minimize the possible blockage of the discharge.
- The discharge location should be below the pynocline, which is the depth at which water density increases rapidly due to changes in temperature or salinity. The intent is that the tailings plume does not mix with surface waters. Where the decline in temperature is responsible for the increase in density, the pynocline is also the thermocline. If an increase in salinity is responsible for the increase in density, then the pynocline is the halocline. Finally, the discharge should be below the euthropic zone, which is the zone of net primary productivity, below which insufficient light penetrates for photosynthesis.

Disposal Site Considerations

The disposal site should be selected based upon the following considerations:

- Suitable bathymetry and physical oceanography---steep submarine slopes, submarine canyons, or natural channels beyond fringing coral reefs; deposition zone such that mine tailings are not dispersed
- Suitable biological site avoiding important spawning grounds, or commercial or local fishing grounds—not a genetic source population or spawning ground for local fish populations
- Soft bottom depositional area
- Anoxic conditions—desirable to reduce rates of leaching of toxics from the mine tailings
- Absence of upwelling and seasonal overturning, and absence of currents that can disperse the initial plume of mine tailings away from the intended deposition site or cause turbidity plumes from the settled tailings to spread outside of the intended footprint

Permit Conditions

Prior to approval and issuance of permits or licenses for discharge, comprehensive environmental impact assessments, including risk assessments should be conducted.

- Permits or licenses to discharge should contain specific conditions capturing the above practices and should also include requirements for monitoring and assessment. Specific criteria should be established such that the results of monitoring can be assessed against criteria and standards.
- Monitoring is an important element as monitoring results allow adjustments and optimalization of discharge design to minimize environmental effects. A monitoring programme should be comprehensive to assure that the effects of the sea disposal develop as planned. If the environmental responses develop differently, actions should be taken and if necessary the disposal should terminate.

Best Management Practices for Management of Mine Tailings On-Land

Management of mine tailings is one of the primary issues addressed in mining operations. Mine tailings, except for the very few mines identified in this report, are disposed/stored in dams or impoundments, placed into abandoned portions of open pit mines, or placed in underground mines. A whole engineering and industry community, as well as many environmental interest groups and government agencies, is devoted to ensuring that mine tailings are properly managed in these on-site facilities.

A large number of best management practice documents, guidelines, and principles have been produced for management of mine tailings by governments around the world, mining companies, mining associations, and environmental interest groups. For example, the government of Australia produced a series of handbooks in the Leading Practice Sustainable Development Program for the Mining Industry that integrate environmental, economic, and social aspects through all phases of mineral production from exploration through construction, operation and mine site closure. The concept of leading practice is simply the best way of doing things for a given site. One of the handbooks is "Tailings Management," from which the general best practices in Box 17 have been extracted (Australia 2007). Another example on tailings management are the Principles of Effective Tailings Management prepared by the Minerals Council of Australia as summarized in Box 18.

Box 17 Best Practices for Mine Tailings Storage Facilities (Australia 2007)

- Tailings storage facilities are among the most visible legacies of a mining operation. Following closure and rehabilitation they are expected to be stable and produce no detrimental effects on the environment in perpetuity.
- Poorly designed or managed tailings storage facilities lead to increased closure costs, ongoing environmental impacts, and a perpetual risk to public health and safety.
- Tailings storage facilities should be designed, operated, closed and rehabilitated to ensure performance that meets or exceeds the criteria agreed to through consultation with key stakeholders. Each stage in the life of a tailings storage facility, from concept design to rehabilitation and aftercare, needs to be fully considered and documented in a series of reports within a tailings management plan, which is a 'living' document and fully shared early and through its development with stakeholders.
- The scale of the tailings management plan should match the scale of the project.
- Underground and pit backfilling need to be considered as alternatives to the surface storage of tailings, where possible. These alternatives act to reduce the mining footprint.
- Key considerations for leading practice tailings management are the siting of the tailings storage facility, geochemical characterization of the tailings, selection of the optimal tailings disposal method, containment of the tailings and design and construction of the containment wall, seepage control, tailings delivery, water management, dust control, and closure, decommissioning and rehabilitation.
- The principal objective of tailings storage facility closure, decommissioning and rehabilitation is to leave the facility safe, stable, and non-contaminating, with little need for ongoing maintenance.

Box 18 Principles of Effective Tailings Management

The Minerals Council of Australia recognises nine key principles of effective tailings management in its Tailings Management Policy adopted in April 2000 (Minerals Council 2003). The key principles are to:

1. Adopt a risk-based approach;
2. Minimise the production of tailings and maximise their safe re-use;
3. Ensure all tailings structures are operationally stable, able to be rehabilitated and retain their long-term integrity;
4. Consider economic, environmental and social aspects in all stages of tailings management to minimise short- and long-term impacts;
5. Contribute to focused and relevant research into strategic issues aimed at improved tailings management;
6. Share knowledge and expertise across industry on best practice approaches;
7. Recognise that effective stakeholder involvement is essential for successful planning, management and closure of tailings storage facilities;
8. Promote understanding of potential community health issues relating to tailings; and
9. Effectively monitor and report on tailings management practice.

Site selection is the most important aspect in tailings storage facility design. Different sites have different characteristics and a suitable location is important in terms of cost and practical operating considerations. The tailings characteristics will have an effect on the type of storage impoundment area, and therefore the site location (European Commission 2009). Primarily the site selection is dependent on the storage capacity required of the facility, the site availability, the construction, operating and closure costs, geotechnical and geological conditions, the hydrology of the area, and the ease of the day to day operations. Other site selection considerations are (extracted from Tailings Info website):

1. Land ownership, rights and boundaries
2. Location of future ore bodies
3. Rare or protected flora and fauna
4. Borrow materials available and locality
5. Surface water management and flood/river diversion
6. Environmental hazards
7. Impoundment area available and expansion potential
8. Proximity to local residents/infrastructure
9. Proximity to local drinking water
10. Distance and elevation from processing plant
11. Seepage control
12. Climate
13. Suitability of reclaim pond

14. Geology and seismic conditions
15. Legislation requirements
16. Historical site data
17. Performance and historical data on other tailings facilities in the area
18. Ease of access to the site for day to day operations (including emergency access during storm conditions).

At the international level, the International Commission on Large Dams (ICOLD) and the National Committees of its 81 member countries, provides a forum for technical interaction amongst dam designers and constructors. ICOLD has numerous technical committees that publish Bulletins providing guidance on various aspects of dam design, construction, and monitoring. As an additional example of the types of information available, Box 19 includes a list of Bulletins available from ICOLD.

Box 19 Information on Sustainable design and post-closure performance of tailings dams from the International Commission on Large Dams (ICOLD publications website)

Bulletin 139 - 2011 -
Improving tailings dam safety - Critical aspects of management, design, operation and closure.

Bulletin 121 - 2001 -
Tailings dams risk of dangerous occurrences - Lessons learnt from practical experiences

Bulletin 114 - 1999 -
Embankment dams with bituminous concrete facing

Bulletin 106 - 1996 -
A guide to Tailings Dams and impoundments - Design, construction, use and rehabilitation

Bulletin 104 - 1996 -
Monitoring of Tailings Dams - Review and Recommendations

Bulletin 103 - 1996 -
Tailings Dams and Environment - Review and Recommendations

Bulletin 101 - 1995 -
Tailings Dams. Transport. Placement. Decantation - Review and recommendations

Bulletin 98 - 1995 -
Tailings Dams and Seismicity - Review and Recommendations

Bulletin 97-1994
Tailings Dams – Design of Drainage

Two final examples:

1. The Mining Association of Canada developed three documents providing guidance on management of mine tailings (www.mining.ca):
   - A Guide to the Management of Tailings Facilities (2009);
   - Developing an Operation, Maintenance and Surveillance Manual for Tailings and Water Management Facilities (2005); and
   - A Guide to Audit and Assessment of Tailings Facility Management (2009).

2. The European Commission's "Reference Document on Best Available Techniques for Management of Tailings and Waste-Rock in Mining Activities (January 2009)" is an excellent background document on mining/mine tailings and a comprehensive guide to best available practices for management of mine tailings (European Commission 2009)

Best Management Practices for Mining

For mining, just not mine tailings, a large number of documents on best management practices, sustainable practices, principles, codes, and guidelines have been prepared by mining companies, mining trade associations, governments at international/federal/local levels, and by interest groups. Some of these are brief statement of principles while others provide detailed guidance and advice on techniques, approaches for conduct of each phase of mining in an environmentally sustainable approach. Within each of these published codes, principles, or BMPs are reference and advice on environmental management of mine tailings. The intent of this report is not to provide a comprehensive list of these BMP-type of statements/codes, but to provide the reader knowledge that they exist and to provide a sample list. See Box 20.

Box 20 Samples of Mining BMPs, Principles, Policies, and Codes of Practice	
Environment Canada	Environmental Code of Practice for Metal Mines 2009
Australia Department of Resources, Energy and Tourism	A Guide to Leading Practice Sustainable Development in Mining 2011
International Council on Mining and Metals	Sustainable Development Framework, 10 Principles, and 7 Position Papers
USA National Mining Association	Sustainable Development Principles, 2002
International Council on Mining and Metals	Good Practice Guidance for Mining and Biodiversity, 2006
International Finance Corporation	Environmental, Health, and Safety Guidelines for Mining, 2007
Conservation International	Lightening the Lode: A Guide to Responsible Large Scale Mining, 2000
Inmet Mining Company	Waste Management Policy, 2012
Newmont Mining Company	Beyond the Mine: The Journey Towards Sustainability

VII Legislation and Regulations: Marine and Riverine Disposal of Mine Tailings

This section provides a brief summary of existing legislation and regulations for countries that allow marine and riverine disposal of mine tailings and for several countries that do not allow disposal of mine tailings into marine or riverine waters. One note: this is not a comprehensive list of countries and their legislation for disposal of mine tailings, but a list that provides information on the key countries that allow marine or riverine disposal and a few examples of countries that prohibit disposal.

Papua New Guinea

The primary environmental protection legislation is the *Environment Act 2000* which was passed in November 2000. See Box 21. Under the Environment Act, the Department of Environment and Conservation is responsible for environmental assessments, monitoring and enforcement, while the Mineral Resources Authority is responsible for monitoring the mining operations and environmental safeguards.

Box 21 PNG Legislation on Mining and the Environment

- 1992 Mining Act – Condition for grant of Mine Production License
- Mining Safety Act – Independent assessment and approval by the Chief Inspector prior to construction
- Environment Planning Act 1978
- Environment Contaminant Act 1978
- Water Resources Act 1982
- Environment Act 2000
  – Set the minimum environment standards that mine operators should meet

  – Assess the scientific and toxicity aspect of the DSTP

  – Ensure Environment Assessment and Management Plans meet international standards

  – Undertake regular inspection and audits
- The Mineral Resources Authority and the Department of Environment and Conservation jointly consult the mining affected community

The key provision in the Environment Act is section 7(1) – —a person shall not carry out an activity that causes or is likely to cause an environmental harm unless the person takes all reasonable and practicable measures to prevent or minimize the environmental harm. Exemptions exist for certain mining operations for which legislation/agreements were already in-place, such as Ok Tedi and Bougainville, when the legislation came into effect.

Draft guidelines for deep sea mine tailings placement are currently under consideration by the Papua New Guinea government. The guidelines were originally drafted by the Scottish Association for Marine Science (Shimmield 2010) and were presented as an information paper to the Scientific Group meeting of the London Convention/London Protocol in 2011 (London Convention Scientific Group 2011) (ramumine.files.wordpress.com)(Scottish Association for Marine Science 2010).

Indonesia

The primary Indonesian environmental protection legislation is the Environmental Management Law 1997. Key regulations under the law for control of marine and riverine mine tailings disposal are the Water Quality Management and Water Pollution Control Regulation 2001. Marine disposal is essentially regulated by the water quality standards set by those regulations. It has been argued that riverine disposal is expressly prohibited under those regulations:[5]

> *Indonesia's parliament ratified the Water Quality Management and Water Pollution Control Regulations 2001 [PP 82/2001 tentang Pengelolaan Kualitas Air dan Pengendalian Pencemaran Air]. Clause 42 of these regulations, in conjunction with the official explanatory text, expressly prohibits riverine disposal of mine tailings:*
>
> *Clause 42:*
> *All persons are prohibited from disposing of solid or gaseous waste into water or water resources.*
>
> *Official explanatory text for Clause 42 (translated):*
> *"The meaning of solid waste includes waste in the form of mud and/or slurry. An example of solid waste disposal is the disposal or placement of industrial waste and/or mining waste in the form of tailings, into water or water resources."*

It appears that the existing riverine discharge at Grasberg has been grandfathered by government agreements signed before the legislation and regulations were in effect. The Governor of Papua issued a permit in 1996 to the Grasberg mine for riverine disposal, but the Indonesian Environmental Minister at the time took issue with the permit saying it "*had no authority to grant permits more lenient than the provisions of national laws*" (Perlez 2005). In 2009, Law No. 32/2009, Protection and Management of the Environment, was put in place.

[5] WAHLI-Indonesian Forum for Environment, The Environmental Impacts of Freeport-Rio Tinto's Copper and Gold Mining Operation in Papua. Jakarta, 2006.

Turkey

Turkey is currently developing Mines Waste Regulations to align with European Union standards, and it is anticipated that continued acceptance of deep sea tailings placement will be included within these regulations. In 2011, Çayeli Bakir mine received its Integrated Environmental Permit from the Turkish regulators which governs the environmental requirements at the site. In compliance with applicable Turkish approvals, Çayeli Bakir disposes of mine waste tailings at a depth of 275 meters in the Black Sea.

Norway

Waste management and pollution prevention in Norway is based on the Pollution Control Act (into force from 1983). The Act includes the precautionary principle and makes it illegal to pollute or to entail a risk of pollution if not specifically allowed by the law. It is an enabling act in the sense that it gives guidelines and legal grounds for decisive considerations, but has few direct standards or minimum requirements. A permit from the pollution authority to operate is mandatory pursuant to the Pollution Control Act (Hagenlund 2009).

All European Union regulations relevant to mining operations are or will be implemented into Norwegian law. Examples are the directives on Landfill, Water Framework, IPPC, and Waste from Extractive Industries.

To obtain a permit for mining operations, one has to start with a formal discussion on the content and scope of the application, including discussions with stakeholders. The assessment need to take into consideration the benefits for the company compared to the effects on the environment. A too high of risk which violates certain minimum environmental requirements could conclude with a refusal for the permit.

The act gives legal basis for further regulations and decisions made on judgment, but rarely puts down specific standards or minimum requirements. As the European Union legislation is implemented, there will be movement towards more specific standards in the regulations, and management of waste and pollution from mining activities will be strengthened when Norway implements the Directive on Waste from Extractive Industries (2006/21/EC) (European Commission 2006). Central points in the directive are:

- A permit is to be issued by the competent authorities.
- When a new waste facility is built or an existing one modified, the competent authority must satisfy itself that:
    - the facility is suitably located;
    - its physical stability is ensured and soil and water pollution are prevented;
    - it is monitored and inspected by competent persons;
    - arrangements are made for the closure of the facility, the rehabilitation of the land and the after-closure phase.

Philippines

As part of the holistic approach to improving the management of tailings and impounding structures, the Philippines Mines and Geosciences Bureau promulgated on November 24, 1999, DENR

Memorandum Order No. 99-32, otherwise known as the "Policy Guidelines and Standards for Mine Wastes and Mill Tailings Management". For mine tailings disposal, the guidelines and standards include:

VI. Marine Tailings Disposal

A. Marine disposal may be considered under strict conditions, to include:

1. The tailings will settle in areas of very low biological productivity (at depths of more than 100m; or

2. The tailings will settle in an area subject to high existing rates of sedimentation, provided that in both situations, the dissolved constituents of the tailings beyond an immediate mixing zone shall conform to the existing and/or relevant Water Quality Criteria of the Department;

3. Marine disposal is not precluded in situations other than those described above. However, it is necessary to demonstrate clearly that:

a. Other disposal means are not feasible or marine disposal will be less environmentally damaging than other alternatives; and

b. Adequate compensation will be paid to any person adversely affected by the actions.

B. Overall benefits of the mining operation will more than offset the environmental losses that will be incurred as a result.

<u>Canada</u>

The regulations that allowed site specific proposals were repealed in 2002. Those previous regulations essentially banned the approval of marine discharge of mine tailings, as there was a very difficult administrative process if a company proposed marine disposal of mine tailings. When the *Metal Mining Effluent Regulations* were promulgated in 2002, this action explicitly prohibited marine disposal of mine tailings.

The Metals Mining Effluent Regulations can be found at:
http://www.ec.gc.ca/Publications/default.asp?lang=En&xml=2EE03F4A-959F-441F-858F-85C9AB71EC43

The Environmental Code of Practice for Metal Mines is designed to support the *Metal Mining Effluent Regulations* under the Fisheries Act and includes other subjects that are not dealt with in the MMER that may have an influence on the environmental impact of mining operations. The Code of Practice can be accessed at http://www.ec.gc.ca/lcpe-cepa/default.asp?lang=En&n=CBE3CD59-1. In addition, the Guidance Document for the Sampling and Analysis of Metal Mining Effluents is located at http://www.ec.gc.ca/toxiques-toxics/default.asp?lang=En&xml=D4AC4420-1FED-434E-A4CF-22F310232C0D.

Environment Canada's perspective is that all deposits of mine waste into natural water bodies should be physically contained and that all effluents from the facility should be through a final discharge point that is monitored and reported upon on a defined basis. These requirements are specified in the *Metal*

Mining Effluent Regulations and the concept is widely accepted as being appropriate to Canadian mining operations (Doiron 2010).

South Africa

Mining in South Africa is regulated by the Water Act 1998, the Minerals Act 1991 and the Mine Health and Safety Act 1996. The Department of Minerals and Energy is responsible for implementing the provisions of the Acts.

The principle management guidance document for tailings facilities in South Africa is the Code of Practice for Mine Residue Deposits published by the South African Bureau of Standards in 1998. The standard, referred to as SABS 0286:1998 (later renamed to SANS 10286), contains fundamental objectives, the principles and minimum requirements for best practice, all aimed at ensuring that no unavoidable risks, problems and/or legacies are left to future generations.

Tailings management in South Africa is regulated by law in the Guideline for the Compilation of a Mandatory Code of Practice on Mine Residue Deposits issued by the Department of Mineral Resources in 2000. This guideline makes implementation of a code of practice mandatory for each tailings facility with compulsory adherence to the SANS 10286, Code of Practice for Mine Residue Deposits (www.Tailings.Info).

Australia

Australia has a system of federal as well as state (Victoria, New South Wales, Queensland, South Australia, Western Australia & Tasmania) and territory (Northern Territory and Australian Capital Territory) governments.

At the federal level, the relevant environmental protection legislation is the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The *Environment Protection and Biodiversity Conservation Act* does not specifically mention tailings discharges per se, however it can provide a mechanism to regulate mining activities. The *Environment Protection and Biodiversity Conservation Act* regulates impacts on matters of national environmental significance. Further information is at the following sites:

http://www.environment.gov.au/epbc/index.html

http://www.environment.gov.au/epbc/protect/index.html

http://www.environment.gov.au/epbc/approval.html

State and territory governments are mainly responsible for regulating mining activities. Each state or territory has its own relevant legislation and/or guidelines for the regulation and management of mining activities. Mostly, regulation occurs through mining/resource departments. For example, in Western Australia, mining is regulated by the Department of Mining and Petroleum. In every state and territory, mining companies must submit a mining proposal (or similar document) to the state/territory regulator for approval. This sets out how it is intended that mining will occur and how environmental impacts will be addressed. It is common practice for all mining proposals to at least include a conceptual closure plan, explaining how closure and rehabilitation would occur and how residual environmental risks would be addressed. An example of closure requirements in Western Australia is at: http://www.dmp.wa.gov.au/documents/Mine_Closure(2).pdf.

Each state and territory government also has a formal environmental impact assessment process where a company must prepare an environmental impact statement (or similar document). Not all mining activities require this level of assessment. The triggers vary from state to state but generally relate to the likelihood of a significant impact on the environment. In Western Australia, this is regulated by the Environmental Protection Authority under the *Environmental Protection Act 1986*. Information on the Western Australian process is at: http://www.epa.wa.gov.au/EIA/assessdev/Pages/default.aspx?cat=EIA%20process&url=EIA/assessdev.

European Union

The European Union introduced measures in 2006 to prevent or minimise any adverse effects on the environment and resultant risks to health resulting from the management of waste from the mining industry, including mine tailings. The Directive applies to waste resulting from the extraction, treatment and storage of mineral resources and the working of quarries.

Directive 2006/21/EC of the European Parliament on the management of waste from extractive industries can be found at:
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:102:00150033:EN:PDF

In addition to Directive 21 of the European Commission, a comprehensive set of Best Available Technologies are specified for management of mine tailings.
http://ec.europa.eu/environment/waste/mining/bat.htm

USA

Regulations in the USA under the Environmental Protection Agency effectively ban discharge of mine tailings into marine waters. Effluent limitation guidelines established under the Clean Water Act prohibit the discharge of process water from new mines into waters of the U.S. (including process water contained in tailings). The 'no discharge' effluent limitations effectively prohibit the use of marine disposal of mine tailings (Kirby 2012). No mines in the United States currently dispose of mine tailings in marine waters.

The USA effluent discharge requirements for mine tailings are included in the United States Code of Federal Regulations Title 40, Protection of the Environment, Subchapter N, Part 440: *Effluent Guidelines and Standards,* Environmental Protection Agency, April 14, 2001 (USEPA 2001).

Russian Federation

Under the Ministry of Natural Resources and Environment in the current Russian Federation legislation, Russian Federation Water Code – Federal Law No.74 of 3 June 2006; Federal Law No.155 of 31 July 1998 on “Inland waters, territorial sea and adjacent zone of the Russian Federation”, the dumping of waste and other matter into water bodies, as well as the dumping of harmful substances, is prohibited.

Brazil

The Brazilian legal framework, specifically the National Environmental Policy (Law 6.938/81), predicts quality standards aiming to control disposal of pollutant substances in the natural environment. Thus, pollutant generating facilities must present an effluent treatment plan addressing certain conditions and limits set by the environmental authority. Mining residues disposal must be done in closed cycle with no spreading to the natural environment (soil or water).

Guidance for Preparation and Evaluation of Environmental Impact Assessments

Preparation of a comprehensive environmental impact assessment prior to approval and to development and operation of mines is a key element in most country’s environmental legislation and regulations. There are a number of guidance documents prepared specifically for the mining industry that provide technical advice on the contents and key points to consider in the evaluation process of environmental impact assessments. Three of these include:

- Environmental Impact Assessment Guidelines for Mine Development and Tailings Disposal at Tropical Coastal Mines; South Pacific Regional Environment Programme, UNEP, SPREP Reports and Studies Series no. 95, 1996. Author: Derek Ellis (Ellis 1996).
- EIA Technical Review Guideline: Non-Metal and Metal Mining; U.S.EPA, U.S. AID, and Central American Commission on Environment and Development; 2012. Included in Volume II, Appendices, to the 2012 EIA Technical Review Guideline noted above is a summary of a number of country’s water quality standards, industrial discharge standards, and drinking water standards (US EPA et al 2012).
- Guidebook for Evaluating Mining Project EIAs; Environmental Law Alliance Worldwide, 2010 (Environmental Law 2010).

VIII Findings and Conclusions

Disposal of mine tailings is a significant challenge and a unique challenge relative to other waste disposal issues. Mining and disposal of mine tailings is not an environmentally friendly activity. However, mining is absolutely essential to work, live, and play. Disposal of mine tailings presents a unique issue in that both on-land disposal and marine disposal result in significant environmental risks and documented damage to habitats and fish/wildlife. The vast majority of mines dispose of mine tailings in well-designed and managed on-land tailings storage facilities. Some believe that even though marine disposal of mine tailings may have substantial impact on marine ecosystems, it may prove to be the best of a damaging set of options for a specific location. Findings and conclusions are the following:

1. A total of 18 mines (i.e., 0.7%) out of approximately 2,500 large scale mines world-wide use marine or riverine disposal for mine tailings.
    - Four mines are disposing mine tailings into rivers, all of which are in Papua New Guinea and Indonesia. Judging by general acceptability criteria in all other parts of the world, disposal of mine tailings into riverine environments is not a sustainable practice, having been phased out in all locations around the world (except Indonesia and PNG) when the extensive damage to riverine environments was recognized.
    - Fourteen mines are disposing of mine tailings into marine waters.

2. All of the mines have government permits (or the equivalent) to discharge mine tailings into marine or riverine waters. The rationale to allow marine or riverine disposal, verses land disposal, is one of feasibility and economics.
    - In Indonesia and Papua New Guinea, the argument is made that it is economically and technically infeasible to construct tailing storage facilities due to topography, high rainfall, instability of land forms, and seismic activity. Special concerns relate to the safety of downstream communities, because the integrity of tailings storage facilities must be maintained in perpetuity.
    - In Norway, the argument is one of economics, feasibility to construct tailings storage facilities, and "temporary" impacts to fjords.
    - In Turkey, the argument is that submarine disposal is an environmentally sound practice, given that the mine tailings are deposited in anaerobic waters at a depth of 2,000 meters.

3. In general, riverine disposal of mine tailings is causing significant damage to the river environments, increasing sediment loading, raising river bed depths causing flooding over river banks, depositing heavy metals in the river, smothering habitats, and providing sulfide-laden sediments that can create acid runoff when exposed to air and water. However, information that is available in reports from the mining companies and sponsored by the mining companies is that they are achieving their permit limits. Independent reports, such as the WALHI sponsored assessment of the mine tailings discharge into the into the Aghawagon-Otomona-Ajkwa river system by Freeport McMoRan's copper and gold mine at Grasberg, demonstrated catastrophic damage to the river and ecosystem. Another example is the Barrick Gold mine at

Porgera, which is achieving permit limits at a specific point of compliance set in the permit in the river which is 100 kilometers downstream of the mine. Upstream of that point, reports show serious impacts to the river water and sediment quality. As stated in IIED:

The main concerns with riverine disposal are that river ecosystems are highly vulnerable to the addition of excessive quantities of sediment. Sedimentation of the river bed creates major problems with flooding and the consequent rising of water tables downstream destroys riverine and floodplain forests and any associated agricultural developments. It is thought that this approach should be discounted on the grounds of sustainability as it leaves a massive environmental burden for future generations (IIED 2002).

4. The concept of submarine tailings disposal or deep sea tailings disposal is to place the mine tailings on the deep sea floor in the denser sea waters below the mixed upper waters and below the ecological productive zone. Deep has different meanings in Indonesia/PNG/Turkey and in Norway, given that the seafloor depths where mine tailings are deposited are greater than 1,000 meters in Indonesia/PNG/Turkey verses 30 to 300 meters in Norway. The objective is the same: to place mine tailings such that they do not mix with surface mixed and biologically productive waters.

5. Known and documented impacts from marine disposal include:
   - Smothering all benthic organisms in the disposal site and physically altering the bottom habitat,
   - Reduction in species composition/abundance and biodiversity of marine communities, and
   - Bioaccumulation of metals through food webs and ultimately into human fish-consuming communities-increases in risk to human health.

   The extent of impacts beyond the intended footprint is the real question, as currents, up-welling, and inappropriate site location may result in spreading the mine tailings to adjacent habitats and to the surface water fisheries.

6. For those mines using marine disposal, an environmental impact assessment (or an equivalent) was prepared prior to mine operations which identified and characterized the disposal site. The issues are whether sufficient scientific information was available to make an informed decision, and, of course, whether the environmental impacts are acceptable. There is no argument that the disposal site and its benthic community will be smothered, changing the ecological community and the numbers and types of aquatic organisms that reside there. The size of the footprint can be quite large, e.g., 150 square kilometers at the Lihir mine in Papua New Guinea. Beyond the size of the footprint and its associated impacts, the question relates to whether currents or up-welling events will spread the mine tailings to upper surface waters or to adjacent habitats. Additional studies and research are needed at most sites to confirm that mine tailings are not causing impacts in adjacent habitats.

7. Each of the countries that allows marine disposal of mine tailings has environmental legislation, environmental regulations, and a system of permitting. In the reports and literature reviewed, it appears that mines are reporting that they are, for the most part, achieving permit conditions, some of which include extensive monitoring requirements for water and sediment quality, bioaccumulation in fish tissues, and ecosystem health. The author did not review permit conditions for each of the mines, but makes the general observation that achieving permit conditions and minimizing damage to the marine environment are not necessarily the same. The issue is one of "stringency." Many permits were issued based upon the results of the environmental impact assessment prepared prior to mine operation; a few have updated permit conditions since that time.

8. Studies indicate that recolonization will occur but not necessarily with the same species that were originally present at the sites. 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. *Recolonization is not the same as recovery.* Long term recovery is likely directly related to natural sedimentation. Average sedimentation rates in the ocean are very low in the deep ocean, and depending upon the location of the disposal site, it may take tens to hundreds of years before the footprint of the disposal site is capped by an appreciable layer of natural sediment. Sedimentation rates in places such as the fjords of Norway are likely to be higher than ocean sites in Indonesia and Papua New Guinea.

9. Many mining companies, federal and local governments, and industry and environmental interest groups have prepared codes/principles/best practices for management of mine tailings, including on-land disposal, marine disposal, and sustainable mining. There is an entire support segment of the mining industry dedicated to effective management of mine tailings on-land.

   No specific guidance for marine disposal of mine tailings is yet available from a country (e.g., draft guidance is under review in Papua New Guinea) or from an internationally recognized regulatory or scientific body, such as the London Protocol's Waste Assessment Procedures (i.e., targeted to an dumping of wastes, not discharging of wastes) or UNEP's Global Plan of Action for land-based sources. Decisions on the disposal of mine tailings by government authorities are based upon a weighing of a number of factors, such as economic, technical, social policy, and environmental considerations; the availability of specific guidance on marine disposal of mine tailings may be useful in the decision-making process for new mine proposals as well as permit renewals.

   The author of this report did not find any best management practices for riverine disposal, concluding that riverine disposal is not compatible with concepts of "best practice."

10. A number of mines around the world are in the early stages of development and are considering marine disposal as one of the alternatives for disposal of mine tailings.

- Comprehensive environmental risk assessments should be conducted comparing alternatives before decisions are reached. Disposal site selection is critical to minimizing environmental damage.
- The chemical and biological characteristics of mine tailings and their potential impacts on water and sediment quality, biological resources, and ecosystems should be assessed.
- Monitoring of pre-disposal conditions should be conducted for several years prior to mine operation to establish a baseline of environmental quality.

Appendices

Appendix 1 List of References

Allens website: http://www.aar.com.au/pubs/res/fores19aug11.htm

Apte, S., and Y.T. Kwong. 2004. Deep sea tailings placement: Critical review of environmental issues. Joint ACMER/CSIRO/CANMET Report. 94 pp.

Australia Department of Industry, “Tailings Management”, Leading Practice Sustainable Development Program for the the Mining Industry, February 2007.

Australia Department of Resources, Energy and Tourism; A Guide to Leading Practice Sustainable Development in Mining 2011; www.ret.gov.au/sdmining; www.ret.gov.au

Australian Government Department of Resources, Energy, and Tourism; Series of Leading Practice Documents on Mining operations; http://www.ret.gov.au/resources/Pages/Publications.aspx

Australian Government Department of Resources, Energy, and Tourism; Cyanide Management; 2008; http://www.ret.gov.au/resources/Pages/Publications.aspx

Batterham, Grant; and Waworuntu, Jorina; *Deep Sea Tailings Placement at Batu Hijau, Sumbawa, Indonesia*, Egersund Conference, 2009.

Brewer, David, “Impacts of gold mine waste disposal deepwater fish in a pristine tropical marine system;” Marine Pollution Bulletin, March 2007.

Berkum, M.*; Submarine tailings placement by a copper mine in the deep anoxic zone of the Black Sea;* Water Research 39:5005-5016, 2005.

Council on Ethics for the Government Pension Fund Global Annual Report, 2011

Davies, M. P. and T. E. Martin (2000). Upstream constructed tailings dams - A review of the basics. Tailings and Mine Waste 00. Colorado, USA, A.A. Balkema, Rotterdam: pp. 3-15.

Doiron, Chris; Chief, Mining and Processing Division, Environment Canada, Response to LC/LP Questionnaire, 2010.

Doiron, Chris; Environment Canada, Chief, Mining and Processing Division, Environment Canada; Email, 4 May 2012.

Ellis, Derek; *Environmental Impact Assessment Guidelines for Mine Development and Tailings Disposal at Tropical Coastal Mines*; South Pacific Regional Environment Programme, UNEP, SPREP Reports and Studies Series no. 95, 1996.

Environment Australia; Cyanide Management, Overview of Best Practice Environmental Management in Mining; 1998.

Environment Australia; Overview of Best Practice Environmental Management in Mining; April 2002.

Environmental Law Alliance Worldwide; Guidebook for Evaluating Mining Project EIAs; 2010.

Environment Canada, Environmental Code of Practice for Metal Mines**,** 2009 1/MM/17

European Commission; "Reference Document on Best Available Techniques for Management of Tailings and Waste-Rock in Mining Activities,"January 2009

European Commission; *Directive on Waste from Extractive Industries* (2006/21/EC) http://www.ec.europa.eu/environment/waste/mining/index.htm

Fosssă, Jan Helge; Aure, Jan; Meier Sonnich, Wennevik; *Effects of mine tailings disposal on the ecosystem and biodiversity in the marine environment - a critical view*; Institute of Marine Research; Egersund Conference, 2009.

Ginting, Pius; Email 23 May 2012.

Hagenlund, Gosta;. Deputy Director, Department of Environmental Protection, County Governor of Sogn og Fjordane, Norway; *Permit to operate according to the Pollution Control Act – processes and legislation;* Presentation at Marine and Lake Disposal of Mine Tailings and Waste Rock Conference; Egersund Conference*,* 2009.

Hoang, Son; *The Los Frailes Tailings Dam Failure (Aznalcóllar, Spain),* undated.

ICMM, Sustainable Development http://www.icmm.com/our-work/sustainable-development-framework

ICOLD Website (International Commission on Large Dams): http://www.icold-cigb.org/

ICOLD publications: http://www.icold-cigb.org/GB/Publications/moteur_bulletin.asp

IIED, Mining for the Future; *Appendix A: Large Volume Waste Working Paper*, April 2002.

Inmet Mining, *Waste Management Policy*, February 2012, http://www.inmetmining.com/corporateresponsibility/policiesstandards/default.aspx

International Finance Corporation; Environment, Health and Safety Guidelines for Mining; 10 December 2007.

Jansons, Karlis, *Managing Tailings for Continual Improvement: Efforts Made by the Mining Association of Canada;* September 2009.

Jarkarta Post, April 17, 2012

Jensen, Tor; "Re-building fauna in marine mining disposal with examples from Titania and Hustadmarmor," Egersund Conference, 2009.

Jones, S.G. and Ellis, D.V., 1995. Deep water STD at the Misima gold and silver mine, Papua New Guinea. *Marine Georesources and Geotechnology*, 13(1-2): 183-200.

Kirby, Ronald; Personal Communication; Retired U.S. EPA, Project Officer for Effluent Limitations for Mining Industry, June 2012.

Kvalsund; http://www.kvalsund.kommune.no/getfile.php/1660155.747.vusqfuvrxa/Reguleringsplan+med+konsekvensutredning+Nussir%2C+03.06.2011.pdf page 154; 2011.

Limu, Pawa; email; 16 July 2012.

London Convention/London Protocol Scientific Group; *Coastal Management Issues Associated with Activities to Prevent Marine Pollution: Co-Operation with UNEP-GPA—Riverine and Sub-sea Disposal of Tailings and Associated Wastes from Mining Operations, Progress report and an example of Deep Sea Mine Tailings Placement Guidelines,* LC/SG 34/8/2, 2011.

London Protocol; *London Convention 1972 and 1996 Protocol*, IMO, 2003 edition, ISBN 92-801-4155-4, IMO Publication No. IA532E.

McKinnon, Elizabeth, *The environmental effects of mining waste disposal at Lihir Gold Mine*, *Papua New Guinea,* Journal of Rural and Remote Environmental Health 1(2): 40-50 (2002)

Mine Engineer website: http://mine-engineer.com/mining/minerals_Computer2.htm

Minerals Council of Australia; Strategic Framework for Tailings Management; 2003

Mines and Communities website: http://www.minesandcommunities.org/article.php?a=10439

Mining Journal website: http://www.mining-journal.com/knowledge/Mining-101#Marketplace

MiningWatch Canada, Two Million Tonnes per Day, A Mine Waste Primer, December 2009.

Ministerial Council on Mineral and Petroleum Resources

MMSD, Mining for the Future, Appendix A:Large Volume Waste Working Paper, April 2002.

Muller, Mark; Mine Wastes; London Mining Network; 2009; http://www.slideshare.net/LondonMiningNetwork/mine-wastes

Murray, Len; Thompson, Mark; Obstacles to On-Land Mine Tailings Disposal in Papua New Guinea, undated.

National Mining Association website: http://www.nma.org/statistics/fast_facts.asp

Newmont Mining; Beyond the Mine: The Journal Towards Sustainability; http://www.beyondthemine.com/2011/about_this_report

NIVA website: http://www.niva.no.

Paul Greisman, *DSTP Site and Substance (No two systems are identical),* Rescan Environmental Services Ltd. Vancouver, Canada, Egersund, Norway, September 2009.

Plumlee, Geoffrey; Morton, Robert; Boyle, Terence; Medlin, Jack; and Centeno, Jose; An Overview of Mining-Related Environmental and Human Health Issues, Marinduque Island, Philippines: Observations from a Joint U.S. Geological Survey – Armed Forces Institute of Pathology Reconnaissance Field Evaluation, May 12-19, 2000; U. S. Geological Survey Open-File Report 00-397.

Project Underground, MiningWatch STD Toolkit; 2002.

PT Newmont Brochure; *Management of Deep Sea Tailings Placement System at Batu Hijau Mine;* www.ptnnt.co.id

PT Newmont Nusa Tenggara (PTNNT) website: www.ptnnt.co.id

Reichelt-Brushett, A. 2012. Risk assessment and ecotoxicology limitations and recommendations for ocean disposal of mine waste in the Coral Triangle. *Oceanography*, http://dx.doi.org/10.5670/oceanog.2012.66.

Scottish Association for Marine Science; Draft Guidelines for Deep-Sea Tailings Placement Project Number: 8.ACP.PNG.18-B/15 Appendix 10, 2010.

Shearman, Phil*, A review of the risks presented by the Ramu Nickel Project to the ecology of Astrolabe Bay in Papua New Guinea*, A research paper commissioned by the Evangelical Lutheran Church of Papua New Guinea; Mineral Policy Institute, 2001. ISBN No. 0-9585457-5-8. *www.actnowpng.org*

Shimmield, Tracy, et.al., SAMS, Final Report, Independent Evaluation of Deep-Sea Mine Tailings Placement (DSTP) in PNG, 2010.

Skei, Jens; Asmund, Gert; Johansen, Poul; Søndergaard, Jens; *Conference Summary;* International Conference in Egersund, Norway; 2nd November 2009

Skei, Jens, Iversen, Eigil, Kristensen, Torstein, Aanes, Karl Jan, NIVA; Fosså, Jan Helge, van der Meeren, Terje, HI; Tor Jensen, Tor, DNV; Rye, Henrik, SINTEF; Løkeland, Mads, Naturvernforbund; Norges Maria Thornhill, Maria, NTNU; Bøe, Reidulv, NGU; Dekko, Trygve Multiconsult AS; Dalen, Marius, Bellona; Sørby, Harald, Storbraaten, Glenn, Braastad, Grethe, Klif; Norwegian Institute for Water Research; *Mining industry and tailing disposal. Status, Environmental Challenges and Gaps of Knowledge;* 2010.

Skotte, Gunnar; *Submarine mine tailings disposal in Norway;* Norwegian Climate and Pollution Agency; 2010. http://www.sydvarangergruve.no/niva-rapport.4903898-146746.html

Slideshare website: http://www.slideshare.net/NBII.SAIN/tva-kingston-fly-ash-pond-spill-photo-slide-show

Spitz, Karlheinz, Trudinger, John; Mining and the Environment: from ore to metal; London : Taylor & Francis; 2008.

Stava website: http://www.stava1985.it/

Sweeting, Amy Rosenfeld, Clark, Andrea P. ; Conservation International; Lightening the Lode: A Guide to Responsible Large Scale Mining, 2000

Tailings Info website: http://www.Tailings.Info.org

Thompson, Mark; Newcrest Mining; Personal communication, 2012.

The World Bank Group and Extractive Industries, Extractive Industries Review, *Striking a Better Balance, Volume I,* December 2002

U.S. Dept of Interior, Case Studies of Submarine Tailings Disposal, Volume II-Worldwide Case Histories and Screening Criteria, Bureau of Mines, OFR 37-94; January 31, 1994.

USEPA, *Effluent Guidelines and Standards-Mining*; http://www.gpo.gov/fdsys/browse/collectionCfr.action?collectionCode=CFR&searchPath=Title+40%2FChapter+I%2FSubchapter+N%2FPart+440&oldPath=Title+40%2FChapter+I%2FSubchapter+N&isCollapsed=true&selectedYearFrom=2001&ycord=2519; 2001.

U.S.EPA, U.S. AID, and Central American Commission on Environment and Development; *EIA Technical Review Guideline: Non-Metal and Metal Mining*; 2012.

WAHLI-Indonesian Forum for Environment, *The Environmental Impacts of Freeport-Rio Tinto's Copper and Gold Mining Operation in Papua*. Jakarta, 2006. http://www.scribd.com/doc/114683933/The-Environmental-Impacts-of-Freeport-Rio-Tinto-s-Copper-and-Gold-Mining-Operation-in-Papua

Waworuntu, Jorina; Newmont Mining; Email 9 May 2012.

Wikipedia.org; http://en.wikipedia.org/wiki/River morphology

Wise-uranium website: http://www.wise-uranium.org/mdafko.html

Appendix 2 Glossary[6]

A

Acceptable risk: that level of risk that is sufficiently low that society is comfortable with it. Society does not generally consider expenditure in further reducing such risks justifiable.

Acid rock drainage or acid mine drainage: the seepage of sulphuric acid solutions (pH 2.0-4.5) from mines and tailings; these solutions are produced by the interaction of oxygen in ground and surface water with sulfide minerals exposed by mining.

Comparative risk assessment: process that generally uses the judgment of experts to predict effects and set priorities among a range of environmental problems.

B

Backfill: Mine waste or rock that replaces the void left from where the ore or rock as been removed.

Best management practices: A suite of techniques that guide or may be applied to management actions to aid in achieving desired outcomes and help to protect the environmental resources by avoiding or minimizing impacts of an action.

Bioaccumulation: The accumulation of contaminants in the tissues of organisms through any route, including respiration, ingestion, or direct contact with contaminated water, sediment, or dredged material.

Bioavailability: The fraction of the total chemical in the surrounding environment which can be taken up by organisms. The environment may include water, sediment, suspended particles, and food items.

Biodiversity: Refers to the variation of life forms within a given ecosystem. Biodiversity is often used as a measure of the health of the biological system.

C

Contaminant: An introduced chemical or biological substance in a form that can be incorporated into, onto, be ingested by or harm aquatic organisms, consumers of aquatic organisms, or users of the aquatic environment.

Cyanidation: A method of extracting exposed gold or silver grains from crushed or ground ore by dissolving it in a weak cyanide solution. May be carried out in tanks inside a mill or in heaps of ore out of doors.

Cyanide: A chemical inorganic salt of hydrocyanic acid (HCN) used in the milling process to dissolve precious metals such as gold and silver.

D

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[6] Glossary extracted directly from Environmental Code of Practice for Metal Mines, Environment Canada 2009, and U.S.EPA, U.S. AID, and Central American Commission on Environment and Development; *EIA Technical Review Guideline: Non-Metal and Metal Mining*; 2012.

Deposit: Mineral deposit or ore deposit used to designate a natural occurrence of a useful mineral, or an ore, in sufficient extent and degree of concentration to invite exploitation.
Direct impact (or effect): This impact is caused by an action that occurs at the same time and same place as the activity.
Discharge: Outflow of surface water in a stream or canal. Discharge may come from an industrial facility and may contain pollutants.
Dump: A spoil heap at the surface of a mine. A pile or heap of waste rock material or other non-ore refuse near a mine.

E
Ecosystem: A dynamic complex of plant, animals and microorganism communities and their non-living environment interacting as a functional unit.
Effect (or impact): A modification of the existing environment caused by an action of the project. The effect, or impact, may be direct, indirect or cumulative.
Environmental Impact Assessment (EIA): A document prepared to analyze the impacts of a proposed action and released to the public for review and comment.
Exploration: Prospecting, sampling, mapping, diamond drilling and other work involved in searching for ore. In some cases exploratory mining is conducted in which small-scale mining activities are carried out to study potential ore deposits.

F
Flotation: A method of mineral separation in which a froth, created in water by a variety of reagents, floats some fine particles of crushed minerals whereas other minerals sink.

H
Habitat: The specific area or environment in which a particular type of plant or animal lives. An organism's habitat provides all of the basic requirements for the maintenance of life. Typical coastal habitats include beaches, marshes, rocky shores, bottom sediments, mudflats, and the water itself. Major components of habitat are food, water, cover and living space.
Heavy metal: Metallic elements with relatively high atomic weights (> 5.0 specific gravity) such as lead, cadmium, arsenic and mercury. Generally toxic in relatively low concentrations to plant and animal life.

I
Impact (or effect): A modification of the existing environment caused by an action of the project. Theeffect, or impact, may be direct, indirect or cumulative.
Impoundment: A naturally formed or artificially created basin that is closed or dammed to retain water, sediment or waste.

L
Leaching: A chemical process for the extraction of valuable minerals from ore. Also, a natural process by which groundwaters dissolve minerals, thus leaving the rock with a smaller proportion of some of the minerals than it contained originally.

M

Mill: A facility in which ore is treated and metals are recovered or prepared for smelting. Also, a revolving drum used for the grinding of ores in preparation for treatment.

Milling: The part of the mining process by which minerals of economic value are recovered by crushing and grinding ore, by ore separation or concentration, and by dewatering the ore. The objective of milling is to separate minerals of economic value from the rock in which they occur.

Mineral: A naturally occurring homogeneous substance having definite physical properties and chemical composition and, if formed under favourable conditions, a definite crystal form.

Minerals verses Metals?

• Metal is an element and mineral is a compound.
• Most metals are naturally present as minerals.
• Metals are more reactive than minerals.
• Metal and the respective minerals of that metal have different appearances and other properties.

Mine Tailings: The waste material, chemical reagents, and water mixture that is left over after the mill removes the targeted metals.

Mining: Excavation for the purpose of extracting valuable minerals from an economic ore deposit. Can be a surface or open pit mine or an underground mine.

Mitigation: The reduction or abatement of an impact to the environment by (a) avoiding actions or parts of actions, (b) using construction methods to limit the degree of impacts, (c) restoring an area to its pre-disturbance condition, (d) preserving or maintaining an area throughout the life of a project, (e) replacing or providing substitute resources, (f) gathering data on an archeological or paleontological site prior to disturbance.

O

Open pit mining: Term used to differentiate this form of mining from extractive methods that require tunnelling into the earth. Open pit mines are used when deposits are found near the surface, where the overburden is relatively thin or the material of interest is structurally unsuitable for tunnelling.Also commonly referred to as strip mining.

Ore: A natural compound of minerals of which at least one is a metal; a mineral of sufficient value as to quality and quantity that may be mined at a profit.

Ore body: A mineral deposit that is a solid and continuous mass of ore that is distinguished from the surrounding rock and which may be worked at a profit.

Overburden: Generally means the material overlying the ore deposit, including rock as well as soil and other unconsolidated (loose) materials. For this document, the term overburden is restricted to unconsolidated materials, including soil, glacial deposits, sand, and sediment.

P

pH: A measure of the acidity or alkalinity of water, sediment or soil. The measure is based on the concentration of hydrogen ions and gives the negative logarithm of the hydrogen (H+) ion, corresponding to 10^{-7}. A pH value of 7 is neutral. All values higher are considered alkaline, and all values lower are considered acidic.

Precautionary Approach: Appropriate preventative measures are taken when there is reason to believe that wastes or other matter introduced into the marine environment are likely to cause harm even when there is no conclusive evidence to prove a causal relation between inputs and their effects.

R

Reagent: A chemical or solution used to produce a desired reaction; a substance used in assaying or in flotation.
Reclamation: The process by which lands disturbed as a result of mining activity are returned to a beneficial land use. Reclamation activity may include the removal of buildings, equipment, machinery, other physical remnants of mining, closure of tailings impoundments, leach pads and other mine features, and contouring, covering and revegetating waste rock piles and other disturbed areas.
Restoration: After mining ceases, bringing the disturbed land back to its original use or condition or to alternative uses. Restoration activities include removing structures; grading and restabilizing slopes, roads, and other disturbed areas; covering disturbed areas with growth medium or soil; and revegetating disturbed areas.
Risk Assessment is the process of quantitatively evaluating the impact of a stressor (e.g., a chemical or physical condition) upon the health of individual humans or the environmental well being of a population or community of animals and plants or microoganisms. The former is called human health risk assessment, and the latter ecological risk assessment.

S

Sediment: Solid fragmental material that originates from weathering of rocks and is transported or deposited by air, water or ice, or that accumulated by other processes, such as chemical precipitation from solution or secretion by organisms. The term is usually applied to material held in suspension in water or recently deposited from suspension and to all kinds of deposits, essentially of unconsolidated materials.
Sedimentation: The result when material is transported by water, wind, gravity or other means and deposited in bodies of water or on land. It is also a method of settling solids out of wastewater during treatment.
Solvent extraction – electrowinning (SX/EW): A two-stage process that first extracts and upgrades copper ions from low-grade leach solutions into a concentrated electrolyte, and then deposits pure copper onto cathodes using an electrolytic procedure
Slurry: A fluid mixture of liquids and solids.
Smelting: A sub-process of pyrometallurgy; its main use is to produce a metal from its ore. This includes the extraction of iron from iron ore (for the production of steel) and the extraction of copper and other base metals from their ores. Smelting uses heat and a chemical reducing agent, commonly a fuel that is a source of carbon such as coke, to change the oxidation state of the metal ore. The carbon or carbon monoxide derived from it removes oxygen from the ore, leaving just the metal.
Stakeholders: Persons, groups, and organizations, who affect or can be affected by the project's actions.
Sulfate mineral: A mineral characterized by the bonding of a sulphate anion with a metal such as barium, calcium, lead or copper. Sulphates may or may not include water in their structure. Common examples include barite ($BaSO_4$) and gypsum ($CaSO_4 \cdot 2H_2O$).

Sulfide mineral: A metallic mineral characterized by the covalent bonding of sulphur with a metal or semi-metal, such as iron, copper, lead, zinc, nickel or molybdenum. An example of a common sulphide mineral is pyrite, which has the chemical formula FeS2. Sulphide minerals occur in a wide range of geological environments. When occurring in sufficient concentrations, sulphide minerals can be important ore minerals for a range of base metals, including copper, lead, zinc and nickel.
Suspended solids: Organic or inorganic particles that are suspended in water. The term includes sand, silt, and clay particles as well as other solids, such as biological material, suspended in the water column.

T

Tailings Management (or Storage) Facility: All components and facilities functionally pertaining to tailings management, including dams, spillways, decant structures, tailings lines, as well as settling and polishing ponds.
Total suspended solids: A water quality measurement. It is measured by pouring a determined volume of water through a filter and weighing the filter before and after to determine the amount of solids.
Toxicity: A term describing the sum of adverse effects or the degree of danger posed by a substance to living organisms. In the context of this document, toxicity is considered to be the level of mortality or other end point demonstrated by an organism or group of organisms that have been exposed to contaminated water, sediment, or dredged material.Toxicity is classified usually as (1) Acute: harmful effects produced through a single or short-term exposure. (2) Chronic: harmful effects produced through repeated or continuous exposure over an extended period. (3) Subchronic: harmful effects produced through repeated or continuous exposure over twelve months or more but less than the normal lifespan of the organism.
Toxic pollutant: Pollutants, or combinations of pollutants, including disease-causing agents, that after discharge and upon exposure, ingestion, inhalation, or assimilation into any organism, either directly from the environment or indirectly by ingestion through food chains, will cause death, disease, behavioral abnormalities, cancer, genetic mutations, physiological malfunctions, or physical deformations in such organisms or their offspring.
Trace metals: Metals in extremely small quantities, which are needed by plants and animals for survival but which, if ingested in large quantities, may be toxic. Examples of trace metals are: selenium, arsenic, iron, molybdenum, etc.
Turbidity: An optical measure of the amount of material suspended in the water. Increasing the turbidity of the water decreases the amount of light that penetrates the water column. Very high levels of turbidity can be harmful to aquatic life.

U

Up-welling: Winds blowing across the ocean surface push water away. Water then rises up from beneath the surface to replace the water that was pushed away. This process is known as “upwelling.”

W

Waste rock: Rock which does not contain minerals in sufficient concentration to be separated from the ore economically, but which must be removed in the mining process to provide access to the ore.

Wetlands: Vegetation that is adapted for life in saturated soil conditions. Examples of wetlands are marshes, swamps, lakeshores, bogs, wet meadows, estuaries and riparian areas.

Wastewater:
Any water that has been adversely affected in quality by anthropogenic influence. In the case of operations at a mine or mill site, wastewater includes all water generated as part of a process prior to discharge, including any mine tailings or site runoff water.

Wetlands: Habitats where the influence of surface or groundwater has resulted in the development of plant or animal communities adapted to such aquatic or intermittently wet conditions. Wetlands include tidal flats, shallow subtidal areas, swamps, marshes, wet meadows, bogs, muskeg, and similar areas.

Z

Zones in water:
A **pycnocline** is the difference in water density.
A **thermocline** is the difference in water temperature.
A **halocline** is the difference in water salinity.
Euphotic zone (**epipelagic** zone; **photic** zone) is the topmost layer of a lake or sea in which there is sufficient light for net primary production, usually less than one hundred meters in depth, where light can still be found and photosynthesis can occur. The depth varies, depending on such factors as turbidity, supply of nutrients in the water, tidal turbulence, and temperature.

Appendix 3 Case Studies of Riverine and Marine Disposal of Mine Tailings

Riverine Disposal Case Studies

Grasberg Copper and Gold Mine in Indonesia

Description of the Mine

Freeport McMoRan's copper and gold mine is located in the remote highlands of the Sudirman Mountain Range in the province of Papua, Indonesia, which is on the western half of the island of New Guinea. The gold mine is at 4,100 meters above sea-level and is the world's largest copper and gold mine in terms of recoverable reserves. Approximately 635,000 tonnes per day of material is mined to produce 230,000 tonnes of ore a day with waste rock and overburden of 400,000 tonnes per day; ore production expansion is planned to 300,000 tonnes per day.

When mining first began in the early 1970s in the Grasberg area, the local population was about 1,000. In the early 2000s, the population was estimated to be 100,000 to 150,000 (IIED 2002).

Three mines are currently in operation: the Grasberg open pit, the Deep Ore Zone mine and the Big Gossan mine. The Grasberg open-pit mine is 2.4 km in diameter and covers 450 ha (Neale 2003). Open-pit mining of the Grasberg ore body began in 1990. Open-pit operations are expected to continue through mid-2016, at which time the underground mining operations are scheduled to begin at the Grasberg Block Cave mine, which is currently in development.

Crushing and conveying systems are integral to the mine and provide the current capacity to transport up to 230,000 metric tons of ore per day (mtd) to the mill and 135,000 mtd of overburden to the overburden stockpiles (Freeport McMorRan website).

The Grasberg mines are officially owned by PT Freeport Indonesia, which is Freeport McMoRan (91%) and the Government of Indonesia (9%). Freeport-McMoRan Copper & Gold Inc. headquarters is in Phoenix, Arizona, USA (Freeport McMoRan website(a)). About 20,000 people are directly employed by PT Freeport Indonesia. Freeport is one of Indonesia's biggest tax-payers. In the last five years, the firm says it has paid about $8 billion in taxes, dividends and royalties to the Indonesian government (West Papua media website). The company reported that total output for 2005 was 662,000 tons of copper and 2.8 million ounces of gold (WALHI 2006).

Riverine Tailings Disposal

Riverine transport of mine tailings is used from the concentrating complex in the mountains to a designated engineered and managed deposition zone in the lowlands and coastal zone, approved by the

Government of Indonesia, using the Otomona River (and previously the Ajkwa River) as the transport mechanism.

The production process that creates the mine tailings is similar to other copper and gold mines, crushing the ore first through a coarse crusher and then to a fine mill, which results in a range of particle sizes from 1,000 um to 40 um. These particles are then processed in a solution containing ore processing and floatation reagents; minerals containing copper, gold, and silver are skimmed off the top and represent about 3% of the ore processed. The remainder, the mine tailings settle to the bottom and are discharged to the East Aghawagon River, carried to the Aghawagon River which joins the Otomona River which carries the tailings to the lowland area, the Ajkwa River and the Ajkwa Deposition Area (WAHLI 2006).

In mid-1990, log debris caused jams in the Ajkwa River resulting in sheetflow conditions over the flood plain, altering the geomorphology of the river system, preventing the Ajkwa River from transporting the mine tailings to the Arafura Sea. Levees were than constructed on the Ajkwa River flood plain to contain the tailings between the levees which were 3 km wide and 40 km long and eventually reach 21 meters high, an area of 130 square km (50 square miles). The area between the levees will eventually have a layer of tailings of 10-15 meters deep. The trees and vegetation in the have been killed in that area, and it is projected that dieback will eventually affect 230 square km (about 90 square miles) of land (WALHI 2006).

It is estimated that 5% of the mine tailings (11,500 tonnes per day) reach the Arafura Sea, but that level is expected to increase to 76,000 tonnes per day (WALHI 2006).

In 2005, the Ajkwa River was diverted from the tailings deposition area, returning it to its original channel. The mine tailings are now carried only by the Otomona River to the deposition area (Freeport Brochure 2009).

Quantities of Mine Tailings Discharged

In 1997, a permit was issued to increase ore processing to 300,000 tonnes per day. The average in 2005 was 238,000 tpd, of which 97% become mine tailings (WALHI 2006). In 2011, 85 million tons of mine tailings were discharged to the river to carry the mine tailings to the modified Ajkwa Deposition Area.

Impacts of Mine Tailings Discharge to the Ajkwa River

In 1994, Salt Lake City-based company EnviroSearch International conducted an assessment of the Grasberg mining operations and that assessment convinced the Overseas Private Investment Corp (OPIC) to cancel the $100 million political risk insurance policy it held on Freeport-McMoRan's Grasberg mine (Enviro Search 1994).

Based on what they saw in 1994, EnviroSearch predicted that the tailings from the mine would eventually reach the Arafura Sea. Satellite photos in 2005 appear to show that that is exactly what is happening. EnviroSearch said, "*Left unchecked, the tailings are anticipated to continue sheeting in an* *uncontrolled fashion, eventually reaching the Arafura Sea via an undetermined and apparently unpredictable course and at an undetermined discharge point*."

The report noted that the disposal into the river system represents *a "mass loading of contaminants into the Irian [West Papua] environment" and these contaminants have "an as-yet undetermined ability, or inability, for the natural system to overcome such an impact."*

They stated that Freeport's "tailings management and disposal practices have severely degraded the rainforests surrounding the Ajkwa and Minajerwi Rivers" and in addition, "the Project ...continues to pose unreasonable or major environmental, health, or safety hazards' for 'the rivers,...the surrounding terrestrial ecosystem and the local inhabitants".

EnviroSearch said *"Freeport represented to us that the impact of the tailings on the river system would be 'difficult to separate from process(es) that occur naturally.' In fact, the project has devastated the river system, through excessive discharge and deposition of tailings*" (Bryce 2005). EnviroSearch was the last known independent auditor to be allowed onto the Grasberg site.

The New York Times (newspaper in USA) conducted an assessment of the overall operations of the Grasberg mine in 2008. The focus was not upon the discharge of mine tailings, but they did report that Freeport stated that the mine tailings in the river system meets Indonesian and American drinking water standards and that the coastal estuary was a functioning ecosystem. The New York Times reported that the Parametric report showed copper in the river at levels acutely toxic to aquatic life. Suspended solids were reported to be 37,500 mg/L as they entered the lowlands.

The Times also stated that Freeport is actively involved in mitigation programs, having planted 50,000 mangrove seedlings in 2007, and that demonstration projects have begun to show that cash crops can be grown in restored areas (New York Times 2005). Freeport's website reports that the monitoring of terrestrial areas that received mine tailings for many years show rapid establishment and colonization by native plants; areas that are now more than 10 years removed from deposition are in secondary growth. When mining is completed, the deposition area will be reclaimed with natural vegetation or used for agriculture, forestry or aquaculture (Freeport 2012).

While restoration is possible and part of the overall plan, concerns have been expressed that the Ajkwa Deposition Area could become a "perpetual pollution machine" being the source of sulphuric acid leaking into the ecosystem for decades as the sulphites in the mine tailings are exposed to air and water. This has major implications for long term ecological effects of lowered pH in the Ajkwa River and the Ajkwa Estuary (Soeriatt 1996).

Independent environmental audits in the mid to late 1990s were conducted by Parametric, Dames & Moore in 1996, and Montgomery Watson in 1999 and 2002, and Montgomery Watson Harza in 2005, but (note that the independence of these audits has been questioned by environmental interest groups given that no independent sampling was conducted). Findings of those audits include (Watson 1999) (Parametric 1996) (Dames 1996):

- At a site approximately 50 km downstream, the mine tailings in the river represent 93% of the sediment load.
- As mine tailings are settling into the Ajkwa Deposition Area (ADA), the river shifts laterally to deposit materials in adjacent areas which eventually will result in 10-15 m thick in the area between the levees. The dieback from the lack of oxygen and sediment deposition will eventually be 230 square km.
- Reclamation testing for the deposition area are on-going to determine the best approach for mine closure.
- In the late 1990s, less than 5% of the mine tailings were reaching the Arafura Sea (11,500 tonnes per day) but as the ADA fills, the quantity expected to reach the Arafura Sea will be about 1/3 of the mine tailings disposed upstream in the river or approximately 76,000 tonnes per day.
- At all sampling locations, water quality met Indonesian drinking water standards. Dissolved copper concentrations far exceeded U.S. EPA and ANZECC standards for protection of aquatic life. Mistrust in the data has been expressed by a number of interested groups.

According to one Kamoro villager living in a small community of 160 people along the Ajkwa River; "*today it is hard to find the yaro, lifao, mufao, irao and ufurao – the traditional fish that we used to catch. […] We have to walk 20 kilometres from here to find food*") (IIEA 2002).

Grasberg's disposal of mine tailings is massively in excess of the assimilative capacity of the river and lowland flood plains. The mine tailings are burying a large area of tropical lowland rainforest and mangroves, and the potential impact on coastal and marine waters has not yet been assessed.

<u>Conclusions from the WALHI Report in 2006</u>[7]

The 2006 report (WALHI 2006) documents severe environmental damage as well as alleged violations of Indonesian law and regulations.

- WALHI contends that Indonesian law and regulations expressly prohibit riverine disposal of mine tailings, but the government has not enforced the regulations. Freeport claims that they have legal agreements for riverine discharge of mine tailings, and that the impacts of the mine tailings conform to both Indonesian and international standards regarding harmful metals.
- The lower Ajkwa River and the freshwater estuary, and the saltwater estuary all contain copper levels exceeding Indonesian (20 ug/l) and Australian water quality standards (5.5 ug/l).
- Total suspended solids in the Ajkwa Estuary were 1,300 mg/l, well above the standard of 80 mg/l.
- The Ajkwa deposition area is both a porous and open-ended system, polluting the local ground water, adjacent rivers and Kwamki Lakes and particles are carried to the Ajkwa Estuary and the Arafura Sea.

[7] WAHLI, the Indonesian Forum for Environment is the largest forum of non-government and community based organizations in Indonesia. WALHI produced a comprehensive assessment of the Freeport mine's impact of riverine mine tailings disposal in 2006.

- The lowland river and floodplain including the rainforest and wetlands have been destroyed, once a vital hunting and fishing ground for the Karmoro traditional landowners.
- Freshwater aquatic life has been largely destroyed via the riverine disposal of mine tailings via smothering, toxicity, and impacts upon habitats. Heavy metals in the mine tailings (copper, lead, arsenic, zinc, manganese, and selenium) exceed Australian sediment guidelines and pose risks to the food chain.
- Riverine tailings disposal will destroy 20-60 square km of mangrove forests due to sedimentation in the estuary. Estuary channels are clogging with tailings, and turbidity in the estuary far exceeds Australian standards..
- The estuary food chain has been majorly compromised in that fish in the estuary have elevated levels of copper and non-mobile aquatic animals living in the Ajkwa Estuary are contaminated at 100 times normal, some up to one gram per kilo.
- There are about 35% fewer species of fish, shellfish, and polychaetes present in the Ajkwa Estuary than in reference sites.
- Restoration of the 230 square km in the deposition area will be futile as tests show that tailings cannot support germination or growth of most native plants without intensive fertilizers or nutrient addition.

Rationale for Riverine Tailings Disposal

Riverine disposal was selected as the method of disposal for mine tailings because the mine is in an area of seismic activity, high precipitation, high mountainous terrain, and no suitable sites for tailings disposal facilities. Downstream of the mine were high groundwater levels, a lack of cross-valley locations, and inadequate embankment material, thus leading to disposal into the Ajkwa River system. One reference states that the riverine disposal worked well when the mine first opened in 1973 with only 7,500 tonnes per day compared to 230,000 tonnes per day of mine tailings discharged to the river in the year 2000 (IIEA 2002).

After the heavy rains and jamming of log debris in the mid-1990s caused mine tailings to spread throughout the lowlands, the company assessed 14 separate alternatives for mine tailings disposal, including marine disposal, land disposal in the highlands, and land disposal in the lowlands via pipeline. Part of the analysis was an environmental impact study and an ecological risk assessment. The selected alternative was to continue riverine disposal and to build levees to contain the mine tailings to the river footprint (3 km apart and 40 km long). Riverine disposal represented "the best alternative option when considering important geotechnical, topographic, climatologic, seismic and water quality critieria." (IIEA 2002) (Freeport website).

The Freeport website reports that the mine tailings and natural sediment not retained within the deposition area are building new islands and wetlands in Ajkwa Estuary, stating that these impacts are physical in nature.

Best Management Practices in Place

Environmental Management Systems certified to ISO 14001 standards are in-place at Grasberg, and operations undergo annual independent audits to ensure standards are met. Critics state that the riverine disposal of such massive quantities of mine tailings masks any apparent benefits of reduction of contaminants at the source in the application of pollution reduction systems.

PT Freeport Indonesia performs an External Environmental Audit every three years, with the first audit conducted in 1996. Montgomery Watson conducted the audit in 1999 and 2002 whereas MWH (formerly Montgomery Watson Harza) conducted the audit in 2005 and 2008. Results of those audits along with the 2002 risk assessment conducted by Parametrix are on the Freeport website.

Monitoring and Assessment

Freeport completed a comprehensive environmental and social impact statement in 1997 which was approved by the government of Indonesia. This is the base document against which potential impacts are assessed; results of monitoring programs are reported to be consistent with the 1997 impact assessment.

Monitoring programs in-place in a typical year collect 7,000 environmental samples and conduct over 50,000 separate analyses on those samples. The biological monitoring program samples more than 200 locations for aquatic fauna, and in last five years, over 15,000 analyses were conducted on 2,000 samples.

Recovery

The PT Freeport Indonesia January 2009 publication, *Controlled Riverine Tailings Management*, provides an overview of the company's restoration program for reclamation and revegetation of the lowlands tailings deposition area (Freeport Brochure 2009). Some of the initiatives are noted below:

- *In the lowlands tailings deposition area, reclamation research has demonstrated that native species successfully colonize and grow on tailings. The tailings area is also suitable for growing various agricultural crops when tailings are enhanced with a small percentage of organic carbon. The objective of PT-FI's reclamation and revegetation program in the lowlands is to demonstrate sustainable ways to transform the tailings deposits in the deposition area into agricultural or other productive land use, or to return them to native vegetation after mining is completed.*

- *Cumulatively through the end of 2007, more than 160 plant species have been successfully cultivated on soils containing tailings. Some plant species that have been successfully tested to date include legume cover crops for fodder; local trees such as Casuarina and matoa; cash crops plants such as pineapple, melon, and banana; and vegetables and grains such as chili peppers, cucumbers, tomatoes, rice, string beans and pumpkins.*

- *There are regular harvests of edible plants and fruit from many of these species and these are continually monitored. Rigorous testing performed on these edible plants and fruits continues to demonstrate that* *metals uptake from the minerals naturally contained in the tailings remains safely below the levels stipulated in national and international standards for these plants.*

- *An animal husbandry program has been developed in the lowlands to demonstrate that cattle can thrive on deposited tailings. This project was established in cooperation with the local government to monitor cattle health. Legumes have been planted along with king grass. The legumes are nitrogen-fixers that add nutrients to the tailings soil. They are harvested as feed for the cattle and the cattle's manure provides further soil enrichment and seed dispersal.*

- *Some of the new land formed in the estuary from tailings and natural sediments have been colonized by mangroves without assistance. Within the past several years, dozens of mangrove species, crabs, shrimps, snails, clams, fish and marine polychaetes (worms) were identified in the mangrove colonization areas. To accelerate the primary succession process in these newly formed lands, PT-FI planted over 200,000 mangroves in the area through 2007.*

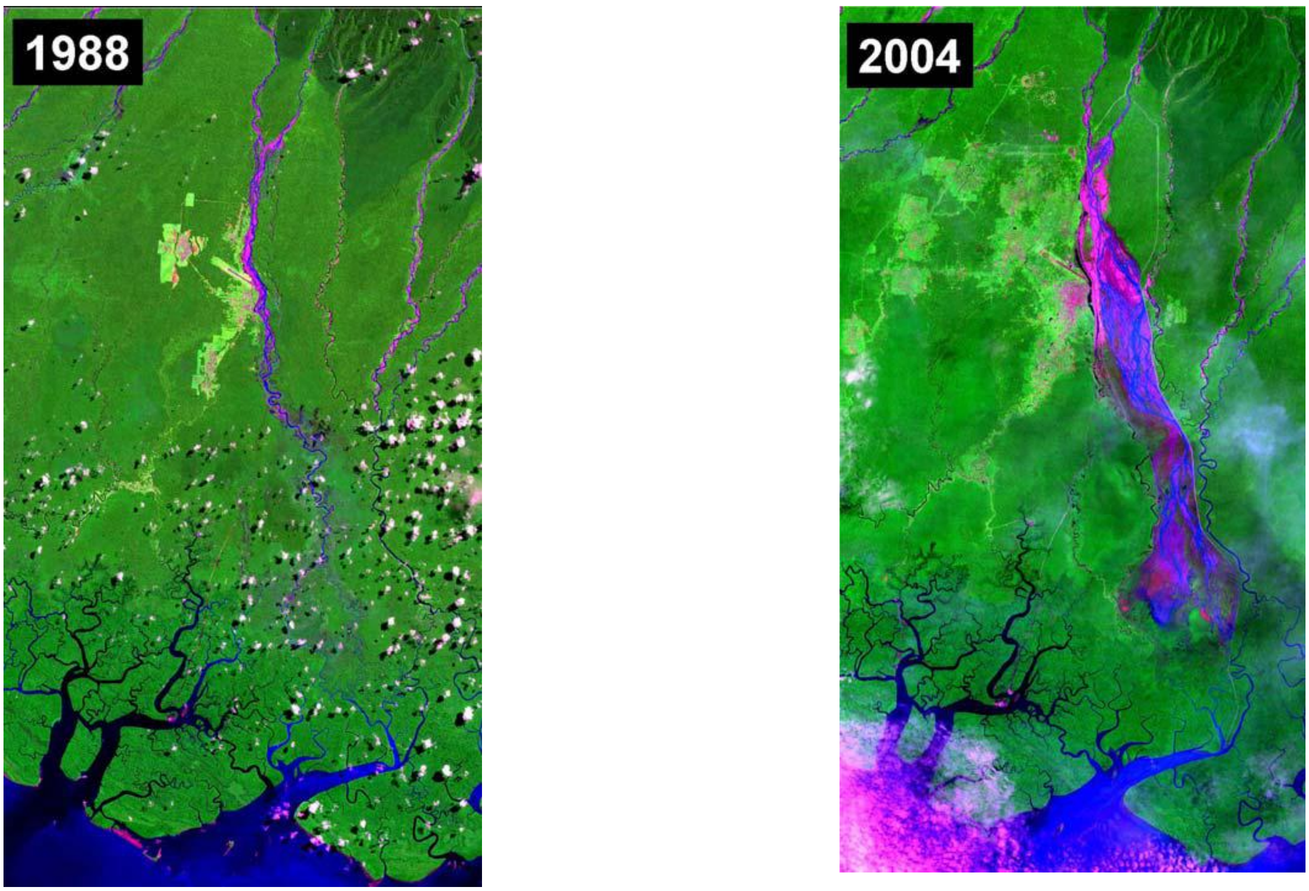

Figure 16 Landsat photos of the expanding tailings deposition footprint in the Timika lowland area, from years as marked. Tailings deposits within the ADA visible as pink (dry tailings) and blue (waterlogged tailings). Dark black are standing water or cloud shadows. Cleared forest area visible as light green (from Paull et al 2006). (Source: WALHI 2006)

References for Grasberg

Bryce, Robert; *Freeport at Grasberg: 'Devastated the river system'*; http://www.austinchronicle.com/news/2005-09-23/292540

Dames & Moore, PTFI Environmental Audit Report, March 1996.

Freeport McMorRan Brochure; Controlled Riverine Tailings Management at PT Freeport Indonesia; January 2009.

Freeport McMorRan website: http://www.fcx.com/operations/grascomplx.htm

Freeport McMorRan website(a): http://www.fcx.com/company/who.htm
IIED, Mining for the Future; *Appendix A: Large Volume Waste Working Paper*, April 2002.

Enviro Search, *Environmental Review of P.T. Freeport Indonesia Copper and Precious Metals Mine Irian Jaya, Indonesia*, 1994.

Montgomery Watson Environmental Process Audit 1999; http://fcx.com/news/fcxaudit.pdf

Montgomery Watson Harza, External Environmental Audit (Grasberg); 2005.

Perlez, Jane, and Bonner, Raymond; New York Times; *Below a Mountain of Wealth, a River of Waste*; December 27, 2005.

R.E.Soeriatt quoted in Frodsham T.,Environmental Impacts of copper mining in Melanesia and the anti-mining movement of the Freeport,Ok Tedi and Bougainville copper mines,a comparative analysis,unpublished, Murdoch University, 1996.

WALHI-Indonesian Forum for Environment; *The Environmental Impacts of Freeport-Rio Tinto's Copper and Gold Mining Operation in Papua*; Jakarta, 2006; website: www.eng.walhi.or.id
West Papua Media Alert website: http://westpapuamedia.info/tag/grasberg-mine/2011

Porgera Gold Mine in Papua New Guinea

Description of the Mine

The Porgera gold mine is located at an elevation of 2,200 to 2,700 meters in the Central Highlands of PNG. Both open pit and underground mines are operated. The mine is operated by Barrick Gold Corporation for the owners (Porgera Joint Adventure (PJV)) of which 95% is Barrick and 5% is the provincial government and local landowners.

Production began in 1990 under Placer Dome Ltd, which was acquired by Barrick in 2006. In 2009, Porgera produced 573,000 ounces of gold with probable reserves of 8.1 million ounces of gold. (Porgera Brochure).

The mine site is in the valley of the Porgera River among peaks that range up to 4,500 meters. The location is seismically active and annual rainfall averages 3.7 meters. The Porgera River carries a naturally high sediment load and flows through mountainous terrain for 240 km joining with the Lagaip River and the Ok Om to the Strickland River which is characterized by lowlands. The Strickland River merges with the Fly River which flows 480 km to the Gulf of Papua (Porgera Brochure). The Fly River enters the Gulf of Papua in a great estuary nearly 80 km across which is filled with a series of low shifting mud islands. The effect of the tide is felt for a distance of 240 km up the river; at the head of tide, the stream is 540 meters wide and averages 12 meters in depth (GluedIdeas website).

Mine Tailings Disposal

Beginning in 1992, mine tailings have been disposed by pipeline into the Porgera River; the current rate is about 14,000 to 16,000 tonnes per day (Porgera 2010 Annual Report). The long term average discharge to the Porgera River is 5-6 million tones of tailings and 12 million tones of erodible waste rock (Porgera Brochure).

The construction of a tailings dam was not deemed to be feasible owing to geotechnical instability and high rainfall. The PNG Government consequently approved in 1988 discharge of treated mine tailings into the Porgera/Lagaip/Strickland River system that included three fundamental elements:

1. Tailings are to be treated to precipitate metals and detoxify cyanide before direct release into the Porgera River.
2. Incompetent waste rock is to be placed in erodible dumps in two small valleys near the mine.
3. Competent waste rock is to be placed in conventional stable dump formations.

Mine tailings contain elevated concentrations of As, Hg, Ni, Cu, Pb and Zn and low concentrations of cyanide. The metals in the tailings are present in both dissolved and particulate forms. Dissolved metal concentrations rapidly decrease downstream of the mine owing to a combination of dilution and adsorption of trace metals onto natural riverine sediments. Metal and cyanide concentrations in mine tailings are reported annually by the mine in their Annual Environmental Report.

Mine-derived sediments mix with natural sediments and are progressively diluted in the river system. In the Lower Strickland River, mine-derived sediments comprise typically 10 to 15% to the total sediment load. A small proportion of mine sediments enter Lake Murray (connected to the Strickland River via the Herbert River) during flow reversal events and deposit at the Southern end of the Lake. Around 15% of the sediment load in the Lower Strickland is lost from the river through the process of overbank deposition onto the adjacent floodplain. The remaining sediments undergo further dilution with river-borne sediments from the Fly River and Fly River Estuary before entering the Gulf of Papua.

<u>Permit by the Papua New Guinea Department of Environment and Conservation</u>

In 2006, the Papua New Guinea government converted the Porgera Environmental Plan to an Environmental Permit under the relatively new Environment Act of 2000. Prior to the opening of the mine, assessment of the mine and potential environmental impacts led to the development of the 1988 Porgera Gold Mine Environmental Plan. Based on that Plan, and an independent review using predictions of potential impacts to the Porgera River based on US EPA and ANZECC (Australian and New Zealand Environment and Conservation Council) water quality standards, the mine was commissioned in 1990, including approval of riverine disposal of mine tailings. The bottom line was that river water quality must meet water quality standards to protect public health and riverine ecosystems.

The environmental permit states that water quality standards must be met at a formal compliance point, termed SG3, which is 165 km downstream of the mine. Monitoring programs are in place for monitoring at SG1, 8 km downstream, at SG2, 42 km downstream, at SG3, and further downstream (Barrick website).

<u>Permit Compliance and Environmental Impacts to Porgera and Strickland River Systems</u>

Extensive biological testing is conducted to determine the impact of the discharges upon the aquatic environment. See Box 22. The water quality, biological testing, and monitoring programs were developed with assistance from the Australian Science Agency's, Commonwealth Scientific and Industrial Research Organization (CSIRO).

<u>Box 22 PJV's Monitoring Indicators and Results</u>

PJV monitors upland river, lowland river and Lake Murray ecosystems using five groups of indicators:

- Dissolved metals – arsenic, cadmium, chromium, copper, iron, lead, mercury, nickel, silver and zinc.
- Metals in sediments – arsenic, cadmium, chromium, copper, iron, lead, mercury, nickel, silver and zinc.
- Conductivity, total suspended solids, pH and cyanide.
- Metals in fish and prawn – arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver and zinc.
- Fish and invertebrate abundance, diversity and condition.

The mine is required to monitor concentrations of potential contaminants in the downstream river system and maintain compliance against those criteria at a point known as stream gauging station #3 (SG3) located 160 river kilometers downstream of the mine. To date water quality at this location is in compliance with the limits set by the PNG Government. In 2010, it was reported that dissolved concentrations of relevant trace metals were below the water quality standards at SG2, well upstream of the compliance point.

After 20 years of monitoring, the observed effects on fish populations downstream of the Porgera–Lagaip confluence have turned out to be less than was predicted in 1988 (prior to mine start-up): some trace metals (e.g. cadmium) have increased in some fish and prawns but are not at levels of human or ecological concern. Fish and prawn populations have been maintained across their full pre-mine range.

The 2010 Annual Report dated June 2011 is a comprehensive summary of the monitoring programs and results. It is prepared by Porgera Joint Ventures (PJV), reviewed by CSIRO, provided annually to the Papua New Guinea Department of Environment and Conservation, and is available to the public.

In addition, an independent group, Porgera Environmental Advisory Komiti (PEAK) (see discussion below), provides an annual report card for the Porgera and Strickland Rivers. The report card (see text box) provides an assessment of 17 river stations for dissolved metals, metals in tissues, sediment metals, and other water quality parameters (e.g., TSS, pH).

The 2009 Report Card and June 2010 Annual Report appear to show moderate impacts to the upper reaches of the river, but provide an improved outlook on water quality, metals in fish tissue, metals in sediments, and species richness/abundance/condition in the lower reaches of the Porgera and Strickland River system.

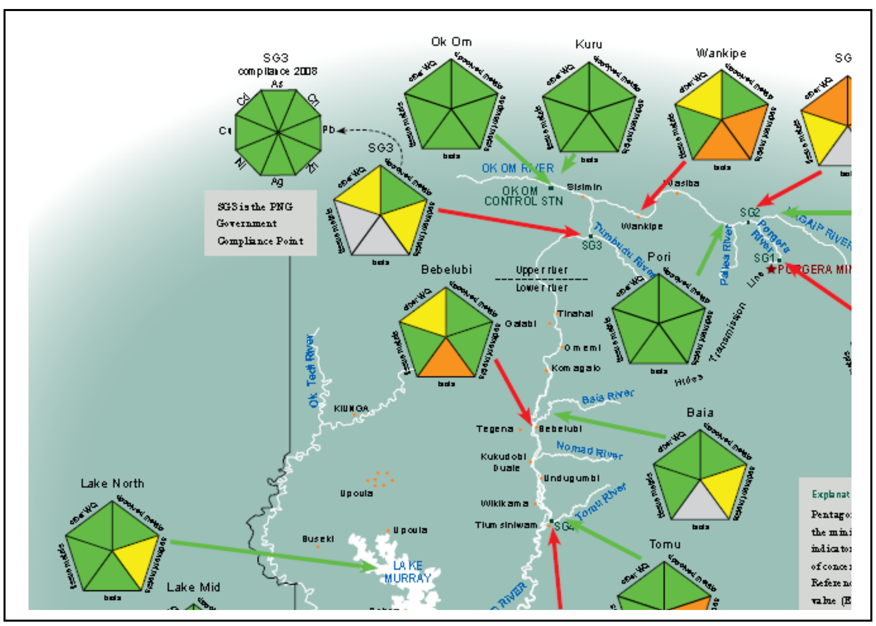

Figure 17 Impact of Mine Tailings from Porgera. Source of graphic: Strickland River Report Card 2009

In-Place Environmental Management Practices

The original approval of the mine tailings discharge to the Porgera River required installation of a treatment system prior to discharge that detoxified cyanide and precipitated metals. In December 2008, an upgraded treatment facility was put in place as the levels of cyanide in the discharge did not meet the most recent Cyanide Management Code Tailings Cyanide Standard for the point of discharge. The new plant has achieved the standard as well as reducing copper at the discharge point from 12 ug/L to 2 ug/L (the standard at SG3 is 10 ug/L). See Figure 18. In 2009, the Porgera mine was certified for safe and responsible management of cyanide use and disposal, given the addition of the upgraded cyanide treatment plant.

Figure 18 Cyanide treatment plant. Source: Porgera Brochure

In mid-2011, a tailings paste plant was commissioned, which removes significant portions of the coarser content of the tailings discharge. Cement is then added to the coarser solids and the "paste" is disposed in the underground mine, resulting in about an 8% less solids in the tailings discharge.

In 2012, PJV reports that they are pursuing ISO 14001 standard certification, which, in essence, certifies that mine environmental management systems are in place to control environmental impacts. (Source: Porgera Brochure).

Rationale for Riverine Tailings Disposal

In 2006, a comprehensive two year review was conducted to assess and evaluate alternatives to riverine mine tailings disposal. The conclusions (Porgera Brochure):

> *The study confirmed significant risk factors in ensuring a stable foundation for a large traditional tailings storage facility due to high rainfall, seismic activity and steep, highly erodible terrain, consistent with research conducted during the original mine permitting process in 1989. In addition, social factors such as the law and order challenges in PNG and, in particular, the presence of illegal miners, were identified as significant risk factors. Reviewers recognized that groups of illegal miners would likely dig and pan for gold from tailings captured within the tailings impoundment, leading to erosion of the dam structure. Given geographic, seismic and other scientific, technical and social considerations, alternative options were subsequently ruled out. Based on extensive analysis, including from independent experts, we concluded that riverine disposal of tailings at this operation was the most viable option from a technical standpoint.*

Other Information

In 1996, PJV commissioned CSIRO, the Australian Science Agency, to conduct an independent review of environmental impacts and permit compliance of the management of mine tailings.

The CSIRO report (CSIRO 1996) pointed out the potential impacts to ecosystems and to potential public health impacts. As reported by the Minerals Policy Institute: "*the presence of heavy metals and chemicals in* *the upper and lower regions of the river are increasing to levels that will have severe and long term impacts on the river ecosystem. Tailings from PJV include Arsenic, Cadmium, Chromium, Copper, Iron, Lead, Mercury, Nickel, Silver, Zinc and three forms of cyanide- total cyanide CAC, weak acid dissociable cyanide WAD and Thiocyanate.* (Mineral Policy Institute, http://eyeonmining.wordpress.com/where-we-work/papua-new-guinea/porgera/).

The 1996 CSIRO review provided 48 recommendations and concluded that:

1) The impact of Placer's waste disposal on the river was significant,
2) PJV should urgently explore options to store tailings solids and waste rock on land,
3) Placer Dome's approach to managing and monitoring the impacts on the river was inadequate.

In response, an independent advisory committee was established, Porgera Environmental Advisory Komiti (PEAK), to review the response by PJV to the recommendations and to provide an independent voice regarding impacts upon the ecosystems of the Porgera and Strickland Rivers. See Figure 19. PEAK continues to be active and in 2010 produced the first ever report card mentioned above. The Minerals Resource Agency of the PNG government spokesperson stated: "*The key findings of the Report Card are clear – the mine is having a measurable effect on the Porgera and Lagiap rivers close to the mining operations, but the rest of the river system is generally in good health.*"

The PEAK has not been without controversy. In 2001, the Chair of PEAK resigned over Placer Dome's misuse of him in its "propaganda materials" and lack of action in the cleanup of river pollution from the company's Porgera Mine.

Figure 19 Members of PEAK in 2010: Porgera Brochure

References for Porgera

CSIRO Australia; *Review of Riverine Impacts, Porgera Joint Venture;* December 1996.

Barrick website: http://www.barrick.com

GluedIdeas website: http://gluedideas.com/Encyclopedia-Britannica-Volume-9-Part-1-Extraction-Gambrinus/Fly-River.html

Mineral Policy Institute website: http://eyeonmining.wordpress.com/where-we-work/papua-new-guinea/porgera/

PJV Environment Department; *Porgera 2010 Annual Report January-December 2010*. June 2011.

Porgera Brochure; *Porgera Gold Mine Riverine Tailings and Waste Rock Management*; undated.

Strickland River Report Card 2009; http://barrickresponsibility.com/2010/en/society/significantincidents.html

OK Tedi Mine in Papua New Guinea

Description of the Mine

The OK Tedi copper and gold mine is situated in PNG hear the headwaters of the OK Tedi (Ok means river in the local language), which is tributary to the Fly River, in the Star Mountains Region of the central range of the Western Province. The mine is on Mount Fubilan at an elevation of about 2,000 meters. The OK Tedi-Strickland-Fly River System is 1200 km long with 500 km of the Fly River navigable from the Gulf of Papua, where the Fly River estuary is 80 km wide as it meets the Gulf.

Production began in 1984 with gold mining from 1984 to 1988 and largely copper from 1987 to the present. OK Tedi is an open pit mine where about 160,000 tonnes is removed per day, of which 78,000 tonnes is ore sent to the processing plant.

In 2010, the mine produced 160,000 tonnes of copper, with contained gold 15,000 kg and contained silver 46,000 kg.

The mine was developed by BHP Billiton and Inmet Mining Corporation, but now is operated by OK Tedi Mining Limited (OTML) and owned by Papua New Guinea Sustainable Development Program Limited (63%) and the PNG government (37%).

Riverine Discharge of Mine Tailings and Waste Rock

The OK Tedi mine discharges approximately 90 million tonnes per year (i.e., about 250,000 tonnes per day) of mine tailings and waste rock into the OK Tedi. The environmental impacts of the disposal are best summed up on the OK Tedi website:

> *A lot has been said about the Ok Tedi mine. Its importance to the PNG economy and development in Western Province combined with its undeniable environmental impacts has resulted in a wide-ranging public debate* (OK Tedi website).

The website acknowledges that the impacts of disposal of mine tailings and waste rock into the OK Tedi are significantly greater than anticipated before the mine was commissioned. Four years after the company ran an advertising campaign that the 90 million tonnes of waste disposed in the OK Tedi were virtually identical to natural sediments, the BHP CEO stated that "*with the benefit of these reports and 20/20 hindsight, the mine is not compatible with our environmental values and the company should never have become involved"* (Asia Times 1999). The primary impacts include sedimentation, vegetation dieback, acid rock drainage, copper toxicity and fish biomass decreases.

Over the first 20 years of mine operation, the main impacts were on the OK Tedi but now the impacts are extending into the middle reaches of the Fly River. The mine tailings and waste rock have caused a rise in the river bed, resulting in over-bank flooding and sediment deposition on the flood plain. This inundation kills vegetation along the riverbanks and on the floodplain, termed dieback. The website notes that the total area of forest affected by dieback is about 1,600 square km and may reach 3,000 square km by the time the mine closes. Recovery is slow, anticipated to take up to 200 years.

The flooding and dieback has impacted people living in villages near the river, as they have lost garden and crop growing areas, lost food supplies including fish and turtles, and have to hunt and fish over larger distances from their villages.

Copper levels in the river system do not exceed World Health Organization, Australian, or PNG drinking water standards, but the levels of bio-available copper are causing impacts to the river ecology (OK Tedi website).

The mine tailings and waste rock contain sulphide minerals which have the potential to generate acid when exposed to air, also releasing metals and lower pH levels. Acid rock drainage has been found in extensive areas in the lower middle and in the Upper Fly River, caused by sedimentation during river overflows to the flood plain.

Acid rock drainage is also occurring as a result of the dredging activities in the lower OK Tedi. Approximately 15 million tonnes of sediment are removed to the riverbanks each year, to reduce flooding and ensure adequate navigation. Acid is leaching from the dredged materials stockpiled along the riverbanks. The company is now adding limestone to the mine wastes prior to discharge into the OK Tedi.

In January 2000, the World Bank reviewed a comprehensive risk assessment commissioned by the PNG government. Their conclusions were that "*from a purely environmental perspective, the risk assessment suggests that the Ok Tedi mine needs to be moving towards closure as soon as possible", but that "immediate closure would appear to carry with it the worst social impact*" (OK Tedi website).

International Water Tribunal in The Hague and Litigation

In 1992, a group of indigenous landowners presented their grievances against Ok Tedi Mining to the International Water Tribunal in The Hague. In the late 1980s, the Yonggom people and their neighbors petitioned the company and the government regarding the pollution of the river and the loss of their traditional subsistence lifestyles. An anthropologist working with the Wopkaimin people described the mine waste's impact on local wildlife and people as "ecocide."

The Hague tribunal ruled in 1992 that PNG should close the mine or prevent further damage to the river and its ecology. The tribunal does not have legal force but it did bring the case into the international spotlight. Litigation followed in Australian courts and the company settled, paying villagers nearly $30 million, along with a commitment to contain mine tailings. BHP's shareholders wanted to close the mine in 2000. But the government and local communities viewed the possibility of the mine's early closure as the worst of all worlds: depriving local residents of jobs and income, and the region of royalties needed to address ecological problems. In 2002, BHP transferred its holdings to Papua New Guinea Sustainable Development Program Company, and received immunity from further pollution liability (Ghazi 2012).

Mine Closure

Under the current open-cut mining plan, mining operations at Ok Tedi are expected to cease around mid- to late-2013 when accessible ore is exhausted. OTML is examining a range of options including a feasibility study to extend mine life as an alternative to closure. OTML management considers this to be a genuine opportunity to extend mine life by another 7 years from 2014 to 2022 by a combination of two underground mines and one open pit operation. Production would be about 60% of current levels (OK Tedi website).

Rationale for Riverine Disposal of Mine Tailings

Prior to commissioning of the mine in the early 1980s, the intention was to build a mine tailings dam for storage of mine tailings. Construction of the storage dam began in 1983, but in 1984 a landslide smothered the site and destroyed the tailings dam. The PNG government then agreed to allow disposal of mine tailings into the OK Tedi, on the basis that tailings treatment was not feasible, given the unstable terrain, geological formations and very high rainfall of the region (OK Tedi 2012). Outside groups allege that "*owners of the mine had consistently argued against the construction of a dam to contain the mine tailings. However, finally, and at the insistence of the PNG government, work began on a tailings dam in 1983 one year before mining was to begin. From the outset the owner's lack of commitment toward the dam was evident. Geological surveys essential to ensure stability and appropriate location for the dam were neglected. In 1984, whilst construction was still proceeding a landslide smothered the site and collapsed the dam*" (MPI website).

References for Ok Tedi Mine

Asia Times Online; http://www.atimes.com/oceania/ah13ah01.html August 13, 1999

Ghazi, Polly; *Unearthing Controversy at the Ok Tedi Mine;* July 2003
http://archive.wri.org/newsroom/wrifeatures_text.cfm?ContentID=1895

MPI website: http://eyeonmining.wordpress.com/

OK Tedi website; http://www.oktedi.com/community-and-environment/the-environment/managing-mine-waste

Tolukuma Gold Mine in Papua New Guinea

Description of the Mine

The mine is located in the highlands of PNG in the Central District at an elevation of 1,550 meters above sea level. Access is only by air as no roads connect the mine to the rest of the island.

The mine is mostly an underground mine (92%) with a small open pit mine. Gold production averages about 69,000 ounces of gold per year. Tolukuma's gold production ranged from 85,000 ounces in 2004 to 44,000 ounces in 2007.

Open pit production began in 1995 and underground mining in mid-1997. The mine is a low capacity, high-grade operation and employs 630 people, including 130 contractors.

The metallurgical plant is compact and follows conventional gold extraction technology. It is located on a steep ridge in very mountainous terrain. Ore is trucked to the plant, then milled and treated through a conventional gravity and CIL circuit, and is capable of processing 18,000 tonnes per month. (Petromin website).

Previously owned by Emperor of Australia, it is now 100% owned by the government of PNG via Petromin PNG Holdings (MPI website).

Riverine Mine Tailings Disposal

Mine tailings are disposed into Iwu Creek at the mine processing plant which flows into the Auga River which flows into the Angabanga River, which reaches the sea 100 km from the mine. It has also been noted that substantial amounts of sediment are being eroded from the on-land overburden waste dumps (Oxfam 2004).

Estimates vary that 160,000 to 230,000 tonnes per year (i.e., about 500 tonnes per day) of mine tailings are disposed into the Auga-Angabanga River system (MPI website).

Environmental Impacts on the Auga-Argabanga River System

Impacts to the Auga-Argabanga Rivers are said to be serious. The death of most aquatic life in the Auga River is reported to be caused by the discharge of mine tailings, and heavy metals, such as arsenic, lead, and mercury, found in the Argabanga River are above WHO guidelines.

Increased levels of mine tailings in the river have been noted to be the cause of downstream flooding affecting crop growing areas, as mine tailings settle to the river bottom decreasing the amount of flood carrying capacity of the rivers (MPI website).

Four tribal groups live downstream of the mine and they were dependent upon the river for drinking, washing, fishing, and water for their crops. Community members attribute the polluted water to increased numbers of illnesses and deaths due to drinking and washing in the river. There are obvious impacts to health, lifestyle, and culture. For example, some women along the Argabanga River now walk four hours a day to collect clean water (MPI website).

Environmental Regulations and Compliance

Based upon the latest compliance information readily available, the previous mine owners, DMD Gold, stated that the mine was in substantial compliance with the environmental and permit requirements, based upon an independent audit of the Tolukuma operations (Oxfam 2004). The PNG legislation provides for river mixing zones downstream of which, water quality standards must be met. The compliance point for the Tolukuma mine is 7 km downstream of the discharge point of the mine tailings.

Best Environmental Management Practices

The process plant incorporates grinding, gravity extraction, leaching, elecrowinning, tailing thickening and filtration, and cyanide destruction (Ausenco website). Very little information is available regarding the processing plant and environmental management practices.

Rationale for Riverine Disposal

The previous owner, DRD Gold, stated that riverine tailings discharge is far safer than the alternative of a tailings dam, because of heavy rainfall, unstable geological conditions, and seismic activity. DRD stated that a tailings dam could result in breaching, leaching, or overflowing (Oxfam 2012).

References for Tolukuma Gold Mine

Ausenco website: www.ausenco.com

MPI website: http://www.mpi.org.au/tolukuma.aspx

Oxfam Mining Ombudsman Case Report: Tolukuma Gold Mine. 2004. www.Oxfam.org

Petromin website: http://www.petrominpng.com.pg/assets.html#Anchor--Toluku-26663

Case Studies Marine Disposal

Batu Hajiu Mine in Indonesia

Description of the Mine

The mine is an open pit copper and gold mine and operations began in 2000.

The owner is PT NMR Newmont Mining Company (PT Newmont Nusa Tenggara (PTNTT)), a subsidiary of US-based Newmont Corporation, Newmont, was founded in 1921 and is one of the world's largest gold producers, the only gold company included in the S&P 500 Index and Fortune 500. Headquartered near Denver, Colorado, the company has approximately 43,000 employees and contractors worldwide**.** (Newmont website).

Production at Batu Hajiu is about 300,000 tonnes of copper and 720,000 ounces of gold. Commercial production began in March 2000. The expected mine life is 2023. The mine directly employs about 7,000 people.

The location of the mine is in the southwest region of Island of Sumbawa.

Mine Tailings Disposal

Mine tailings are transported 6 km from the mine processing facilities by pipeline to Senunu Bay where they are discharged at 125 meters depth and 3.2 km from the shoreline, which is the edge of Senunu Submarine Canyon. The mine tailings are deaerated, mixed with seawater, and are denser than seawater enabling them to flow by gravity as a slurry, to the lower depths of the Canyon of 3,000 to 4,000 meters without a plume of turbidity via upwelling (Newmont Batu Hajiu brochure).

There are two offshore pipes installed, one as the active disposal pipe and one as a backup. The offshore pipe is changed every 2 to 4 years; the wear is regularly measured to ensure that the pipe is greater than the permitted pipe thickness of 33 mm (Waworuntu 2012).

Permit by the Indonesian Ministry of Environment

The government of Indonesia approved the DSTP in 1996 based upon an environmental impact assessment study completed in 1996. The permit was issued in 2003, and reissued in 2005, 2007, and 2011. (Batterham and Waworuntu 2009)

The permit allows 140,000 tons per day of mine tailings to be disposed by pipeline into Senunu Bay. Jarkarta Post, April 17, 2012. Actual disposal over 2000-2012 averaged 112,000 tons per day (Waworuntu 2012)

Characteristics of the Mine Tailings

The mine uses physical techniques to separate the copper and gold from the ore. The four main components of the process include crushing the ore to an average diameter of 15 cm, grinding to the size of sand or smaller, adding seawater, and then pumping to the flotation tanks. Organic reagents and lime are added to help float the mineral components to the surface where they are removed, dried, and shipped to smelters. The liquid and fine solids remaining in the tank are the mine tailings and are discharged as a slurry at 20-45% solids.

Studies of the Potential Impacts to Senunu Bay

Comprehensive chemical and biological testing of the mine tailings has been conducted under the permit. As stated in Newmont's brochure (Newmont Batu Hajiu brochure) on the mine tailings:

- The TCLP (Toxicity Characteristics Leaching Procedure) generally shows that the tailings are not classified as hazardous material, and that there is little difference, except for copper, between the mine "tailings and natural materials like soil, river and sea sediment, and (locally made) building bricks."
- Dissolved copper in the mine tailings as measured at the deaeration box is consistently below the permit level of 1 mg/L. Similarly, other chemical parameters are below permit limits.
- Acute toxicity testing using juvenile sea bass and tiger grouper and chronic testing on marine diatoms indicated no acute or chronic toxicity due to the mine tailings at 100% tailing concentration.

Marine water quality standards are being achieved as specified in the permit. The water quality standards do not apply in the depositional zone. The mine tailings are not causing a turbidity plume that reaches the surface and the mine tailings flow down the steep walls of the Senunu Canyon to greater than 3,000 meters depth. The tailings are confined to that canyon and have not been identified in other nearby areas. Quarterly monitoring of the tailings deposition area in 2002 confirmed that the tailings were travelling down the submarine slope and were not being deposited on the upper shelf area (Shimmield 2012). Supported by a survey by the Fishery Agency of West Sumbawa in 2011, it was informally reported by WALHI (Indonesian environmental interest group) that fishery folk living nearby Sununu Bay were experiencing decreasing fish catchments since the initiation of marine disposal of mine tailings and that species such as squid, which were abundant before mine tailings disposal, were now nearly extinct (Ginting 2012).

In 2012, the Jakarta State Administrative Court threw out the lawsuit brought by a coalition of environmental interest groups challenging the validity of the Ministry of Environment's renewal of the deep sea tailings discharge permit issued in May 2011 (Jakarta Post, April 17, 2012). The court's judgment is consistent with the findings of ongoing inspections, monitoring, environmental and social studies and tests conducted over the past 12 years by the Government of Indonesia, PTNNT and independent third parties. All of those studies consistently show that the STP system at Batu Hijau complies with applicable regulations and is operating as designed (PT Newmont Nusa Tenggara website). The environmental groups planned to appeal to the Indonesian High Court/Supreme Court.

Best Management Practices

Best management practices include:

- Ore Processing Management Practices
    - Ore and water management (mine-mill planning, on-going communication and evaluation) to optimize the ore feed and the process water usage.
    - Mine water treatment plant operation to minimize the metal content used in process water
    - Metal recovery optimization and improvements in the ore processing including the use of controlled potential sulphidization to enhance copper recovery.
- Mine tailings marine disposal
    - On-line / continuous monitoring of mill performance and tailings effluent quantity & quality
    - Toxicity testing before changes in reagents
    - Regular inspection, maintenance and replacement of DSTP pipeline system (deaeration box, onshore and offshore pipeline)
    - Offshore pipeline construction facility and improved construction techniques
    - Trained personnel to conduct various tasks in DSTP management and monitoring
    - State of the art offshore inspection tools: ROV (remotely operated vehicles), in-line inspection
    - Comprehensive marine monitoring program supported by a survey vessel and multiple oceanographic equipments
    - Multiple studies and due diligence monitoring related to DSTP (required by permit and additional PTNNT initiatives)
    - Government and stakeholder involvement in inspections, monitoring and studies
    - Regular reporting and publication to stakeholders
- Other notable practices
    - Application of Safety-Environmental- External Relation Integrated Management System (OSHAS 18001 and ISO 14001 certified)
    - Formal EIA, Environmental Management & Monitoring Plan, and DSTP Permit – including the evaluation process (Waworuntu 2012)

Rationale for Deep Sea Tailings Disposal

Before the permit was issued, an environmental impact assessment was conducted. The basis for the permit decision included:

- *On-land disposal would have impacted over 2,310 hectares of productive jungle and agricultural lands;*
- *Annual precipitation exceeding 2,500 millimeters would have made management of water within land-based impoundments extremely difficult;*
- *Water management challenges within a tailings impoundment constructed in an area prone to earthquakes could have threatened the safety of nearby communities; and,*
- *Tailings placed deep in the sea below the biological productive photic zone minimize impacts on the environment. (*Newmont Batu Hajiu Brochure)

Legislation, Regulations, and Permits

The primary Indonesian environmental protection legislation is the Environmental Stewardship Law No. 32, 2009. Under this law, marine disposal of mine tailings is categorized as dumping and requires a permit (article 60). Government regulations are not yet in place to provide additional requirements or guidance on marine discharge of mine tailings. Key regulations under the government regulation for control of marine and riverine mine tailings disposal are the Marine Disposal No. 19, 1999, Hazardous Waste No. 18, 1999, and Water Quality Management and Water Pollution Control Regulation No. 82, 2001. Marine disposal is essentially regulated by those regulations.

References for Batu Hajiu

Batterham, Grant; and Waworuntu, Jorina; *Deep Sea Tailings Placement at Batu Hijau, Sumbawa, Indonesia*, Egersund Conference, 2009.

Ginting, Pius; email of May 23, 2012

Newmont Batu Hajiu brochure: *Management of Deep Sea Tailings Placement System at Batu Hijau Mine;* http://www.newmont.com

Newmont website: http://www.newmont.com

PT Newmont Nusa Tenggara website: www.ptnnt.co.id

Shimmield, Tracy, et.al., Scottish Association for Marine Science, Final Report, Independent Evaluation of Deep-Sea Mine Tailings Placement (DSTP) in PNG, 2010

Waworuntu, Jorina; Newmont Mining; Email 9 May 2012

Lihir Gold Mine in Papua New Guinea

Description of the Mine

The mine is located on Niolam Island in the New Ireland Province which is the main island of the Lihir Group of islands. Generally referred to as Lihir, the island is 600 meters at its highest point and 22 km by 14.5 km at its widest and longest points. Located in an area of regular seismic activity, earthquakes up to 7.5 on the Richter Scale have been recorded since the early 1900s. Rainfall is about 3.7 meters per year. See Figure 20.

Operations began in 1997, and three linked open pit mines generate approximately 50 million tonnes of material moved from the pits each year. Of this amount, 40 million tons is waste overburden and 10 million tons is ore, 4 million tonnes of which is stockpiled for future processing. The eventual size of the pit will be 2 km by 1.4 km at a final depth of 200 meters below sea level.

Figure 20 Location of Lihir Mine (Source: Mining Technology undated)

The process plant first crushes the ore followed by flotation, high pressure oxidation, and conventional CIL (carbon in leaching) technology. The plant's capacity is being expanded from 6 million tonnes of ore per year producing 800,000 ounces of gold in 2008 to 11-12 million tonnes of ore per year and over 1 million ounces of gold per year. The expanded operations are targeted to commence in 2012.

In 2010, Newcrest Mining Limited of Australia became owner of the Lihir mine following the merger of Newcrest and Lihir Gold Limited (Newcrest website).

Waste Rock and Overburden Dumped into the Sea

The waste rock and overburden, mainly sulphide minerals including pyrite, is placed on a vessel and hauled to a point in Luise Harbour approximately 1 km offshore and dumped into deep ravines. Approximately 40 million tonnes per year have been dumped which will increase to about 70 million tonnes per year when the expansion commences in 2012. Four vessels operate 24 hours per day year round, which translates to a total dumping average of 4,600 to 8,000 tonnes per hour. The total dumped since the mine started operating in

Figure 21 Location of Dump Site and Tailings Discharge Point McKinnon **2002**

1995 totals 510 million cubic meters (Limu 2012). See Figure 21 and 22.

Figure 22 Waste Rock Barges for Dumping as Sea. Courtesy Newcrest Mining

Marine Disposal of Mine Tailings

In 2009, it was reported that 3.8 million tonnes per year of mine tailings are disposed by pipeline into Luise Harbour at a depth of 115 meters and 1.5 km from the shoreline (Brewer 2009). The total mine tailings disposed since the mine started operating is 3,060 cubic meters (Pawa Limu 2012). The intent is for the mine tailings to slide down an ocean trench such that the surface waters are not impacted. See Figure 23. The original Lihir environmental plan states that benthic macro invertebrates will be exposed to high concentrations of cyanide and metals in the tailings sediments, which could result in an uncertain level of bioaccumulation in the food chain.

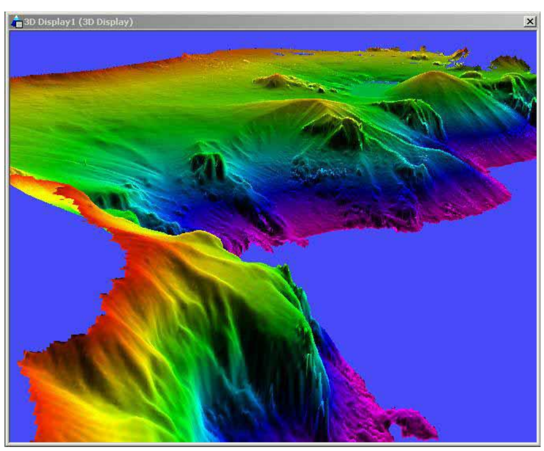

Figure 23 Lihir marine disposal site showing steep canyons. Courtesy Newcrest Mining

Monitoring

Routine monitoring of the mine tailings chemistry involves sampling of the tailings waste stream within the deaeration tank prior to marine discharge. Samples are collected every 2 hours and combined over each shift providing two composite samples per day. These composite samples are analyzed for % solids, pH, conductivity, temperature, TSS, weak acid dissociable cyanide and free cyanide. Weekly composites are analyzed for filterable metals including As, Cd, Cu, Fe, Pb, Hg, Ni, Ag and Zn. Results are used to characterize the physical and chemical composition of the tailings stream and ensure compliance with National Regulations. Detoxification of the tailing stream is achieved by reacting free cyanide with ferric and ferrous ions from the oxidation of pyrite to form stable iron-cyanide complexes.

Fish tissues are also tested for heavy metals bioaccumulation once every 3-4 months. Results are presented to the PNG National Government through the Department of Environment and Conservation (Limu 2012).

Environmental Impacts of Mine Tailings Deep Sea Tailings Placement by Pipeline and Waste Dumping

Dumping of the overburden and waste rock has covered a large area, but information on the extent of the area is not available. One report states that 7 square km of coral reef has been directly destroyed by smothering, and that heavy metals have been bioaccumulated making fish and shellfish unacceptable for consumption. Analyses have confirmed high levels of arsenic and copper and elevated levels of mercury in both the overburden and the waste rock. Studies have shown excessive concentrations of either arsenic, mercury, lead, or cadmium in local fish populations (MPI 2012). As reported by a PNG government official, the main impacts of dumping the rocks and tailings are expected to be damage to the coral reefs due to increased turbidity of the water, the smothering of sea floor benthos, and high concentrations of heavy metals ending up through the food chain to eventual health concerns for the people who very much depend on marine resources and food (Limu 2012)

The Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia's national science agency, reported at the International Conference on Marine and Lake Disposal of Mine Tailings in Egersund, Norway, September 7-10, 2009, on studies that had been conducted of the effects on marine life of the dumping and discharge of mine tailings from the Lihir mine. These included assessments of shallow reef communities, impacts of coral bleaching, intertidal communities, aquaculture and fishery potential (deep water demersal fish), pelagic communities, and bioaccumulation. The conclusions (Brewer 2009):

- *Higher abundances of pelagic species in mine region*
- *Species diversity not impacted*
- *Some bioaccumulation in lower levels of the food web only –less mobile species*
- *No bioaccumulation into pelagic food fish*
- *Mechanisms for trace metal uptake poorly understood*
- *No apparent impacts on human health*

In the technical paper reporting on the studies, Dr. Brewer and colleagues state that:

> *Little is known about the impacts of mine waste disposal, including deep-sea tailings, on tropical marine environments and this study presents the first account of this impact on deepwater fish communities. The Lihir gold mine in Papua New Guinea has deposited both excavated overburden and processed tailings slurry into the coastal environment since 1997. The abundances of fish species and trace metal concentrations in their tissues were compared between sites adjacent to and away from the mine. In this study (1999-2002), 975 fish of 98 species were caught. Significantly fewer fish were caught close to the mine than in neighbouring regions; the highest numbers were in regions distant from the mine. The catch rates of nine of the 17 most abundant species were lowest, and in three species were highest, close to the*

> *mine. There appears to be limited contamination in fish tissues caused by trace metals disposed as mine waste. Although arsenic (several species) and mercury (one species) were found in concentrations above Australian food standards. However, as in the baseline (pre-mine) sampling, it appears they are accumulating these metals mostly from naturally-occurring sources rather than the mine waste* (Brewer 2007).

The bottom line of the studies is that fewer deepwater fish are found adjacent to the area impacted by mine waste and tailings, likely due to migration away from the area. The studies of shallow water fish demonstrated similar impacts as well as local depletion of reef habitat in the area adjacent to the mine. Thus, the mine is having a significant impact on local habitat and demersal fish communities, but not through mine induced toxification but more likely through habitat modification (Brewer 2012).

In a separate scientific assessment by CSIRO of the potential impacts upon shallow water habitats and fish, the study found that fish were less abundant and live coral cover was much less in the vicinity of the dump site and in the vicinity of the mine tailings discharge area. From 1999-2007 the relative abundance and biodiversity remained about the same, and abundance and biodiversity of areas outside of the impacted zone remained relatively constant. Thus, impacts to fish were localized around the mine area (Shimmield 2010).

<u>Permit Issuance</u>

The department of Environment and Conservation issued the Environment Permit for the mine tailings and waste rock disposals.

<u>Rationale for Deep Sea Tailings Placement</u>

In the original environmental plan for the mine, the plan stated that pipeline disposal into the sea was the best alternative based upon a number of factors: the plan stated that there was insufficient space on the island for land-based tailings management which would become a hazard for the community and the environment, whereas the marine discharge would not pose a hazard to the environment. The plan notes that marine water is naturally alkaline and therefore would neutralize the acidity of the mine tailings, and the density of marine water would keep the mine tailings from mixing with the surface waters (McKinnon 2002).

<u>References for Lihir</u>

Brewer, David, "Impacts of gold mine waste disposal deepwater fish in a pristine tropical marine system;" Marine Pollution Bulletin, March 2007.

Brewer, David, "Long term monitoring of shallow water communities at the Lihir Island Group: Investigating mine impacts on reef fish and benthos;" Egersund Conference, 2009.

Brewer, David; Personal Communication, email; July 16, 2012.

Limu, Pawa; email; July 16, 2012

McKinnon, Elizabeth, *The environmental effects of mining waste disposal at Lihir Gold Mine*, *Papua New Guinea,* Journal of Rural and Remote Environmental Health 1(2): 40-50 (2002)

MPI website: http://eyeonmining.wordpress.com/where-we-work/papua-new-guinea/lihir/

Newcrest website: http://www.newcrest.com.au/

Shimmield, Tracy, et.al., SAMS, Final Report, Independent Evaluation of Deep-Sea Mine Tailings Placement (DSTP) in PNG, 2010.

Ramu Nickel Cobalt Mine In Papua New Guinea

Description of the Mine

The nickel cobalt mine is located on the north coast of Papua New Guinea in the Province of Madang, near the town of Madang. The Kurumbukari mine site is located west of the refinery plant. A 134 km pipeline carries the slurried ore from the mine to the processing plant at the shoreline on Astrolabe Bay which is part of the Bismarck Sea.

Planning for the mine began in the 1990s, and the application for a mining permit and the Ramu Environment Plan were both submitted in 1999. Production began in 2012 with full capacity targeted for mid-2013. Between those two points in time, there was a great deal of controversy and litigation over the potential environmental damage due to the planned pipeline discharge of mine tailings to Astrolabe Bay.

Annual production is targeted at 32,000 tonnes of nickel and 3,000 tonnes of cobalt over 20 year mine life, plus another possible 15-20 years based upon the known nickel and cobalt deposits (MPI 2012).

Metallurgical Corp of China leads a Chinese consortium that owns 85 percent, with the rest held by the Highlands Pacific at 8.56 percent, the PNG government at 3.94%, and a landowner company at 2.5%. (Island Business website).

Marine Disposal of Mine Tailings

Mine tailings are discharged in a pipe that extends 450 meters from the shoreline and discharges at 150 meters. The mine tailings are predicted to form a sedimentary apron within the submarine canyon and seaward between the 500 and 1500 meter depth contours, over an area of at least 150 square km of ocean floor, to a thickness of tens of meters.(Science Alert 2012).

It is projected that 5 million tonnes of mine tailings will be disposed by the pipeline each year, resulting in some 100 million tonnes over the 20 years of mine life.

Potential Environmental Impacts of Discharging Mine Tailings into Astolabe Bay and the Bismarck Sea

Upon publication of the Ramu Nickel Environment Plan in 1999 which was accepted by the government of PNG, the debate began over the adequacy of the environmental assessment in the document and the high risk of serious environmental damage to Astrolabe Bay. Major studies were commissioned, one by the government conducted by the Scottish Association of Marine Science (SAMS) (Shimmield 2010). The summary of the SAMS report stated:

> *An extensive baseline survey has been carried out on the Rai coast at stations that are likely to be impacted by the proposed DSTP at Basamuk as well as at more distant stations in similar depths that are unlikely to be influenced by the tailings. This will allow future surveys to compare changes at impacted stations with the environmental conditions pertaining before impact and, by analysing changes at control stations over time will determine the level of natural temporal variability that will inform interpretation of the results at the impacted stations. This is the most*

> *comprehensive baseline study yet carried out for a DSTP mine in PNG and, as far as we know, in the world.*
>
> *Detailed investigations have been made on benthic macro-and meiofaunal communities together with high resolution studies of both benthic and pelagic biogeochemistry. The physical oceanography of the area has been further characterised although there is much more that could be done to better understand the hydrodynamics of the region, especially relating to temporal variability.*
>
> *The Basamuk site and the adjacent continental slope appear to conform to the fundamental requirements of a DSTP, i.e. steeply sloping from close to the coast leading quickly into very deep water. Provided the DSTP system is optimally specified and subsequently maintained it should perform as well as the system at Lihir (See section 3). However, there is always uncertainty in any prediction and a robust monitoring programme must be implemented once the DSTP becomes operational to ensure that the system performs as planned with minimal interaction with shallow water ecosystems.*

The Mineral Policy Institute was commissioned by the Lutheran Church of PNG to conduct an assessment of the Ramu Nickel project, the Environment Plan prepared by Natural Resource Systems for Ramu Nickel, and the potential environmental impacts of pipeline disposal into Astrolabe Bay. A team of three independent scientists prepared a report for the Minerals Policy Institute (Shearman 2001). The executive summary states:

> *There can be no doubt that disturbance on the scale of a Submarine Tailings Disposal operation will have significant biological impacts………*
>
> *…….Natural Systems Research compiled a well presented but fatally flawed case for the discharge of mine tailings via a submarine pipe into Astrolabe Bay. The Natural Systems Research Environmental Plan attempts to show that Submarine Tailings Disposal is not only the best solution for tailings disposal from the Ramu mine, but that it is to the utmost degree, environmentally responsible. The fundamental finding of this review is that the behaviour of tailings discharged into Astrolabe Bay is not adequately explained in the Environmental Plan. While NSR claim that tailings will be deposited safely on the deep-water floor of Vitiaz Basin, on the basis of their own data, this is extremely improbable……...*
>
> *……..In conclusion, Natural Systems Research has not presented a convincing scenario for the fate and impact of the tailings material. While it is remotely possible that the discharge of 100 million tonnes of mine tailings into Astrolabe Bay may have no impact at all, this is exceedingly unlikely. Neither Natural Systems Research nor Highlands Pacific can have any certainty as to the short and long term effects of Submarine Tailings Disposal on the ecology, fish, animal, and plant life of Astrolabe Bay.*

The environmental concerns noted in the Shearman report were the impacts of a footprint of mine tailings on the sea floor of 10-15 meters thick over an area of 150 square km. The area is within the "Coral Triangle," an area which has been described as having the highest diversity of corals, fish, crustaceans, mollusks, and marine plant species in the world. The report stated that "*virtually nothing is known about the deep area that will be buried in Fe/Mn rich silty clay refinery tailings, that are enriched in a chemical soup of trace elements and refinery reagents."* The report pointed out the potential effects of up-welling and the lateral currents and the implications for toxicity to marine life near the discharge and along far reaches of the shoreline.

In response to the concerns raised in the MPI report and other entities, the government of PNG commissioned the Scottish Association of Marine Science to conduct a comprehensive assessment of the potential environmental impacts of deep sea mine tailings placement from the Ramu Nickel mine and the Lihir Gold Mine.

Permit to Discharge Mine Tailings

The Director of PNG's Department of Environment and Conservation issued an amended permit on 10 August 2009 to Metallurgical Corp of China to discharge mine tailings in accordance with the 1999 Environment Plan, and it specified requirements of the discharge. These included the location of the discharge point, the mixing zone and compliance point, discharge quantities, effluent limits for heavy metals, water quality criteria, and monitoring and reporting requirements.

Litigation

Proceedings were instituted in the National Court of PNG, as WS No. 1192 of 2010. The plaintiffs alleged that the DSTP processes that Ramu proposed would:

- constitute a private and public nuisance;
- breach the *Environment Act 2000* (Papua New Guinea); and
- breach National Goal and Directive Principle (*NGDP*) No. 4 (natural resources and environment) of the PNG Constitution.

The court found there was a reasonable probability that the proposed DSTP processes would cause environmental harm that may have catastrophic consequences, cause irreparable damage to the ecology of coastal waters, and seriously harm the lives and futures of the plaintiffs, and of thousands of other people in Madang Province. In particular, the court made the following findings (MPI 2012):

- It was likely that the tailings would smother benthic organisms over a wide area of the ocean floor (at least 150 km^2), which would inevitably alter the ecology of that part of the ocean;
- It was very likely that the tailings would be toxic to marine organisms; and
- There was a real danger that the tailings would not settle on the ocean floor but be subject to significant upwelling, which meant that substantial quantities of tailings would be transported towards the PNG mainland.

While Judge Cannings did not grant the injunction sought, he made it clear what he thought of DSTP, (National Court of Justice 2010):

> "I therefore feel obliged to state that my considered opinion as a Judge, having heard extensive evidence on the likely environmental effect of the DSTP and made findings of fact on that subject, is that the approval of the DSTP and its operation has been and will be contrary to National Goal No 4. It amounts to an abuse and depletion of Papua New Guinea's natural resources and environment – not their conservation – for the collective benefit of the People of Papua New Guinea and for the benefit of future generations, to discharge into a near-pristine sea (a widely recognised hotspot of biodiversity), mine tailings at a rate of 5 million tonnes of solids and 58.9 million cubic metres of tailings liquor per year. It constitutes unwise use of our natural resources and environment, particularly in and on the seabed and in the sea. It amounts to a breach of our duty of trust for future generations for this to happen. It is a course of action that shows deafness to the call of the People through Directive Principle 4(2) to conserve and replenish our sacred and scenic marine environment in Astrolabe Bay. It puts other coastal waters of Madang Province at risk. Inadequate protection has been given to our valued fish and other marine organisms.
>
> Having expressed that opinion, I do not consider that Section 25(3) requires that I proceed to make orders under Section 23 of the *Constitution* to enforce that opinion; and I decline to do so. "

The ruling was appealed to the Appeals Court which agreed with the lower court's ruling.

References for Ramu Nickel

Island Business website: http://www.islandsbusiness.com/

National Court of Justice 2010

Science Alert website: http://www.sciencealert.com.au/features/20112403-21988.html

Shearman, Phil, *A review of the risks presented by the Ramu Nickel Project to the ecology of Astrolabe Bay in Papua New Guinea*, A research paper commissioned by the Evangelical Lutheran Church of Papua New Guinea; Mineral Policy Institute, 2001. ISBN No. 0-9585457-5-8. *www.actnowpng.org*

Shimmield, Tracy, et.al., Scottish Association for Marine Science, Final Report, Independent Evaluation of Deep-Sea Mine Tailings Placement (DSTP) in PNG, 2010.

Simberi Gold Mine in Papua New Guinea

Description of Mine

Owned by Allied Gold, an Australian-based company, the mine is located on the eastern side of Simberi Island in the New Ireland Province of PNG.

The mine began gold production in February 2008, with seven open pit mines using a conveyor system to move the ore to the processing facility. The mine has a relatively low strip ratio of 1:1 (overburden to ore).

Simberi Island is about 10 km by 8 km, with a steep coastline, and surrounded by a fringing reef and depths of seawater that fall off rapidly given the volcanic origins of the island. Mean annual rainfall is 3 meters, and about 1,100 people are residents of the island. See Figures 24 and 25.

During 2012, the plant is being expanded to 3.5 million tonnes of ore per year. Options to expand to 5 million tonnes per year are under review (Allied Gold website)

Production is expected to continue for up to 10 years with targeted gold production at 60,000 ounces per year.

Mine Tailings Disposal

Mine tailings are disposed by pipeline into Pigiput Bay through a 528 meter pipeline that discharges at a depth of 130 meters. The mine tailings are mixed with seawater prior to disposal (Mineral Policy Institute website).

While citable information is not available, it is estimated that approximately 3.3 million tons per year of mine tailings are disposed into marine waters (i.e., 97% of 3.5 million tons of ore processed per year) or about 9,000 tons per day.

Figure 24 Location of Simberi Mine

Figure 25 Simberi Island and Allied Gold ore processing facility (Allied Gold 2012)

Environmental Impacts and Monitoring

In a presentation prepared by Allied Gold Mining Company, it was noted that the discharge of the mine tailings at the discharge point does not cause the marine water quality at the boundary of the mixing zone to exceed the marine water quality criteria in the Environmental Permit in most cases. In addition, metals and cyanide concentrations did not exceed the Australian and New Zealand maximum limits or WHO codex standard.

References for Simberi

Allied Gold website: http://www.alliedgold.com.au/

Lole, Howard and Yoba, Ninkama; Allied Gold Mining, Simberi Gold Company; DSTP-*Simberi Experience*, Environmental Seminar, July 19-20, 2011

Mineral Policy Institute website: http://eyeonmining.wordpress.com/

Hidden Valley Mine in Papua New Guinea

Description of the Mine

The mine is located in PNG's Morobe Province and operates two open pits, approximately 5 km apart. Annual production at Hidden Valley mine is expected to be around 250,000 ounces of gold and 4 million ounces of silver. Construction began in 2007 with the bulk of the work completed in 20090. The mine has an expected 14 year mine life. Approximately 4.7 million tonnes of ore will be processed annually.

Ownership is Morobe Mining Joint Venture (50% Newcrest Mining: 50% Harmony Gold), and the workforce is about 2,000 employees and contractors (95% Papua New Guinean's with 50% from local communities)

The processing plant utilizes conventional gravity and CIL circuits for gold and a Merill Crowe circuit for silver. When fully commissioned, the process plant will treat 4.7 million tonnes of ore per year (Morobe website).

Tailings Storage Facility

Hidden Valley is also the first major open pit mine in PNG to build a tailings storage facility as shown in Figure 26 to contain all tailings permitted under the new Environment Act 2000 (Limu 2012).

Figure 26 Tailings Storage Facility at Hidden Valley Mine--The first of its kind in PNG. Source:

References for Hidden Valley

Limu, Pawa; email; July 16, 2012

Morobe website: http://www.morobejv.com/

Bougainville Copper Mine (closed) in Papua New Guinea

Description of the Mine

Bougainville copper mine closed in 1989, primarily due to social unrest resulting from massive environmental damage from riverine discharge of mine tailings and due to unmet claims from landowners.

Bougainville mine is located in PNG on Bougainville Island about 20 km from the east coast and 25 km from the west coast at 670 meters elevation. The mine is in steep, rugged highlands in tropical forest with rainfall about 4.4 meters per year.

Approximately 300,000 tonnes of ore and waste were removed from the open pit mine daily.

Owned by Rio Tinto, with corporate offices in England and Australia, the mine dominated the economy of the island during the 1970s and 1980s. It also was highly significant to the overall PNG economy: in the 1970s and the 1980s, the company's tax and dividend payments added up to approximately 20% of PNG's national budget.

Riverine Disposal of Mine Tailings

Mine tailings of about 130,000 tonnes per day were discharged to the Kawerong River which then flowed into the Jaba River and into the coastal plain. The tailings that did not settle in the coastal plains reached the sea in the Empress Augusta Bay, forming an extensive delta. One researcher stated that the rivers had been converted into a “tailings flume” resulting in unconfined and uncontrolled flooding.

In 1989, the company initiated the construction of a tailings pipeline to the existing tailings-derived delta in Empress Augusta Bay, because of the severe damage to the river and coastal plain. One estimate was that acid drainage and leaching of heavy metals would last 600 years.

Environmental Effects of Riverine Disposal

The riverine disposal of mine tailings destroyed most marine life in the estuary where freshwater fish also breed. The problem with such tailings lies in a complex of factors, including intense acidification caused by metal sulphides oxidizing to produce sulphuric acid sufficient to give soil pH as low as 2.5, and leaching of heavy metals. The entire 480 square kilometers tributary system is essentially devoid of fish. The mine tailings have raised the river bed by 40 meters in some places, causing contaminated groundwater to spread into surrounding lands.

As Basil Peutalo of the PNG Catholic Commission for Justice, Peace and Development commented:

> *"This ecocide was done without warning, without permission having been asked or granted, and in areas where the inhabitants had thought that they would not be touched by the mining activities. Here is a people who fear that they are no longer in control of their destiny and land. They are losing control of the patrimony of their children. For thousands of years, our ancestors lived out their interconnectedness with the natural world. However, this view of nature and the relationship of the human person with it is challenged today by a spirit of utility which views the earth as property to be used.”*(McIntosh 1990).

Closing of the Mine: 20,000 Lives Lost

In 1987, Francis Ona won election to the Panguan Landowners Association, giving a new voice to the frustrations of the poor communities living in mountainous areas around the mining operation that faced land shortages, lack of income generating opportunities, and an environmental catastrophe.

Ona declared outright guerrilla war proclaiming, "*Our land is being polluted, our water is being polluted, the air we breathe is being polluted with dangerous chemicals that are slowly killing us and destroying our land for future generations. Better that we die fighting than to be slowly poisoned.*" (McIntosh 1990).

In 1988, Ona and other disenfranchised landowners began a campaign of industrial sabotage. This campaign started a civil war, a succession movement, and the PNG defense force assaulted villages using mortars, attack helicopters and automatic rifles. A blockade was placed around the island. The civil conflict lasted 8 years until a cease-fire was put in place. Some 20,000 Papua New Guineans lost their lives.

The mine closed in 1989. In 2012, there are discussions on-going about reopening the mine between the current owner, BCM, a Canadian company, and the PNG government and local stakeholders (Mine Watch website).

References

Bureau of Mines, Case Studies of Submarine Tailings Disposal: Volume II-Worldwide Case Histories and Screening Criteria, U.S. Department of the Interior, OFR 37-94, 1994

McIntosh, Alastair, The Bougainville Crisis: A South Pacific Crofters' War, 1990
http://www.alastairmcintosh.com/articles/1990_bougainville.htm

Mine Watch website: http://ramumine.wordpress.com/
Papua New Guinea Mine Watch, August 6, 2012

Talu, Patrick, Landowners Irate over BCL Talks, Mineral Policy Institute, Summer Newsletter, 2010.

Frieda River Copper and Gold Project in Papua New Guinea (Proposed)

Description of the Mine Project

The mine project is located in northwestern PNG near the border of the Sandaun and East Sepik Provinces. Feasibility studies are underway with construction targeted to begin in 2012 and production in 2017.

The mine project is owned by Xstrata (76%), a Swiss company, Highlands Pacific (17%), and OMRD Frieda Co Ltd (7%). Overall estimated resources are estimated at 14 million ounces of gold and 7.5 million tonnes of copper, collectively one of the world's largest deposits. Production is expected to be 240,000 ounces of gold per year and 200,000 tonnes of copper per year.

Environmental Aspects

Xstrata has stated that it will not discharge mine tailings into the Sepik River System (Hriehwazi 2010), and thus, a mine tailings storage dam/facility is likely to be built. No other information is available.

There is the risk of pollution of lower, middle and upper Sepik wetlands. The wetlands of the Sepik are world-renowned and tailings from copper and gold production, if not properly contained, would have a devastating impact on these fragile wetlands causing the death of water fowl, fish populations and river-side vegetation. Indigenous peoples living in the Middle and Lower Sepik River and depend on forest and swamp resources, particularly the groves of sago palm which provide the staple food of the region (MPI website).

References for Frieda Mine

Hriehwazi, Yihiura, The PNG National, *No wastes into river: Xstrata,* 1 February 2010, http://www.minesandcommunities.org/article.php?a=9841

Joku, Harlyne, *Frieda Project to be largest open pit mine in the world* 2010 http://www.minesandcommunities.org/article.php?a=9841

Minerals Policy Institute website: http://eyeonmining.wordpress.com/where-we-work/papua-new-guinea/frieda-river/ 2012.

Wafi-Golpu Gold Copper Mine in Papua New Guinea (proposed)

Description of the Mine Project

Located in moderately mountainous terrain about 90 km from the seaport of Lae in Morobe Province, the mine is in the final feasibility analysis stage. See Figure 27. Recent estimates indicate that the project area, including Wafi, Golpu and the nearby Nambonga, contains mineral resources total that total 27 million ounces of gold, 9 million tonnes of copper. Production is targeted at 400,000-580,000 ounces of gold per year and 250,000-300,000 tons of copper per year (MPI Wafi website) (PNG Mine Watch 2012).

The project is 50:50 owned by Harmony Gold Mining Company of South Africa and Newcrest Mining Limited of Australia. Production is targeted to begin in 2019.

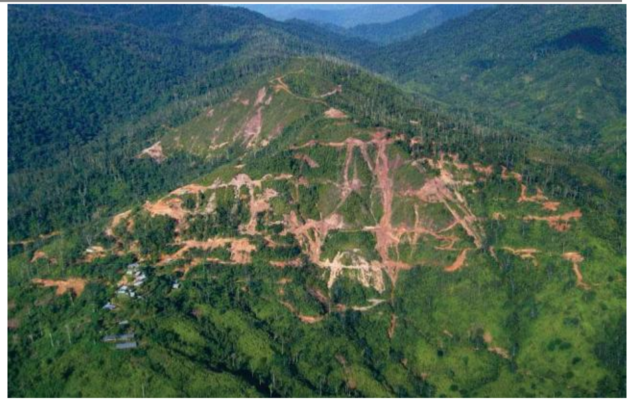

Figure 27 Wafi Golpu Exploration Source: Morobe Analyst Tour 2011

Environmental Aspects

The environmental management plan is currently being developed. This includes gathering baseline environmental data, water quality monitoring, flora and fauna surveys, and establishing nurseries for rehabilitation.

Disposal of mine tailings is an unknown at this point, except that marine disposal is no longer being considered. Newcrests's other major mine in PNG is Hidden Valley, at which a mine tailings management facility was built (i.e., a tailings dam).

References for Wafi-Golpu

Minerals Policy Institute website, Wafi; http://www.mpi.org.au/wafi-golpu.aspx 2012

Morobe Mining Joint Ventures, *MMJV Analyst Tour, Wafi Golpu – A World Class Project*, March 2011 *www.harmony.co.za/im/files/.../analyst-visit-mar2011-wafigolpu.pdf*

PNG Mine Watch; 8-30-12: http://ramumine.wordpress.com/2012/08/30/newcrest-faces-10bn-png-bill/

Inwauna Gold Project in Papua New Guinea (proposed)

Description of the Mine Project

Located 65 km northeast of Alotau in Milne Bay Province in southeast PNG Norman Island on, the mine is in the development stages. The preliminary/definitive feasibility study was submitted to the PNG Mineral Resources Authority in April 2010. The study concluded that further evaluation work is needed before a "decision to mine" is ready (New Guinea Gold website).

The property terrain varies from broad valleys to steep mountains with relief of 1,073 meters from the highest peak of Mt. Hobiya to sea level. The property is mainly primary rainforest with secondary overgrowth in areas of shifting gardens. Rainfall varies from about 4.5-5.5 meters per year in the project area.

The mine is being developed by New Guinea Gold Corporation of Canada.

Environmental Aspects

No information is available on the plans for disposal or storage of mine tailings. Marine disposal has been studied. One report noted the precedent has been for deep sea tailings placement in other mines in similar physical locations (MPI website).

References for Inwauna Project

Minerals Policy Institute http://eyeonmining.wordpress.com/where-we-work/papua-new-guinea/imwauna/

New Guinea Gold website: http://www.pnggold.com/s/Imwauna.asp

Mt Sinivit Gold Mine in Papua New Guinea (proposed)

Description of the Mine Project

The Sinivit gold project is located 50 kilometers south south-west of Rabaul in the Baining Mountains of the Gazelle Peninsula, East New Britain Province, PNG. The Company is currently mining gold oxide ore from a series of shallow open pits within the Sinivit vein system (New Guinea Gold website).

The mine is owned by New Guinea Gold Ltd (92%), headquartered in Vancouver, BC, Canada, and by Gold Mines of Niugini Holdings Pty Ltd (8%). Production of gold began in 2008. Production in 2008 was 7,400 ounces of gold and 1,200 ounces of silver, levels likely to increase. It is noted that a great deal of exploration is on-going on the site to assess potential reserves (MPI website).

Environmental Aspects

No information is available regarding disposal of mine tailings. Because the only complaints reported were in regard to potential spills in the river, it is assumed that riverine discharge or DSTP is not used for disposal of mine tailings. Waste rock is stored on-site.

References for Mt Sinivit Gold Mine

Minerals Policy Institute website: http://eyeonmining.wordpress.com/where-we-work/papua-new-guinea/sinivit/ 2012

New Guinea Gold website: http://www.newguineagold.ca/projects/sinivit/Sinivit.html#pr 2012

Yandera Copper/Molybdenum/Gold Mine in Papua New Guinea (Proposed)

Description of the Mine Project

Located 95 km west of Madang in Madang Province, the Yandera (sometimes called the Marengo Mine) is located relatively close to the Ramu Nickel mine. Construction is planned to be complete and production beginning in 2013.

The project is 100% owned by Marengo Mining of Australia. Ore processing will begin at 25 million tonnes per year and increase over the lifetime of the mine (MPI website). Based upon an estimate of 1% copper in the ore, the ore processing plant will generate about 67,000 tonnes per day of mine tailings (Marengo Mining website).

Environmental Aspects

Early discussions indicated that deep sea tailings placement was the preferred disposal alternative. Bathymetric surveys to determine placement of mine tailings discharge pipes were completed in early 2010.

On May 5, 2012, it was reported that Marengo Mining had determined that DSTP would not be used for mine tailings disposal. The selected alternative is a combined rock waste dump and tailings storage facility (Ramumine MineWatch website).

References for Yandera

Marengo Mining website: http://www.marengomining.com/projects-yandera.html 30 May 2012

MPI http://eyeonmining.wordpress.com/where-we-work/papua-new-guinea/yandera/ 2012-06-28

Ramumine MineWatch website: http://ramumine.wordpress.com/2012/05/31/yandera-confirms-it-has-dumped-marine-waste-disposal-plans/

Cayeli Bakir Copper-Zinc Mine in Turkey

Description of the Mine

The Cayeli Bakir copper-zinc mine opened in 1994 and is located in Turkey in the Buyuk Dere Valley near the southeastern Black Sea Coast. An underground mine, the mine and processing facility produced 29,000 tonnes of copper and 48,000 tonnes of zinc in 2011. The mine milled 3,300 tonnes per day of ore and a total of 1.2 million tonnes of ore in 2011 (Inmet 2011). The mine is expected to operate until at least 2017.

The mine employs 471 people and is 100% owned by Inmet Mining Corporation, a Canadian company.

Disposal of Mine Tailings into the Black Sea

Mine tailings are discharged though a 350 meter long outfall at a depth of 275 meters into the anoxic zone. The initial proposal from the company was to discharge at a depth of 150 meters but the Turkish regulatory agency required the discharge to be at 350 meters. The Black Sea had been subjected to many years of oceanographic and marine biological assessments, which served as the basis for the design of the outfall pipe and the discharge location. The tailings are de-aerated and diluted with seawater taken from a depth of 15 meters prior to discharge (Berkun 2005). The final tailings deposition zone is in anoxic water at a depth of greater than 2,000 meters. The Black Sea is a highly stratified inland sea with a large anoxic zone (90% of the water column), and a permanent pycnocline at depths of 35 to 150 m, which limits exchanges between surface and deep water. More recently, continuing monitoring and studies of the deposition of the mine tailings has determined that 275 meters is an appropriate discharge depth (Shimmield 2010).

The discharge into the Black Sea takes advantage of the anoxic conditions below about 150 meters depth with hydrogen sulfide concentrations greater than 3 mg/l. The depths are thus devoid of marine life other than sulfide metabolizing bacteria, and the hydrogen sulfide serves to precipitate heavy metals in the mine tailings. Studies have shown that upwelling is not occurring the plume of the mine tailings is not reaching surface waters (Interior 1994). Predictions of tailings flow and deposition by Rescan (1992a-c, cited in Berkun 2005) indicated that there could be some separation of buoyant plumes comprising very fine tailings particles, which would be trapped within the deep anoxic zone and thus would not surface. Further calculations and tank experiments by Berkun confirmed that buoyant plumes could potentially separate from the main tailings plume prior to deposition, and that they could rise to about 89 meters above the discharge depth, and thus stay in the deep anoxic zone beneath the permanent pynocline of 150 meters depth (Berkum 2005).

Quantities of Mine Tailings Disposed in the Black Sea

Mine tailings containing such heavy metals as arsenic, cadmium, chromium, lead, and mercury, and are disposed at a rate of about 3,000 tonnes per day. About half of the mine tailings are backfilled into the underground mine (Earth Works 2012).

Permit to Discharge

In 2011, the mine received its integrated environmental permit from the Turkish regulatory authority (which is a comprehensive update of previous discharge permits). The long term environmental monitoring program has shown no change in water quality as a result of the mine tailings discharge.

In issuance of the permit, the Turkish regulatory authority took into account the fact that the eastern Black Sea has been noted to contribute 57% of the Turkish sea fish harvesting and 23% of Turkish shell fish harvesting (Interior 1994).

Turkey is currently developing Mines Waste Regulations to align with the European Union Extractive Industry Directive, and the regulators anticipate continuing acceptance of marine discharges within these regulations.

References for Cayeli Mine in Turkey

Berkun M., *Submarine tailings placement by a copper mine in the deep anoxic zone of the Black Sea;* Water Research 39:5005-5016. 2005

Earth Works and MineWatch Canada; *Troubled Waters How mine Waste dumping is Poisoning our Oceans, Rivers, and Lakes;* February 2012.

Inmet Mining Corporation; 2011 Annual Report.

Shimmield, Tracy, et.al., Scottish Association for Marine Science, Final Report, Independent Evaluation of Deep-Sea Mine Tailings Placement (DSTP) in PNG, 2010.

U.S. Dept of Interior, Case Studies of Submarine Tailings Disposal, Volume II-Worldwide Case Histories and Screening Criteria, Bureau of Mines, OFR 37-94; January 31, 1994.

Sydvaranger Mine in Norway

Description of the Mine

The mine is located on the northern tip of Norway, about 400 km north of the Arctic Circle. Sydvaranger was the company that operated the Bjørnevatn Mine in Kirkenes, Norway, between the start in 1906 until 1996, when the mine closed due to economic reasons. The current project to restart the iron ore mine began in 2007 with production beginning in 2009.

The Sydvaranger iron ore mine is an open pit mine and is 100% owned by Northern Iron Limited, an Australian company. Approximately 14 million tonnes of ore was mined in 2011 with 1.4 million tons of concentrate produced. The target under existing permits is 2.8 million tonnes per year with a longer range goal of 5.6 million tonnes per yeaar. The life expectancy of the mine is 25 years. From 1910 to 1996, approximately 200 million tonnes of ore was mined (Martinsen 2011).

Marine Disposal of Mine Tailings

Mine tailings are disposed by pipeline into Bokfjorden fjord near Kirkenes, Norway. The pipeline discharges at 28 meters depth below mean sea level, about 500 meters offshore. The mine tailings are first thickened, then slurried with seawater, deaerated, and discharged (Hogaas 2009). Figure 28 shown the old mine's discharge of mine tailings into the fjord.

Figure 28 The old mine tailings disposition area at Sydvaranger (Source: Høgaas 2009)

Permit to Discharge

The permit from the Norwegian Climate and Pollution Control Agency allows annual discharges of 4 million tonnes of mine tailings along with 35 tonnes of flocculants to be discharged via pipeline (about 11,000 tonnes per day) (Skotte 2010). The chemical Lilaflot is not used at Sydvaranger, as the company operating the mine has withdrawn the application for discharge of Lilaflot (Skotte, Gunnar 2011).

Impacts of Marine Discharge of Mine Tailings

The deposit at Sydvaranger covers about 4.4 square km (Email 2011).

Norwegian Climate and Pollution Control Agency reported the results of 2010 monitoring in a status report to the meeting of the Contracting Parties of the London Convention and London Protocol in 2011. The results (Skotte 2011):

- Turbidity in the surface layer in the whole fjord was similar to reference,
- Some influence was found from tailings in deeper waters as far as 4.5 km from the discharge point;
- Conditions for soft bottom organisms at 2.5 km from discharge point became less favorable from 2007 to 2010;
- Hard bottom organisms in the top 20 meters seemed not to be influenced by tailings. The situation was unclear below 20 meters depth; and
- Acrylamide was not detected in any of the water-or sediment samples analyzed.

A report from 2010 shows that the ecological situation of the fjord is deteriorating, and in a hearing by the Institute of Marine Research (Havforskningsinstituttet, www.imr.no), it was concluded that "*the monitoring of the fjord environment shows that the ecosystem in the fjord system is heavily negative impacted, especially the conditions on the sea floor. The dumping affects the fjord heavily, at least 10 km outwards, and there is a strong opposition to this pollution of a National Salmon Fjord*" (Haltbrekken 2012).

References for Sydvaranger Mine

Email; Answers to questions following the Norwegian presentation about submarine tailings disposal Scientific Group meeting (LC/SG 34 - LP/SG 5), Tallin 11-15 april 2011; www.londonconvention.org

Halkbrekken, Lars; Letter from Friends of the Earth Norway and Norwegian Society for the Conservation of Nature to International Maritime Organziation; Oslo, 23.04.12.

Harald Martinsen, CDO, Northern Iron; *Kirkenes Næringshage; Juleseminar 2011-12-16*

Høgaas, Helge; *Reopening the old Sydvaranger kommune, Finnmark County, Norway operations in Sør-Varanger;* Presentation-Egersund, Norway; September 2009.

Skotte, Gunnar; Response to questions from the Scientific Group meeting in Tallin, 2011

Skotte, Gunnar; *Submarine mine tailings disposal in Norway;* Norwegian Climate and Pollution Agency; 2010. http://www.sydvarangergruve.no/niva-rapport.4903898-146746.html

Hustadmarmor at Elnesvågen in Norway

Description of the Mine

The Norwegian company Omya Hustadmarmor supplies calcium carbonate slurry to European paper manufacturers from a single processing plant, using chemical tank ships of various sizes to transport its products (Haugen website). The raw material is marble from mines in Eide, Fræna, and Brønnøysund. Most of it is transported to the facility by boat. The marble is ground, washed and sieved at the production plant in Elnesvågen (Omya website). See Figure 29.

Figure 29 Mine processing facility , Hustadmarmor A/S at Elnesvågen Source: Omya website

Marine Discharge of Calcite Tailings at Elnesvågen

Hustadmarmor has operated a marine deposition area for calcite tailing since the early eighties at Elnesvagen, with the tailing requirements specified by the Norwegian Pollution Control Authority in 1982. Investigations by marine biologists began in 1988 and the results contributed to the revised defined deposition volume. The investigations show that the marine sediments after a short period of time will recover to a healthy habitat not very unlike the original conditions. Also the acceptable environmental impact from the deposition is defined, giving specific values for certain parameters at the deposition borders. The Norwegian Agency stated in the new tailing allowance: *"Outside the deposition area, the deposition shall not have a significant influence on the environment, including turbidity in the water, increased sedimentation on the sea bed and changes in the benthic fauna".* (Amundsen 2009).

Approximately 500,000 tonnes per year of mine tailings are disposed through their marine discharge (Skotte 2011) (Earthworks 2012).

Rationale for Marine Disposal

As stated by the Hustadmarmor's Chief Engineer: "*We of course know that under water disposal of mine tailing has numerous advantages comparing to land deposits. Why do we then have the feeling that borrowing the sea bed for some years are of much greater importance then destroying the land areas forever? The marine environment offers a great potential of recolonization and recovering" (*Amundsen 2009).

References for Hustadmarmor at Elevagen

Amundsen, Arnstein; Hustadmarmor AS, Chief Engineer SEQ; *Marine calcite tailing deposition – the best environmental solution.* Proceedings 2009 Egersund Conference

Earth Works and MineWatch Canada; *Troubled Waters How mine Waste dumping is Poisoning our Oceans, Rivers, and Lakes;* February 2012.

Haugen website; http://himolde.academia.edu/KjetilHaugen/Papers/1303319/Omya_Hustadmarmor_optimizes_its_supply_chain_for_delivering_calcium_carbonate_slurry_to_European_paper_manufacturers

Omya website: http://www.omya.no/

Skotte, Gunnar; *Submarine mine tailings disposal in Norway;* Norwegian Climate and Pollution Agency; 2010. http://www.sydvarangergruve.no/niva-rapport.4903898-146746.html

Rana Gruber in Norway

Description of the Mine

Rana Gruber's mines with iron ore deposits are located in the Dunderland valley near the village of Storforshei approximately 35 km north of Mo i Rana, about 40 km south of the Arctic Circle. The processing plant is located in Mo i Rana in Nordland County on the Rana Fjord.

The iron ore is spread over an area of approximately 45 square km. The current mining is concentrated around Ørtfjell with three major deposits. After more than 30 years of open pit mining, Rana Gruber AS started underground mining using the sublevel open stoping method at the Kvannevann Mine in 2000. The open-pit mines at Ørtfjell are closed and from 2000 onwards the iron ore comes from the new Kvannevann underground mine in the vicinity of the Ørtfjell area.

The iron ore resources have been estimated to approximately 500 million tonnes.

With 200 employees, 3.3 million tonnes of iron ore are mined which are processed into 1.3 million tonnes of iron ore concentrates (hematite and magnetite) and specialty products (RanaGruber website).

Marine Disposal of Mine Tailings

Approximately 2 million tonnes of mine tailings are disposed annually into Ranafjord. No other information is available regarding depth, footprint, characteristics of the mine tailings, or environmental impacts (Skotte 2011). In 2002, it was reported that the quantities disposed in the fjord were 500,000 tonnes per year (IIED 2002).

In another reference, it was stated that 1-2 million tons of mine tailings from an iron ore mine and processing facility, mixed with chemicals, are disposed in Ranafjorden each year, with a deposition depth of about 80 meters. It was stated that the ecological system in the fjord is seriously endangered, and the primary biological production in the surface layers is severely restrained. It was also stated that there is a strong local opposition to the pollution which has severe negative effects to this National

Salmon Fjord, and the mining company has been under investigation for possible violation of their waste discharge permit (Haltbrekken 2012).

References for Rana Gruber

Halkbrekken, Lars; Letter from Friends of the Earth Norway and Norwegian Society for the Conservation of Nature to International Maritime Organziation; Oslo, 23.04.12.

International Institute for Environment and Development (IIED); Mining for the Future; Appendix A: Large Volume Waste Working Paper. Mining, Minerals, and Sustainable Development report; 2002.

Rana Gruber website: www.Ranagruber.no

Skotte, Gunnar; *Submarine mine tailings disposal in Norway;* Norwegian Climate and Pollution Agency; 2010. http://www.sydvarangergruve.no/niva-rapport.4903898-146746.html

Skaland Graphite Mine in Norway

Description of the Mine

The Skaland mine on the island of Senja in Troms has been a supplier of graphic since 1932 in the Skaland mountains in Norway. Production of pure graphite is 11,000 tonnes per year.

The regulatory authority of Skaland Graphite AS is, from 2006, the County Governor of Troms.

The mine is permitted to dispose of 40,000 tonnes per year of mine tailings into Bergsfjorden. In 2011, the amount disposed was 20,000 tonnes (Storbraten 2012). The tailing consists mainly of fragmented granite with some quartz, feldspar and micas. The tailing pipeline ends approximately 150 meters from the shore, and at a depth of 30 meters.

The conclusion of an environmental survey in Bergsfjorden, made by Norway Institute for Water Research (NIVA 1994) in 1994; is that the metals copper, nickel and chrome can be traced up to 7 kilometers from the end-point of the tailing pipeline. The biological effects in sediment are mainly limited to the discharge area, less than 500 meters from the pipeline discharge point.

There has been no monitoring of the content of the tailings, and their impact on the marine environment since 1994 (Karlsen 2012).

References for Skaland

Bjorn.Arne.Karlsen, Bjorn Arne; email; 25 September 2012.

NIVA; *O-92168 – Miljøundersøkelser i Bergsfjorden, Senja – effekter fra avgang fra en grafittgruve, 1994.*

Storbraten, Glenn Kristian; Klif; email; 9 September 2012.

Sibelco Nordic Mine in Norway

Description of the Mine

The Sibelco Nordic Stjernøy plant produces nepheline syenite. The plant which was acquired in 1993 is located on the island of Stjer in the county of Finnmark in northern Norway. There is no road access to the plant. The nepheline syenite is mined during the summer and autumn in an open pit at an elevation of 700 meters above the sea. Ore is stockpiled in a stope from the earlier underground mine. The plant is located at the seaside and includes the following processing steps: Crushing, drying, milling, sieving, magnetic separation and air (Sibelco Nordic website).

Sibelco Nordic disposes mine tailings into a fjord in Finnmark (Earthworks Canada 2012).

References

Earth Works and MineWatch Canada; *Troubled Waters How mine Waste dumping is Poisoning our Oceans, Rivers, and Lakes;* February 2012.

Sibelco Nordic website; http://www.sibelconordic.com/locations/norway/stjernoy

Proposed Nordic Mine at Engebo (Fordefjord) in Norway

Description of the Mine

Nordic Mining owns one of the world's largest rutile (titanium dioxide) deposits at Engebøfjellet in Naustdal municipality in Western Norway, estimated to be 382 million tonnes, of which 250 million tonnes is considered mineable (Engebo website). A by-product will be garnet.

Plans are for an open pit mine for 15 years, with total ore of 45 million tonnes, followed by an underground mine for 35 years with total ore at 200 million tonnes. The contemplated rutile production at Engebø will have approximately 170 employees (Fossum 2009).

Marine Disposal of Mine Tailings

Plans are to dispose of mine tailings in Fordefjorden from a pipeline 150 meters offshore at a depth of approximately 250 meters; the depth of the fjord at that point is 300 meters. See Figure 30.

From the open pit mine for the first 15 years, 3 million tonnes will be deposited per year (8,200 tonnes per day) and for the next 35 years from the underground mine, 6 million tonnes will be deposited each year (16,000 tonnes per day). A total of 250 million tonnes are anticipated to be deposited during the life of the mine (Skotte 2011).

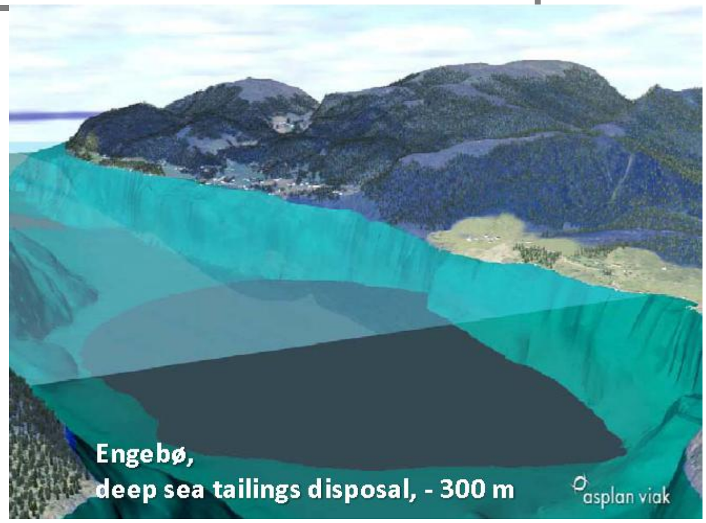

Figure 30 Proposal for marine disposal at Engebo. Source: Fossum 2009.

Disposal of Waste Rock

Waste rock will be disposed on an upland site, which for the open pit mine is estimated to be a total of 35 million tonnes.

Chemical characteristics of the Mine Tailings

The tailings are said to be inert silicate materials with heavy metals well below unacceptable levels. Flocculants and flotation chemicals are added to the processing of the ore and are discharged with the mine waste. Nordic Mining reports that tests showed that the flocculants and flotation chemicals are biodegradable and show no toxicity at the levels expected (Fossum 2009).

Approximately 10 tonnes of flocculants and 3,000 tonnes of flotation chemicals will be used in the ore processing each year, and be discharged with the mine tailings (Fossum 2009).

One news report noted that the mine tailings had been approved to be used as capping material for contaminated sediments, as they will have a high specific gravity and low heavy metals and radioactive materials content.

Environmental Effects of the Marine Discharge of Mine Tailings

Little information is available regarding potential environmental impacts of marine disposal of the mine tailings, other than the known impact of smothering. The deposit will cover about 4.4 square km with a thickness varying between 0 and 150 meters (Skotte 2011).

Deposition depth will begin at 300 meters and rise to 150 meters during the life time of the mine and cover many square kilometers. Fordefjorden is an ecologically important sound fjord, important for fisheries with the up-fjord part designated as a National Salmon Fjord (Haltbrekken 2012).

References for Engebro

Engebo website: http://www.engeboprosjektet.no/

Fossum, Ivar; *Planned marine disposal of tailings from a rutile mine*; Egersund, 2009.

Halkbrekken, Lars; Letter from Friends of the Earth Norway and Norwegian Society for the Conservation of Nature to International Maritime Organziation; Oslo, 23.04.12.

Skotte, Gunnar; Response to questions from the Scientific Group meeting in Tallin, 2011.

Nussir ASA Copper/Gold/Silver Mine in Norway (Proposed)

Description of the Mine

The mine is located near the municipality of Kvalsund in northwest Norway, near Hammerfest. The area is well known as a primary vacation area in Finnmark with 1,200 vacation homes and salmon fishing, golf, and skiing. The ore body was first discovered in the 1970s, with renewed interest in the mid to late 2000s for further exploration and drilling (Rushfeld 2009). See Figure 31.

Based on 2007 drill results, the latest estimates calculated according to the Jorc Standard are that the ore body contains 3.9 million tonnes indicated resource and 19.5 million tonnes of inferred resource. The ore body tracks from the shoreline to 10 km inland.

Figure 31 Exploration at Nussir mine near Kvalsund, Norway. Source: Rushfeld 2009).

Nussir plans to use underground mining which will reduce the amount of waste rock that needs to be deposited. It would also cancel the need for further open pits (Nussir website).

Marine Disposal of Mine Tailings

Current plans are to dispose of mine tailings into Repparfjord, near the processing plant. The application for a permit to discharge stated that the mine tailings would be mixed with seawater before it is pumped into marine waters to keep the tailings from mixing with the surface waters, limiting the spread of the fine particles and the footprint of the deposit. Previous mining operations on the site are reported to have discharged mine tailings to the Repparfjord. See Figure 32.

One reference stated that the discharge would be 2.1 million tonnes per year at a depth of about 60-80 meters. The tailings will contain copper, nickel, and chromium, and compared to Norwegian sediment thresholds would be classified as “very polluted” (Haltbrekken 2012).

Figure 32 Site of Proposed Nussir mine and processing plant. Source: Rushfeld 2009.

Environmental Assessment

A decision from the Climate and Water Pollution Agency is under consideration regarding the permit to discharge mine tailings to Repparfjord, but the Kvalsund municipality must adopt a local plan prior to any decision. The company website provides the draft permit application and the Environmental and Safety Assessment.

The Norwegian Institute of Water Research conducted toxicity studies of the mine tailings at Nussir and found effects at the top concentration of 100% mine tailings for the copepod and the polychaete worm test; the polychaete test resulted in 50% mortality and the LC50 may be expressed as 100%. The conclusion was that at the maximum concentration of mine tailings released, there may be some indications of effects (NIVA 2011).

The discharge of mine tailings into Repparfjord is the recommended alternative by the Norwegian Institute for Water Research (Rushfelt 2009).

References for Nussir

Halkbrekken, Lars; Letter from Friends of the Earth Norway and Norwegian Society for the Conservation of Nature to International Maritime Organziation; Oslo, 23.04.12.

NIVA ; Determination of the acute toxicity of mine tailings from Nussir ASA to the marine alga Skeletoneman costatum, the marine copepod Tisbe battagliai and the polyshaete Arenicola marina; Report Sno 6163-2011; 2011.

Rushfelt, Oeystein*; Nussir Company Presentation*; Egersund Conference; 2009

Rogaland Mine Proposed

Description of the Mine

An application for Norsk Stein was submitted on April 2, 2012, for disposal of 400,000 tonnes per year of mine tailings into Sandsfjorden at Jelsa in Rogaland, which has the only coral reef in the region (Halkbrekken 2012). The application for a discharge permit is in review. The company website: http://www.mibau-stema.de/en/. No other information is available.

References

Halkbrekken, Lars; Letter from Friends of the Earth Norway and Norwegian Society for the Conservation of Nature to International Maritime Organziation; Oslo, 23.04.12.

Cleveland Potash at Boulby, England

Description of the Mine

Cleveland Potash Limited mines 3.0 million tonnes per year ore at their Boulby underground mine in northeastern England producing 1.0 million tonnes per year saleable potash using a conventional flotation processes. Two tailings streams are produced:

- 1.8 million tonnes per year centrifuge cake –coarse salt particles (soluble waste)
- 0.2 million tonnes per year filter cake fine particles of insoluble clay, salt, and calcium sulphate

Prior to a pilot scale and then full scale research and demonstration project in the late 1990s and early 2000s, all process waste was re-pulped with sea water and discharged to the North Sea. Due to presence of heavy metals, mercury and cadmium, in the insoluble clay (i.e., the filter cake), the permitted level that is allowed to be discharged into the North Sea was substantially reduced.

From publically available information on the Cleveland Potash website and technical papers prepared by the engineering company that conducted the research and engineering of the demonstration plant to use the filter cake to backfill parts of the mine, it appears that all of the filter cake is being disposed in the mine. No information is available following the 2004 publication.

However, the Cleveland Potash website says "reduction in waste discharge" and not elimination of waste discharge. The author can only guess that this means the filter cake is being backfilled into the mine while the centrifuge cake is being disposed in the North Sea. The centrifuge cake is primarily made up of compounds of salts, but technically is mine tailings and is therefore listed in this report at 1.8 million tonnes per year or approximately 5,000 tonnes per day discharged into the North Sea.

References for Cleveland Potash

Cleveland Potash Website:
http://www.iclfertilizers.com/Fertilizers/ClevelandPotash/Pages/BUHomepage.aspx

Wilkins, M.J., C. Gilchrist, M. Fehrsen and R. Cooke (2004) "*Boulby Mine Backfill System: Design, Commissioning and Operation*", 16th Int. Conf. on Slurry Handling and Pipeline Transport, Hydrotransport 16, Chile, April 2004, also presented at Minefill 2004, Beijing, China, September 2004.

Rio Tinto Alcan at Gardanne, France

Producing 560,000 tons per year of Aluminum, the refinery at Gardanne pipes it bauxite wastes (i.e., red mud) to a discharge location near Marseilles in the Mediterranean Sea. The pipeline discharges into the Cassidaigne Canyon to a depth of 330 meters.

In 2002, the red mud covered an area of at least 1,600 square kilometers. Studies had shown that deposits on the seafloor had a depth of 0.25 meters at 25 kilometers from the discharge location and 0.1 meter at 50 kilometers from the discharge location.

Regulatory changes in 1987 and 1996 required the Gardanne facility to do the following:

1. Study the hydrodynamic circulation in the Cassidaigne canyon to evaluate the potential dispersion and transportation of the residues and its impacts on pelagic ecosystems.

2. Analyze the marine environment every 5 years to determine the degree and thickness of the tailing deposits, and compare the re-colonization rate of the bentonic ecosystems in areas affected, with referenced sites.

3. Analyze the effect of the discharges on fish.

4. Research the toxicity of the tailings and the potential bio-accumulation of chromium and vanadium.

A scientific committee was created to ensure an independent evaluation of the findings of these studies.

References for Rio Tinto Alcan at Gardanne

Dauvin JC; Université des Sciences et Technologies de Lille, Wimereux, France; *Towards an impact assessment of bauxite red mud waste on the knowledge of the structure and functions of bathyal ecosystems: The example of the Cassidaigne canyon (north-western Mediterranean Sea).* Marine pollution bulletin 60:2 2010 Feb pg 197-206.

Aluminum of Greece at Agios Nikolaos, Greece

The facility produces 800,000 tons of alumina and 165,000 tons of aluminum per year. The aluminum processing plant has been discharging bauxite tailings (i.e., red mud) for over 40 years into the Gulf of Corith, Bay of Antikyra. The morphology of the northern area of the Gulf consists of a wide platform in the Bay of Antikyra, which passes through a slope and ends in a basin with a depth of 890 meters.

Since 1970, the refinery and foundry discharged bauxite (red mud) residues at 85-100 meters into the Gulf of Corinth through two 2 kilometer long pipelines. In 1989 the two pipelines were replaced by a new one that discharges the tailings at a depth of 120 meters and is currently operating. The depth of the final accumulation is approximately 800 meters.

Throughout a 20 year period, four (1982-83, 1987, 1994, and 2007) multidisciplinary environmental surveys were carried out in Antikyra Bay and in the Corinth Gulf basin, in order to monitor the STD system and study the dispersion and transportation mechanism of bauxite tailings as well as the distribution of heavy metals concentration.

Geophysical studies have shown that the bathymetry in the discharge area has been strongly modified by the red mud. The tailings have been deposited in "mounds" at depths between 85 and 125 m at the outfall of the pipes. The accumulation of the tailings has taken the shape of three oval mounds. The first has a height of 14 m, the second has accumulated at a depth between 70 and 120 m and reaches 27 m across the ocean floor. These two mounds were formed in 19 years from the initial STD operation until the replacement of the pipes in 1989.

- The third mound is the most recent, developed between 1989 and 1994, reaching a height of 23 meters.
- The high accumulation rates at the outfall of the pipes, associated with the area's high seismicity makes the mounds unstable and promotes gravitating movements of these masses.
- The red-mud deposits at the mouth of the outfalls, are not stable and very often red-mud masses are detached from the two main deposits and are transported to the Corinth central basin, by turbidity currents, at a water depth of 850 meters and about 17 kilometers away from the main deposits. Thus, at the Antikyra bay, the red-mud has formed a surficial veneer (0.5-2.0 cm) on the sea floor.

The effects on marine ecosystems have been identified as indirect impacts on benthic organisms, through the change of particle size and composition.

References for Aluminum of Greece at Agios Nikolaos

World Wide Science. *Natural radionuclides in bauxitic tailings (Red-Mud) in the Gulf of Corinth, Greece;* http://worldwidescience.org/topicpages/m/mud+bauxite+processing.html

Varnavas, Soterios; Ferentinos, George; and Collins, Michael; *Dispersion of bauxitic red mud in the Gulf of Corinth, Greece;* Marine Geology, Volume 70, Issues 3-4, March 1986.

CAP Minería at Huasco, Chile

Initiating operations in 1978, the iron ore pellet plant at Huasco, Chile, discharged iron ore mine tailings directly into the intertidal zone. In 1994, the discharge pipe was moved to a location offshore in Chapaco Bay at 25 meters depth. In 2002, the pipeline was again moved to discharge at 35 meters depth and 350 meters offshore in Chapaco Bay.

Figure 33 Chapaco Bay, Husaco, Chile

In 2013, the company is preparing an environmental impact assessment proposing to move the discharge pipe to 6.4 kilometers offshore, off the continental shelf, and at final deposition depths of 200 to 800 meters.

Extensive monitoring has been conducted of Chapaco Bay by Chile's Catholic University of the North.