Tailings disposal at Titania.

*Ann Heidi Nilsen, Titania as, Norway:*

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Marine calcite tailing deposition - the best environmental solution.

Arnstein Amundsen, Hustadmarmor AS, Norway.

The marine environment has a great potential to recover its biological diversity on mineral sediment deposits. Hustadmarmor has collected environmental information through investigations in the marine calcite tailing deposition area for more than 20 years. 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. Compared to deposition of mineral tailing on land or in freshwater the deposition in the marine environment offers great advantages both environmentally and for safety reasons.
Planned marine disposal of tailings from a rutile mine.

Ivar Fossum, Nordic Mining ASA Norway

Nordic Mining is a mineral development company with operating activity and focus on high-end minerals in Norway and internationally. Nordic Mining is undertaking a large-scale project development of a world class deposit of titanium bearing eclogite at Engebøfjellet in Sogn and Fjordane county in Norway.

The Engebø deposit is likely one of the largest known resources of hard rock natural rutile, and represent one of Norway’s largest unexploited resources of industrial minerals. The current development plans includes production of high grade rutile concentrate and concentrate of garnet, with a production period of approximately 50 years.

The mining project at Engebø consists of a 15-year open pit production phase, followed by a 30-year period of underground mining. The in situ resource is estimated to 380 million tons of eclogite ore, of which approximately 250 million tons are considered mineable.

Tailings from the processing of ore, is planned placed in a deep sea deposit in the Førde fjord. The rock characteristics, in combination with the physical parameters of the deposit and the fjord, make an ideal configuration for a deep-sea disposal. The eclogite consist of inert silicate minerals with a negligible content of sulphides and heavy metals. The tailing will be placed in a delta shaped deposit at 300 meters below sea level to limit the effects on the fjords ecosystem and ensuring optimal stability. Investigations of the fjord currents and topography and the tailings characteristics shows that a controlled deposition can be achieved. The upper 100 meters of the fjord basin is unaffected allowing this ecosystem to be intact throughout the mine life.

The eclogite tailings may also have commercial applications. Nordic Mining undertakes an evaluation of possible commercial products and applications for the tailings material i.a. as concrete aggregate, soil conditioner and material for dike enforcement at the European continent. In the future, parts of the tailing may represent a positive additional value to the project, both financially and with regard to new industrial activity. In addition, waste disposal from the mine can be reduced.
Overview of the Skaergaard Gold project and possible tailings deposition sites.

Lars Lund Sørensen, GrontMilj CarlBro, Denmark:

See the pdf version of the PowerPoint presentation.
Marine Tailings Placement Studies at Saaqqa Fjord, Greenland

Jim Stronach\textsuperscript{1}, Bob Draho\textsuperscript{1}, Edwin Wang\textsuperscript{1}, Gert Asmund\textsuperscript{2}

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Abstract

Starting in 1999, oceanographic and meteorological studies were commenced at the Nalunaq gold mine site, located near Saaqqa Fjord at the southern tip of Greenland. The proposed ore processing plant would produce about 5 Mt/annum of waste rock as fine tailings. The oceanographic and meteorological studies were designed to provide the engineering and environmental information required to evaluate the suitability of marine tailings placement for the processing plant. This paper describes first the oceanographic and meteorological observations at Saaqqa Fjord, including a year-long ADCP mooring and a coincident program of CTD profiles, obtained approximately every two weeks. The observations revealed distinct and seasonally-varying layer structures in both currents and water property profiles, and strong mid-depth intrusions.

The second part of the paper describes numerical modelling that was used to determine the behaviour and fate of the tailings if discharged into Saaqqa Fjord. The modelling system consisted of a three-dimensional circulation model, and a two-dimensional density current model, operated at two spatial resolutions. The proposed discharge was into a basin with maximum depth of about 260 m.
Deep Sea Tailings Placement at Batu Hijau, Sumbawa, Indonesia

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Key words: Deep Sea, Submarine, Tailings, Environmental, Management, Monitoring

Abstract
The Batu Hijau Copper/Gold Mine in Sumbawa, Indonesia, operated by P.T. Newmont Nusa Tenggara (PTNNT), uses deep sea tailings placement (DSTP) technology to manage the tailings residue from processing approximately 130,000 tons of ore per day. The DSTP system includes a 3.4 km offshore pipeline that conveys tailings to the head of the Senunu Canyon off the South coast of Sumbawa, where the tails is discharged at a depth of over 100 meters and flows down the canyon to settle at depths of around 3000 meters. Both DSTP and traditional on land tailings management were evaluated in the Environmental Impact Assessment (EIA), with the Government of Indonesia approving DSTP as the most appropriate management option in 1996. The DSTP system was designed to be protective of coastal resources, biologically productive surface waters and the communities that use these. The system began operation in year 2000 and has been extensively monitored by PTNNT, Government and third-party institutions. All of the monitoring results demonstrate that Batu Hijau is an example of an operation and coastal environment where DSTP operates very effectively and in accordance with the predictions made in the EIA.
Iron ore from the old mines in Sør-Varanger kommune, Finnmark County, Norway was mined from 1906 – 1997.

The mines were closed down in 1997 after years with financial losses.

Sydvaranger Gruve AS was established in 2007 and acquired from Sydvaranger AS all mining rights and infrastructure previously used for iron ore production. Sydvaranger Gruve is a wholly owned company of Northern Iron Ltd, who is listed on the Sydney ASX stock exchange. Sydvaranger Gruve is fully funded and iron ore concentrate production will start in October 2009.

Annual iron ore production will be app. 7 MT, corresponding to 3 MT of iron ore concentrate.

Iron ore will be mined in the open pits at the Bjørnevåtn mine area, transportation to the processing facility in Kirkenes by train and magnetic separation to produce iron ore concentrate.

4 MT of mineral tailings will annually be disposed into a submarine tailing disposal area in Bøkfjorden outside Kirkenes. The tailing disposal system is based on previous solutions, but has been modernized to sustain a long operational horizon.
Canada is one of the leading nations to practice sustainable development of natural resources, including the mineral resources sector. This encompasses all aspects of resource development including: environmental, energy requirements and carbon footprint implications, social-economical impacts, and ultimate land use and management. Recently, the government of Canada has announced a new “Green Mining Initiative” to support the development of new and innovative technologies which will advance the development of technologies to reduce the footprint and environmental impact of mining, maximize mine site remediation and rehabilitation, and ecosystem risk management.

The Canadian mining industry has been proactive in the environmental aspects of mining including: waste disposal and management, wastewater treatment and post operational site rehabilitation as well as closure. Underwater disposal of reactive mining waste in man-made impoundments or natural, low productivity headwater lakes has been a preferred option at most new or developing mines. Inactive waste sites, where acid generating wastes were previously deposited in land-based impoundments have been rehabilitated with in-situ shallow water covers to minimize acid generation. Regulatory permission for use of a natural headwater lake is considered on a case by case basis and requires federal ministerial approval at the cabinet level to amend the metal mining effluent regulatory stature. Each case has to meet the requirements of the Canadian Fisheries and Navigational Waters Acts. Presently, submarine disposal of mining waste is neither pursued nor entertained.

The case histories and performances of selected man-made water cover impoundments and in-lake waste repositories would be presented and discussed. A much debated, past historical case of disposal of reactive uranium mine tailings in a large natural lake would also be present.
Long-term impacts in the sea of disposal of waste rock and tailings at the Black Angel Mine, Greenland.

Gert Asmund and Poul Johansen, NERI, Denmark:

The Black Angel lead-zinc mine was in operation from 1973 to 1990. Tailings were disposed to the nearby fjord where it settled on the bottom. But the tailings contained soluble compounds of lead and zinc. This resulted in a massive pollution of the water around the mine. Waste rock was placed in several waste dumps, one of them reaching the shoreline of a fjord. This waste rock contains sulphides that are being oxidized, and dissolved lead and zinc are transported with the tides to the fjord. Also spreading of dust was a significant source for pollution of the environment. Elevated lead and zinc levels were found in sea water, sediments, seaweed, blue mussels, fish, prawns, lichens etc. in most of the surrounding fjords. These species have been monitored both during the mining and after close-down for lead and zinc contamination. After mine closure the contamination of the seawater with lead dramatically went down and is today close to the natural level. However several organisms still contain elevated levels of both zinc and lead. Data indicates a shift from tailings to dust and waste rock as the dominating source of lead pollution. Zinc is still released from the tailings and waste rock that is deposited on the bottom of the fjord. The contamination with both lead and zinc may be expected to continue for decades and will only slowly decline, particularly for zinc.
Marine impacts of waste rock disposal in the shoreline at the cryolite mine at Ivittuut, Greenland.

Poul Johansen & Gert Asmun, NERI, Denmark:

The cryolite mine was in operation from 1854 to 1987. Waste rock was placed on the shoreline of a fjord. This waste rock contains sulphides that are being oxidized, and dissolved lead and zinc are transported with the tides to the fjord. 1-3 kg lead is estimated to be released daily to the fjord. Elevated lead and zinc levels are found in seaweed and blue mussels in most of the fjord. These species have been monitored for lead and zinc contamination since 1982 and levels are only slowly declining. The contamination may be expected to continue for hundreds of years. We recommend not placing reactive waste rock on the shoreline.
Background investigation for marine tailings deposition at the Nalunaq Gold Mine

Tanja Nielsen, Grontmij | Carl Bro A/S

(Environmental Coordinator 2000 – 2003 for Nalunaq Gold Project I/S)

In 1992 an outcrop of high grade quartz gold vein was found in South Greenland. The place was named Nalunaq (in Greenlandic: difficult or not certain). This presentation gives an overview of the different environmental baseline studies that were performed for the EIA concerning the marine tailings disposal option (from 2000 – 2001/2002) and basis for a discussion of the studies and whether there were enough data for a decision for or against the tailings option. Crab and Arctic char fishing were among the important activities for the local people in the area. Among the studies were: Biological sampling in the different depths, sediment studies, oceanography (currents, weather, tidal, and bathymetry), toxicity testing, kinetic and static geochemical testing. In 2002/2003 it was decided to ship out the ore for processing elsewhere.
Response of reef communities under pressure from mine waste disposal and other impacts.

Mick Haywood, CSIRO, Australia

See the pdf version of the PowerPoint presentation.
Impacts of DSTP on benthic and pelagic communities at Lihir Island, PNG.

David Brewer, CSIRO, Australia

See the pdf version of the PowerPoint presentation.
Re-building fauna in marine mining disposal with examples from Titania and Hustadmarmor.

*Tor Jensen, DNV, Norway:*

See the pdf version of the PowerPoint presentation.
Bioavailability of trace metals in runoff from mining and mobilization of river transported metals in estuaries due to mixing of salt water.

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The speciation, bioavailability and toxicity of trace metals in acidic mine discharge (AMD) have been studied in the receiving River Stjørdal. Atlantic salmon (Salmo salar L.) parr and smolt were captured by electrofishing and placed in exposure cambers both at sites influenced by AMD and at reference sites. Mortality occurred rapidly for fish exposed in tributary water influenced by AMD. Sampling of gills from fish exposed to AMD demonstrated high levels of metal accumulation compared to reference fish, i.e. 20 µgCu/g gill d.w., 560 µg Fe /g gill d.w. and 30µg Al /g gill d.w. Based on in situ fractionation of the water influenced by AMD, the results demonstrated that the concentration of total Cu and cationic Cu species was 26±10 ug/L and 13 ±7 µg/L, respectively. Despite that a large fraction of Al and Fe, was associated with organic material in the freshwater (pH 5,7-6,5), the water was toxic. However, when saltwater was added to freshwater, metals associated with organic material (not bioavailable) in the freshwater could be mobilized. Experimental mixing of saltwater with river water to 6 ‰ was performed and Atlantic salmon were exposed to the mixture. Based on in situ fractionation of the mixture waters and sampling of gills from exposed smolt, the results demonstrated that Al and Fe-species were mobilised from colloidal river transported material, forming species that accumulated on gills in the freshwater – saltwater mixture. Thus, AMD could cause critical water quality for fish in influenced freshwaters, and probably also in estuaries. This implies that processes related to bioavailability of metals and toxicity not only the freshwater influence by AMD, but also estuaries have to be included in risk assessments for AMD.
The Grong Mine, an underground mine, situated in the central part of Norway in Røyrvik municipality in the county of Nord-Trøndelag was operated in the period 1972-1998. The main products were concentrates of copper and zinc. Due to market prices and transportation costs the pyrite was not extracted and was disposed of under water in a part in the inner part of Lake Huddingsvatn together with the tailings. The total production during 25 years of operation was about 11.5 mill tonnes ore giving about 624000 tonnes of copper concentrate and 243000 tonnes of zinc concentrate. The pollution problems in the area were mainly related to the discharge of tailings to Lake Huddingsvatn and transport of particles from the tailings disposal area downstream the Huddingselva River. Relatively large particles were found several kilometres downstream Lake Huddingsvatn. This had a substantial negative effect on the bottom fauna. To reduce the transport of particles from the disposal area a dam separating Lake Huddingsvatn in two parts was built in 1989-90. In the following years up to mine closure in 1998 and the final recipient survey in 2004 a gradually improvement in the biological conditions was observed. The heavy metal levels in the recipient were always relatively low showing that the underwater disposal technique was very efficient considering the release of metals from this highly reactive material. The mine water was always weakly alkaline. However, the zinc concentrations were increasing during the whole period of operation. In 1999 the mine was almost completely flooded during one month diverting a small creek into the mine. Observations of the final mine water during 5 years after the flooding measure showed that the metal release from the mine was relatively low. Zinc was the only metal of importance. The latest recipient survey was accomplished in 2004. The pollution situation was found acceptable according to the demands of the Norwegian State Pollution Control Authority.
Permanent water covers are now accepted as an appropriate approach for the long-term prevention of acid rock drainage (ARD), particularly for fresh sulfide-rich tailings. But this technology must be applied selectively, for there are examples where particular geochemical characteristics or processes—some of which were unanticipated—confound the expected environmental benefits. Three such examples—all of which have been revealed by high-resolution analyses of pore- and bottom-waters, and all from Canadian mine sites—will be reviewed. In the first, arsenic remobilisation resulted from anthropogenic eutrophication of an existing treatment pond and dissolution of arsenic-bearing sedimentary iron oxyhydroxides resulted in degraded water quality. Such release is predictable, and could be controlled by reducing nutrient inputs to the pond. In the second, radium was released from submerged uranium mill tailings due to the dissolution of radiobarite [(Ra,Ba)SO₄] where sulphate-reducing bacteria lowered the dissolved sulphate concentration. Limiting sedimentary oxidant demand by, for example, lowering organic inputs to the pond, could control such unanticipated release. And in the third, geochemically-conflicting uses of a pond into which had been disposed sludges from an ARD lime-treatment plant led to the release of Cu to the overlying water. The release was traced to oxidation of cyanide and its product ammonium, an associated decline in the pH, and the dissolution of Cu(OH)₂.

These case studies reinforce the need to characterize and understand—before discharge: 1) the solid-phase characteristics of the tailings material; 2) the physical, chemical and biological characteristics of the depositional environment; and 3) likely post-depositional influences on gross pond-water geochemistry during operations and mine closure. Moreover, they highlight the importance of restricting changes to pond water chemistry in the years following tailings disposal. Multiple geochemical uses of single ponds that are intended to be environmentally responsible can backfire. Our results are applicable to a broad suite of potential tailings repositories including constructed impoundments and pit lakes as well as natural water bodies.
Applicability of marine tailings disposal: Site and Substance.

Paul Greisman, Rescan, Canada:

See the pdf version of the PowerPoint presentation.
Resuming sea deposits in Repparfjord – technical and political challenges.

Øystein Rushfeldt, Nussir ASA, Norway:

See the pdf version of the PowerPoint presentation.
Permit to operate according to the Pollution Control Act – processes and legislation.

Gøsta Hagenlund, County Governor of Sogn and Fjordane, Norway

This presentation gives a short overview on the current legislation on pollution prevention and waste management from extractive industries in Norway. A permit from the pollution authority to operate is mandatory pursuant to the Pollution Control Act. An application for a permit to operate a large mining operation for titanium dioxide is currently under formal processing. Insights in the process and environmental considerations from the authority are given.
European mine waste directive and guidelines: implications for marine and lake disposal of mine waste.

*Ingar Walder, Kjeøy Research and Education Center, Norway*

Ingar Walder could not participate in the conference due to illness.