Two Million Tonnes a Day
A Mine Waste Primer

MiningWatch Canada

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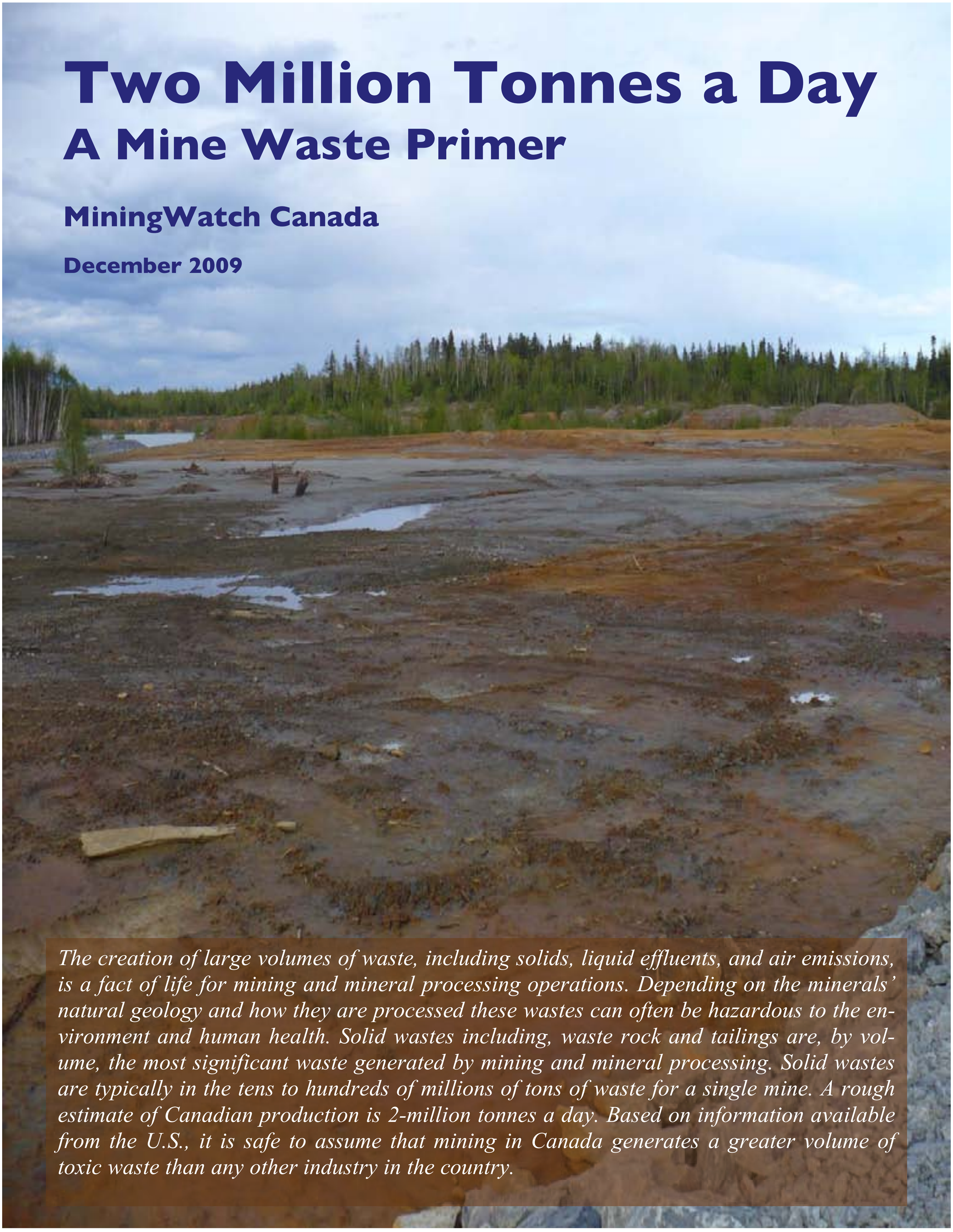


The creation of large volumes of waste, including solids, liquid effluents, and air emissions, is a fact of life for mining and mineral processing operations. Depending on the minerals' natural geology and how they are processed these wastes can often be hazardous to the environment and human health. Solid wastes including, waste rock and tailings are, by volume, the most significant waste generated by mining and mineral processing. Solid wastes are typically in the tens to hundreds of millions of tons of waste for a single mine. A rough estimate of Canadian production is 2-million tonnes a day. Based on information available from the U.S., it is safe to assume that mining in Canada generates a greater volume of toxic waste than any other industry in the country.

There are two principal types of solid mine waste: **waste rock** and **tailings.**

Waste Rock

In order to get at the rock or "ore" that holds the mineral or minerals of economic interest, a mining operation must move and dispose of a large amount of blasted rock that does not have useful concentrations of minerals - this is called "waste rock". The volume of waste rock is especially large for open pit mines, but underground mines also generate waste rock as shafts are dug to access ore bodies. The amount of waste rock, compared with the amount of ore is called the **strip ratio.** A strip ration of 1 (volume of ore = volume of waste rock) is considered low for an open pit mine. Australia's largest open pit gold mine has a strip ratio of 6. The total volume of waste rock generated will depend on the scale of the project but mid-size projects typically generate several hundred million tonnes of waste rock.

Waste rock is typically dumped into large piles within the mines *waste rock storage area,* which can spread over an area of several square kilometres. Both the physical and chemical characteristics of the waste rock must be considered if it is to be properly disposed of. The course texture of waste rock allows air and water to easily move through the pile. Because much of the waste rock has never before been exposed to the elements it can be very reactive with the air, water and micro-organisms and may cause *acid mine drainage* (see page 2) and release metals to surface and ground water.

Tailings

Modern mines process huge quantities of ore, on the order of the tens of thousands to hundreds of thousands of tonnes a day. Once blasted and hauled from the mine shaft of pit, ore is crushed and processed using massive volumes of water and a variety of chemical and physical processes. The mineral content of an ore can be in the 5 % range for base metals or as low as 0.00005% for precious metals like gold. This means that 95% to 99.9995% of the mined and processed ore becomes a waste product – known as tailings.

Tailings are usually deposited as a slurry - a thick liquid made up of water, the finely ground ore (minus the recovered minerals), and any residual chemicals from the processing stages. Because the rock has been finely ground, tailings can be very chemically reactive and can pose serious environmental risks from acid rock drainage and the release of toxic metals, and toxic reagents used in processing. The combination of liquids and fine-grained solids make many tailings physically unstable. If left exposed to the air and dried, tailings can also be blown on the wind causing air pollution and washed into waterways, harming aquatic ecosystems.

Toxic pollutants that are commonly found in tailings include: cyanide, mercury, copper, lead, arsenic, cadmium, selenium, zinc and nickel.

ACID MINE DRAINAGE

Sulphide Minerals
(e.g. pyrite)
+
Other metal-bearing minerals
+
Water
+
Oxygen
+
Micro-organisms

→

Sulphates
+
Sulphuric Acid
+
Dissolved heavy metals

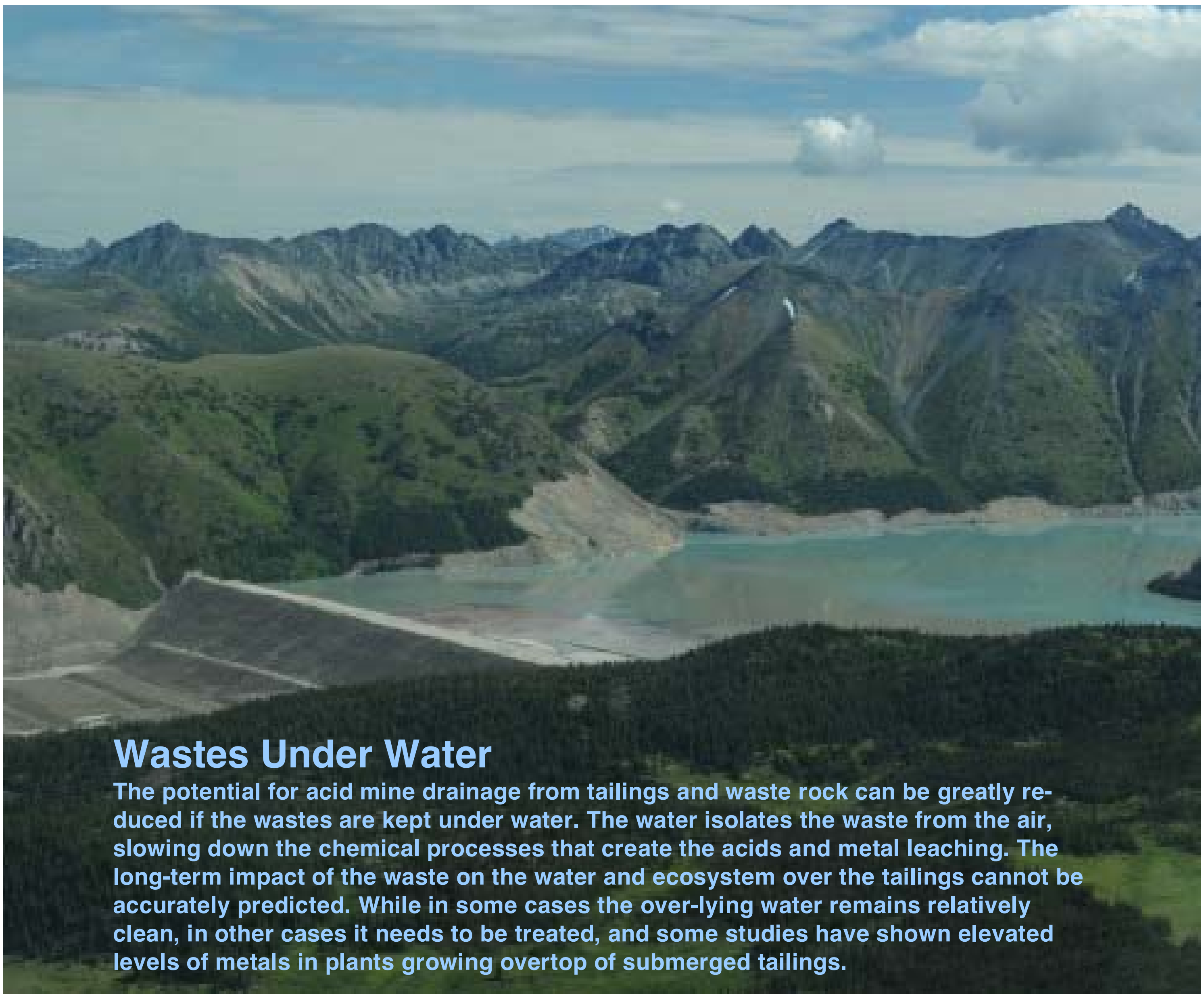
Acid mine drainage occurs when rocks with sulphur bearing minerals are exposed to air, water and micro-organisms. The sulphur in the minerals turns into sulphuric acid, which can have very harmful affects on aquatic ecosystems.

The chemical changes within the minerals also release significant amounts of toxic heavy metals like nickel, copper and cadmium. These metals can contaminate surface waters and find their way into food webs resulting in both acute and chronic impacts on wildlife and people.

It is not necessary to have acid rock drainage to have metals leach from mine wastes. Significant quantities of metals, including arsenic and selenium can be leached from mine wastes with neutral or alkaline pH.

What to do with mine waste?

Because of the large volume of wastes generated at mine sites, and their potential for negative environmental impacts, managing waste rock and tailings can be one of the greatest challenges in responsibly operating a mine. Historically mine wastes were simply dumped in a convenient location including lakes and rivers with little regard for the environment. This uncontrolled dumping of waste is still practiced in some parts of the world but was phased out in Canada as stricter environmental regulations came into force. There is, however, a disturbing trend towards using natural water bodies as impoundments for mine waste.



Wastes Under Water

The potential for acid mine drainage from tailings and waste rock can be greatly reduced if the wastes are kept under water. The water isolates the waste from the air, slowing down the chemical processes that create the acids and metal leaching. The long-term impact of the waste on the water and ecosystem over the tailings cannot be accurately predicted. While in some cases the over-lying water remains relatively clean, in other cases it needs to be treated, and some studies have shown elevated levels of metals in plants growing overtop of submerged tailings.

Impoundments

An impoundment is a disposal area with raised embankments that contains both the solid and liquid components of the tailings and may also be used to dispose of waste rock (if acid generating). The embankments may surround the full impoundment or natural landscape features may be used in combination with impoundments to contain the waste.

Once released, the solids in the tailings slurry settle to the bottom and a pond will usually form over a portion of the tailings. This ponded water can be recycled to reduce the demand for additional water at the mill and to reduce the amount of water that is discharged from the impoundment. If the tailings are acid generating then additional water will be added or retained within the impoundment to keep the tailings under water. Modern mines may have tailings ponds from 20 to 50 hectares in size (1 hectare = 2 soccer fields).

One of the greatest risks associated with storage of tailings in an impoundment is from failure of the impoundment resulting in a spill of the tailings inside. Because the tailings solids often don't hold together or form a solid mass, if an embankment breaks, the tailings can flow out of the impoundment and travel some distance down-stream creating serious risks to the environment, human safety and infrastructure such as buildings and roads. Surveys of international databases suggest that around the world at least two significant tailings impoundment failures occur every year. In Canada in 2008, at least two impoundment failures occurred one at the Ekati Diamond mine in the North West Territories and the other at the old Opemiska Mine in north-western Quebec.

Keeping the water in the tailings impoundment from mixing with natural surface water or groundwater is another challenge associated with impoundments. Water that would otherwise flow into the impoundment must be diverted and water that does accumulate in the impoundment from rain or snow may need to be treated before being discharged into natural surface waters. In some cases the treatment processes will need to be continued long after the productive life of the mine.

Amazay (Duncan Lake), pictured above, was the proposed tailings impoundment area for Northgate Minerals Kemess North project. In 2008, a joint federal and provincial environmental assessment panel rejected the project as proposed. The loss of the lake, the long-term environmental risks and the negative impacts on the The Tse Keh Nay First Nations were the principal reasons for the decision.

Natural Water Bodies

The Canadian Fisheries Act is supposed to prevent the destruction of fish habitat or the release of substances harmful to fish into fish bearing waters. Thanks to a regulation introduced in 2002, mining companies are able to request that fish bearing water bodies (i.e. lakes, wetlands and streams) be designated as Tailings Impoundment Areas, which are then exempted from the protective measures of the Act.

When a lake is used as an impoundment the lake basin and lake water are used to contain and cover the waste. In many cases dams or embankments are also required to increase the storage volume. Where a stream is re-classifed, it is the stream valley combined with at least one down-stream embankment that is used to contain the waste. Using lakes and stream valleys results in a substantial cost savings to mining companies and is becoming an increasingly common alternative in Canada.

MiningWatch Canada and many other organizations and communities have been speaking out against the use of Canadian lakes and streams for mine waste dumps. While the companies benefit from cost savings, the long-term costs of losing a valuable natural ecosystem are born by the public today and into the future.

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Ocean Dumping

Disposal of mine waste into the ocean is a preferred option for mining companies operating in coastal areas with more permissive governments. Dumping into shallow water near the shore is widely recognised as very damaging to marine ecosystems and is seldom condoned today. Some in industry do, however, claim that the more refined technique of disposing tailings into deep water using a submerged pipeline is a responsible choice for tailings disposal. As with the use of lakes and streams, submarine disposal is less costly to the company but comes with substantial ethical and environmental implications. Submarine disposal involves mixing the tailings with seawater and depositing them by pipe onto the ocean floor. The tailings are not contained in anyway and in some cases currents have moved the tailings several kilometres from the deposition site. The tailings smother the natural ocean bottom and the ability of marine life to return is uncertain.

Deep ocean environments are very complex and there is much we don't know about how metals will react in deeper ocean water, how currents could affect transport of metals or even basic ecology of the species present and their role in the ecosystem. Thorough medium and long-term studies on the ecological effects of sub-marine tailing disposal are difficult to come by. Research has shown that submarine disposal has negatively impacted the development, abundance and diversity of marine fish in the disposal area. No mines in Canada currently use submarine deposition but the Island Copper Mine on Vancouver Island did use submarine disposal for most of its 24 year operating life, which ended in 1995.

Backfilling

Mine wastes can be returned from whence they came - a process known as backfilling. Backfilling is fairly common in underground mines as it can be used to fill mined-out voids, increasing the stability of the surrounding rock and decreasing the risk of collapses and surface subsidence. When back-filling underground, tailings are usually mixed with cement to solidify the slurry and chemically stabilise the tailings. In open pit operations tailings and waste rock must be stored until excavations in all or a part of the pit is finished. Because of the extra storage and handling requirements backfilling can be more expensive than other alternatives, at least in the short term.

The advantages to backfilling are the eventual reduction of the physical footprint of the mine, rehabilitation of excavated pits and shafts, and eliminating the need for maintaining an impoundment. When projected into the future, the economic benefits of backfilling become more competitive.

After a mine closes the water table typically rises and back-filled tailings or waste rock may come in direct contact with ground water creating a risk of groundwater contamination. Techniques to reduce this risk are currently being developed.

In gold mines where tailings contain cyanide, there is a risk of cyanide gas poisoning if tailings are backfilled while workers are still underground.

Paste and Thickened Tailings for Land Disposal

One way to reduce the risks of tailings spilling out across the landscape, and to reduce the costs associated with tailings impoundments is to remove most of the liquid from the slury, creating thickened tailings. Additives can also be used to further thicken the tailings into a paste. The tailings can then be spread out in a disposal area, often from a high point in the local landscape. Depending on the amount of water left in the tailings and the slope of the ground, an embankment may be needed to catch any water that drains out of the tailings and/or to prevent the tailings from continuing to slide down-slope. Eventually the tailings should dry out into a solid, self-supporting mound.

These disposal methods reduce the engineering challenges and uncertainties of embankments and may have the added advantage of reducing the amount of air and water that can move into the tailings and cause acid mine drainage. Another advantage is that water taken from the tailings can be recycled in the mine processes, reducing the overall consumption of freshwater. While the costs of removing the liquid and adding the thickeners are substantial, overall this method may be cost-competitive to conventional tailings impoundments due to savings on constructing embankments and long-term water management. Thickened and paste disposal systems can also be incorporated into disposal of dry waste rock (see Option 7), and could be integrated into a continuous cover and rehabilitation system that sees mine waste covered and the surface rehabilitated throughout the operating life of the mine, rather than waiting until the end of mine operation.

Dry Disposal

The most common method for disposing of waste rock is dry land disposal where the waste is piled in a designated area and eventually covered with soil and rehabilitated (in a responsible operation). Initial dry disposal of tailings is quite rare as it requires the almost complete separation of the liquid and solid parts of the tailings slurry, and because the dry tailings must be transported to the disposal area by truck or with a conveyor system, rather than less expensive option of using a pipeline and pumps or gravity. The added processing and handling costs can be a disadvantage when considering initial costs but these costs can be balanced out by savings in operation and maintenance of a tailings impoundment and with the relative speed and ease of rehabilitating the tailings as the mine closes. Another option is to dispose of tailings as a slurry but allow them to drain on their own, treating the water if necessary, and then rehabilitating as dry tailings. This can only be done if the tailings are the right texture to allow the water to drain.

If wastes are potentially acid generating, an impermeable cap of engineered materials and / or clay is needed to reduce penetration of water and air into the tailings. Water that does flow over or through dry tailings dumps may need to be collected and treated to prevent contaminants from spreading into surface and ground waters. Because of this risk, surface and ground waters around the disposal area should be monitored throughout the mine life and after closure. Unfortunately, in some cases, we have little certainty that these protective systems will last as long as the wastes' potential to contaminate the environment.

At the abandoned Kamkotia Mine in Ontario tailings that were originally discharged into an impoundment and freely onto the land and are now being rehabilitated using a dry cover. The large area of tailings in this picture is only one of tailings managemen areas. As this site was abandoned Ontario tax payers are covering the $60-million cost of rehabilitating this site.

Co-disposal of Waste Rock and Tailings

Co-disposal is a relatively new approach to mine waste disposal that takes advantage of the characteristics of waste rock and of tailings. If disposed of together, waste rock can provide the structure and strength that tailings lack, while the tailings can fill in the voids between the larger pieces of waste rock. Filling the voids reduces the amount of air and water that can come in contact with the waste rock, reducing the potential for acid drainage and leaching of metals. Combining the tailings and waste rock also reduces the footprint required for disposal and eliminates the risks associated with a tailings impoundment failure. Though economic savings are gained by not requiring a tailings dam, there may be additional costs in handling the wastes. This is a relatively new approach and still in the experimental stage. As with dry stacking, an impermeable cover may be required to further reduce the risks of acid and metal leaching.

Regulating mine waste disposal

Metal mines in Canada must follow the standards set by the Metal Mining Effluent Regulations, which are part of the Fisheries Act. The MMER regulate the release of 8 contaminants, pH and the acute toxicity of effluents that come from tailings impoundments and other mine waste facilities. Mines that fall under the MMER are also required to conduct environmental effects monitoring that is meant to document the impacts of their operations of fish and fish habitat. The first report on the monitoring program has found mine effluents are having consistent negative impacts on aquatic ecosystems including: reductions in condition and liver size of fish, and reduced density and diversity of benthic invertebrates (insects and other small critters living in the bottom sediments of streams and lakes).

The MMER do not apply to non-metal mines such as diamond, coal or potash mines, however, the general provisions of the Fisheries Act do.

Another important Federal law relating to mine waste is the National Pollutant Release Inventory (NRPI), which requires companies transferring, storing, releasing or disposing of toxic materials to make annual reports to a national database that is available for public review. If they exceed the reporting threshold, mine sites have been reporting the toxics contained in mine effluent. However, since 1998 the industry was operating under a questionable exemption from reporting the toxics in their waste rock and tailings. In 2007, MiningWatch Canada in partnership with Great Lakes United and EcoJustice took their Federal government to court over their failure to apply the NPRI to the disposal of waste rock and tailings. In June 2009, The Federal Court found in favour of MiningWatch and ordered the industry to begin reporting. This data will be available through the NPRI website in mid 2010.

In addition to the Federal legislation summarised above all the provinces and territories have their own pollution control laws and regulations. In some, but not all, cases the provincial or territorial laws may be more protective, for example New Brunswick's water classification system may protect streams and lakes from being "re-classified" as tailings impoundments. The provincial laws and regulations also cover air emissions including dust that can be a problem with mine waste facilities.

There's No Easy Fix

Clearly there is no easy, one-size fits all solution for mine wastes. Choosing waste management options must consider site-specific geological, ecological and social conditions. When considering costs of various options it is important to consider not just the up-front and short term costs to the mining company, but also the mine life cycles costs, long-term liabilities and the natural values lost with each option.

In some cases, the absence of a waste management system that is acceptable to local communities and other stakeholders, could mean that a project should not proceed. For Mining Watch Canada, the use of our lakes, rivers, streams and oceans for mining waste dumps is not an acceptable solution given the long-term impacts this will have on these natural ecosystems and their valuable, renewable resources. We must stop the erosion of our environmental assessment programs so that mine waste management decisions are the right ones, and not simply the most cost effective for the company. Much greater efforts also need to be made to assess newer technologies like paste systems, and for reducing the demand for virgin minerals through vastly improved recycling programs.

For More Information

Mining Watch Canada: www.miningwatch.ca
Centre for Science in Public Participation: www.csp2.org
Tailings Info: www.tailings.info
National Environmental Effects Monitoring Office: http://www.ec.gc.ca/esee-eem/
Natural Resources Canada, Mining, Minerals, Metals and Materials Technology:
http://www.nrcan-rncan.gc.ca/com/tectec/minexp-eng.php
Mine Effluent Neutral Drainage Program:
http://www.nrcan-rncan.gc.ca/mms-smm/tect-tech/sat-set/med-ndd-eng.htm

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Page1: Kemess South Waste Rock Pile, near Peace River BC; Centre for Science and Public Participation (CSP2)
Page 2: Acid Drainage at Kam Kotia Mine, near Timmins ON; Ramsey Hart/MiningWatch Canada
Page 2: Kemess South Tailings Impoundment; CSP2
Page 4: Amazay (Duncan Lake); Tse Keh Nay First Nation.
Page 6: Kemess South Open Pit; CSP2
Page 7: Grassed Tailings Pile at Kam Kotia; Ramsey Hart/MiningWatch Canada

MiningWatch Canada is a pan-Canadian initiative supported by environmental, social justice, Aboriginal and labour organisations from across the country. We address the urgent need for a co-ordinated public interest response to the threats to public health, water and air quality, fish and wildlife habitat and community interests posed by irresponsible mineral policies and practices in Canada and around the world.

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