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Addressing barriers to filtered tailings adoption: bridging feasibility and operational reality

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Abstract

As the mining industry navigates increasing demands for safer and more-sustainable tailings management solutions, the implementation of frameworks such as the Global Industry Standard on Tailings Management *(GISTM) (International Council on Mining and Metals et al. 2020) are raising expectations for tailings performance, governance, and transparency. Filtered tailings offer a clear pathway to achieving these requirements.*

Filtered tailings have gained global attention for their ability to reduce environmental and geotechnical risk, minimise water loss, and improve closure outcomes. From the perspective of a filtration technology supplier, filtered tailings represent a proven and increasingly viable solution – but one that still faces significant barriers to widespread adoption.

Drawing on Metso's global experience with high-throughput filtration systems, this paper examines the most common barriers to implementation, including high capital and operating costs, scalability challenges in large operations (including bulk material handling), site-specific geotechnical and climatic constraints, undervaluation of water, regulatory uncertainty, risk aversion, and supply chain limitations.

These barriers are explored from both the equipment supplier's and the mining operator's perspectives.

Filtered tailings solutions must be aligned with evolving standards and expectations. Delivering reliable, safe, and cost-effective performance over the full life cycle of a system. In alignment with the themes of surface disposal, emerging technology, and design with closure in mind, the paper presents practical, technology-driven strategies to overcome these constraints.

Advances in filter press design, automation and modular concepts are helping reduce technical, operational and economic risk. By aligning technological innovation with evolving environmental, social, and governance standards, filtered tailings can become a future-ready, cost-effective, and socially acceptable solution, bridging the gap between feasibility and operational reality.

Keywords: *tailings, filtered stacks, environmental, social, and governance, GISTM, design with closure in mind, emerging technology, surface disposal*

1 Introduction and context

The mining industry is entering a decisive phase for tailings management. A decade of high-impact failures has exposed the systemic risk of water-rich storage, with global incident records and recent case histories underscoring the human, environmental, legal, and reputational consequences of catastrophic dam releases. Non-conventional strategies – especially filtered tailings – are gaining traction because they directly reduce stored water and runout potential while enabling progressive closure and clearer accountability over long-dated liabilities. This shift aligns with the *Global Industry Standard on Tailings Management* (GISTM)

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(International Council on Mining and Metals et al. 2020) and investor expectations on environmental, social, and governance (ESG), water stewardship, and transparent closure planning.

Figure 1 shows an example of a high-altitude water-rich tailings storage facility (TSF) in the Andes region.

Figure 1 Example of a high-altitude, water-rich tailings storage facility

From a technology supplier perspective, the feasibility barrier that once limited filtration to niche applications has eroded. Advances in high-throughput filter press design, closed-loop process control, and modular, phased delivery shorten critical paths, stabilise cake moisture across variable feeds, and let capacity track mine ramp-up. Equally important, integrated bulk-handling systems – conveying, stacking, dust control – address historical bottlenecks in placement logistics, making large-scale stacking practical in a wider range of climates and geotechnical settings.

Independent evidence bases reinforce the risk case and the ESG case for dewatering. A comprehensive review of historical tailings failure records indicates that the vast majority of major tailings disasters are associated with water-rich slurry impoundments as discussed in (Fitton 2024). dewatering reduces the energy available to drive runout and shrinks dependence on high-consequence dam systems – benefits that matter even more as extreme rainfall events intensify. At the same time, capital markets are increasingly screening for water use and total risk indicators that filtration improves directly, creating durable demand for low-water deposition methods

Economically, the perceived premium of filtration persists largely because comparisons are often made against partial accounts of conventional TSF costs. Traditional evaluations foreground low initial capex/opex for slurry systems while aggregating or discounting sustaining dam raises, long-dated closure and post-closure care, social and regulatory costs, and the true value of water. To correct this bias the industry must agree on a reporting method that facilitates like-for-like comparisons.

When full life cycle costs are surfaced, filtration's competitiveness strengthens – particularly where water is scarce/costly, land is constrained, or closure confidence is a permitting and social license determinant. Two complementary studies expand this lens. First, a 2018 conceptual comparison for Western Australia shows that while filtered systems carry higher capex and opex under base assumptions, they dramatically reduce footprint, minimise make-up water, and enable progressive rehabilitation – elements that can dominate net present value under alternative scenarios (e.g. real water pricing, land cost, or heightened closure obligations). Second, a 2019 life cycle analysis across 6 scenarios (closure escalations with lower discount rates, water price, land price, carbon pricing, and a 'potential total life cycle' case) finds filtered tailings to be the most cost-resilient option when hidden and deferred costs are internalised; in the composite scenario, filtered tailings outperforms thickened and slurry alternatives precisely because it externalises fewer future liabilities.

Regional operating contexts reinforce these conclusions. In Chile, daily tailings generation is massive, regulations are tightening, GISTM adoption is advancing, and water scarcity is driving a structural shift toward recirculation and sea water make-up – conditions that increase the relative value of process-water recovery from filtration. Contemporary practice reviews show high-density thickeners and filters have improved efficiency and capacity, enabling larger-throughput non-conventional tailings operations; major operators are now advancing feasibility work on high-density and filtered systems at scales of 50–240 kt/d, often in staged implementations that manage execution risk.

From a risk-engineering perspective, filtration shifts the hazard profile by removing large impoundments and reducing reliance on embankments to contain ponded water; failure modes linked to hydraulic energy (overtopping, liquefaction runout) are correspondingly curtailed. Comparative matrices consistently show lower post-closure obligations for filtered stacks versus slurry dams and lower overall footprint than central thickened discharge, which, while operationally attractive, can drive very large landforms and high closure volumes.

The remaining debates are, in essence, execution questions: scale effects in cake handling, climate-robust trafficability, dust control, and supply-chain readiness. Here, practice is evolving quickly. Site-specific design adaptations (outer-slope compaction bands, drainage layers, seasonal placement strategies), coupled with automation and conveyor-based stacking to de-risk haulage, are now common tools to deliver consistent performance. These strategies convert filtration from a 'unit operation' decision into an integrated systems solution for risk, water, and closure – precisely the outcomes that GISTM and ESG-sensitive capital are rewarding.

Finally, the industry must fix its tailings disclosure reporting so boards and regulators can make like-for-like choices. The US dollar/dry metric tonne (USD/DMT) approach and improved TSF line-item segmentation recommended by Benjamin Cox complement the scenario-based life cycle methods in Carneiro. Together, these frameworks reveal when filtration's higher up-front spend is more than offset by reduced water dependence, smaller land take, progressive closure, lower residual risk, and fewer long-tail surprises. That is the business case we develop in this paper: filtered tailings are not merely safer; with modern technology and full-cost accounting, they are commercially and socially viable at scale.

2 Reframing filtered tailings

The perception that filtered tailings are prohibitively expensive has long shaped industry decision-making. However, when the full life cycle is considered – including closure, rehabilitation, and long-term risk – the cost profile of filtered tailings changes fundamentally. This section breaks down the main cost levers and demonstrates why closure and risk management are decisive factors in the business case for filtration.

2.1 Capital expenditure (capex)

Filtered tailings systems require significant upfront investment in filtration plants, stacking equipment, and automation. While this capex is higher than conventional slurry or thickened tailings, advances in equipment design, modular plants and phased implementation allow operators to defer and optimise capital outlays. Importantly, the initial premium must be weighed against downstream savings in closure and risk.

2.2 Operating expenditure (opex)

Operating costs for filtration include energy, maintenance, filter cloths, and cake transport. Automation and process control are reducing labour and variability, while conveyor-based stacking is lowering haulage costs. Equipment technology has improved remarkably for large-scale operations with much-improved utilisation, and minimisation of consumables such as cloths and membranes. Although opex remains higher than for conventional systems, these costs are increasingly offset by savings in water, land and closure.

2.3 Water savings

Filtered tailings maximise water recovery, reducing make-up water costs and the need for expensive supply infrastructure. In arid regions or where water costs are high (e.g. USD 5/m^3), filtration can offer significant savings over the life of a mine. These savings directly offset both capex and opex costs and are increasingly valued by regulators and investors focused on water stewardship.

2.4 Land and footprint

Land is not just a financial asset – it often holds cultural, historical, and ecological significance for local communities and Indigenous peoples. Large tailings facilities can disrupt traditional land uses such as grazing, agriculture, hunting, or spiritual practices, and may impact areas of ecological or cultural importance. Community opposition to new or expanded tailings dams is frequently rooted in concerns about loss of access, changes to landscape character, and long-term stewardship.

Dry stack filtered tailings require much less land than conventional or thickened tailings dams, reducing acquisition, permitting, and rehabilitation costs. The smaller footprint translates to lower annual rehabilitation fund levies and minimises environmental disturbance, which is especially important in remote or sensitive regions.

The land efficiency of filtered tailings not only delivers financial and regulatory benefits, but also supports responsible mining by reducing impacts on traditional land use and responding to community expectations for sustainable development and respectful stewardship.

2.5 Closure and rehabilitation costs

Closure and rehabilitation are where filtered tailings offer the most compelling advantages. Conventional slurry dams often require decades of active management, complex capping, and ongoing water treatment. Rehabilitation costs can escalate due to large footprints, saturated materials, and regulatory changes. Filtered tailings, by contrast, enable progressive reclamation as shown in Figure 2 – side slopes can be capped and revegetated during operations, spreading closure costs over the mine life and reducing post-closure monitoring obligations.

Figure 2 Ongoing reclamation of filtered stack slope

For example, studies show that closure costs for thickened tailings can be up to 4 times higher than for filtered tailings, primarily due to the vast area requiring topsoil and long-term care. Filtered stacks, with their smaller footprint and dry, stable material, allow for faster relinquishment and lower long-term liabilities. In scenarios with extended monitoring (e.g. 50 years), the ability to minimise closure costs is a decisive advantage, both financially and in terms of regulatory compliance.

2.6 Long-term risk and bonding

The risk profile of filtered tailings is fundamentally different. By eliminating large impoundments and reducing stored water, filtration curtails failure modes linked to hydraulic energy, such as overtopping and liquefaction runout. This translates to lower insurance premiums, reduced bonding requirements, and fewer regulatory delays. The financial impact of risk reduction is often underestimated but can be substantial, especially in jurisdictions with strict tailings governance and high public scrutiny.

2.7 Social license and environmental, social, and governance

Filtered tailings align with evolving community expectations and ESG criteria. Improved safety, water stewardship, and progressive closure enhance reputation and facilitate permitting. Mines that adopt filtration are better positioned to access ESG-linked capital and avoid costly delays or opposition. As global standards like GISTM become the norm, filtration's alignment with best practice is increasingly rewarded.

Cost levers:

- capex
- opex
- water savings
- land savings
- closure and monitoring
- risk/bonding
- social/ESG
- energy/carbon
- net life cycle cost (final value after all levers).

Economic comparisons between filtered and conventional tailings storage are highly sensitive to which life cycle components are included and how long-dated obligations are discounted. Published scenario analyses (e.g. Carneiro & Fourie 2017, 2018; Cox et al. 2022) show that while filtered systems generally carry higher initial capital and operating expenditure under base assumptions, their relative competitiveness improves when water pricing, land constraints, closure complexity, bonding requirements, and long-term risk exposure are explicitly incorporated. In many cases, conventional slurry TSFs appear economically favourable only when closure, monitoring and failure-related costs are heavily discounted. When these life cycle elements are valued more transparently, filtered tailings can become the more cost-resilient option, particularly in water-scarce environments or jurisdictions with community impacts and stringent closure and regulatory requirements.

3 Site-specific barriers

Filtered tailings implementation succeeds or stalls onsite realities: how much material you must move (throughput), how you can place it (bulk handling/trafficability), where you are placing it (geotechnics and climate), who must approve it (regulators/boards), and whether you can keep it running (supply chain and service).

3.1 Throughput, scalability and bulk handling

Large operations worry that filtration 'doesn't scale', or that cake logistics (haulage, stacking, dust) will bottleneck the system even if the filters perform. Historic pain points include variable cake moisture causing transport issues and non-trafficable surfaces, slumping, wet-weather downtime, and placement rates that fall behind the plant.

Documented projects and studies report increasing capacities (tens of kt/d to ~50 kt/d and above) and demonstrate that the bottleneck is often bulk material handling, not the presses per se. Conveyor systems, mobile stackers, and staged lifts now underpin reliable large-scale placement, while improvements in equipment technology and automation stabilises moisture and cycle times.

To mitigate these issues, the following should be carefully planned from the beginning of the mine plan.

- Cake/slurry transport and logistics with mobile trippers/radial stackers: use trucks only for short hops or contingency. Dust: enclosed/tubular conveyors, moisture set-points linked to wind forecasts.
- Moisture control and analytics (closed-loop press control; alarm bands tied to stack trafficability).
- Lift strategy (outer 'structural' bands compacted under fair weather; interior placement in wet season). Surge pads to decouple filter press availability from stacking rate.

3.2 Geotechnical and climatic constraints

Sites with intense rainfall, freeze/thaw, soft foundations, high seismicity, or fine/clay tailings are viewed as unsuitable for filtration; concerns include trafficability, dust, drainage, and liquefaction/slumping risks on stack slopes.

Independent reviews conclude these concerns are not overriding technical impediments to broader filtration when designs are climate-aware and geology-aware. Case histories show filtered placement working in rainy climates (with water management), and for finer tailings when filter selection and stack drainage are properly engineered.

To mitigate these issues the following should be carefully planned from the beginning of the mine plan**.**

- Water management: perimeter drains, lined ponds sized for local intensity/duration/frequency storms; keep ponded water off the landform; maintain runoff controls during construction and operation.
- Stack design for stability: conservative benching and overall slopes; drainage layers, wick/drainage trenches, and compaction QA/QC to meet shear strength targets. Seismic checks include cyclic resistance and post-event stability.
- Climate operations: seasonal placement windows; outer-slope 'structural' zones for wet season resilience; dust plans (binder, progressive cover, vegetation) for dry/windy periods.

3.3 Regulatory uncertainty and organisational risk aversion

Boards and regulators may default to 'what we know', citing permitting risk, schedule exposure, and lack of local references. Financial models that discount long-tail costs (closure, monitoring, failure exposure) can bias decisions toward low-capex slurry dams, even when total obligations would favour dewatering.

GISTM expects rigorous alternatives analyses and encourages dewatering; recent economic studies show that with segregated TSF disclosure (USD/DMT) and scenario analyses (water/land/closure/carbon), filtered solutions are often more cost-resilient, particularly where water is a cost and land/closure liabilities are meaningful.

To mitigate these issues, the following should be carefully planned from the beginning of the mine plan:

- Pilot and phased adoption with performance-linked guarantees (availability, cake moisture, throughput, energy/kWh-t) to de-risk approvals and internal investment cases.
- Transparent economics: adopt the USD/DMT TSF metric and publish line items (capital, sustaining lifts, water, closure, bonding) so boards and regulators see apples-to-apples comparisons.
- Regulatory engagement early: align design criteria with GISTM, share monitoring/assurance dashboards (moisture, placement rate, stability factors) to build confidence.

3.4 Supply chain, spares and operability

Long lead items (presses, plates/cloths, pumps), remote locations, and thin local service networks create perceived operability risk; unplanned downtime can cascade into stockpiles or temporary wet disposal.

Reputable suppliers with global presence and operators have developed internal processes and systems that facilitate standardisation, local stocking strategies, and modular plants that materially improve resilience. For this exercise, original equipment manufacturer global presence and size does matter for the operations.

4 Technology innovations

The step change in adoption of filtered tailings solutions is driving the industry to consider a whole tailings system upgrade across filtration, thickening, bulk handling and control. The technologies below reduce execution risk, stabilise performance, and unlock life cycle value (water, closure, risk) that traditional capex/opex comparisons often miss.

4.1 Systems view: from unit operations to an integrated tailings system

Recent projects succeed when the thickener–filter–handling chain is engineered as one process: thickeners deliver consistent, high-density feed; filters turn variability into predictable cake moisture and throughput; and conveyors/stackers place cake efficiently to build a stable landform. Digital control loops sit across the system to hold targets despite feed or climate swings.

4.2 Filters

There are many technological advances that allow modern mining-specific designs to deliver the throughputs and moisture consistence that filtered tailings demand. A modern high-throughput, fast-opening plate filter press designed for tailings duty is very different to filters designed for industrial or other lighter applications and then adapted for tailings. In filtered tailings applications, the press's role is to convert rheology and solids variability into repeatable cake moisture and discharge behaviour – at the sustained rates large operations require.

How it advances adoption:

- Throughput and availability: fast opening/closing sequences; robust hydraulics and automated discharge sequences reduce cycle losses; modular trains allow phased capacity (N+1 redundancy) to match ramp-up and de-risk commissioning.
- Moisture stability: closed-loop cycle control (fill/press/air-blow logic, diaphragm controls, cloth wash automation) narrows moisture variance – critical for trafficability, dust control and slope stability during stacking.
- Maintainability: standardised plate/cloth packages and predictive maintenance lower unplanned downtime, spare-parts standardisation across trains simplifies stocking at remote sites.
- Execution risk: containerised/skid modules, pre-wired auxiliaries and repeatable system 'blocks' shorten critical path and reduce integration risk, which historically deterred first-time adopters.
- Equipment: a good example of a dedicated tailings filter is Metso's FFP series (Figure 3), where every feature is engineered to extend component life, improve reliability, and maintain consistent performance under high-throughput conditions.

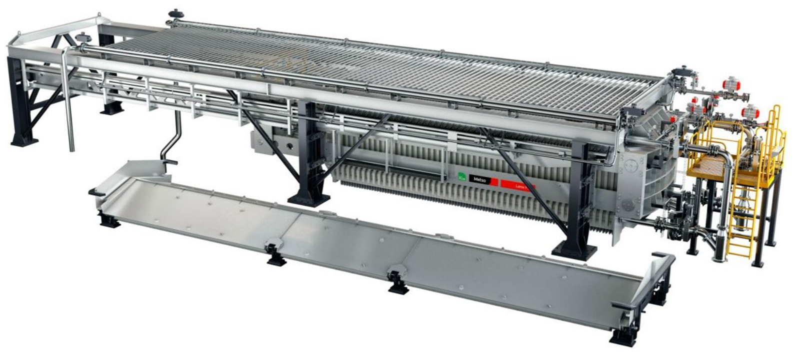

Figure 3 Larox Fast Filter Press (FFP) filters

Figure 4 shows METSO's FFP plates with rubber membranes and Metso's unique holeless cloth.

Figure 4 Monoblock heavy duty membrane plates and holeless cloths

Mining-grade plates – have replaceable ports positioned outside the filtration area, protecting the cloth and sealing surfaces from wear.

Inlets and outlets are designed for high flow rates and abrasive resistance, ensuring uniform filling and efficient filtrate removal without compromising plate integrity.

The rubber membrane is critical for cake compression – can be replaced independently of the plate, reducing maintenance cost and downtime.

This modularity keeps life cycle costs predictable and availability high.

Slurry feed enters tangentially to the cloth, reducing direct impact and turbulence. This simple but critical detail extends cloth life, improves cake release, and eliminates cloth bypass and allows for our unique holeless cloths.

These features allow for a stable cake, enables conveyor-first logistics, steeper placement productivity, less wet-weather interruption, and earlier progressive closure – all central to the risk and closure value proposition for filtered stacks. Safer TSF designs link these performance gains to safer landforms and improved ESG outcomes.

4.3 Thickeners

A good-performing thickener is the foundation for reliable, efficient, and cost-effective filtered tailings stacking. It ensures the filters receive the right feed, at the right density, enabling high throughput, optimal cake quality, maximum water recovery, and smooth downstream handling. Figure 5 shows a Metso Reactorwell.

Figure 5 Reactorwell

The reactorwell is a high-efficiency feedwell/reactor system integrated into tailings thickeners to pre-condition and flocculate feed more effectively than conventional feedwells, reducing short-circuiting and shear degradation. It promotes the following:

- Consistent underflow density: better mixing/floc kinetics produce higher, more stable per cent solids in thickener underflow, which improves filter press throughput and moisture control (filters perform best when the 'front end' is steady).
- Lower reagent and energy exposure: improved floc efficiency can cut flocculant usage and stabilise rake torque; steadier underflow reduces recirculation and rework.
- Water stewardship: higher overflow clarity and reliable internal water recovery close the site water balance – a key lever in jurisdictions with high water value or tight allocation.

When thickeners deliver predictable feed, filters run at design, reducing nameplate 'derate' and helping realise the water, land and closure benefits quantified in life cycle studies.

4.4 Bulk material handling and stack formation

Modern filtered tailings systems prioritise conveyor placement (fixed/mobile conveyors, trippers, radial stackers) with dust controls (enclosures, binders) tied to cake moisture setpoints. Lift strategies use compacted 'structural' outer bands for wet seasons and interior placement during rainfall windows to maintain stability and productivity. These practices resolve the historical bottleneck – moving cake at the rate the plant produces it, and as a last resort, temporary storage to decouple filter press availability from stacking rate.

4.5 Automation, sensing and assurance

End-to-end control blends local programable logic controller/process control systems logic with plant-wide analytics:

- Closed-loop moisture control using cycle telemetry, cake weight proxies and lab feedback.
- Placement assurance: rate, lift geometry and compaction QA/QC captured for reporting; ties directly to GISTM evidence requirements.
- Predictive maintenance for filters, pumps and drives reduces unplanned outages that previously forced temporary wet deposition.

4.6 Modularity and phased delivery

Standard plant sizes, repeatable utility skids and pre-tested control blocks let owners add capacity in steps, reducing up-front capex and commissioning risk while building the operational muscle memory for full-scale stacking. This phased approach is a recurring success pattern in recent projects and a practical answer to board/regulator risk aversion. Figure 6 shows a typical Metso dewatering plant.

Independent reviews highlight that adoption barriers – perceived cost, scalability, climate/variability, and supply-chain risk – are being dismantled by exactly these innovations. More-efficient thickeners (with advanced feedwells) plus fast, automated filter trains reduce total water loss, shrink land take, and accelerate closure – the drivers that flip life cycle economics in many scenarios.

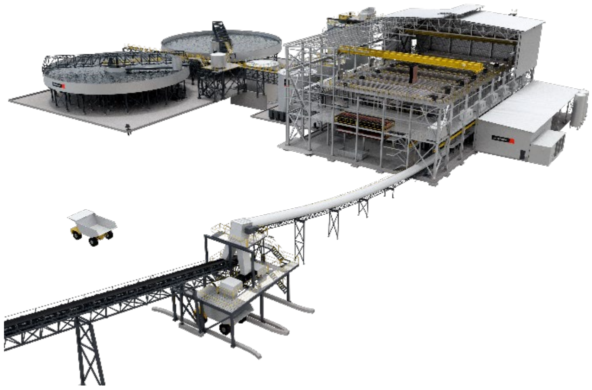

Figure 6 Typical modular plant solution

5 Filtered stacks versus conventional tailings storage facilities: a risk comparison

The mining industry's approach to tailings management is under unprecedented scrutiny, driven by catastrophic failures, evolving regulatory standards, and heightened community expectations. At the heart of this scrutiny is the comparative risk profile of filtered tailings stacks versus conventional TSFs. Figure 7 shows a progressive stacker in operation in Western Australia. This section provides a clear, evidence-based comparison demonstrating why filtered stacks represent a step change in risk reduction and long-term stewardship.

Figure 7 Filtered stack deposition

5.1 Failure modes and consequence pathways

Conventional TSFs (slurry or thickened tailings dams) are characterised by large volumes of saturated material retained behind engineered embankments. The principal failure modes include:

- overtopping (from extreme rainfall or operational error)
- liquefaction and static/dynamic instability (triggered by earthquakes, rapid drawdown, or internal erosion)
- piping and seepage
- structural failure of embankments.

These failures can result in catastrophic, high-energy releases of water and tailings, with runout distances measured in kilometres, causing loss of life, environmental devastation, and massive financial and reputational liabilities. Historical data show that the vast majority of major tailings disasters have occurred at conventional TSFs, with consequences that persist for decades.

There is also possible soil contamination by chlorides in operations that use sea water, acid mine drainage, and water-quality process implications for water-rich TSFs.

Filtered stacks, by contrast, are engineered landforms constructed from dewatered, compacted tailings 'cake' with minimal free water. The principal risk pathways are fundamentally different:

- No large impoundment of water: eliminates overtopping and drastically reduces the potential energy available for runout.
- Dense, unsaturated material after compression and layering: greatly reduces the risk of liquefaction and flow failures.
- Progressive, engineered lifts: allow for ongoing compaction, drainage, and stability monitoring.
- Smaller, more-stable footprint: reduces the area and population at risk.

5.2 Semi-quantitative risk matrix

Failure mode	Conventional tailings storage facility	Filtered stack
Overtopping	High	Negligible
Liquefaction/flow failure	High	Low (if well compacted)
Seepage/piping	Moderate	Low
Slope instability	Moderate	Low
Dust generation	Low	Moderate (manageable)
Closure/post-closure risk	High	Low

Table 1 Conventional tailings storage facility versus filtered stack risk matrix

The key takeaway from the risk analyses is that filtered stacks eliminate or drastically reduce the most catastrophic failure modes associated with conventional TSFs. The remaining risks (e.g. dust, localised slope instability) are lower consequence, more predictable, and manageable with established engineering controls.

5.3 Risk-reduction mechanisms

- Reduced potential energy: with little or no stored water, filtered stacks cannot generate high-velocity flows in the event of a failure. Any material movement is slow, localised, and far less hazardous.
- Progressive closure: stacks are built in lifts, allowing for ongoing compaction, capping, and revegetation. This not only improves geotechnical stability but also enables early closure of completed areas, reducing long-term exposure.
- Enhanced monitoring and assurance: modern filtered stack operations employ real-time instrumentation (e.g. moisture, density, pore pressure) and automated reporting, supporting proactive risk management and GISTM compliance.

- Simplified emergency response: in the unlikely event of a localised failure, the absence of a large water body and the dense, unsaturated nature of the stack mean that emergency response is more straightforward and less time-critical.

5.4 Closure, long-term liability, and costs

One of the most significant advantages of filtered stacks is the dramatic reduction in long-term liability and associated costs. Conventional TSFs often require perpetual water management, dam maintenance, and environmental monitoring – sometimes for decades or even centuries – due to the persistent risk of dam failure, seepage, and instability. These ongoing obligations translate into substantial, uncertain financial liabilities that can burden operators and, in some cases, be transferred to governments or communities if companies exit.

In contrast, filtered stacks are engineered for progressive closure and rapid achievement of post-mining land-use criteria. Their dense, unsaturated structure allows for earlier capping, revegetation, and regulatory sign-off, minimising the duration and cost of post-closure monitoring. The absence of large water bodies and the stability of the landform mean that long-term risks – and therefore bonding, insurance, and contingency costs – are much lower and more predictable. This clarity and reduction in liability not only improve the project's financial profile but also support responsible mine legacy management and community trust.

5.5 Social and regulatory risk: community acceptance and environmental, social, and governance

Community acceptance is decisive for project viability and schedule. Filtered stacks help earn and sustain a social licence because they remove the large, impounded water body that communities most fear, shrink the physical footprint, and recover process water, easing competition with local users. These attributes translate visibly onsite – fewer high-consequence scenarios, progressive revegetation of completed lifts, and earlier hand-back of land for culturally appropriate or traditional uses.

On ESG, filtration demonstrates risk elimination, water stewardship, and credible closure pathways – the very themes embedded in GISTM, lender frameworks, and ratings methodologies. Operators that couple filtered stacks with early, ongoing engagement, plus transparent dashboards (stack stability, dust, water balance) and third-party assurance, typically see smoother permitting, fewer objections, and access to ESG-linked or sustainability-labelled finance at improved terms. Practical elements – dust control tied to cake moisture setpoints, conveyor-first logistics to reduce traffic impacts, and grievance mechanisms with rapid response – further reinforce trust.

Bottom line: filtered stacks convert tailings from a high-consequence, perpetual-care liability into a managed, progressively closing landform, aligning operational reality with community expectations and ESG capital requirements. Figure 8 shows multi-criteria relative cost analyses.

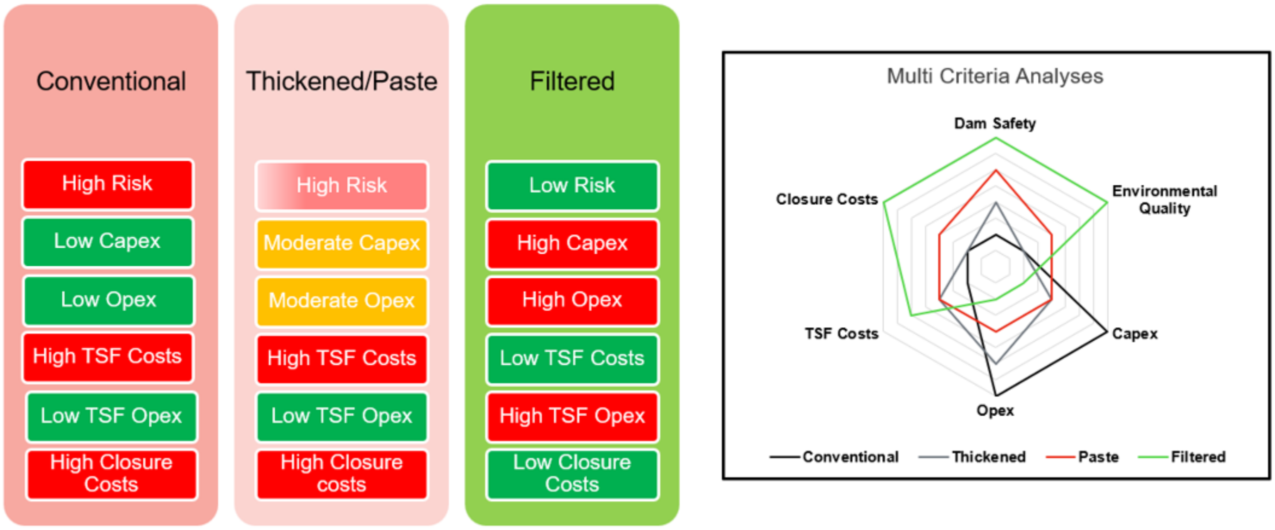

Figure 8 Multi-criteria analyses

6 Summary

This paper demonstrates that filtered tailings are not only technically feasible but also operationally, financially, and socially advantageous for modern mining operations. Advances in high-throughput filtration (such as Metso's FFP filter presses), automation, modular delivery, and integrated thickening (notably with reactorwell technology) have mitigated the traditional barriers of scale, reliability, and cost. These innovations enable filtered tailings to be deployed at throughputs and in climates previously considered out of reach, with robust performance and predictable outcomes.

A holistic, life cycle-based evaluation – grounded in recent research, case studies, and unified cost metrics – shows that the perceived cost premium of filtration is largely a function of incomplete accounting. When water savings, land efficiency, progressive closure, and risk reduction are fully valued, filtered tailings often emerge as the most resilient and cost-effective solution, especially in water-scarce or high-risk jurisdictions. The ability to recover and re-use water, minimise land disturbance, and progressively reclaim and close the stack delivers tangible financial, regulatory and social benefits.

It is important to acknowledge that the relative financial performance of filtered tailings is not universal; it depends on site-specific cost drivers and the valuation of long-term obligations. Evidence from published life cycle evaluations indicates that filtered systems may become economically robust when water value, progressive closure, land reduction, bonding, and risk mitigation benefits are explicitly recognised (Carneiro & Fourie 2017; Cox et al. 2022). Conversely, when evaluations discount closure and risk at high rates or exclude them from the economic framework altogether, conventional slurry or thickened systems may appear more attractive. Accordingly, filtered tailings should not be presented as inherently financially superior, but rather as a potentially cost-resilient alternative under conditions where license to operate, community concerns, long-term liabilities and water-related constraints materially influence project economics.

Critically, filtered stacks offer a step change in risk reduction. By eliminating large impoundments of water, they remove the most-catastrophic failure modes associated with conventional TSFs. The dense, unsaturated, and compacted nature of filtered stacks means that even in the event of a localised failure, the consequences are far less severe and more manageable. This translates into lower long-term liabilities, reduced bonding and insurance costs, and a clearer path to regulatory sign-off and relinquishment.

6.1 Filtered tailings and access to finance

The risk profile of a tailings facility is now a central concern for investors, lenders, and insurers. In the wake of catastrophic failures – such as Brumadinho and Mount Polley – financial institutions have become far more risk-averse, with many requiring robust alternatives analyses and explicit demonstration of risk mitigation before providing capital. The adoption of filtered tailings directly addresses these concerns:

- Lower catastrophic risk means lower insurance premiums and bonding requirements, improving project economics and freeing up capital for productive use.
- Predictable closure and liability profiles make it easier to model and manage long-term obligations – a key requirement for lenders and institutional investors.
- Alignment with ESG frameworks and GISTM signals to the market that the operator is committed to best practice, responsible stewardship, and transparent reporting.

As a result, projects that adopt filtered tailings are increasingly favoured by risk-averse investors and are more likely to secure financing on favourable terms. In some jurisdictions, access to ESG-linked or sustainability-labelled finance may depend on the adoption of filtered tailings or equivalent best-available technology.

6.2 Reputation risk and the cost of failure

The financial and reputational consequences of conventional TSF failures are massive and enduring. Recent disasters have resulted in:

- Multi-billion dollar compensation claims (e.g. Vale's multi-billion dollar settlement for Brumadinho, ongoing litigation against BHP and Vale for Samarco).
- Long-term loss of social license, with projects delayed or cancelled due to community opposition and regulatory intervention.
- Share price collapses and loss of market capitalisation for companies involved in high-profile failures.
- Increased scrutiny from regulators, investors, and the public, raising the bar for all future projects.

Filtered tailings, by eliminating the most severe failure modes and enabling progressive closure, provide a credible pathway to reducing these risks. Operators who invest in filtration are not only protecting their balance sheets but also safeguarding their reputation and long-term viability.

6.3 Social license, environmental, social, and governance, and community trust

Filtered tailings align with the expectations of investors, regulators, and local stakeholders. They support water stewardship, reduce the mine's environmental footprint, and enable earlier and more-meaningful engagement with traditional land users. Smaller, more-stable landforms are easier to integrate into post-mining land-use plans that respect traditional practices and community priorities. Adoption of filtered tailings demonstrates a proactive commitment to responsible mining, transparent closure planning, and long-term legacy management.

7 Recommendations

Based on the technical, economic, and social considerations discussed in this paper, a set of practical recommendations is proposed to support informed decision-making and reduce barriers to the adoption of filtered tailings. These recommendations are intended to help operators, designers, and regulators move beyond narrow, short-term evaluations and toward integrated, life-cycle-based approaches that explicitly account for water stewardship, closure performance, risk reduction, and stakeholder expectations. Together, they reflect lessons learned from recent project experience and emerging best practice and provide a structured pathway for implementing filtered tailings solutions in a manner that is technically robust, economically transparent, and socially responsible.

- Adopt a life cycle, scenario-based approach to tailings management decisions, explicitly valuing water, land, closure, and risk.
- Engage early with technology suppliers and communities to tailor solutions to site-specific needs and expectations.
- Require transparent, segregated disclosure of tailings costs and risks (e.g. USD/DMT), enabling fair comparison of alternatives.
- Implement pilot programs, modular deployment, and performance-based contracts to de-risk adoption and accelerate learning.
- Continue supporting innovation in filtration, thickening, and bulk handling, with a focus on automation, monitoring, and assurance.

8 Conclusion

Filtered tailings are a proven, future-ready solution that bridges the gap between feasibility and operational reality. With current technology, they deliver safer, more-sustainable, and more socially acceptable outcomes – meeting the rising standards of the industry and society. They also facilitate access to capital from risk-averse investors, reduce long-term liabilities, and protect operators from the devastating financial and reputational consequences of catastrophic failures. The time to mainstream filtered tailings is now.

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