Tailings Co-Disposal™ & Sustainable Development

By Marc Leduc, Mark Bachens and Mark E. Smith

ABSTRACT[1]

The authors present a case history of the first commercial-scale application of co-disposal technology to cyanide mill tailings. Recognized as an emerging technology for sustainable development in mineral development, tailings co-disposal™ is a means to dispose of conventional mill tailings within the void space of a waste rock dump. This method, while not applicable to all tailings systems, can offer a significant reduction in short-term and long-term environmental liability, land disturbance, closure costs, and negative public image. The concept is to dispose of the tailings simultaneously with the waste rock or leach ore, controlling the ratio of tailings to course material such that the resulting dump is stable both physically and chemically. The resulting co-disposal dump can be as safe as a conventional waste dump, and in the case of alkaline tailings in a potentially acidic waste dump, the chemistry can be complimentary.

INTRODUCTION

This report summarizes the evaluation of co-disposal technology to the management of cyanide mill tailings at the Esquel project. The project is owned by Meridian Gold Inc. (Meridian) and is located in the Chabut State of Argentina, approximately 6 kilometers northwest of the city of Esquel. From the onset of the engineering studies Meridian was attempting to utilize a method of tailings disposal other than a conventional tailings impoundment. The main reason for this was that they felt the increased risks during operation and closure of a conventional facility were not warranted. Further, preliminary meetings with the lead regulatory agency suggested that a conventional tailings dam would be considered negatively in the Esquel context. Meridian had pioneered an alternative tailings disposal method at their operations in Chile, but that technology was not deemed suitable in the wet Patagonian climate. Thus, the design team was tasked with finding another alternative.

TAILINGS CO-DISPOSAL™

Tailings Co-disposal™ is a novel concept which uses the open void space in mine waste rock for disposal of the finer grained tailings. Because waste rock is a coarse run-of-mine product created from blasting of rock, there are large voids created when the waste is placed in a dump. When applied to competent waste, these large void spaces can make a perfect place for tailings. Clayey and sandy wastes may not be suitable for this technology, depending on the gradation and, ultimately, the available void ratio. Some of the advantages of this technology are summarized in the following table.

How Tailings Co-Disposal™ Works

There are a many ways to accomplish mixing of tailings with waste rock and each was evaluated to determine their feasibility. The first step was to evaluate the tailings and waste rock to determine their suitability for use in co-disposal. This involves a detailed program of geotechnical testing and analyses to first find technically feasible options, then to optimize these in terms of cost and performance. Probably the most important geotechnical criteria are strength and permeability: strength controls short- and long-term stability and permeability effects issues such as contaminate migration and drainage.

Table 1: Some Benefits of Co-Disposal[2]

Issue	Benefits
Land disturbance	Less impact on wildlife habitat and agricultural uses.
	Less watershed disturbance.
	Less impact to local waterways.
Water	Reduced consumption.
	Reduced seepage through waste rock mass, thus lower risk of water quality impacts.
	Reduced exposure to water and air, reducing ARD generation.
Long-term risks	More stable tailings deposit.
	No tailings dam to breach.
	Risk of catastrophic failure much lower.
Closure	Smaller area to close.
	Better substrate for vegetation.
	Less dusting problems.
	Low permeability cap easy to construct using tailings and cement.
	Less post-closure maintenance

Typically (and intuitively) the strength will show a relationship between the ratios of waste-to-tailings, with the internal friction angle approaching that of tailings alone at very low ratios. What is of particular concern is if and where there is a sharp reduction in the strength with an incremental reduction in waste, showing that the mix starts to behave more like tailings than waste rock. Figure 1 shows the variation in friction angle with the different blend ratios. It is clear that the between 4:1 and 2:1 (waste:tailings by weight) that the strength characteristics of the mix changes from behaving like rock to behaving like tailings.

[1] Presented at the Special Symposium on Environmental Sustainability, SME Annual Meeting, Denver, Co, 2004, and published in the proceedings.

[2] In part from *Breaking New Ground*, report of the Mining, Minerals and Sustainable Development project, Earthscan Publications, ch. 10, 2002.

The response of the permeability tests is similar, with the permeability decreasing with decreasing ratios of waste, approaching the permeability of tailings at very low blended ratios. The relation of permeability to waste tailings blends are shown in Figure 2 which shows in this case a 5 order of magnitude drop in permeability for a 4:1 (waste:tailings) to a 1:1 blend.

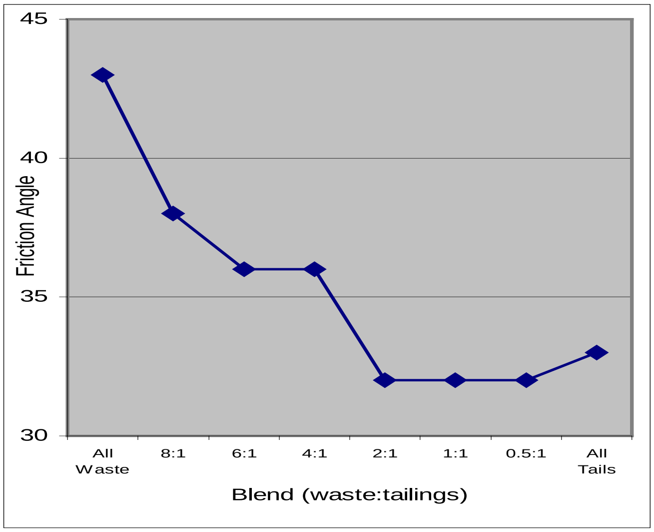

Figure 1. Variation in Angle of Friction with Blend

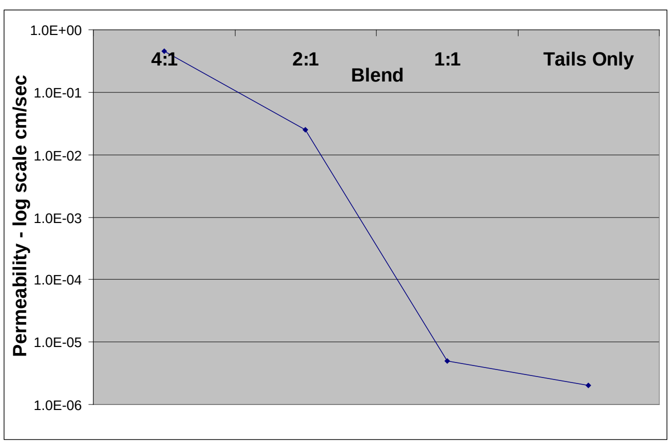

Figure 2. Variation in Permeability with Blend

Another important test is to determine a drained moisture content test on the "free draining" blends. This is critical in understanding the potential for saturation (or near saturation) in the field, which could possibly result in the liquefaction (either static or dynamic) of the waste dump. Since flow slide liquefaction is potentially the most catastrophic form of failure of a waste dump, proper study and adequate factors of safety must be applied in this area.

Other key geotechnical parameters are unconfined compressive strength and consolidation. The unconfined compressive strength is critical in determining the stability of a tailings pond when a waste lift is placed over the top, and this parameter can be enhanced by addition of binders if needed. Binders can also improve erosion resistance and thus wet weather behavior. Consolidation testing determines the rate of strength gain after initial deposition.

Options for Tailings Co-Disposal™

There are several (possibly endless) ways to commingle the tailings with the waste rock. We have presented below some of the methods we have considered for the Esquel site and these are;

1. Placing the tailings in discrete ponds or layers in the dump, which can then be buried as new lifts of waste are placed,

2. Blending the waste rock and tailings together to make a relatively homogeneous material – either by blending in a haul truck or by mixing at the dump crest,

3. Injecting the tailings as a paste or thickened slurry into the waste rock dump, either by drilling holes for injection or simply installing injection lines along the working face for use after the dump has advanced sufficiently, and

4. Placing a thin veneer of tailings on the face of the waste rock dump and allowing the tailings to infiltrate into the dump and dry, then the veneer can be covered by another layer of waste rock.

Each of these methods is discussed in greater detail below. Included in the discussion are the advantages and disadvantages of each method.

The analyses of co-disposal alternatives focused on how each method will perform. The stability of mixed waste and tailings and also how each method will perform with regards to environmental issues such as dump drain water quality and production of Acid Rock Drainage (ARD) was examined. From a stability standpoint, the most critical point is to control the buildup of pore pressure in the dump as it is constructed. The development of excess pore pressure could cause a slope failure, resulting in a major dump failure.

Tailings placed in layers within the waste dump: One way to create this configuration is to build berms that would form discrete ponds where the tailings could be placed. While one pond is being filled, another cell would be constructed, and so on. The berms would form containment structures and also form flow paths in the tailings layer so that infiltrated rainwater would not be blocked by the tailings layer. After a period of time, the next waste lift will be placed on top of the tailings and the cycle repeated. A typical cross-section of this configuration is seen in Figure 3.

This option provides many advantages, but one of the primary advantages is that mobile equipment will not be required for the placement and handling of tailings. However, the major disadvantage is if the covering waste lift is placed too quickly, pore pressure will buildup in the tailings and the tailings layer could be subject to a sudden failure, risking not only the active area of the dump but also equipment working near the crest. To overcome the major concern of lift failures as the dump progresses, Portland cement or some other binding agent could be added to improve the cohesion and overall strength of the material. Take this example: for a case of no cement and a reasonable rate of waste advance for the 20 m of waste placed over 5 m of tailings, the resulting factor of safety might be less than 1.0. But for the same advance rate if we assume improvements in strength due to cement addition, using values obtained the laboratory, the factor of safety improves to 1.4 with the addition of 1% cement and to 2.4 with the addition of 3% cement.

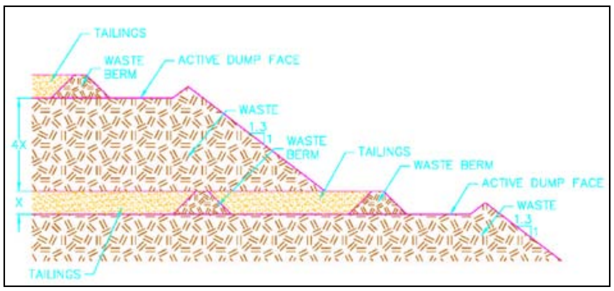

Figure 3. Ponds of tailings placed in waste dump

Blended tailings with waste rock at the face: Three methods of blending have been considered for Esquel. The first is to mix the material at the face by placing both tailings and mine waste near the crest of the active dump area and then pushing it over the face. The second method would be to place the tailings in a haul truck with the waste rock and then dump the un-mixed material out at the dump face. The third method is similar to this second method and is to mix the waste and tailings together on a conveyor belt. This would be feasible if the mine transported the waste by conveyor.

The principal advantage of this methodology is homogenization of the mix, providing more uniform and therefore reliable properties throughout the dump. This also reduces the likely need for a binding agent and may result in a higher allowable proportion of tailings in the final mix. The principal disadvantages are related to operating costs and having mobile equipment in regular contact with the tailings, creating worker hygiene concerns.

Injected into the waste dump: This third method involves injecting the paste or thickened tails into the body of the waste dump. It is believed that the optimal way to achieve this is to place pipes on the dump face and then cover them with waste. Once the dump face has advanced sufficiently, the pipes in the dump will be connected to the tailings distribution system and tailings will be injected into the body of the dump. This method is seen in Figure 4. If the method of laying the pipe on the face is not feasible then pipes can be put in place by drilling vertical holes and placing a slotted pipe in the hole, this method is seen in Figure 5. The drill hole option also allows old waste dumps to be used for new tailings disposal.

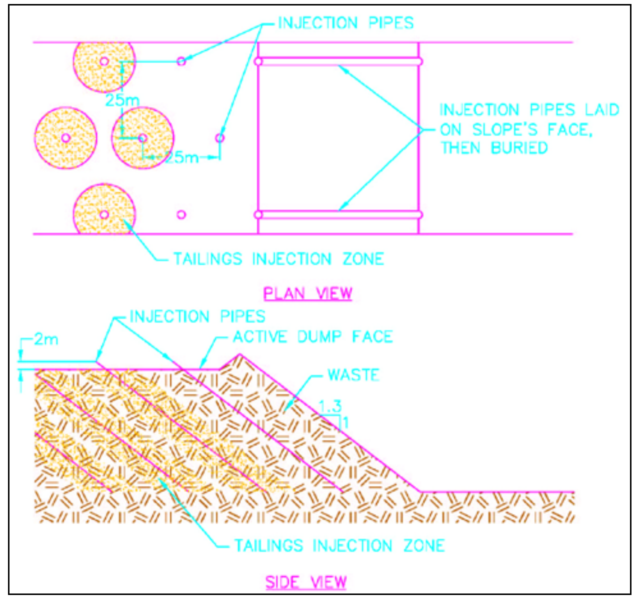

Figure 4 Injection by a pipe initially placed on the advancing dump face

Initial studies of tailings rheology and typical waste rock gradations at Esquel have indicated that tailings will penetrate radially as much as 30 meters into the body of the dump (for open graded rock). In underground mines in Canada where paste tailings has been injected in rock fill, 10 meters of tailings penetration has been achieved. This is based on experience where a similar method was used to construct backfill for an overhand and underhand cut and fill mining method.

Injecting the tailings into the dump has the advantage of holding the mixture as far away from the active or ultimate dump face as desired, as well as minimizing equipment contract with tailings. It may also result in higher proportions of tailings and a reduced need for binders. Injection also allows co-disposal to be applied to old waste dumps. However, the costs for this option are the highest of the methodologies considered.

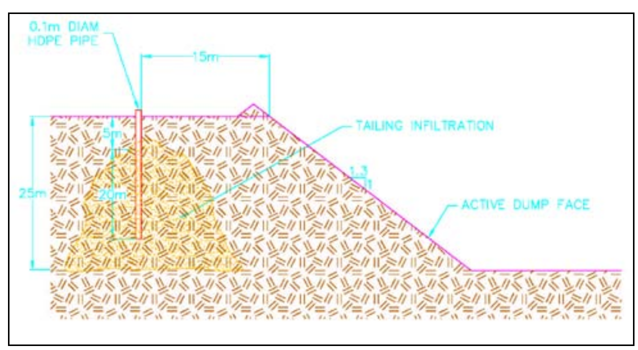

Figure 5 Injection of tailing in a drilled vertical hole

Applying a Veneer of Thickened Tailings on the Waste Face (Gravity Grouting): This forth method involves placing a thin veneer of paste/thickened tailings on the waste rock face and then allowing the tailings to infiltrate into the waste and dry. After a short period of time, another mine waste rock layer will cover the veneer. Figure 6 shows a cross-section of this method. At this time we anticipate the tailings layer would be 20 to 40 cm thick and the waste would be 1.5 to 3 m thick. The veneer would be placed on the face by laying a perforated pipe at the top of the waste face and allowing the tailings to slowly be applied to the face. The width of the application area is dependent on the dump face height and the rate of tailings production but the application area will be moved on a daily basis.

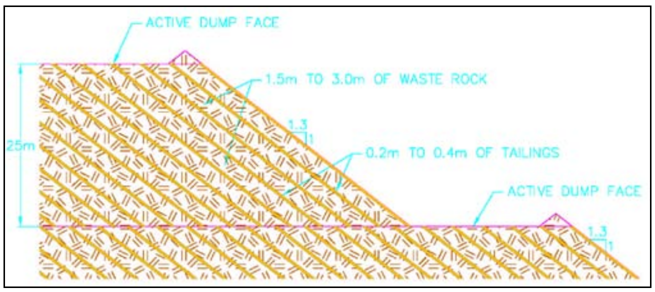

Figure 6 Layering of tailings on the dump face

Since the tailings layers are very thin, the pore water buildup concerns of method 1 are far reduced. Also, a considerable infiltration of tailings into the waste is anticipated (as verified by a pilot scale tests). Further, since the run-of-mine waste rocks are very large relative to the layer of tailings, there should be a significant amount of interlocking between layers above and below the veneer of tailings.

Advantages include low cost and easy visual monitoring of results. The system does require a lot of operator judgment, especially during the wet season to avoid sediment discharges and erosion. Concerns about inhomogeneity in the mixture are likely to lead to more conservative designs.

Cost Implications of Tailings Co-Disposal™

Every mine has to look at the site-specific conditions when evaluating the feasibility of tailings co-disposal™. An economic trade-off study will need to be undertaken that compares other tailings management methods, such as a conventional tailings impoundment, underground backfill, etc. The evaluation takes into account the benefits of co-disposal such as water conservation, reduced capital costs because there is no need for a tailings impoundment, and reduced closure costs.

From the first estimates for costs, tailings co-disposal™ at Esquel will likely have an operating cost of approximately 50 cents a tonne, versus over $1.00 for a lined tailings impoundment. Both costs are before consideration of closure. Tailings impoundment closure can be complex and expensive while the cost for closing a co-disposal dump is similar to or less than a conventional waste dump.

CO-DISPOSAL & SUSTAINABLE DEVELOPMENT

The main benefits of tailings co-disposal™ are the lack of a tailings dam, and the reduced access to water and oxygen in the waste dump, reducing ARD potential from both the rock and tailings. Lately, because of the well-publicized problems with tailings containment systems, it is beneficial to use a system that eliminates the need for a dam. In many regulatory environments, co-disposal may find greater acceptance than conventional tailings management systems.

The total land area required for a waste dump/tailings co-disposal system is much smaller than for separate facilities. In the optimum scenario, the volume of tailings is completely absorbed in the free voids of the waste dump. By reducing land disturbance one of the greatest unmitigable impacts of mining is reduced: permanent diversion of land from other uses, such as agriculture and wildlife habitat.

For the Esquel project, the total land disturbance will be reduced by 40 ha due to co-disposal. Further, the optimum tailings impoundment location is a valuable agricultural site. The post-closure risk associated with the waste dump is also reduced because a stronger waste dump is constructed and therefore poses less long-term risk to those who must be near the dump. In addition, with proper binder selection the effluents form the dump should be reduced and less harmful to the surrounding environment.

In the case of Esquel, and probably many other high-stripping ratio sites, the net effects on the environment will be reduced and therefore the effects on post operational uses will be greatly reduced making the a site more valuable for post operational activities.

CONCLUSION

Tailings co-disposal™ can offer a significant reduction in short-term and long-term environmental liability, land disturbance, closure costs, and negative public image associated with conventional tailings impoundments. The resulting co-disposal dump can be as safe or safer, depending on binder addition as a conventional waste dump, and in the case of alkaline tailings in a potentially acidic waste dump, the net chemistry can be less likely to produce acid rock drainage.

The tailings co-disposal™ system should be added to the methods that are considered for the tailing disposal is mines throughout the world. Mines that are best suited for using this system are mines with high ore to waste stripping ratios and mines that are restricted in the amount of surface area that can be disturbed.