Designing waste for value: coupling ore sorting with commingled tailings and mine rockfill

By Todd Wisdom and Adrian Dance, SRK Consulting

The mining industry has a growing interest in evaluating pre-concentration (e.g. ore sorting) and commingled tailings as separate innovations, yet both are often constrained by conventional flow sheet design and project evaluation methods. When implemented early in the value chain, ore sorting can reject low-grade or deleterious material before milling, reduce plant capacity requirements, energy and water consumption as well as reagent use. Commingled tailings and rockfill technologies, in turn, can improve the physical and chemical performance of tailings deposits, enhance underground rockfill quality, and reduce long-term geotechnical and environmental risks.

It is well recognised that waste is introduced into the ore stream between the mine and the mill by both internal (geological) and external (mining) processes. The objective of a pre-concentration circuit is to identify and reject waste as a coarse byproduct. Early rejection of this waste can reduce the size of the required concentrator and reduce the amount of fine-grained tailings that needs to be managed. Often handling and disposal of this waste stream is seen strictly as a cost, but what if this material filled a need? Filling a role where coarse, low-grade, crushed material is in demand – such as commingled tailings or underground mine rockfill.

As a generic term, ore sorting can be any combination of bulk sensor (monitoring a shovel, haul truck or conveyor belt), screening, and/or particle sorter. The concept is shown in Figure 1 for a conventional particle sorter fitted with a combination of sensors. These sensors can detect colour, mineral density, magnetism, infrared or ultraviolet light, or radioactivity. An example set of X-ray transmissive (XRT) sensor responses to high-grade and waste particles are shown in Figure 2.

After measuring each particle (or bulk properties every 30 s or so), the feed ore stream is separated into concentrated and rejected products.

Commingling is a subset of co-disposal processes (Figure 3).

Co-disposal is the placement of waste rock and tailings in the same footprint, while commingling is the mixing of waste rock and non-

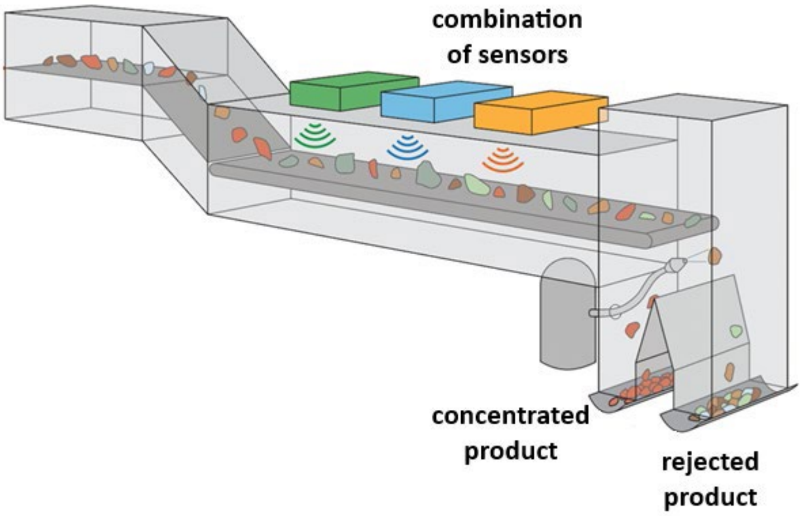


Figure 1 Example multiple sensor particle sorter

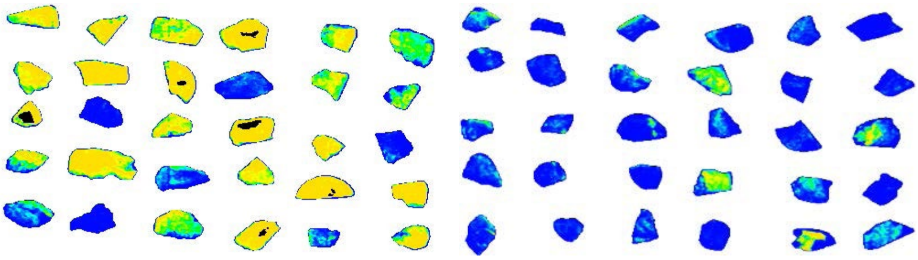
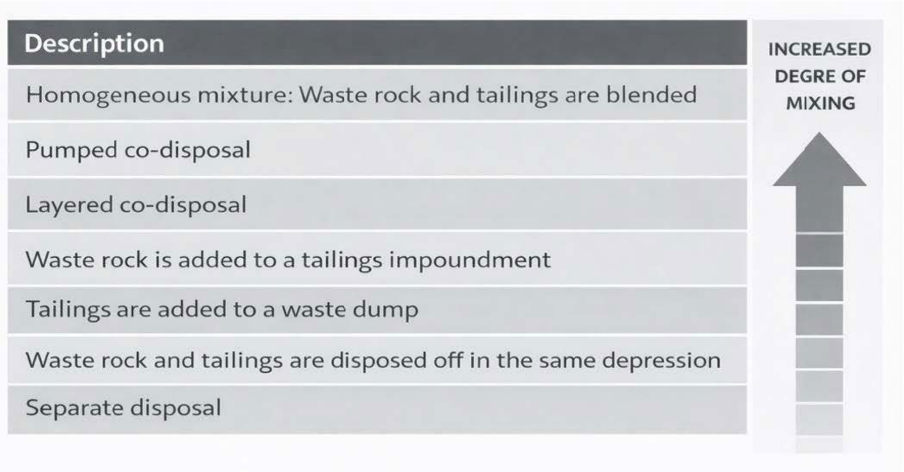


Figure 2 Relative atomic density of high-grade and waste particles under XRT sensor



Description
Homogeneous mixture: Waste rock and tailings are blended
Pumped co-disposal
Layered co-disposal
Waste rock is added to a tailings impoundment
Tailings are added to a waste dump
Waste rock and tailings are disposed off in the same depression
Separate disposal

Figure 3 The relationship between mixing, co-disposal, and commingling

segregating tailings and placement of the mixture in the same footprint. For the tailings to be non-segregating, typical mine tailings must be dewatered to the extent that the fines do not separate from the coarse tailings. An additional benefit of dewatering tailings is early recovery and re-use of water associated with mine tailings.

Commingled waste disposal has been used successfully at small-scale mine sites using bulldozers, excavators, trucks, dewatered tailings, waste rock, and significant manpower to produce a suitable mixture. Alternatively, if the dewatered tailings and waste rock are transported using conveyors, the energy of conveyance can be used to mix the 2 streams (Figure 4).

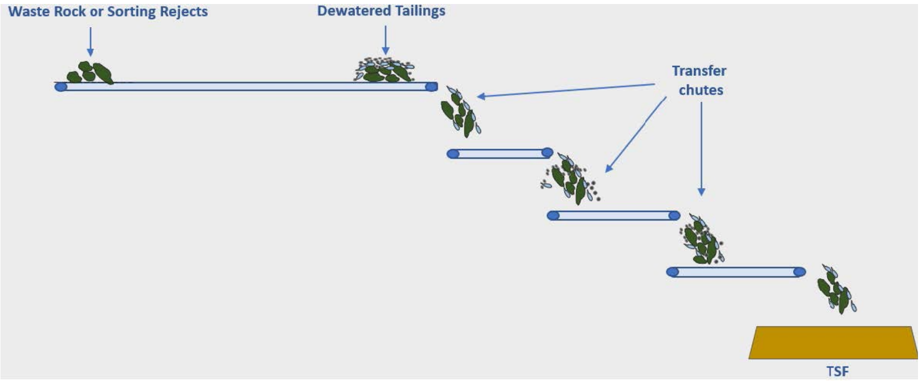


Figure 4 Using the energy of conveyance for mixing

The kinetic and potential energy of the conveying system is used to supply mixing energy to the tailings and waste rock mixture.

The mixture can contain different ratios of waste rock and tailings. Changing the mixture ratio changes the mixture matrix (Figure 5).

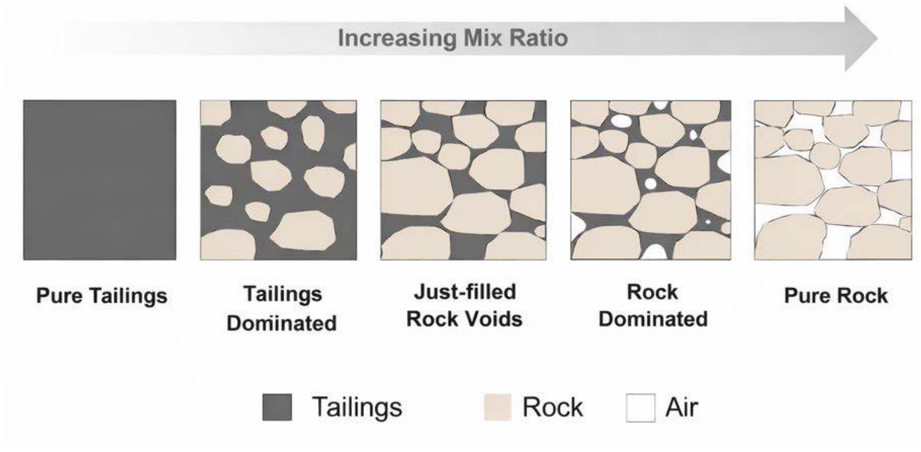


Figure 5 Visual representation of different commingling mix ratios

Typically, ratios between 2 and 6-parts (by weight) waste rock to one-part dry tailings are targeted. This range is between the 'tailings dominated' and 'rock dominated' matrix conditions.

Investigations over the years have demonstrated that the resulting commingled mixture has better geochemical or geotechnical properties compared to waste rock or tailings alone. Highly saturated tailings reduce the oxygen permeability of the waste rock, improving its geochemical stability, while high-shear strength low moisture waste rock improves the geotechnical stability of tailings (Figure 6).

Other benefits of commingling include earlier closure of waste rock and tailings storage facilities and reduced waste footprint. By using the void space of waste rock for tailings storage, less land is required for tailings and waste rock storage facilities.

As commingling requires waste rock masses that are 2 to 6 times the mass of tailings to improve geotechnical stability, ore sorting applied to the typical plant feed will not be sufficient to meet the waste rock requirements, as it contains 40% or less waste. For example, rejecting 40% of the plant feed still leaves 60% being processed which almost entirely ends up as fine-grained tailings. The resulting commingled stream mix ratio is only 40/60 by weight, so additional waste rock would need to be sourced to achieve the desired commingled mix ratios. However, sorting marginal or low-grade stockpiles (after crushing) could produce sufficient waste rock for commingling. The added value is any high-grade material in these stockpiles would be recovered by sensor sorting (being used in a scavenging duty).

As part of any project development path, commingling or underground mine rockfill and pre-concentration may be studied, but they are typically evaluated by a different team of specialists which does not allow the synergies of the technologies to be fully recognised.

Co-designing allows ore sorting rejects to be used directly as underground mine rockfill or used with dewatered tailings to produce a commingled mixture, which is used for surface disposal. Either option can transform ore sorting reject streams into value-adding materials while also enabling safer, lower cost, and more sustainable tailings solutions.

Operating a pre-concentration circuit along with commingled tailings deposition has shared cost benefits. From an ore sorting perspective, the rejected waste is not simply a cost burden but serves a valuable purpose with tailings management. From a commingling perspective, the crushing costs associated with ore sorting are adding value as the sorted waste has recovered some or all of the valuable metal prior to being mixed with tailings. This sorted concentrate can be sent directly to the plant to increase metal production. The waste rejects are now barren of metal value and will not be considered a future orebody that needs to be reprocessed.

Mining innovations such as pre-concentration, commingled tailings, and underground mine rockfill can have a synergistic benefit when the byproduct of one matches the material requirements of another. However, appreciation of such collaborative advantage is lacking due to studies typically being done in isolation. Ore sorting can be done on marginal or low-grade stockpiles to recover valuable metal and offset the cost of waste rock crushing. In addition, waste rejection on plant feed streams can provide some of the coarse, low-grade material requirements for commingling.

The combined benefits of ore sorting with commingling or underground mine rockfill can be summarised by the following:

- lower costs associated with reduced plant capacity requirements
- lower water, power, reagent consumptions per pound of metal produced
- smaller tailings management facilities
- lower geochemical and geotechnical risks of mine waste storage
- smaller overall mine waste footprint
- early closure of commingled facility

The challenges and risks associated with introducing technology and innovation to the mining industry can be lessened by considering holistic project synergies. This involves a more integrated approach between disciplines for both greenfield and brownfield projects.

Figure 6 Benefits of commingling

Adrian Dance
Principal Consultant
SRK Consulting, Canada

Todd Wisdom
Principal Consultant
SRK Consulting, USA