doi:10.36487/ACG_repo/2655_59

Modular containerised flocculant systems: a fast-track and cost-effective solution for tailings treatment

Julien Bonnier [a,*], **Flavien Gathier** [a]

[a] *SNF, France*

Abstract

This paper presents recent operational insights and technological advances in the application of modular and containerised systems for flocculant preparation and dosing in tailings treatment. While the mining industry has increasingly adopted containerised units, our work introduces design refinements, integration of innovative equipment, optimised automation strategies, and deployment methodologies that elevate their performance, adaptability, and sustainability.

To support continuous and large-scale operations, the paper presents innovative containerised storage solutions for flocculant in powder form. These systems address logistical and operational challenges in remote or high-throughput mining environments through bulk handling features, and compact enclosures that preserve product integrity. Their modular design allows for scalable capacity and rapid deployment, ensuring reliable supply and seamless integration with preparation and dosing units.

This paper will also show how enhanced mixing technologies accelerate polymer dissolution, delivering more uniform and stable solutions that improve treatment consistency. These are complemented by integrated digital monitoring that further strengthens system reliability. Real-time tracking of dissolution and dosing parameters, as well as equipment behaviours, enables predictive maintenance and centralised oversight. Remote access tools reduce unplanned downtime and enhance responsiveness across dispersed mine sites.

Beyond pure technical performance, containerised systems offer strategic deployment advantages. Their plug-and-pump design reduces installation timelines and capex, while modularity supports phased expansion and rapid relocation. Case studies illustrate benefits including optimised capex and opex, minimised site work, improved maintainability, and resilient operation under challenging climates.

By combining operational efficiency with practical implementation, containerised flocculant systems are positioned as a transformative technology for tailings management and other flocculant usage in mining applications. The innovations described here demonstrate measurable gains in sustainability and operational resilience, underscoring their role in supporting the mining industry's shift toward safer and more sustainable tailings practices.

Keywords: *flocculant, modular, tailings treatment, containerised, polymer*

1 Introduction

The mining industry is undergoing a significant transformation in tailings management (long considered a necessary byproduct), driven by evolving safety regulations, sustainability objectives, and the need for operational agility. The tragic failures of several tailings storage facilities (TSFs) in the last decade, alongside tightening regulations and public scrutiny, have accelerated the adoption of best available technologies for tailings dewatering and water recovery. Modular containerised flocculant systems have emerged as a

[*] Corresponding author. Email address: jbonnier@snf.com

practical solution, offering advantages in deployment speed, scalability, and adaptability compared to traditional fixed installations.

These systems leverage recent advancements in polymer dissolution technology, automated dosing, and digital process monitoring. By integrating these features, operators can achieve more consistent treatment results, reduce manual oversight, and optimise resource use. The modular design allows for phased expansion and straightforward relocation, minimising the need for extensive civil engineering and supporting flexible project development. Industry reports and technical reviews highlight the growing adoption of modular solutions across various mining regions. For example, the Integrated Modular Plant and Containerised Tools project has demonstrated the feasibility and benefits of modular, containerised mineral processing plants, showing how such approaches can reduce installation time and improve operational flexibility (Moore 2018). Recent publications at the various tailings-oriented conferences have further emphasised the role of modular systems in improving water recovery, process reliability, and sustainability in mining (Wait & Cooper 2025; James et al. 2021)

Recent news also reflects the sector's focus on digitalisation and Environmental, Social, and Governance (ESG) priorities. Innovations in flocculant dosing optimisation and process water monitoring (Fester & Werner 2022) are helping mining operations achieve better performance and compliance with environmental standards. As regulatory and societal expectations continue to rise, modular containerised flocculant systems are increasingly recognised as a forward-looking choice for modern tailings management, aligning with industry goals for safety, sustainability, and operational excellence.

2 Background and industry context

2.1 Flocculant use in mining operations

Flocculants are indispensable in mineral processing, particularly in:

- tailings thickening: enhancing sedimentation rates, increasing underflow density
- clarification: improving overflow clarity in thickeners, critical for water recycling
- filtration: increasing cake permeability, reducing moisture content.

Annual polymer consumption in large mines can exceed 3,000–5,000 t/ year, with reagent costs representing a significant portion of opex (up to dozens of millions USD per year). Thus, inefficiencies in polymer preparation or dosing translate directly into increased opex and reduced treatment consistency (Brown 1987).

Most flocculants are polyacrylamide-based (PAM) polymers, modified with varying ionic charges. These are typically supplied in dry powder form due to storage and transport advantages (emulsion or liquid forms are also conceivable in some cases). Flocculants, supplied as powders, can present unique challenges:

- Hygroscopic nature: polymers absorb moisture, leading to clumping and reduced solubility.
- Dust hazard: airborne particles pose occupational health risks.
- Dissolution difficulty: improper wetting creates 'fisheyes,' undissolved polymer clumps that affect solution quality by reducing available active polymers (Figure 1).
- Sensitivity to shear when in solution: polymer chains might be broken by excess of velocity or mechanical shearing.

These constraints require careful design of storage, handling, and mixing systems.

Figure 1 Example of fisheyes in maturation tank.

2.2 Conventional flocculant plants: a potential bottleneck

Traditional flocculant preparation and dosing plants have long been the backbone of reagent management in mineral processing. These installations are typically designed as large, fixed facilities, featuring extensive civil works such as reinforced concrete foundations, custom-built silos, and sizable dissolution tanks. The construction and commissioning of such plants often span 12–18 months, requiring significant capital investment and specialised labour for both installation and ongoing maintenance. However, as Sidorenko et al. (2020) emphasise, the rigidity of such plants is misaligned with the current industry trend toward shorter project cycles and the need for rapid adaptation to changing ore bodies and regulatory requirements.

While these conventional plants have proven effective in stable, long-life mining operations, their inherent rigidity poses several challenges in today's rapidly evolving mining landscape. Modern mines increasingly face shorter project cycles, fluctuating ore throughput, and the need to operate in remote or logistically challenging environments. Scaling up capacity in conventional plants often demands major retrofits or complete redesigns, resulting in significant costs and operational disruptions. This inflexibility is particularly problematic in remote or logistically challenging environments, where, as Moore (2018) and Wait & Cooper (2025) note, the ability to quickly deploy or modify processing infrastructure is critical for project viability and sustainability.

Maintenance complexity further exacerbates these challenges. Conventional plants depend on bespoke equipment and intricate piping, requiring highly skilled technicians for both routine operation and troubleshooting. In remote locations, this can lead to increased downtime and reduced reliability, as highlighted by Koenig et al. (2023), who found that lack of automation and remote monitoring in traditional systems often results in excessive reagent consumption and inconsistent dewatering performance.

Moreover, the lengthy construction timelines and high capex associated with conventional reagent plants can delay project start-up and revenue generation. Stimpson et al. (2025) point out that such delays can hinder the integration of advanced process technologies, such as modular concentrators, which require flexible and responsive reagent management. As the mining sector shifts toward greater agility, cost discipline, and sustainability, the limitations of conventional flocculant plants have become increasingly apparent, prompting the search for more adaptable and efficient alternatives.

2.3 Modularity: a need from the market

In response to the constraints of conventional reagent plants, the mining industry is rapidly adopting modular, containerised flocculant systems – a trend validated across multiple sectors and increasingly recognised as best practice in mining (Moore 2018; Sidorenko et al. 2020). These systems, engineered as pre-assembled, factory-tested units within standard ISO shipping containers, offer transformative advantages in deployment speed, scalability, and operational flexibility.

Sidorenko et al. (2020) argue that modularity is essential for technologically advanced raw materials production, enabling rapid adaptation to evolving operational and regulatory demands. Stimpson et al. (2025) further demonstrates that modular integration supports the deployment of advanced concentrator technologies, facilitating phased expansion and seamless relocation as throughput increases or site conditions change.

The core benefit of containerised systems lies in their scalability and transportability. Operators can expand capacity simply by adding modules, avoiding disruptive retrofits and oversized initial investments. This 'building block' approach, as described by Moore (2018) and Rivas & Chalieux (2022), allows mines to start with a single preparation and dosing unit and scale up as needed; without the risk of stranded assets when operations wind down or relocate.

Technologically, containerised systems incorporate advanced features tailored to the unique challenges of flocculant management. Environmental controls within storage modules preserve polymer integrity even in humid climates, while enclosed powder transfer systems minimise dust emissions and protects worker health (Rivas & Chalieux 2022). Multi-stage mixing processes, such as those enabled by the polymer slicing unit (PSU), ensure rapid and uniform polymer activation, reducing the risk of undissolved agglomerates and improving treatment consistency (Rivas & Bonnier 2021; Bonnier et al. 2025).

Automation and digital monitoring are integral to the containerised approach. Koenig et al. (2023) and Wait & Cooper (2025) highlight the value of real-time process monitoring and predictive maintenance, which enhance reliability and reduce reagent waste, even in remote or logistically challenging environments. Remote access capabilities further support efficient technical support and minimise unplanned downtime.

In summary, the shift toward modular containerised flocculant systems reflects a broader industry trend toward flexible, scalable, and resilient infrastructure. By integrating operational efficiency with advanced process control and digitalisation, these systems align with the mining sector's drive for safer, more sustainable, and future-proof tailings management.

3 Features of modular containerised system

The design of containerised flocculant systems is based on the principle of modularity, in which each functional element of the system – powder storage, preparation, dissolution, dosing, and control – is encapsulated within a dedicated transportable container. This approach contrasts with conventional flocculant plants, which typically rely on large-scale, civil-intensive installations. By condensing functions into pre-engineered modules, containerised systems achieve a balance of robustness, flexibility, and ease of deployment, – what can be called a 'Plug & Pump' concept.

3.1 Structural concept

Each module is constructed from standard ISO 20- or 40-foot shipping containers. Containers are modified as little as possible to accommodate process and all ancillaries' equipment (Figure 2) and facilitate access and operations. These minimal modifications allow these containers to be recertified as regular sea containers at the end of the construction, which has a huge interest in terms of shipping cost and time.

(a)

(b)

Figure 2 Details of containers during construction. (a) After completion of painting and openings; (b) During installation of equipment

The modular concept allows operators to assemble systems progressively. A mine may begin with a single preparation and dosing unit and later add bulk storage or additional dosing modules as throughput increases. This 'building block' architecture avoids oversizing at the early stages of mine development, when tailings production may still be ramping up. It also ensures that when expansions occur, they can be supported by additional modules rather than complete re-engineering of the reagent plant.

3.2 Powder storage and preservation

Storage is one of the most critical functions in flocculant management. Sizes of polymer storage is dependent on several parameters, such as daily consumption, logistics chain, packaging, and safety stock; they can vary from hundreds of litres for small plants to dozens of tonnes for larger units. The large silos can be challenging, especially in humid environments where polymer powders are prone to caking and clumping, which drastically reduces dissolution efficiency. Additionally large vertical storage silos require deep concrete foundation, that can be bigger in seismic and/or windy areas.

To address this, containerised storage modules that integrate environmental control features and require smaller site preparation have been developed based on sea containers (Rivas & Chalieux 2022). The storage containers are equipped with hybrid silo-container systems capable of holding between 30–80 t of polymer depending on configuration (Figure 3). These modules include:

- a load cells system for constant weight monitoring
- an active dry air blanketing that maintains relative humidity below 20% and removes any moisture from the headspace.

Together, these technologies preserve polymer integrity over extended storage periods, minimising waste and ensuring consistent dissolution quality.

Powder transfer from delivery packaging (big bags, truck) to the silos is managed either by enclosed conveyors or pneumatic loading systems. From silos installed on top of the polymer preparation container, powder will flow by gravity and transfer auger to the dissolution device that will mix it with water. These designs reduce dust emissions, protecting workers from respiratory hazards and minimising product loss. By ensuring controlled, dust-free transfer, containerised systems also align with occupational health and environmental compliance requirements.

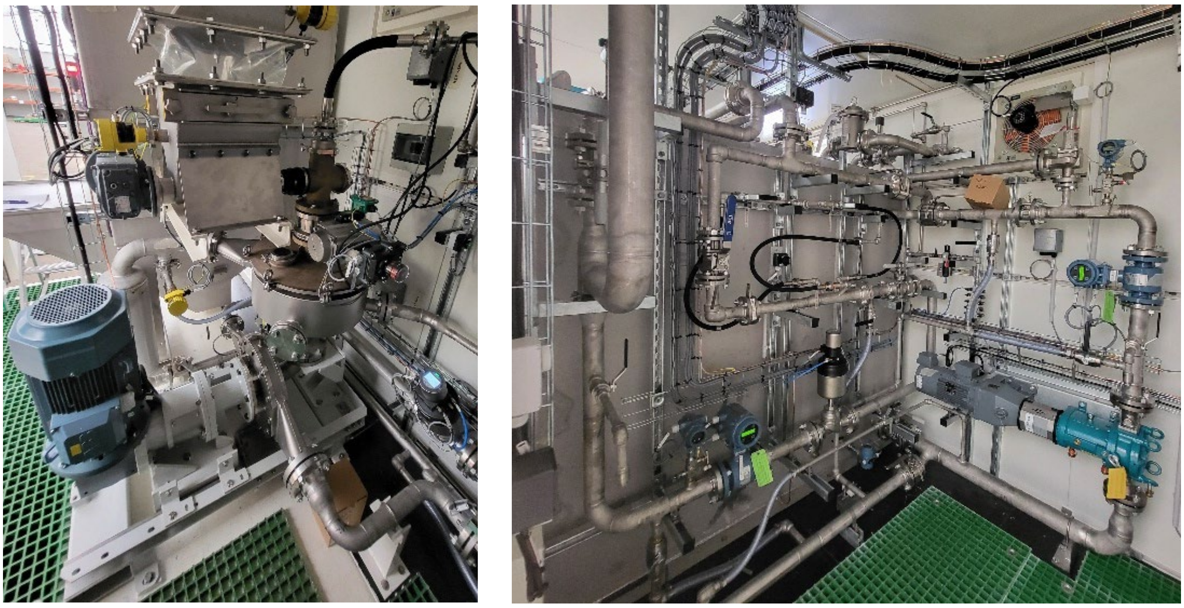
(a) (b)

Figure 3 Containerised horizontal silo. (a) Single silo 30 t capacity; (b) Double silo 80 t capacity

3.3 Dissolution and mixing

The dissolution of flocculant powder into a usable polymer solution is increasingly done by novel technologies such as a PSU, shown in Figure 4, which offers a promising solution (Rivas & Bonnier 2021) to address limitations and challenges associated with conventional dissolution systems (Bonnier et al. 2025). By significantly improving the dissolution process, reduction of dissolution time and higher concentration of preparation, PSU has a direct impact on the sizes of downstream equipment such as maturation tanks and application pumps – generally a reduction of 2–4 times. This will lead to a reduction of the overall footprint of the flocculant facilities and support the use of containerised units.

Dissolution devices always operate with a maturation tank, shown in Figure 4, that uses moderate agitation to achieve complete dissolution. Optimised tank volume – thanks to higher concentration of preparation and reduced maturation time, as well as rectangular shape design – allows, on most cases, installation of this tank into the sea containers.



(a) (b)

Figure 4 Process equipment installed in containers. (a) Polymer slicing unit 300; (b) Maturation tank and metering pump

3.4 Metering and injection

The final stage of the flocculant system is the controlled delivery of the prepared polymer solution into the process stream. While often considered a routine task, metering and injection play a decisive role in determining the overall efficiency of tailings treatment. Even if dissolution and storage are optimised, poor injection design can result in wasted reagent, suboptimal floc formation, and inconsistent thickener or filtration performance.

Containerised systems address this by integrating high-precision metering pumps (Figure 4) and engineered injection points directly into the modular design. Typically, dosing is carried out using progressive cavity pumps or rotary lobe pumps, selected for their ability to handle viscous polymer solutions without excessive shear degradation. Flow rates can be adjusted across a wide operating window, from a few l/min to several cubic meters per hour, ensuring that both start-up conditions and full-scale production are adequately supported.

Injection points are engineered to maximise contact between the polymer solution and the slurry. In thickeners, this may involve multi-port injection rings or lance systems placed strategically in the feedwell, ensuring rapid dispersion and minimising localised overdosing. In filtration circuits, polymer solution is often injected upstream of mixing tanks or conditioning pumps, where shear forces assist in distributing the reagent uniformly. The location and configuration of injection points are critical and typically determined through pilot testing simulations to optimise mixing and floc formation. When paired with SNF’s high-energy mixers, such as Flomix, it ensures optimal polymer activation and dispersion.

Automation enhances the precision of metering and injection. Flowmeters provide real-time feedback, allowing the control system to adjust dosing rates dynamically in response to changes in slurry flow, solids content, or water recovery targets. This closed-loop control reduces reagent waste and stabilises process performance, which is particularly valuable in operations with variable ore types or feed rates.

By integrating metering and injection into the modular framework, containerised flocculant systems provide a seamless end-to-end solution – from powder storage to dissolution, to precise delivery into the process. This integration ensures that reagent effectiveness is maximised, operational variability is reduced, and downstream performance in thickeners, filters, and TSFs is consistently improved.

3.5 Monitoring and control

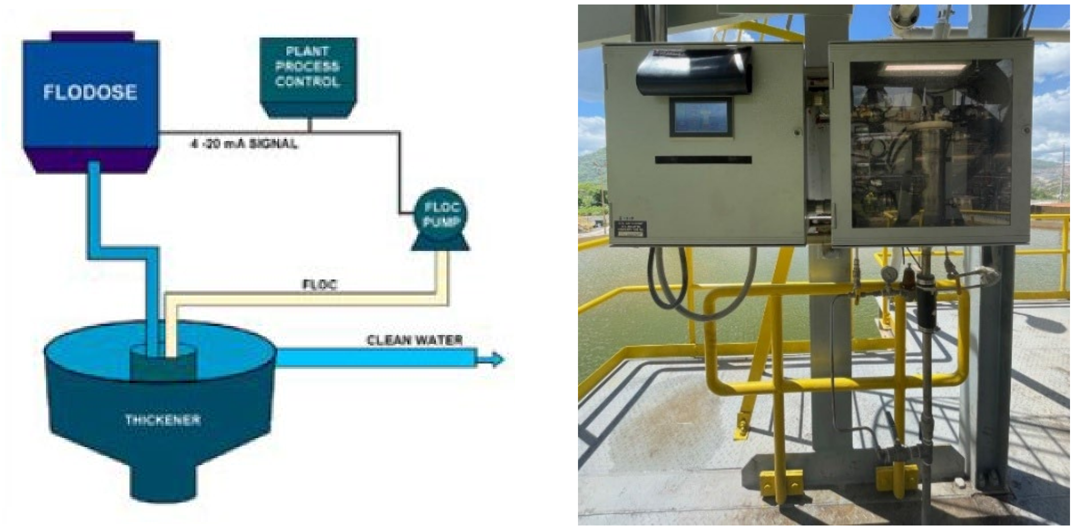
Modern containerised flocculant systems increasingly rely on advanced automation to ensure precise and reliable polymer dosing, especially in variable and demanding tailings environments. Traditional dosing approaches often depend on manual adjustments by operators, who tend to overdose flocculant to maintain process stability and minimise the risk of underdosing events. However, this practice can lead to excessive reagent consumption, increased costs, and inconsistent dewatering performance.

Recent advances, as demonstrated by Koenig et al. (2023), show that automatic, continuous measurement and control systems can significantly improve dosing accuracy and process outcomes. These systems utilise real-time monitoring (such as laser triangulation sensors or similar technologies) to assess the topography and behaviour of sludge belt filters. Proprietary algorithms then dynamically adjust the polymer dose to maintain optimal conditions, responding rapidly to changes in feed characteristics, flow rates, or sludge density. Field trials have shown that such automation not only reduces the frequency of operator intervention but also enhances the stability and reliability of dewatering equipment. For example, Koenig et al. reported a 29–37% reduction in flocculant consumption and an 8–11% decrease in filter cake moisture content when automatic dosing was implemented.

Other devices such as SNF’s Flodose system (shown in Figure 5), which regularly measures the flocculation time and the turbidity of overflow water of a sample taken in the feedwell of the thickener, play a critical role for optimised flocculant dosage.

Designed to precisely control polymer dosing. The Flodose Unit can respond to numerous process variables affecting flocculation of thickener or clarifier feed such as:

- changes in solids concentration
- solids distribution
- effect of primary coagulant dosing
- changes in surface chemistry of the solids
- pH
- flocculant dilution rate changes.



(a) (b)

Figure 5 Flodose system. (a) Process overview; (b) Overview of the unit at site

All the above variables affect settling rates, and the Flodose Unit can respond rapidly to compensate for and maintain optimum flocculation without the need for operator input.

By integrating smart sensors and proprietary algorithms, it minimises chemical waste, improves cake dryness, and enhances overall plant performance. It also reduces manual intervention, streamlining operations and lowering costs.

3.6 Automation

A defining feature of modern containerised systems is the integration of advanced automation. Each module is equipped with a programmable logic controller (PLC) that governs the operation of feeders, pumps, agitators, and valves. The PLCs are linked to supervisory control and data acquisition systems, which provide operators with real-time visibility over solution concentration, tank levels, dosing rates, and equipment status.

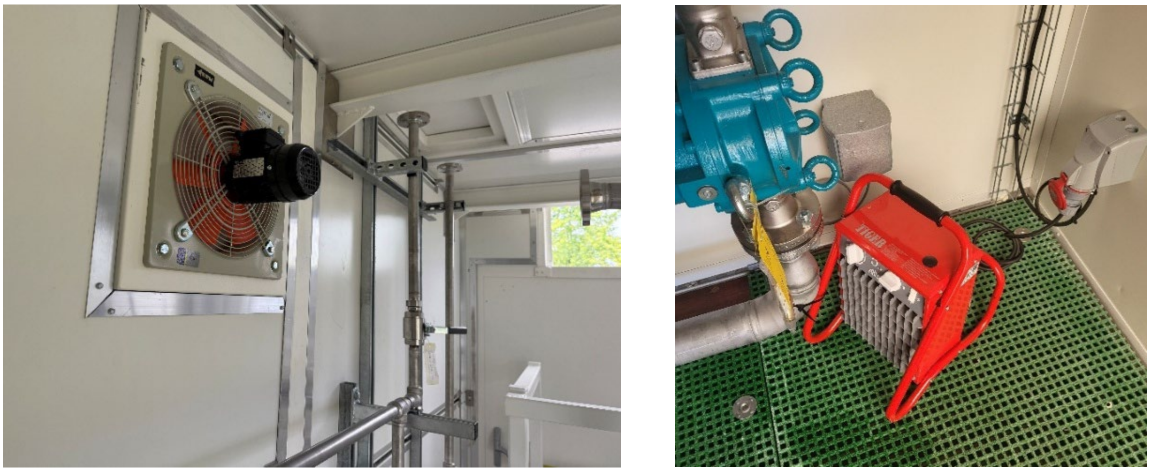
Automation reduces reliance on manual intervention, which is particularly valuable in remote mines where skilled labour may be limited. Beyond basic control, many systems now include predictive maintenance features. Sensors monitoring vibration, power draw, and flow rates can identify early signs of wear in pumps or feeders, enabling maintenance to be scheduled proactively rather than reactively.

Remote access is another key enabler. With secure internet connections and development of Internet of Things (IoT) based systems, original equipment manufacturer (OEM) engineers can monitor performance and troubleshoot issues without traveling to site, significantly reducing downtime and travel costs. This capability proved particularly valuable during the COVID-19 pandemic, when site access was restricted but technical support was still essential.

3.7 Other features

Containerised units are now designed in such way that they act as real operation buildings. In the past we could have seen so-called containerised units that were only containers with equipment laying inside without any consistency and operator friendly approach. Safety and economics are now embedded in the design of containerised systems, to ensure that operators can safely access hatches, valves, and panels without excessive manual lifting or awkward postures. Floors equipped with grating prevent risk of slipping (Figure 6b), which is one of the most important hazards while handling flocculant.

By consolidating powder handling and dissolution within sealed modules, containerised systems also reduce the environmental footprint of reagent plants. Fugitive dust emissions, common in traditional installations, are minimised, supporting both regulatory compliance and community expectations around environmental stewardship. Effective ventilation devices (Figure 6a) ensure a constant renewal of the atmosphere inside the containers, leading to minimising risk related to dust and overheating in hot environments. Insulation (Figure 6a) is also added in both hot and cold environments to maintain stable internal conditions, while external painting provides resistance to UV degradation and corrosive atmospheres.



(a) (b)

Figure 6 Containers features. (a) Details of insulation and ventilation; (b) Grating and heating

4 Deployment and operational methodology

The deployment of containerised flocculant systems follows a fundamentally different trajectory compared to conventional reagent plants. While traditional plants involve lengthy design, procurement, and construction cycles, containerised systems are manufactured and tested offsite, transported as standard freight, and assembled on simple civil foundations. This shift from ‘construction project’ to ‘installation project’ is the key driver of deployment speed and cost savings.

4.1 Fast-track deployment

In a typical project, the supplier fabricates and assembles the modules in a controlled factory environment, where all mechanical, electrical, and control systems are pre-installed. Factory acceptance testing is conducted to validate performance before shipment. This means that when the modules arrive at site, they are already proven systems, requiring only utility connections and functional checks before operation.

At the mine site, civil works are minimal. Instead of large and reinforced buildings, the system requires only flat concrete pads for container placement and utility tie-ins for water, power, and polymer solution to treatment. Assembly is therefore rapid; in some projects, site preparation, installation and commissioning have been completed in as little as 5–10 weeks, compared to 5–12 months for traditional plants (see comparison in Table 1). The reduced construction activity not only lowers capex but also minimises the number of contractors on site, reducing safety exposure.

Table 1 Deployment timeline comparison

Stage	Conventional plant	Containerised system
Design	4–6 months	2–3 months
Procurement and fabrication	4–6 months	2–4 months
Civil and construction/installation	6–9 months	1–2 months
Commissioning	1–2 months	2–3 weeks
Total duration	12–18 months	6–9 months

4.2 Cost savings over the entire project life

Containerised modular systems offer substantial economic advantages over conventional fixed plants. They dramatically reduce both capex and opex, enable faster deployment, and improve operational reliability and sustainability. Their modularity also avoids stranded assets and supports flexible, future-proof tailings management. Table 2 summarises the main differences in capital and opex based on case study data and industry benchmarks.

Table 2 Costs comparison

	Conventional plant	Containerised system	
capex	Baseline	30–50% lower	Major savings
opex (polymer, operations)	Baseline	15–40% lower	Significant savings
Unplanned downtime	Baseline	10–25% lower	Improved reliability

4.3 Operational flexibility

Operational flexibility is one of the strongest advantages of containerised systems. Because modules are self-contained, they can be easily scaled or reconfigured to match changes of mine’s requirements. For example, an operation starting with a throughput of 3,000 t/day of tailings may initially install a single preparation and dosing module. As throughput increases to 6,000 t/day, a second module can be added in parallel, doubling capacity without disrupting the existing installation.

Relocation is another benefit. In multi-mine operators or satellite projects, modules can be transported to new sites once the original operation is completed or closed. This avoids the common problem of stranded infrastructure, where conventional plants become obsolete and represent sunk capital once a mine is decommissioned.

4.4 Workforce and training

Operating a flocculant plant has traditionally required significant operator oversight, particularly during powder transfer and dissolution. Containerised systems reduce this burden through automation and user-friendly interfaces. Touchscreen HMIs display clear process graphics, allowing operators to monitor and adjust settings with minimal training.

Suppliers often provide standardised training programs, enabling local personnel to operate and maintain the system confidently. Remote support, facilitated through digital connectivity, allows more complex troubleshooting to be performed by OEM specialists. This dual approach strengthens local workforce capabilities while ensuring access to expert knowledge when required.

4.5 Sustainability contributions

Containerised systems contribute to sustainability in several ways. From a resource perspective, their smaller footprint and reduced civil works minimise land disturbance and embodied carbon. Because they are modular and re-deployable, they can be reused at multiple sites, extending their life cycle and reducing the need for new construction. Operationally, optimised mixing reduces energy consumption, while improved dissolution efficiency reduces polymer waste. Enhanced water recovery at the TSF supports the mine's water stewardship goals, lowering reliance on freshwater withdrawals. Finally, the enclosed handling systems improve both environmental performance and worker safety by reducing dust emissions.

5 Case studies

5.1 Case study 1: pressure oxidation feed thickener (Dominican Republic)

5.1.1 Project context and challenges

The mine, in the Dominican Republic, is one of the world's largest gold and silver operations. The site's pressure oxidation (POX) feed thickener processes tailings at an average rate of 1,400 t/h, with peaks up to 2,000 t/h. The tropical climate, with average annual temperatures ranging from 21–30°C and relative humidity between 79–85%, presents significant operational challenges, particularly for equipment reliability and polymer handling. As ore throughput increased, the existing traditional hydration unit became insufficient, necessitating a more robust and scalable solution for flocculant preparation and dosing. This has been accomplished by the installation and start-up in April 2019 of a modular containerised unit.

5.1.2 Solution: modular containerised system

To address these challenges, a modular, containerised flocculant preparation and dosing system was deployed. The system consists of 2 stacked containers (Figure 7).

- The upper container houses the flocculant silo feed and the electrical room. An external dry flocculant hopper and conveyor transfer system facilitate bulk powder handling.
- The lower container houses the hydration and secondary dilution water booster pumps, water filtration units, a PSU 300 preparation unit, a 16 m³ cascading maturation tank, application pump, and a secondary dilution manifold with an inline mixer feeding directly to the thickener.
- The system is fully automated and integrated with the site's distributed control system (DCS), though remote access was not implemented at this stage.
- Installation required only a concrete pad and was completed within 45 days, minimising civil works and site disruption. The system operates continuously (24/7), with flocculant supplied in 750 kg bags.

(a) (b)

Figure 7 Various views of the unit at site. (a) Outside view; (b) Details of civil foundations

5.1.3 Operational performance and outcomes

After 5 years of operation, overall performance of the system exceeds the original expectations.

- Treatment achieved a minimum of 45% solids in the thickener under challenging conditions, with a maximum of 58% solids observed.
- With utilisation of the PSU 300, polymer dissolution time is consistently maintained at a minimum of 30 min, ensuring optimal flocculant performance. Dissolution of powder is done at a concentration of 0.75% without any 'fisheye' issues, then post diluted after maturation down to 0.15%.
- Manual intervention is limited to 750 kg bag loading, with a forklift, reducing operator workload and exposure.

5.1.4 Lessons learned

Operator feedback highlighted the original complexity of the HMI; this was addressed by introducing user-specific access levels (operator, mechanical, control, SNF), improving usability and reducing errors. These insights informed subsequent installations, leading to continuous improvement in both system design and operational documentation.

5.2 Case study 2: flotation tails thickener (Dominican Republic)

5.2.1 Project context and challenges

A second containerised system was deployed at the same site as Case study 1, this time serving as the flotation tails thickener. This unit treats tailings at an average of 850 t/h, with peaks up to 1,250 t/h. The thickener's performance was constrained by downstream piping, requiring a flexible and reliable flocculant dosing solution capable of adapting to variable process conditions. The decision of going with a containerised unit with PSU, was made based on positive feedback and reliability of the initial unit. Deployment was very fast for the start-up in June 2023.

5.2.2 Solution: enhanced modular system

The system architecture mirrored the POX feed thickener installation (Case study 1), with again a 2 stacked containers configuration (Figure 8).

(a) (b)

Figure 8 Various views of the unit at site. (a) Outside view; (b) Maturation tank

5.2.3 *Operational performance and outcomes*

After more than 2 years of operation, the system has consistently demonstrated high performance levels:

- Enhanced thickener efficiency: solids concentration reached up to 60% in the thickener, compared to the initial operational limit of 40% imposed by piping constraints.
- Optimised polymer preparation: with PSU integration, polymer dissolution time is reliably maintained at a minimum of 30 min, ensuring superior flocculant performance. The powder is dissolved at a concentration of 0.75% without any ‘fisheye’ formation, followed by post-dilution after maturation to 0.15%.
- Streamlined operations: manual intervention is limited to loading 750 kg bags using a forklift, significantly reducing labour requirements and improving workflow efficiency.
- Improved usability and maintenance: feedback from the initial installation was incorporated, resulting in enhanced HMI user experience and more comprehensive maintenance documentation.

5.2.4 *Lessons learned*

The second deployment benefited from lessons learned during the first installation, particularly in terms of assembly procedures and user interface design. The system’s modularity and rapid deployment capability were validated, demonstrating the scalability and adaptability of the containerised approach.

5.3 Case study 3: thermal coal tailings treatment (Alberta, Canada)

5.3.1 *Project context and challenges*

The operation site, located in Alberta, Canada, is a thermal coal mine that faces unique operational and environmental challenges. While not considered remote, the site is subject to harsh northern Canadian winters, with temperatures regularly dropping to −40°C. The mine’s tailings system treats thickener underflow at approximately 680 m^3/h, requiring robust, winterised, and highly adaptable flocculant preparation and dosing solutions. Prior to the deployment of the containerised system, a temporary mobile unit was used, but it lacked the capacity, automation, and reliability needed for full-scale, continuous operations.

5.3.2 *Solution: containerised make-down and application system*

In 2020, a two-container modular system was installed (Figure 9). The first container houses the make-down unit, including a PSU 300, powder hopper and feed system, and compressors. The second container serves as the application unit, featuring a 19 m^3 split tank (9.5 m^3 hydration compartment and 9.5 m^3 application compartment), application pumps, and dilution pumps. The containers were placed on levelled ground using rig mats and timbers for stability, with minimal civil works required – just clearing and compacting the ground with a front-end loader.

Installation was completed in just one week, demonstrating the rapid deployment advantage of modular systems. The system is fully automated, with remote access enabled via TeamViewer, allowing for offsite monitoring and troubleshooting. Flocculant is supplied in 750 kg bags, and the system is designed for minimal manual intervention.

(a) (b)

Figure 9 Various views of the unit at site. (a) Outside view; (b) Maturation tank and metering pump

5.3.3 Operational performance and adaptations

The system delivers excellent water clarity, enabling the plant to reclaim and re-use process water and improving settling and water release in the ponds. Flocculant consumption is approximately 2,500 kg/day, with dosing set at around 750 g/t (based on estimated slurry density). Dissolution of powder is done at a concentration of 1% without any ‘fisheye’ issues, then post diluted after maturation down to 0.5%. The system requires only one operator, who attends the unit as needed for powder refilling and routine checks. The site’s environmental conditions required several technical adaptations:

- Freeze protection: all lines and injection points are heat traced to prevent freezing, and both heaters and AC units are installed in the containers to manage temperature extremes. This is critical, as freezing is a risk for 5–6 months of the year.
- System relocation: as the tailings ponds filled and the discharge point moved, the floc skid had to be relocated to maintain optimal flocculant addition and minimise shear of formed floc. The move, completed in September 2024, involved disconnecting cables, cleaning out the skid, and transporting the containers with cranes and flat decks. The entire process took about 3 days and demonstrated the system’s flexibility and ease of relocation.
- Powder loading: a dense phase transfer pod is used to fill the powder hopper. During some environmental harsh conditions, capacity of air compressor dryers is not sufficient and leads to moisture entering the powder system, that can ultimately cause blockage of the auger. Adding another dryer was studied as a technical solution, but currently, we rely on a standard operating procedure to regularly empty the hopper and remove any potential moist material.

5.3.4 Operational feedback and lessons learned

Operator feedback has been positive regarding the system’s low maintenance requirements and the effectiveness of remote monitoring. The system’s modularity and rapid deployment were validated not only during initial installation but also during subsequent relocations as operational needs evolved. The ability to move the skid with minimal disruption and adapt to changing site conditions has proven invaluable. The experience at site underscores the importance of designing containerised systems for both environmental resilience and operational flexibility.

5.4 Summary of case studies outcomes

The transition to a modular, containerised flocculant system enabled rapid installation with minimal site impact, unlike traditional systems that require extensive civil works, permanent buildings, and longer timelines. With integrated automation and a stacked design, the system ensured reliable flocculant preparation, achieving higher performances in thickeners while reducing manual intervention and operator risk. Its modularity allowed for easy expansion, quick implementation of improvements (such as enhanced HMI usability and simplified maintenance), and fast adaptation to process changes – capabilities that would be complex and costly with fixed systems. At Case study 3, the system's mobility enabled multiple relocations in just 3 days, with full winterisation for −40 °C conditions and remote monitoring, delivering flexibility and resilience that traditional installations cannot match. Overall, the containerised solution provided significant operational, economic, and safety advantages, whereas a conventional system would have been slower, less flexible, and more expensive to modify.

6 Conclusion

Containerised modular flocculant systems represent a transformative advancement in tailings treatment, offering a compelling combination of technical, economic, and sustainability benefits. Their enhanced dissolution efficiency and automation improve treatment consistency while reducing operator error, and their compact footprint makes them ideal for space-constrained sites. Economically, these systems deliver significant value, with capex reductions of 30–50% compared to conventional plants and lower operational costs through efficient mixing and minimised downtime. They also help avoid stranded assets in mine closure scenarios, supporting long-term financial resilience.

From an ESG perspective, containerised systems align with industry sustainability goals. They promote water management through higher recycling rates, reduce embodied carbon via minimised construction, enhance worker safety through enclosed handling, and support governance through standardised, auditable reagent management. Future research should explore life cycle carbon footprint comparisons with conventional plants, integration with renewable energy and hybrid microgrids, and real-time linkage between reagent systems and tailings rheology monitoring. As mining continues its transition toward resilient and flexible infrastructure, containerised flocculant systems are poised to become a new standard in tailings management.

Acknowledgement

The authors would like to thank SNF for permission to publish this paper. We also thank our colleagues for their feedback and information on cases studies from operating sites.

Use of artificial intelligence disclosure statement

In the preparation of this work, the authors used Copilot (GPT-5) to refine certain sentences for improved fluency in English. The authors have reviewed the content and edited it where required and take full responsibility for said content.

References

Bonnier, J, Gathier, F, Matinin, A & Geneyton, A 2025, 'Ensuring efficient tailings treatment: the importance of optimal flocculant dissolution', in AB Fourie, A Copeland, V Daigle & C MacRobert (eds), *Paste 2025: Proceedings of the 27th International Conference on Paste, Thickened and Filtered Tailings*, Australian Centre for Geomechanics, Perth, pp. 89–104, https://doi.org/10.36487/ACG_repo/2555_05

Brown, DW 1987, 'The effect of make-up procedure on the efficiency of flocculant solutions', *International Journal of Coal Preparation and Utilization*, vol. 4, no. 1–2, pp. 51–78.

Fester, V & Werner, R 2022, 'Optimization of polymer dosing for improved belt press performance in wastewater treatment plants', in T.F Jones (ed.), *Advances in slurry technology*, IntechOpen, London, pp. 131–147.

James, R, Mancini, S, Holmes, A, Goldemund, H, Dufresne, K & Cox, E 2021, 'Passive treatment of mine influenced water', *Proceedings of the Tailings and Mine Waste Conference 2021*, University of Alberta, Edmonton.

Koenig, J, Dowd, A, Ballantyne, J & Schroeter, R 2023, 'Evaluation of automatic polymer dosing control to optimise the performance of belt presses', in GW Wilson, NA Beier, DC Sego, AB Fourie & D Reid (eds), *Paste 2023: Proceedings of the 25th International Conference on Paste, Thickened and Filtered Tailings*, Australian Centre for Geomechanics, Perth, pp. 308–315, https://doi.org/10.36487/ACG_repo/2355_23

Moore, K 2018, 'IMPaCT, Integrated modular plant and containerised tools for selective, low-impact mining of small high-grade deposits, Horizon 2020', *Impact*, vol. 2018, no. 8, pp. 27–29.

Rivas, C & Bonnier, J 2021, *Device for Dispersing Water-Soluble Polymers*, *Patent EP4186585A1,* SNF Group, Andrézieux-Bouthéon.

Rivas, C & Chalieux, N 2022, *Installation for the storage and use of water-soluble polymers, Patent US11933151*, SNF Group, Andrézieux-Bouthéon.

Sidorenko, O, Sairinen, R & Moore, K 2020, 'Rethinking the concept of small-scale mining for technologically advanced raw materials production', *Resources Policy*, vol. 68.

Stimpson, E, Moolman, J, Van Sliedregt, J & Anderson, C 2025, 'Modular integration of Jameson concentrator technology for enhanced base metal recovery from various feed sources', *Ni-Co 2025, 6th International Symposium on Nickel and Cobalt Proceedings of the Extraction 2025 Meeting & Exhibition*, Springer, Cham.

Wait, S & Cooper, L 2025, 'Enabling dry stack tailings disposal through enhanced vacuum belt filtration', in AB Fourie, A Copeland, V Daigle & C MacRobert (eds), *Paste 2025: Proceedings of the 27th International Conference on Paste, Thickened and Filtered Tailings*, Australian Centre for Geomechanics, Perth, pp. 627–640, https://doi.org/10.36487/ACG_repo/2555_45