Paste thickening optimizes tailings disposal and water recovery at iron ore mine in South Africa

By Jim McMahon

Disposal of mine tailings, and their impact on water usage and environmental issues, is one of the most important concerns for any mine during its life cycle. Regardless of the mineral extracted, the challenge today in the management of tailings is stable and contained disposal, with maximum water reuse and minimal surface footprint.

In countries such as the United States and Canada, significant pressure is placed on mining projects to adhere to stringent water conservation and environmental standards in their disposal of tailings. Now, in other parts of the world, an increasing number of nations are instituting significant steps requiring water reuse and environmental damage mitigation.

In Chile, for example, where desalination plants along its coast are needed to provide water for that country's vibrant mining operations, the need for water reuse management is critical. This has prompted mining operations to explore efficient options for water reclamation in tailings disposal. In Peru, which has a huge mining sector, and similarly in Brazil, stiffer environmental regulations are being put into place for mining operations, largely because of the environmental impact concerns on local populations.

Mines throughout the world face challenges as their tailings dams are nearing capacity, or are unstable, increasing the potential for failure. Both conditions require heavy capital investment to rectify, yet many of these mines could minimize or delay this liability by reducing the volume of water put into their tailings disposal facilities. This would improve capacity and stability, while reclaiming more water for reuse in their upstream washing, screening and jigging processes.

In South Africa's semi-arid climate, where water availability is limited and usage is closely regulated by government mandates, water reuse in mining tailings disposal is particularly critical. The Khumani iron ore mine was successful in adapting its tailings disposal and water reuse procedures to this environment.

Traction thickener at the Khumani iron ore mine in South Africa.

Khumani iron ore mine – focus on water recovery

Situated in Northern Cape Province, South Africa, Khumani's iron ore deposits are located approximately 60 km north of the Beeshoek mine on the Bruce, King and Mokaning farms, adjacent to Kumba's Sishen iron ore mine. The Khumani mine is part of Assmang Ltd., which is jointly owned and controlled by African Rainbow Minerals Limited and Assore Ltd.

Beginning operation in 2008, Khumani is a large iron ore mine, producing approximately 16 million tons of product annually. After primary and secondary crushing, processing of Khumani's iron ore involves wet washing and screening, jigging and fines recovery through the use of de-grit cyclones. From the initial design stage it was evident that water recovery would need to play an integral part for the mine to be successful, as each of these processes requires large volumes of water.

"The area supports a number of large mining operations, an ever-growing local population and assorted infrastructure, so there is a limited quantity of water available for distribution," said Thomas Du Toit, metallurgical manager, Assmang Iron Ore. "This created a number of challenges for the Khumani mine. Our preferred process involved wet processing, but we did not have the available water."

Further complicating matters was the area's high evaporation rates, and lack of suitable sites for a conventional tailings facility.

To maximize its water reuse capability, the Khumani plant contracted WesTech Engineering Inc., which designed and implemented a two-stage tailings thickening process.

The first stage consists of two primary high-rate traction slurry thickeners, each 90 metres in diameter, situated at the main plant. The first thickener was installed in 2008, with the opening of the mine. The second thickener was added in 2012 to accommodate a 100 per cent increase in the plant's production line and throughput capacity. The two high-rate thickeners operate as clarifiers, returning the bulk of clarified water to the main plant at the combined hydraulic flow rate of 14,866 to 17,981 m^3 per hour. These thickeners recover approximately 90 per cent of the slurry water by volume.

Most mining facilities would then deposit the tailings slurry directly into a tailings pond at approximately 40 to 50 per cent solids. But this type of high-rate primary thickener was inadequate to produce the slurry densities required for the desired water reclamation. An additional thickening and disposal option needed to be implemented to maximize recovery.

Secondary stage – paste thickening

WesTech engineered a solution utilizing paste thickening technology to facilitate the second-stage process. The dilute slurry from the primary high-rate thickeners is pumped approximately five kilometres, to an area with adequate storage capacity for the expected 25-year life of the mine. It then feeds two 18 metre diameter paste thickeners at the plant's paste disposal facility (PDF). The first of these paste thickeners was put into place when the original plant was built in 2008, and the second installed in 2012 to accommodate the mine's increased capacity.

Khumani tailings pond with secondary paste thickener.

"The size of the two secondary paste thickeners was determined from the residence time required for the slurry to reach terminal solids concentration," said Philip Lake, WesTech's international business unit leader.

"Each of the two secondary paste thickener systems accommodates feed tonnages varying from 147 tons to 300 tons per hour. Volumes up to 450 tons per hour can be buffered in each of the secondary paste thickeners for short periods of time. The paste thickeners recover at least 75 – 80 per cent of the water by volume from the primary thickeners, increasing total water reclamation to over 95 per cent. These rates ensure adequate capacity in the thickeners to achieve high-density paste."

The PDF requires a minimal solids concentration of approximately 58 to 60 per cent by mass, in general. This is due in part to enable pumping of the thickened slurry to the outer limits of the dam wall using centrifugal pumps. It also allows

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the material to be deposited in layers of less than 10 centimetres to ensure effective drying and consolidation.

The PDF was three-dimensionally modeled for an accurate determination of the relationship between the height, area and capacity. This information was used to calculate the rates of rise for average production rates and, eventually, the life of the PDF. It was designed as an impoundment (compacted earth embankments) into which the tailings stream is deposited. Phased construction allows the facility to accommodate tonnage expansions.

Paste, or thickened tailings, has become an increasingly important method to address many environmental problems facing the mining industry. Originally developed by the alumina industry in the 1970s, it has been applied worldwide in other mining applications. Yet today, less than one per cent of iron ore mines employ systems for paste thickening, despite the benefits it can provide for optimizing tailings disposal.

"Khumani's secondary paste thickening process delivers substantial benefits," said Lake. "Not only does it recover water that can be reused in the plant, it also leaves less water in the deposit site."

According to Lake, in paste disposal, particles within the paste tailings are well distributed. Coarse particles (200+ microns in size) are uniformly intermixed with finer material (less than 20 microns). Therefore, in the non-segregating deposit, this homogeneous particle distribution facilitates the pulling up of water to the surface by capillary suction, where it can be evaporated. In addition, the beach angle of the deposition forces free water to accumulate at the low point of the PDF, where it is collected and reused.

Aerial view of the 18 m paste thickeners at the paste disposal facility.

In a conventional slurry tailings dam, slurry segregates into coarse material that settles at the deposition point with the ultra-fines carried further into the tailings facility. When ultra-fines segregate from the coarse material, they tend not to settle over time. This means free water in the tailings pond cannot be reclaimed for reuse "as is." Paste deposition's balanced distribution of course and fine particles, coupled with the reduced water content, provide more compact space utilization and much better structural integrity within the tailings dam. According to Lake, this makes dam failure unlikely.

An additional environmental benefit of paste tailings is their tendency to form a hard crust as they dry. In comparison, conventional tailings have a powder deposition of ultra-fine material which is likely to create dust pollution.

Studies indicate that thickened paste tailings can provide up to a 40 per cent reduction in tailings dam construction, both in material quantities and capital costs, allowing for flexibility in choosing dam locations, compared to conventional slurry systems.

Unique installation

The Khumani project demonstrated that it is possible to successfully build and operate a wet processing iron ore mining operation in an arid environment, where water supplies are limited.

"The two-stage water recovery and paste disposal system that has been successfully implemented at the Khumani iron ore mine is a unique installation, by any standard," said Du Toit.

"The combined use of primary and secondary thickeners in iron ore mining has rarely been implemented, particularly with the integration of a very large-sized primary thickener, linked to a secondary paste thickener. This system provides long-term environmental and cost efficiencies that few iron ore mines can realize."

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