Choosing the right tailings management strategy requires balancing a complex matrix of technical, operational, business, and environmental considerations. Treatment solutions need to deliver key performance attributes, including operational simplicity, high reliability, minimal containment cost and footprint, effective fines management, sustained water recovery, and the capability to achieve regulatory compliance.

Benefits of Particlear™

- Improved consolidation and shorter time to closure
- High water recovery rates and storage efficiency
- Protected drainage and improved permeability
- High reliability achieved through a low-cost simplified process
- Wide operating window for a range of fluid tailings
- Flexible treatment options for direct in-pit or ex-pit disposal
- Simplified capping with a flowable tailings cover material
- Release water suitable for mine processing
- Improved environmental sustainability

What Is Particlear™?

DuPont has been a leader in silica chemistry for over 70 years, encompassing a wide range of applications: from semi-conductor wafer polishing to industrial process water treatment. Unlike a flocculant, Particlear™ is a novel silica-based, in-line solution for treatment of mine tailings that generates a synthetic soil-like structural network within the water phase of the tailings, providing immediate strength and allowing for sustained consolidation and dewatering.

Particlear™ is a dynamic chemistry. When used alone, it can act as an effective dispersant for clay particles, but upon addition of an activator, Particlear™ quickly imparts very different material properties, through a polymerization reaction, resulting in the formation of the structural network as seen in Figure 1.

Applications

Particlear™ treated fluid fine tailings (FFT) possess properties desirable for a range of fluid tailings for thick or thin lift direct disposal in-pit or ex-pit. The rheological and strength properties of the treated FFT are aligned for capping of soft deposits and support both subaerial and subaqueous placement. The ability to control strength also offers the flexibility to manage build-slopes and flow distance.

Simple Process

A basic in-line injection of Particlear™ plus an activator (Figure 2) is all that is required to initiate the Particlear™ effect. Particlear™ technology can be used as a stand-alone alternative to flocculation or mechanical separation, or it can be an addition to improve the performance of existing upstream dewatering processes. Particlear™ chemistry is supplied ready-to-use and does not require a separate make-down process or added water. It can also be generated on site when particularly large volumes are required.

Equipment

The Particlear™ implementation can be adapted to an existing facility with minimal impact to the current infrastructure and with minimal capital expenditure. Discharge is typically at the end-of-pipe distribution. Injection skid designs with capacities to treat from 50 to 1,000 t/hr are available to support both pilot and commercial operations. Skids are engineered to meet site specifications and cover a wide operating window.

Figure 1: Silica Network in a Tailings Stream

Figure 2: Particlear™ Treatment Process
Pipe train injection locations are flexible, with options to locate the injection near the source or the tailings discharge. Our engineers can provide the knowledge, direction, and specifications required for Particlear™ treated tailings to implement into your existing facility or future design.

**Placement**
A key difference from other processes is that there is no dependency on large initial water release to achieve faster overall consolidation. In fact, the retained water aids tremendously in placement options and control. Flow into the deposit is typically unassisted by channel/sheet flow, with distances of hundreds of meters achievable. Build slopes can be controlled with dose and reaction timing to achieve long shallow slopes or short steep slopes, allowing for a range of options.

**Reliability**
The benefits and reliability are seen at several points in the overall disposal process, from injection, transport, and placement through to robustness of the deposited material.

Particlear™ is relatively insensitive to feed variability because it works within the water phase of the tailings stream. This decouples the solution from the mineralogy and solids variability effects that are a challenge for traditional flocculation methods. In addition, the central component of Particlear™ is silica, an inherently robust and predictable material.

One of the interesting and unique properties of Particlear™ treated tailings is its response to shear. Within a transport pipe, the viscosity and yield strength of the tailings can be markedly reduced. This has the potential to reduce pumping energy and eliminate the need for positive displacement pumps for high solids streams. The shear response can also improve placement flowability, which can allow for long flow distance mentioned above. Once shearing ceases, the tailings quickly acquire strength—usually within just a few hours.

FFT deposits treated with Particlear™ typically possess much higher peak and remolded strengths and lower sensitivity versus other methods at similar void ratios. Even if re-sheared after placement, the silica network is capable of repairing itself in place without any intervention—recovering considerable pre-event strength. Tests also indicate that such an event would not impact the final strength of a consolidated material.

**Geotechnical**
Particlear™ treated slurries tend to act like soil, at void ratios far above the levels of conventional soil theory. How can this be? As mentioned earlier, Particlear™ creates a silica network within the water phase of the tailings slurry. The network can be envisioned as a netting, providing structure while trapping the fines in place. Because the structure is an open, three-dimensional network, free water is able to drain easily—leaving the fines behind.

The strength of the treated FFT slurry is proportional to the dose, as seen in Figure 3. Unlike a flocculant, the strength can be tailored with a simple dose adjustment to meet a range of needs. This improved strength (stiffness) causes the FFT to possess predictable soil-like consolidation characteristics at much higher void ratios than is typical for clays. This improvement in stiffness aligns well to applications requiring thick lift stacking, surcharge loading, or higher erosion resistance. It would also improve access to the surface of a deposit, reducing operational risk and offering simpler, lower cost cover options.

**Controlling Fines Mobility**
While the strength capabilities attributed to the Particlear™ silica network are impressive, the permeability benefits that it provides to fines-dominated streams may be more impactful. Figure 4 is a pictorial illustration of one of the fundamental differences between flocculated tailings (left) and Particlear™ treated tailings (right). Several methods have been developed to accelerate the dewatering of tailings prior to final placement, but they fail to address the issue of fines migration within the deposit: fines tend to follow water and accumulate at drainage interfaces, resulting in the effective plugging and shutdown of these critical pathways. Even deposits that dewater well initially can soon slow dramatically due to this effect. The accumulation of fines at drainage boundaries is evidenced by low permeable filter cakes that blind the dewatering pathways. As a consequence, large amounts of water remain trapped within the deposit. This can impact process water availability for mine processing and delay reclamation activities for many years. It also adds complexity and cost to surface stabilization, ties up valuable mine space, and increases liability associated with storage of large volumes of unstable tailings materials.

The Particlear™ silica network maintains more uniform permeability, helping to prevent the fines buildup discussed above. The result is easier movement of water through the drainage boundary regions, resulting in faster dewatering and consolidation. As the water is removed, the silica network slowly collapses until strength is dominated by particle-to-particle contact.
**Drains**

The ability to restrict fines mobility also leads to additional drainage options. Tests indicate that when Particlear™ is used in conjunction with conventional sand or geotextile drains, sustained drainage is achieved—due to the immobilization of the fines discussed previously. This infers that both vertical wick drains and low-cost lateral strip drains would be very effective when used in combination with Particlear™ and offer a step change in consolidation performance. Numerical predictions based upon large strain consolidation testing indicate that thick deposits could achieve settlement 10x faster with the addition of sustainable intermediate drainage, Figure 5. The operational, cost, and risk mitigation benefits of such an improvement could be significant.

**Stiffness**

The early strength and reduced compressibility also distinguish Particlear™ treated FFT from other treated or untreated tailings. The ability of Particlear™ to output hundreds of pascals yield strength within hours means that treated tailings can be placed in thicker lifts with earlier access to the surface and can carry higher surcharge loads. These all contribute to higher driving forces to positively affect consolidation and dewatering.

Understanding the relationship between compressibility (stiffness) and hydraulic conductivity (Figure 6) is fundamental to appreciating the consequential benefit to hydraulic conductivity. The strength improvement provided by the silica network provides the opportunity to design for higher effective stress to help drive faster dewatering. As seen in the compressibility chart (Figure 6), for a given stress, the void ratio of Particlear™ treated tailings is higher. It is apparent that this results in a measurable improvement in corresponding hydraulic conductivity, based on the supporting evidence in this chart. This phenomenon explains the demonstrated consolidation improvements in both self-weight and surcharge loading applications. This stiffness benefit is maintained throughout consolidation until particle-to-particle effects dominate soil behavior.

**Water Recovery**

With an understanding of the attributes of the silica network discussed previously, one can begin to appreciate that water recovery benefits are due to a number of contributing factors:
- An open, free-draining structure
- Improved permeability and drainage by trapping fines in place
- Higher effective hydraulic conductivity through improved stiffness
- Earlier and higher surcharge load capability

Modeling of head-to-head large strain consolidation test results (Figure 7) indicates that the improved consolidation performance gained from Particlear™ could also provide more recovered water than a successfully flocculated tailings stream. This would translate to more water available for plant processing, reduced volumes of stored fluid tailings, and lower overall cost and liability.

**Water Quality**

Because Particlear™ comprises chains of silicon dioxide particle beads (illustrated in Figure 1), the network is easily able to generate structure within the fines—capturing even the smallest particles. Not surprisingly, the turbidity of the release water is very low, as easily seen by clarity of the unfiltered release water in Figure 8. This is typical for laboratory and field operations and achievable at quite low doses. This may have the potential to eliminate or reduce the need for added water treatment, both for mine processing and release back to the environment.

In limited batch extraction unit (BEU) testing, no adverse effect on recovery was observed using 100% Particlear™ treated tailings recovery water.
Liability
Events in recent years have elevated concerns over the storage of mine tailings, placing increased demands on mine operators to reduce tailings storage volumes and associated risks to the ecology, environment, and human health. Particlear™ may have a role to play as one part of a larger risk mitigation strategy, by helping to reduce the long-term liabilities through faster stabilization and earlier closure and reclamation.

Safety and Environment
The use of Particlear™, a liquid silicate, has a long, well understood commercial track record. Particlear™ is a non-regulated product, supplied as a liquid, and a low risk material to handle using standard, well established practices. Particlear™ contains no heavy metals and does not decompose in the environment. Additionally, when chlorine dioxide is used as an activator, it can provide an opportunity to consume an available waste stream, reducing the environmental footprint, and contribute to enhanced sustainability.

Cost
The minimal capital equipment required to implement Particlear™ technology could translate to an immediate benefit in direct equipment and infrastructure cost, as well as the time savings to put a simplified treatment solution in place.

The elimination of several handling, processing, and re-work steps associated with many traditional treatment methods could potentially provide direct operational cost savings. In addition, secondary cost savings associated with reduced management of tailings storage containment and increased flexibility to mine operations could deliver added benefits and value.

Tailored Solution
The ability to tailor Particlear™ to enable cost effective, reliable disposal of a range of tailings materials makes it an attractive technology to evaluate as part of a tailings management strategy.

Published Papers
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