E.1a. A Brief Overview of the Environmental Concerns with the Subaqueous Disposal of Metal Mine Tailings in Natural Water Bodies

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Introduction

Most mining waste from metal mines today is disposed terrestrially. Waste rock is generally placed near the mine's open pit or shaft opening in order to minimize the cost of transporting this material. Tailings, the waste material that remains from the ore once the mineral of value (e.g. gold, copper, etc.) has been removed, is generally placed in a water slurry behind a constructed tailings dam, or, in the case of low grade ore that is leached to remove the valuable mineral, the material is left on the leach pad and reclaimed in place. If any of this material has the potential to produce acid, not only does this pose a long term risk to the environment, but it also creates a difficult and potentially expensive problem of designing waste disposal/storage facilities to minimize long term risk.

Terrestrial disposal of acid generating material has generally been approached by attempting to isolate the acid generating material to as small an area of the mine as possible, and by restricting the amount of water that reaches this material. For waste rock this is generally done by isolating the acid generating material in cells of non-acid generating waste that contains enough buffering potential to neutralize any acid produced. This approach has met with only limited success.

Slurried tailings that are potentially acid generating are placed in a lined impoundment in many, but not all, cases. The liner is designed to stop the migration of contaminated water into nearby ground and surface water systems. Heap leach tailings also sit on a liner, which is used to collect the leachate containing the valuable mineral. This liner can also be used to restrain and collect contaminated leachate coming from the heap after processing has ceased. Liners can also be placed on top of the abandoned heap in order to limit the amount of water infiltrating the heap from precipitation. However, many abandoned heaps and tailings ponds, even if reclaimed as described above, still pose long term problems because of the cost associated with collecting and treating the leachate that is collected.

Today it is recognized by most authorities on acid mine drainage that the safest way to store potentially acid generating mine waste, both tailings and waste rock, is to place the material under a water cover. In most cases this effectively limits the amount of oxygen that is available to decompose the sulfide minerals into weak acids and suspended metals.[1]

Subaqueous storage of potentially acid generating material can take place in a number of different storage environments, including: (1) in a designed impoundment; (2) below the water table as backfill in an underground mine or pit; (3) in a natural lake; and, (4) in the ocean. The latter two locations present the advantages of low cost and dilution for the toxins that are produced, but also pose risks to the environment since natural water bodies are generally areas of high aquatic production, and may also have high economic value associated with the aquatic organisms (e.g. fishing), and are much more difficult to

[1] Oxygen, water, and sulfide minerals all need to be present in order to generate acid mine drainage.

model in terms of their long term impacts, and usually represent a physical environment where it is impossible or impracticable to recover the mining waste should problems arise in the future..

Some Concerns with the Subaqueous Disposal of Mine Tailings

Although subaqueous disposal of tailings offers geochemical advantages over terrestrial disposal, there are a number of issues that fuel the concern for the disposal of minewastes in natural bodies of water. The following issues are of general concern:

1. *Processes involved during the introduction of minewaste into a natural waterbody (including the impacts of dissolved metals, residual process chemicals, effects of suspended sediment in the discharge plume, near continuous interaction of particulate materials with relatively well-oxygenated water, etc.).*

During the milling process, where the ore is crushed and then subjected to various process chemicals to either remove the mineral of interest, or to concentrate that mineral so that it can be affordably shipped to another site for final processing, introduces numerous 'process' chemicals into the ore slurry. Not only are some of these process chemicals of environmental concern, but also the nature of the milling process almost always causes chemical changes in the ore to take place. These changes may mobilize metals, or metal complexes, in toxic forms and toxic concentrations in the tailings. Arsenic, selenium, manganese, and iron are examples of metals that are often liberated during the milling process, but which are seldom the target mineral for extraction, and often end up being introduced into the environment with the tailings disposal.

An example of a process chemical of environmental concern is cyanide, which is used in the processing at almost all gold mines. Very small amounts of cyanide can cause toxic effects on fish and macroinvertebrates. Although the amount of dilution available in a lake is large, it does not take a large amount of residual cyanide in a tailings discharge to create an area where chronic, or sublethal, effects on aquatic organisms can take place. In the ocean, although the amount of dilution is almost infinite, the toxic effects of cyanide are even more pronounced, so there is still concern about possible negative effects of cyanide near the point of discharge.

2. *The effects of solids ingestion on metal uptake by benthic and pelagic organisms.*

When tailings are discharged into a natural water body, the finer material contained in the tailings can remain suspended in the water for a significant amount of time. During this time the fine material, which will contain some metals, can be ingested by aquatic organisms. Once this material is in the digestive system of the organism, it is more readily converted into a form that can be bio-accumulated by the organism.

Similarly, once the tailings have settled on the bottom, organisms that re-colonize the tailings can bio-accumulate toxins by living in, working in, or eating the contaminated material.

3. *Modifications of food-web structures.*

Deposition of tailings into a lake/marine environment can cause physical and/or geochemical changes to the bottom environment. These changes may make it less desirable for certain species to re-colonize the tailings, may affect the density of organisms that can now live in this environment, or may provide an environment that gives preference to a whole new set of species. These changes are very difficult to predict both in their magnitude, and in the length of time that the effects will last. A change in species density or distribution could have significant effects on other species up the food chain. For example, changes in the bottom organisms, or the small plant or animal organisms that swim above the bottom, could have an effect on fish that inhabit the waters, but never come in direct contact with the tailings yet use these smaller organisms as food.

4. *The burial of benthic biota.*

The physical burial of existing biota will have short term, but often significant, impact. However, if the physical environment of the bottom is changed significantly from its pre-mining character, then the burial could cause long-term changes. For example, changing from a hard, rocky bottom to a soft, sandy bottom, or from a soft, sandy bottom to a hard, sandy bottom can cause significant changes in the type of biota occupying a particular ecological niche.

5. *The geochemical, biological and physical reworking of minewaste underwater.*

Once the minewaste/tailings have been placed under water, organisms that recolonize the wastes can affect the physical stability of that material. For example, in the process of burrowing worms can bring waste material from a few centimeters below the surface to the water/solid interface where the waste is more readily exposed to oxygen. This could prolong the time necessary to provide a geochemically stable layer on top of the deposited waste.

Since most of the material that has been placed in a subaqueous environment is tailings, or other fine grained wastes that are amenable to transport in a slurry, this material is also subject to remobilization in its depositional environment if subjected to changing currents, for example due to storm surges. If the waste initially comes to rest on a submarine slope, turbidity currents could later remobilize the waste material as it seeks move down slope in response to the forces of gravity and currents. If the waste material is remobilized, the process of the waste assuming chemical or physical stability can be prolonged.

Scientific Review of Subaqueous Tailings Disposal

The Rawson Academy of Aquatic Science convened a Scientific Review Team (SRT) in 1992 to provide a technical assessment of the studies of Canada's Mine Environment Neutral Drainage (MEND) program, which had compiled the most comprehensive set of studies and data on subaqueous tailings disposal to that date. The Rawson Scientific Review Team came to some revealing observations about the advisability of the disposal of minewastes in natural water bodies. Some of those observations were:

> "The consensus of the SRT was that apart from the difficulties and inadequacies in dealing with actual in-lake conditions, the conceptual approach of disposal of large volumes of mine tailings in most lakes was unsound; particularly, it was not reasonable to expect that it would be possible to retain biological use during (large volume) tailings introduction. In very large lakes the problems are localized rather than lakewide. True, negative effects could be established within a rather short time frame (probably 2 or 3 years). But to show that no significant detrimental effects occurred would be very difficult (if at all possible), it would take a long time (10 years, plus), it would be costly and, at best, uncertain." [Rawson, p. 9][2]

and;

> "Disposal in a deep lake may be possible but, from the point of view of environmental impact, it is clearly the least desirable option." [Rawson, p. 10]

and:

[2] A Critical Review of MEND Studies Conducted to 1991 on Subaqueous Disposal of Tailings, The Rawson Academy of Aquatic Science, July 21, 1992, p. 9.

> "The SRT concluded, while it is appropriate to suggest geochemical evidence supports the view that subaqueous disposal of tailings results in a substantially less reactive environment than terrestrial disposal, the nature and extent of biological response in the aquatic environment is (at best) unclear. It is probable that severe physico-chemical effects occur during subaqueous disposal of tailings and although amelioration and subsequent remediation may be possible, the effectiveness of many measures is not yet predictable, with reasonable certainty." [Rawson, p. 15]

and, finally;

> "It was felt that no new disposal in a large lake would be considered unless under extremely limited circumstances in which other forms of placement proved infeasible. Unconfined disposal in a large or deep lake would not be acceptable." [Rawson, p. 18]

Conclusion

Subaqueous disposal of mine waste, whether in a saltwater or freshwater setting, should be approached with, at best, a great deal of caution. Even if a subaqueous mine waste disposal is given an appropriate level of site-specific study, there will always remain a level of uncertainty about the conclusions of these studies. The risk of some unpredictable event happening which adversely effects the subaqueous environment, where in most instances it is virtually impossible to recover the mine waste once it has been released, must be weighed against the cost of storing the waste in the terrestrial environment where it is accessible should unpredicted adverse environmental impacts arise.

If a the natural waterbody is utilized for the disposal of mine wastes, then it should be 'converted' to a waste disposal facility because there is a relatively high level of uncertainty involved in predicting long term impacts of subaqueous disposal. To consider it a temporary use for waste disposal, with the assumption that the waterbody will return to its original aquatic productivity after the cessation of waste deposition, would not be prudent given the uncertainties involved, even though the lake may eventually recover to the point where all its pre-deposition aquatic functions are restored.

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