HIGH-PRESSURE SLURRY ABLATION (HPSA) – AN INNOVATIVE LIBERATION TECHNOLOGY FOR IMPROVEMENT OF GRADE AND RECOVERY IN MINERAL PROCESSING

High-Pressure Slurry Ablation (HPSA) is Disa's patented process for liberation of valuable minerals from gangue and other impurities. Originally developed for treating low-grade uranium waste rock, HPSA has also demonstrated promising ability to improve grades and recoveries while reducing grinding and downstream operation costs. HPSA processing is an autogenous grinding process using particle-on-particle collisions, selectively liberating target minerals without overgrinding, to improve efficiencies of flotation and size classification processes. System development continues, in parallel with commercial applications and production scaling, priming HPSA to revolutionize the mineral processing industry and significantly reduce costs associated with mineral liberation processes.

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INTRODUCTION AND BACKGROUND

High-Pressure Slurry Ablation (HPSA) technology is a patented process owned *by Disa Technologies Inc.* that has been shown to offer sustainable solutions for the mineral processing and remediation industries (Coates & Lee 2022, Coates 2022, 2018, 2014). The process consists of a liquid processing circuit with several collision chambers where two opposing slurry jets cause particle-particle interactions that fracture and selectively liberate feed material. Autogenous processes, like HPSA, utilize feedstock materials to act as mineral grinding/liberation media, HPSA specifically results in selective liberation rather than the random comminution performed by traditional ball/rod mills. The process can be inserted into traditional grinding circuits and inherently does not require grinding media (or associated costs) or chemicals. A typical HPSA system consists of:

- Power, Controls and Safety Systems integrated into the HPSA Circuit;
- a HPSA Circuit Slurry Feed Supply & Discharge System to homogenize, suspend, and discharge minerals; and
- a HPSA Circuit System to impart consisting of pumps to impart kinetic energy to the particles and collision chamber circuits where particle-to-particle collisions occur.

The liberation efficacy of HPSA processing is significantly influenced by the mineralogy of the feedstock, particularly favoring materials with multi-modal hardness and surface-exposed minerals over those with locked mineral. Desired size reduction and mineral liberation can be further achieved through process variable controls. These variables include nozzle exit stream velocity, circuit residence time, particle size distribution, slurry solids mass fraction, and other factors that can affect either the collision probability or fracture probability. The process enables more efficient liberation at coarser particle sizes than traditional mills. Studies from *Disa Technologies Inc*. (Disa) have shown further advantages of HPSA including: (1) efficient concentration of target minerals earlier in the processing sequence, (2) improved grade and/or recovery, and (3) reduced material requiring downstream processing.

On-site and field applications are discussed in this paper; however, there have been lab studies including chalcopyrite and molybdenite in Cu-Mo bulk sulfide concentrates (Harvey, 2023) and gold-bearing pyrite in cyanide-leach tailings (Antoniak, 2020). Results for Cu-Mo suggested that product grades could be obtained with HPSA and effectively eliminate some, if not all, of the regrinding circuits. Likewise, for pyrite studies, results removed oxidation products from the pyrite surface which better enabled pyrite flotation thereby reducing reagent schedule (Harvey, 2023). Furthermore, simulation and model verification studies have been developed by Weaver et al. (2024) directly related to future development and selective liberation mechanisms of HPSA systems (Weaver, 2024).

High-Pressure Slurry Ablation Background

HPSA processing found its first application in the remediation of abandoned uranium mining waste. Initial studies led to HPSA currently being the only technology validated by the United States Environmental Protection Agency (US EPA) as a viable solution for treatment of abandoned uranium mines (Tetra Tech & Disa Technologies, 2023). This processing was done on site with batch units at abandoned uranium mine sites. The next steps for HPSA system development were for continuous unit development and improved performance and functionality of the systems. Next generation designs have been developed to ensure modularity of HPSA units, such that they can be used as stand-alone system or as a “plug and play” units in the grinding/regrind stage of any processing circuit. HPSA technology has the potential to replace some, or all the grinding achieved by ball mills, rod mills, and attrition scrubbers. Depending on processing requirements, HPSA systems can compete with or outperform existing energy intensive mills to reduce CAPEX, OPEX, and overall emissions in processing circuits.

Both single jet, three phase flow (Weaver et al., 2024) and opposed jet simulations with three phase flow (Weaver, 2024) using Computational Fluid Dynamic-Volume of Fluid-Discrete Element Method (CFD-VOF-DEM) simulations were investigated at the University of British Columbia. In these studies, various design parameters for converging nozzle designs were considered and verified with particle tracking software. These trade studies were conducted to develop relationships between design parameters and performance metrics like collision frequency or particle-particle collision energies. In the cases tested, it was found that increasing the nozzle-to-nozzle distance increases the probability of collision due to spreading of the jets in the collision region; however, the impact energy decreases as the spreading of the jet occurs reducing the probability of fracture. Weaver specifically noted “the main benefit of this machine is that it selectively breaks particles of different sizes depending on the changes in operating parameters" (Weaver 2024). Additionally, Weaver (2024) determined effects that changing the nozzle angle of inclination had on particle size and material properties as well as subsequent impact on fluid flow, particle flow, and collision behavior. In particular, Weaver (2024) used particle tracing methodologies to monitor particles in the colliding jets and was able to discern that particles of different size classes behave differently in the collision region depending on their Stokes number. Smaller particles in the jet have low enough inertia that fluid flow in the jet collision area can change their trajectories while larger particles decelerate at a reduced rate, allowing for the particles to traverse the collision boundary between the jets. The difference in deceleration rates of the particles, creates lower velocities for smaller particles, and thus lower collision energy for fracture—demonstrating the mechanism for how the technology inherently prevents overgrinding of small particles.

In mineral processing, comminution is the reduction of ore particle size for liberation of minerals, in preparation for separation and extraction in downstream processes. Grinding is the most energy intensive step in most circuits (Valery, 2016). Traditional comminution techniques such as SAG mills, ball mills, and rod mills fracture the ore by applying impact, compressive, and shear forces using steel balls, rods, or other grinding media. Furthermore, traditional grinding processes use randomness of impact to accomplish fracture which inherently wastes potential energy that could be used in fracture. Figure 1 illustrates comminution fracture categorization detailed in Parapari et. al. (2016) to better focus future particle fracture studies. The Figure categorizes various loading conditions, loading rates, breakage and fracture methods required for intergranular and selective breakage results found in HPSA processing, compared to random fracture in ball milling and attrition and chipping that occurs with scrubbers. Traditional millimeter scale comminution processes have very high energy consumption with very low efficiency. A 2021 study calculated that the entire mining industry consumes 3.5% of total energy consumption globally, with comminution being the largest single consumer of final energy in mining (Allen, 2021).

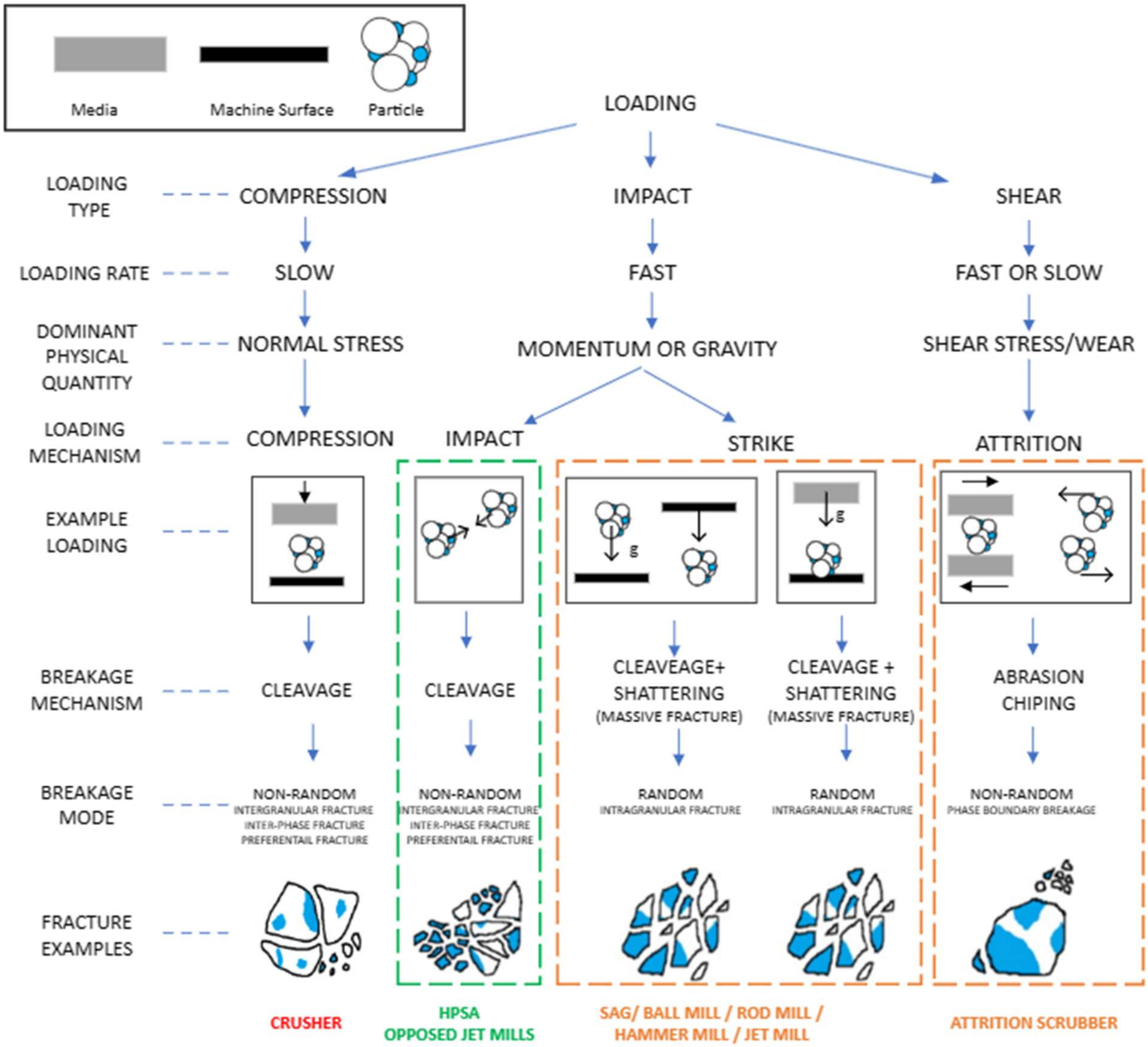

Figure 1: Particle loading, loading rates, breakage mechanisms, and fracture/liberation examples where blue represents targeted minerals (adapted from Parapari et. al, 2016).

HPSA technology aims to replace traditional millimeter-to-micron scale mineral processing and grinding equipment like ball, rod, impact, hammer mills and attrition scrubbers. Opposed jet steam assisted jet mills create similar particle-particle collisions albeit the water medium used in HPSA for particle entrainment and acceleration allows for the increased input particle sizes listed in Table 1 compared to the 800-1200-micron input particle size limit for fluidized jet mills (Krzywanski, 2020). During impact, the particles collide, distort, deform, and either rebound or fracture. During the distortion and rebound, grains of the processed particles with contrasting mineral properties can distort and fracture disproportionately, resulting in more selective liberation of processed materials, making HPSA technology distinct from other millimeter scale mineral processing technologies. HPSA's selective mineral liberation can potentially reduce downstream processing costs by selectively liberating desirable minerals and separating them from downstream minerals that have high processing/removal costs.

Mineral Processing Requirements

The current target particle size range for HPSA technology is a feed 100% passing (F100) of 6.35 millimeters to 100 microns. However, future units may have the capacity to process top sizes of 25 millimeters and larger. The relationship of comminution energy vs particle size is well known where energy input significantly increases as particle size decreases (Valery, 2016). In traditional grinding and HPSA liberation, larger particles create more breakage events due to more energy transferred during collisions. Furthermore, HPSA technology can be applied to any circuit with minerals exhibiting bi-modal hardness. Simple Mohs Hardness comparison analysis of minerals can be used to evaluate the likelihood of fracture. Minerals with larger differences in hardness will facilitate intergranular fracture and detachment during the particle-particle interactions. However, HPSA does not work well if the target mineral is a soft ore inclusion inside of a hard host material as illustrated in Figure 2. Testing on high inclusion material feedstock has shown conventional milling is generally more efficient than the HPSA process. Successful applications currently include but are not limited to uranium, vanadium, phosphate, potash, graphite, copper, molybdenum, gold, rare earth elements, and filter sand. Furthermore, studies have been conducted at Montana Technological University (Harvey, 2023). HPSA testing at Disa has focused process development for feedstocks with diameters 6.35 mm and below; however, HPSA has been tested with up to 9 mm particles, see Table 1.

Table 1: Mineral Feedstock Targets

	Units	Low	Target	High
Input Feed Particle Size (F100)	mm (in)	-	6.35 (0.25)	9 (0.35")
Difference in Moh's Hardness	-	1<	-	-
Material Feedstocks tested:	uranium, vanadium, phosphate, potash, graphite, copper, molybdenum, gold, rare earth elements, and filtration filter sand,			

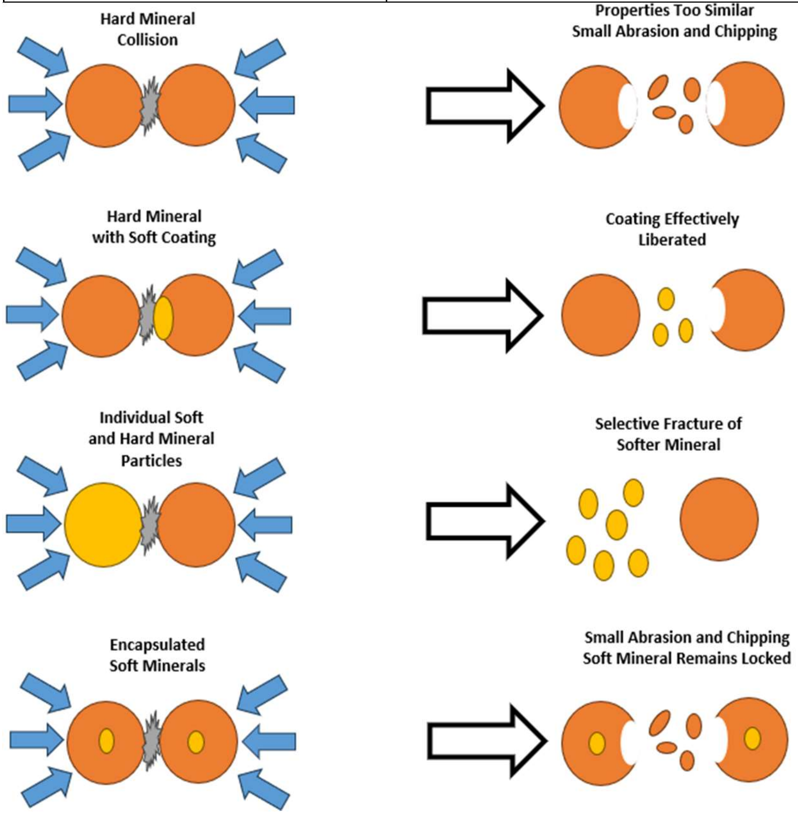

Figure 2 Mineral collision principles.

HPSA System Development

Industrial and government collaborations with Disa have fueled the continuous improvement design process for HPSA prototype units for batch units for lab studies and industrial scale units for operation. Table 2 lists details about the current batch and industrial units used for the remedial and mineral processing applications detailed in this paper.

The technology has grown from batch units for lab testing, to continuous prototypes to validate future large-scale systems.

Table 2: HPSA Unit Design Metrics

Design Parameter	Unit	DISA HPSA Batch Units	Disa HPSA Gen A	Disa Gen B	Prototype Header Unit	Disa Gen C 10t*
Material Input/Load	kg (lbs)	91 (200)	continuous	continuous	continuous	continuous
# pumps	-	1-2	1-2	4+	1	4+
# collision tanks	-	1	1	4+	4	4+
Dimensions (L W H)	m (in)	2.4 (96) 1.2 (48) 2.1 (84)	1.9 (76) 1.5 (60) 4.6 (180)	6.7 (264) 2.8 (112) 3.1 (125)	3.3 (131.5) 1.4 (55) 2.5 (98.5)	8.5 (216) 7.8 (198) 5.2 (132)
Est. Production Capacity*	Mg/hr	1.5-2.0	5.0	7.5	1.0-3.7	10.0

* A 10 t/hr Gen C is under development as of January 2024 and is expected to be in operation by Q2 of 2024, while

**A 50 t/hr Gen C is also under development and is expected to be in operation by Q3 of 2024.

Batch Test Unit Evolution— Disa currently uses HPSA laboratory batch units for material amenability testing and process optimization. The batch units are used in a controlled testing environment to quantify HPSA's mineral liberation, grade, recovery, and specific energy potential to benchmark against current milling/processing operations. Test systems have various sample ports, sensors, and configurations used to assess process and design performance throughout testing. The batch unit design has undergone multiple improvements to become more modular and adaptable for testing campaigns. Improvements have included nozzle optimization (velocity, angle, and distance), collision chamber design, and slurry fluid flow design. Additional modifications led to the design of a next generation prototype and a bench scale unit to facilitate a smaller unit footprint and smaller sample volumes required for testing. Figure 3 displays the evolution of the HPSA batch unit design, from the original patent to the current units.

Figure 3: Evolution of the HPSA batch unit from the original patent to first prototype, to Lab and Lab Bench Scale units.

Continuous Unit Evolution— The first continuous HPSA unit, Generation Alpha (Gen A), was piloted in 2018 at an iron mine, displayed in Figure 4. The lessons learned from Gen A were used to design Generation Bravo (Gen B) in 2022 and deploy it in the field in 2023, Figure 5. Process design improvements included the addition of agitation, increased unit throughput, the design of an easily transportable HPSA skid, mitigation of equipment wear, and the addition of process monitoring and controls.

Gen B was initially designed to process Abandoned Uranium Mines (AUMs) waste piles; however, the unit has now been applied to multiple additional mineral processing and remediation applications. Currently Gen B is capable of processing approximately five metric tonnes of material per hour (tph). The circuit includes all equipment necessary to process material on site and is mounted on skid frames that can be easily hauled on a flatbed trailer. The HPSA skid in Gen B features three agitated HPSA tanks with dedicated pumps that push material through collision chambers and deliver material into the next tank. This allows the material to circulate through the system in a "round robin" style. With this system, the operating parameters of residence time and nozzle velocity can be fine-tuned, allowing the unit to be used in many different applications and tailored to sites with distinctive mineralogy.

Disa’s Gen Charlie (Gen C) design consists of three tanks in parallel with two pumps on each tank: one transfer pump and one recirculation pump. The transfer pumps feed a set of collision chambers between tanks this guarantees a minimum of 3 circuits through collision chambers for every particle, preventing material from short circuiting through the unit. Furthermore, with transfer pumps, Gen C also has incorporated collision chambers into recirculation circuits to reduce settling and increase the probability of particle-particle collision events, thus increasing liberation probability for minerals from their host rock. The collision recirculation pumps allow Gen C to fine tune the extent of material processing and dispersion based on each site’s specific mineral requirements. Furthermore, to allow for higher throughputs and lower energy requirements Gen C units utilizes a N:1 parallel chamber to pump configuration for each HPSA circuit to utilize higher efficiency, higher throughput pumps. The parallel chamber design also provides the option to bypass individual chambers for maintenance, as opposed to powering down the entire process. Through pilot validation testing, Disa will continue to scale and improve continuous unit designs.

Figure 4: Gen A HPSA system at an iron tailings site.

Figure 5: Gen B continuous on-site remediation HPSA system.

Prototype Header Units—Various configurations of header units, composed of collision chambers and the systems that feed the chambers, are being designed and tested as HPSA systems scale. Specific modifications are being done to improve the performance of the systems; the designs are focused to increase collision frequencies, reduce operational costs, and increase operational availability of the systems. For example, increasing the number of active nozzle pairs in a unit directly increase the collision frequency in the system. The developed configurations adapt the number and orientation of the jets, manifold types and geometries, and chamber inter-nozzle distances—all which have been found to affect the performance of the chambers (Weaver, 2024). A prototype test unit is shown in Figure 6, the unit features four collision chambers that operate from one pump. Header Units are also being designed to increase operational availability by developing integrated bypass systems, that also allow for in-operation repairs or maintenance to occur. These prototype header units are designed with the functionality to operate on continuous units, on batch units, or in the shown case, on a hybrid batch unit at 2-3 metric tons per hour in continuous operation.

Figure 6: Prototype header unit HPSA system.

REMEDIATION APPLICATIONS

Overview

A significant application for the technology is for environmental remediation, especially in remote, disadvantaged communities. Currently, the only commercially available option to remediate contaminated soil is to haul all the material offsite or to cap all the material onsite. The modular, scalable, and transportable nature of the HPSA process offers an effective and economically viable solution to remediate legacy mine sites, addressing the prohibitive costs typically associated with remote location remediation.

Currently, 85% of homes on the Navajo Nation are contaminated with uranium, causing significantly higher rates of cancer and kidney failure (Calvert, 2021). The only commercially available solution to reduce the radiation levels is to haul all material from the contaminated sites to a disposal facility or bury and place a cap on all the material on-site. However, HPSA has shown great potential in remediation for AUMs, allowing for on-site decontamination of soils and waste piles. In 2022, the U.S. Environmental Protection Agency (EPA), in coordination with the Navajo Nation and Tetra Tech, funded a HPSA uranium treatability study for three different remediation sites. The results of the study validated HPSA as a viable option to treat AUMs (Tetra Tech, Disa Technologies, 2023). Furthermore, HPSA was further validated for uranium and vanadium processing by Idaho National Laboratory in a study treating uranium waste rock (Williams, 2022).

Uranium Remediation – Case 1

In a 2022 study, a HPSA Batch Unit was used to process mixtures of waste mixed in (1) ore, (2) coarse to fine grain sand, and (3) sandy clay soil. Samples were taken from three different sites with varying concentrations of contamination deemed high, medium, and low and cleaned with a HPSA system. For each case, the host mineral quartz (Mohs hardness of 7) was used to liberate natural uranium-bearing minerals, such as carnotite (Mohs hardness of 2). The objective of HPSA processing was to separate the radionuclides and metals into a small volume of the fine size fractions 53 µm (-270 US mesh), so the bulk volume of material remaining in the coarse particle size fractions were “clean enough” to remain onsite. Characterization of the minerals pre and post HPSA for one of the feedstocks are shown in Figure 7. The automated scanning electron microscope mineral and chemical identification technique used for Mineral Liberation Analysis (MLA) indicated fracturing detachment of carnotite from +149 µm (+100 US mesh) quartz particles during HPSA, which were captured in the -53 µm (-270 US mesh) samples. The effect of HPSA processing is clearly shown in Figure 8 where 93% of the total uranium concentrated into 15% of the total mass, specifically in the -53 µm (-270 US mesh) size fraction. The remaining 85% of the mass had low enough uranium levels to remain safely onsite. Furthermore, HPSA processing reduced leachable metals and radionuclides in the treated coarse fraction +53 µm (+270 US mesh) by approximately 96%, negating the need for a soil cover to protect surface water and groundwater (Tetra Tech, Disa Technologies, 2023) (United States Environmental Protection Agency, 2023). The studies show the promise in HPSA as a methodology to prevent harm to indigenous communities while providing a 50 - 80% more economical disposal solution.

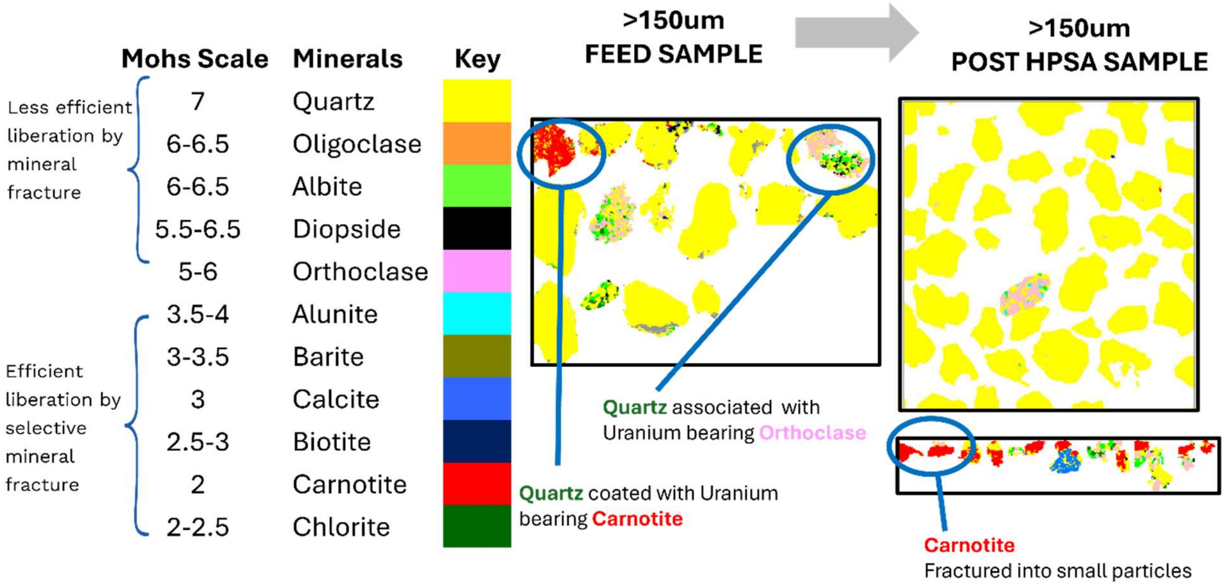

Figure 7: Automated Mineralogy particle maps for pre and feed and post HPSA samples for uranium remediation study.

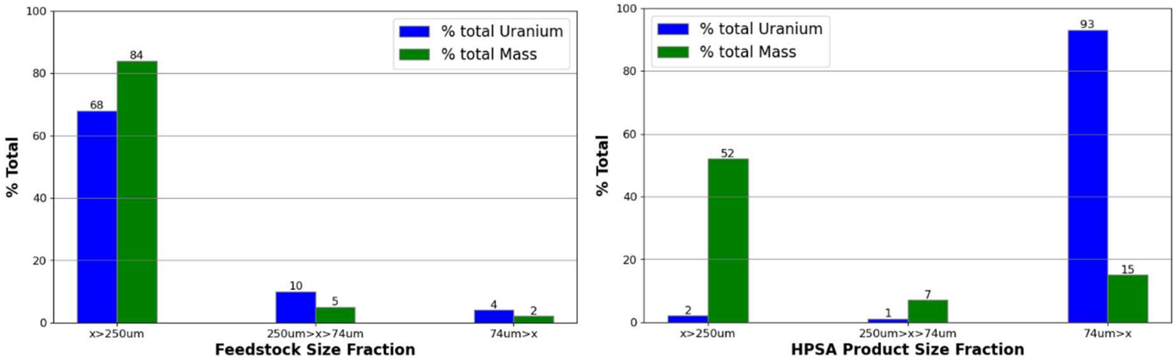

Figure 8: HPSA processing for AUMs.

Uranium Remediation – Case 2

Similar concentration of uranium and vanadium in the fine fractions were found to occur during HPSA Processing in another abandoned uranium mine waste test case. The resulting compositions of three different size fractions measured via ICP-MS and the associated mass fractions from dry screening before and after HPSA processing are displayed in Figure 9. HPSA processing was found to increase the -53 µm (-270 US Mesh) size fraction concentration of uranium by 30% and vanadium by 40%. This second case provides another example of HPSA concentrating uranium and vanadium in the fines because of the softer carnotite fracturing from the harder, larger quartz particles during processing. Concentrating materials to the fines allows for on-site separation of radionuclides which reduces the amount of material that must be transported offsite, while leaving an inert material for reuse onsite. Furthermore, because source material is retained in the isolated mineral fraction, post-processing of this material will be more efficient and produce significantly less waste (Disa Technologies, Environmental Restoration Group, 2022).

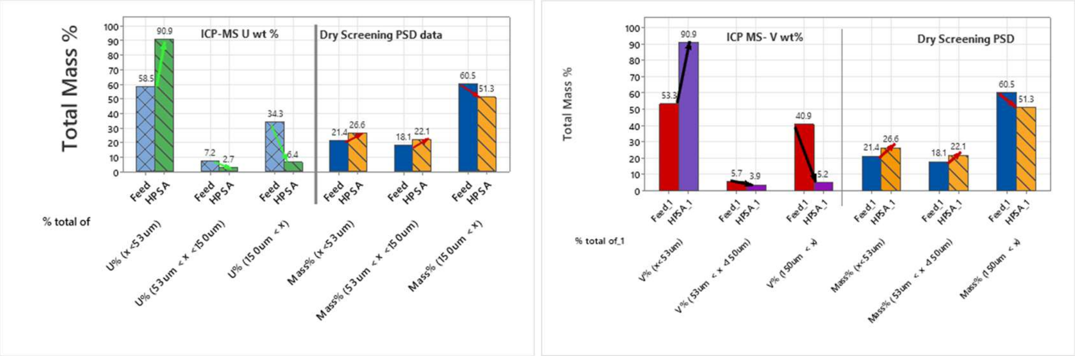

Figure 9: Uranium and vanadium HPSA processing.

MINERAL PROCESSING APPLICATIONS

Batch Testing Case: Graphite

HPSA optimization tests demonstrated a significant opportunity for economic improvements when graphite material was processed in a HPSA batch unit and benchmarked against the given ball mill process parameters. The same flotation procedure was used to calculate grade and recovery for the ball mill and HPSA. Figure 10 displays the HPSA process increased graphite flotation concentrate grade by approximately 25% at a larger P80, while maintaining similar recoveries. HPSA has the potential to replace the current ball mill, multiple downstream regrind mills, by achieving higher grades further upstream in the circuit, lowering their utilization to achieve the same final concentrate grade of 95%. Furthermore, HPSA can selectively liberate graphite at a larger flake size unlike the indiscriminate grinding of a traditional ball mill. These larger flakes hold a higher value in niche markets, which can increase the total value per ton of the final product. Figure 10 shows Backscatter Electron Images of graphite flakes resulting from the two processes to illustrate the improved size retention resulting from HPSA. For the customer, switching to HPSA would create an estimated annual OPEX and total CAPEX savings equal to $13M and $15M, respectively.

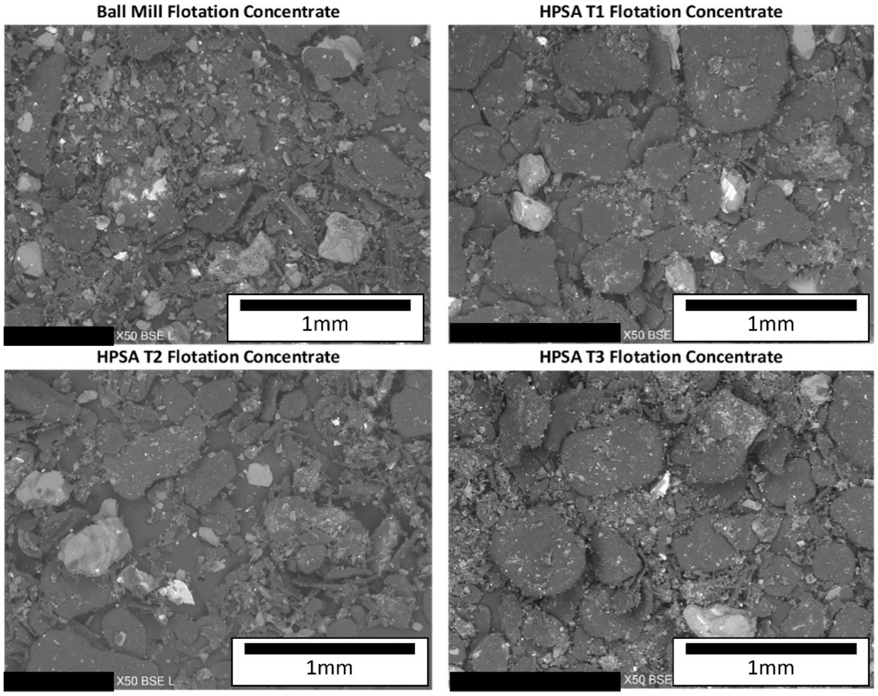

Figure 10: (top right) Graphite Flake Product from ball mill processing, (others) Graphite flakes produced via HPSA processing indicating graphite flake size retention with HPSA Processing.

Test results indicate that HPSA can more effectively liberate graphite from the gangue materials while preserving flake size, as opposed to traditional grinding methods.

Batch Testing Case: Rare Earths

In a Rare Earth Element (REE) application, HPSA demonstrated a more efficient size separation using the base mineral orthoclase to liberate the target minerals: monazite, cerite, bastnasite, and rhodochrosite. It is noted that two target minerals (bastnasite and monazite) have a Mohs hardness of 4.5 and 5, respectively; whereas, the base mineral (orthoclase) has a Mohs hardness of 6. Figure 12 shows that HPSA processing improved concentration of the Total Rare Earth Elements (TREEs) in the fine fraction from 29.0% in the feed, to 95% in the post HPSA product.

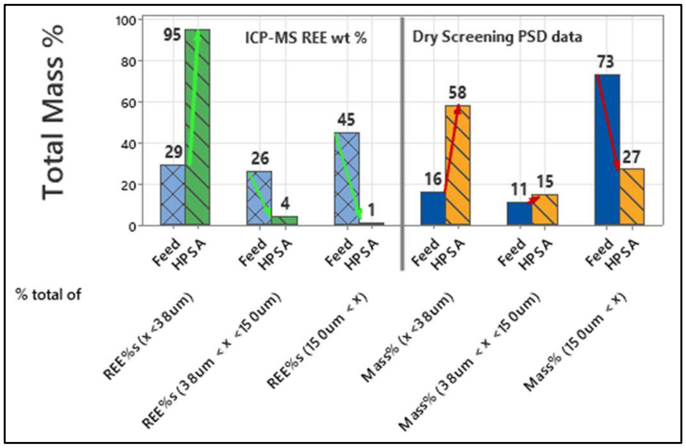

Figure 11: Size Classification of the Feed and Post HPSA Material

Figure 12 displays the MLA of the feed material and post-HPSA samples. Pre-HPSA, the REE bearing bastnasite and monazite are associated with the host mineral orthoclase. Images of the post HPSA material clearly show that the bastnasite and monazite have been liberated from the orthoclase. The results demonstrate how the unique application of energy provided by HPSA leads to selective liberation of softer minerals.

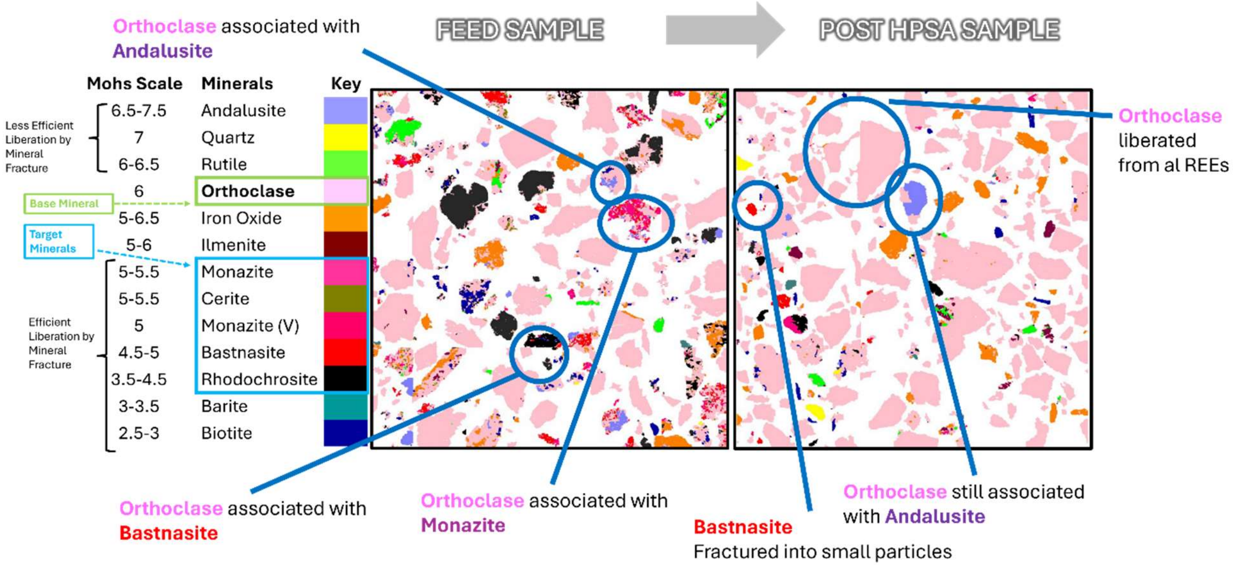

Figure 12: Automated Mineralogy particle maps for pre and feed and post HPSA samples for REE materials.

Batch Testing Case: Copper

HPSA was benchmarked against a rod mill for a regrind circuit processing ore containing copper. The objective of this case study was to quantify the selective liberation capability of HPSA relative to the traditional size-reduction focused liberation technology of a rod mill.

In one case study, in a comparison to the rod mill, HPSA increased copper recovery by 22% for the -74 µm (-200 US mesh) size fraction. HPSA provided an increase in both the grade and recovery for the copper minerals. Although the grade and recovery results were positive, HPSA generated a significant number of fines to liberate the copper from the host rock. For this ore body, the copper was encapsulated within the host rock and post process flotation required a specific particle size of -74 µm (-200 US mesh). HPSA concentrated 63% of the total copper into the minus -74 µm (-200 US mesh) fraction as compared to the rod mill grinding, which had only 41% of the total copper concentrated into the same fraction. However, the HPSA process was not able to achieve particle size reduction for a product with a p80 of -74 µm (-200 US mesh), only achieving a p80 of 250 µm (-60 US mesh). The selective shift of copper into the finer fraction shows some promise for HPSA's ability to pre-concentrate the copper into the finer fraction, which can then be separated from the coarser material that has lower grade. This would allow for a size separation prior to flotation that would increase the grade entering rougher flotation and potentially yield higher grades and recoveries of copper bearing minerals.

Continuous Testing Case: Phosphate

In a phosphate application, HPSA uses the base phosphate mineral (hydroxyapatite) to liberate acid consuming minerals and silicate from the phosphate rock. Figure 13 displays that HPSA processing increased the content of apatite in the +44 µm (+325 US mesh) by 3%, while also increasing total apatite recovery by an average of 4%. Figure 13 further details the MLA results, showing apatite liberated in the +149 µm (+100 US mesh) size fraction and gangue minerals concentrated in the -44 µm (-325 US mesh) size fraction. Furthermore, Table 3 displays HPSA processing was able to increase apatite grade by an average of 5% while, decreasing silica and magnesia gangue by 4.8% and 0.4%, respectively.

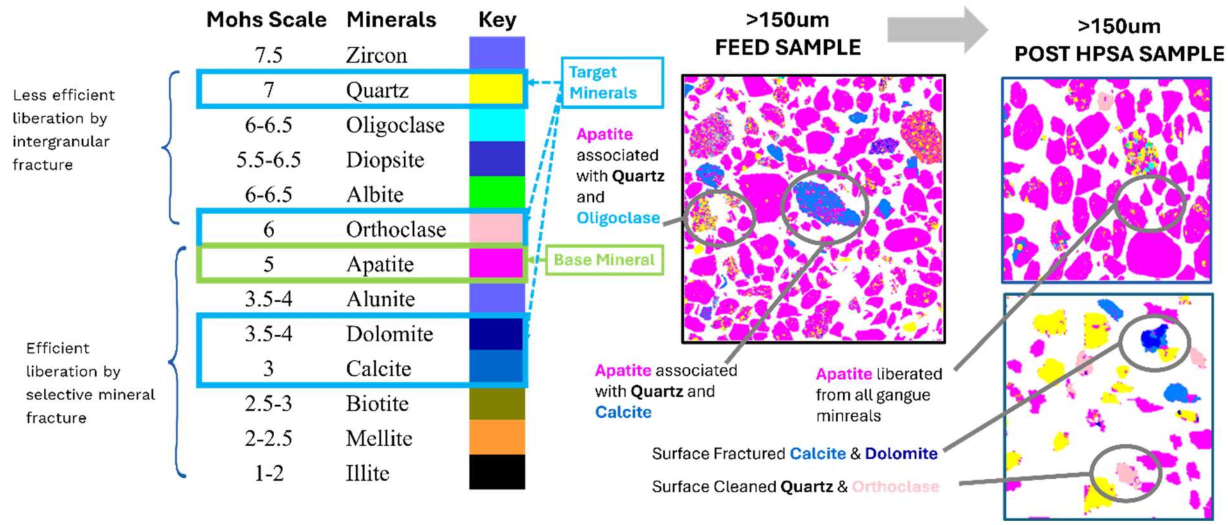

Figure 13: Phosphate MLA results pre-HPSA (left) and post-HPSA (right)

Table 3: Phosphate Optimization Testing. HPSA Product Comparison to Rod Mill Product

Test No.	HPSA Operation time	P_2O_5 Grade Increase	P_2O_5 Recovery Increase	SiO_2 Conc. Decrease	MgO Conc. Decrease
1	5 min	2.9%	8.3%	2.3%	0.3%
	10 min	3.8%	5.0%	4.2%	0.3%
	15 min	4.7%	2.9%	4.9%	0.3%
2	5 min	4.2%	6.4%	3.3%	0.2%
	10 min	5.0%	3.4%	4.1%	0.3%
	15 min	5.5%	0.3%	4.7%	0.4%

The initial optimization results concluded that HPSA effectively liberated acid consumers and insoluble minerals into the fine fraction, leading to an increase in both grade and recovery. HPSA's selective liberation also decreased the amount of material required for downstream processing, resulting in savings for pipeline transportation and phosphoric acid plant processing. Reduction of phosphoric acid plant processing has environmental benefits such as the reduction of sulfuric acid use and mitigating the hazardous byproduct phosphogypsum. In this case, a technoeconomic analysis (TEA) was developed to quantify potential value added. The TEA calculated that the implementation of a 5 tph HPSA unit has potential to add up to $500,000/year in economic value. Furthermore, a 250 tph HPSA unit has the potential to add $26 M/year in economic value.

A 5 tph continuous Gen Bravo HPSA unit was installed in a phosphate milling circuit in December 2023, shown in Figure 14. The engineering unit has a target minimum operation time of 6-months with the end goal of proving through sampling and economic analysis that a larger HPSA unit can eventually replace the current rod mill. Previous batch unit results defined operating parameters for maximum throughput, residence time, and optimal nozzle velocities to maximize grades and recoveries for downstream processes. This unit is operating off a feed slip stream, in parallel to the rod mill. Disa will continue to work towards fully replacing the rod mill with a 250 tph HPSA unit.

Figure 14: Gen B installed at a phosphate mill.

Continuous Testing Case: Filter Sand

Filter sand is used in a variety of mining applications including well water filtration, water reuse, source water filtration, leaching pads, tailings, and many more. Over time, this filter sand becomes coated with a layer of calcite which degrades the filtration properties of the sand. Eventually, it must be discarded and replaced with new, clean sand. This replacement is both manually laborious and expensive.

In a case study, calcite coated filter sand material was processed using HPSA technology. This study proved that HPSA was able to separate the calcite layer from the sand, regenerating the filtration properties so that it can be re-used in the filtration process. Material was processed in a HPSA lab unit, and the post process material was separated into +105 µm (+140 US mesh) and -105 µm (-140 US mesh) material. The +105 µm (+140 US mesh) material was successfully cleaned, replicating the regenerated sand that could be reused in the filtration system, while the contaminants were concentrated in the -105 µm (-140 US mesh) material. Figure 15 shows the separation of clean and contaminated material. Figure 16 shows images of the dark calcite layer breaking off the coarse sand (+105 µm /+140-mesh) over time. Further XRD analysis was performed on the feed and 10-minute HPSA samples. The analysis revealed the quartz content increased from 67% in the feed to 94% in the product, and the calcite content decreased from 26% in the feed material to 3% in the product, shown in Figure 17.

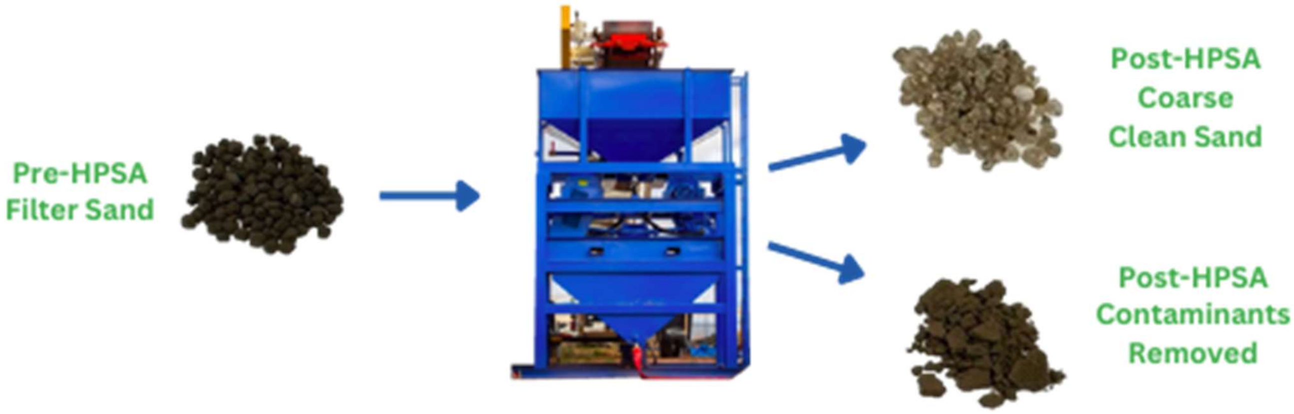

Figure 15: HPSA process for regenerating filter sand.

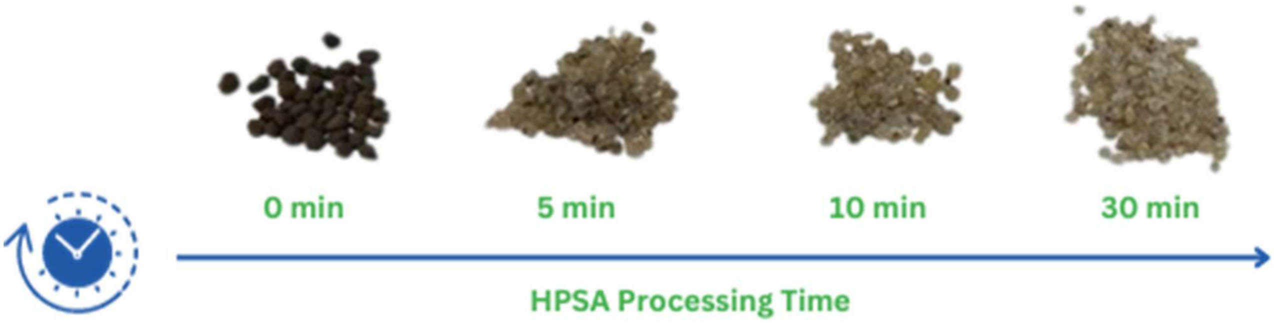

Figure 16: HPSA processing filter sand over time.

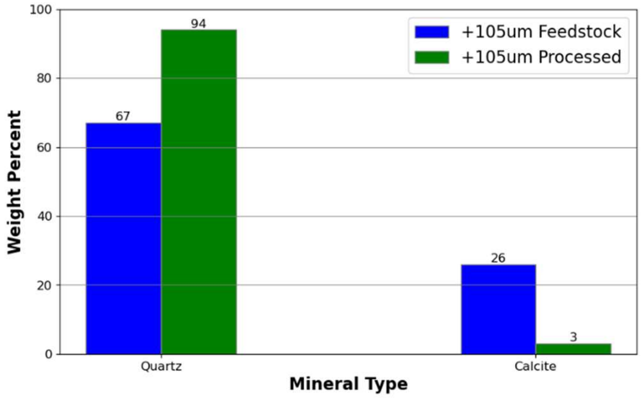

Figure 17: XRD comparison of pre and post HPSA processing of filter sand.

Expanding on the filter sand lab case study, Disa deployed the Gen B continuous unit to a water treatment facility for a filter sand regeneration pilot project. The objective of this pilot was to use HPSA processing to clean and recycle filter sand to negate the need to fully discharge and replace contaminated sand.

Contaminated filter sand was size classified over a 6.35 mm (¼ inch) vibratory screen to remove any large particles that could clog the HPSA system. The undersized material was then conveyed into a mix tank where the slurry was formed. From there, the slurry was pumped into the HPSA tanks for selective liberation. The HPSA processed material was then pumped over a vibratory shaker with a 105 µm (140 US mesh) panel to separate the contaminants from the cleaned sand. The regenerated, clean sand was pumped back into the sand filters and the fine contaminants were disposed of in the tailings pond. Figure 18 shows the Gen B processing circuit at the water treatment plant. A total of 20 metric tons of material was processed during this pilot project.

XRD analysis was performed on the feed and post-HPSA material. Figure 19 displays the results of quartz content increasing from 80% in the feed to 96% in the Gen B sample, and calcite content decreasing from 16% in the feed material to 2% in the Gen B sample. This data concluded that the continuous Gen B unit was able replicate results observed in the lab scale batch unit.

Figure 18: Gen B piloted at a water treatment plant.

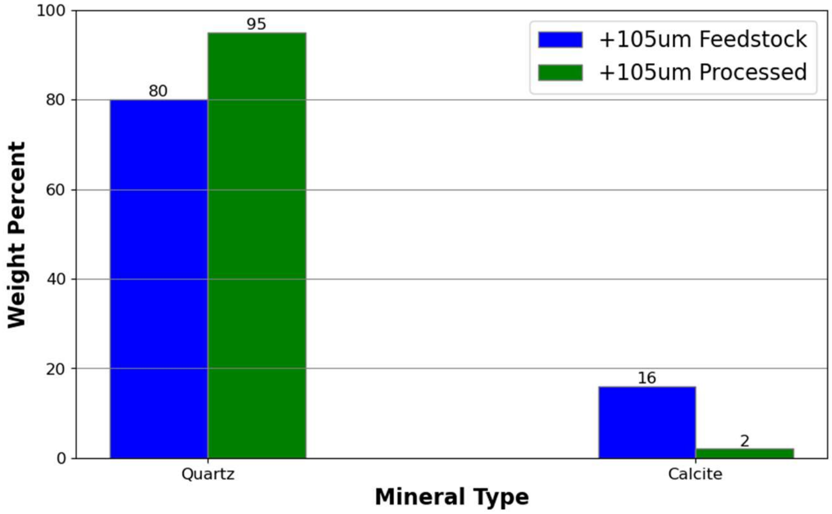

Figure 19: Gen B filter sand mineral content.

FUTURE DIRECTION & CONCLUSIONS

Designs for HPSA units are currently being scaled to 20-50 tph, with intentions to further suit industrial needs near the 250 tph range. To do this, Disa is collaborating with Fluor Corporation for the design of the third-generation continuous units. These Gen C units will utilize lessons learned from Gen B pilot projects, CFD+DEM modelling (Weaver, 2024), academic studies (Mitchell, 2023 & Antoniak, 2020), and model verification testing. The first iteration of Gen C will be a 20 tph unit, which will be the platform of design for a 50 tph unit. Finally, any developed improvements to HPSA technology can be directly applied to improve the viability and efficiencies and operations related to HPSA AUM and mineral processing.

As HPSA is an emerging technology, many feasible design considerations are under consideration for future trade studies to facilitate improvements in performance, operation efficiency, durability and deployability. Moreover, this development should be coupled with simulations and verification testing to improve system designs to optimize probability and frequency of collision and fracture events in the system. These studies will inform specific modifications to slurry transportation systems, slurry dispersion systems, and the collision systems involved with HPSA processing. Furthermore, these studies should balance system performance with the goal of reducing overall energy consumption of the system in all iterations and various design configurations investigated. Additionally, the durability and reliability of the systems can be improved through a combination of materials selection and system design choices to reduce wear, remove failure modes, and optimize machine uptime.

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