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Process Wastewater Treatment Options

Technical Memorandum

Sio Silica Corp.

60640258

June 2022

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June 24, 2022

Project #
60640258

Subject: Process Wastewater Treatment Options – Technical Memorandum

Dear Ms. Weeden:

AECOM is pleased to submit this draft Technical Memorandum (TM) report for the Sio Silica as part of the review of options available for treatment of silica process water. This TM describes the investigations undertaken related to the options.

Sincerely,
AECOM Canada Ltd.

Cliff Samoiloff, M.A.Sc., P. Eng.
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CS:ag
Encl.

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AECOM: 2015-04-13

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1. Introduction

1.1 Background

Sio Silica Corp. (Sio) plans to extract sand from groundwater obtained via extraction wells located through mining claims located within the Rural Municipality of Springfield, Manitoba. After the desired fractions of sand are recovered at the Processing Facility a significant volume of extracted groundwater (process wastewater) which will be laden with fine sand and silt, will be returned to the aquifer. This process wastewater will be treated to improve water quality before being returned to the environment or recycled.

This memo reviews the regulatory requirements for wastewater and drinking water standards, presents the available information on process wastewater characterization as well as available options to meet the required water quality standards.

1.2 Environmental Act License

The Sio Processing Facility has an approved Environment Act License (EAL) No. 3367. No water is currently being planned to be discharged to surface water bodies; however, no stipulations have been applied to the water that is being treated and returned to the aquifer as the extraction activities are yet to been approved and an EAL is pending.

The current EAL for the Processing Facility (the “Development”) defines the process wastewater as a liquid stream, containing or comprised of process water or any chemicals used by the Development, which is designated for release into the environment. The EAL demands that the process wastewater be reclaimed or recycled as much as possible but does not provide treatment objectives. Additionally, provisions for surface tanks for excess process water storage are to be provided according to the EAL. All surface water collected by the drain system beneath the sand stockpiles is to be combined with the process wastewater stream and recycled within the Facility.

EAL for the extraction process has been applied for but not yet approved. The treatment options described in this report focus on treating the extraction water and not the processing facility.

2. Review of Regulatory Requirements

2.1 Wastewater Effluent Standards

Wastewater effluent standards are regulated by Federal and Provincial legislation. Based on the provincial effluent discharge standards (Manitoba Water Quality Standards, Objectives and Guidelines, Nov 28, 2011), the following discharge standards apply to treated wastewater effluent discharged locally to surface water streams and bodies.

Table 2-1 summarizes the federal wastewater effluent limits.

Table 2-1: Provincial Wastewater Effluent Limits

Parameter	Limit	Basis of Compliance
$CBOD_5$	≤25 mg/L	monthly arithmetic mean
BOD_5	≤25 mg/L	monthly arithmetic mean
TSS	≤25 mg/L	monthly arithmetic mean
TN	≤15 mg/L	monthly arithmetic mean
TP	≤1 mg/L	monthly arithmetic mean
TDS	≤3000 mg/L	monthly arithmetic mean
E. coli	≤200 CFU per 100 mL	monthly geometric mean
Fecal coliforms	≤200 CFU per 100 mL	monthly geometric mean
Total ammonia	varies	monthly arithmetic mean

2.2 Drinking Water Standards

2.2.1 Drinking Water Standards Current Regulatory Framework

Drinking water quality in Manitoba is regulated at the provincial level through the *Drinking Water Safety Act* and its associated regulations, which are in turn affected by federal and international policy. *The Act* often follows the recommendations set out by the technical supplements surrounding the *Guidelines for Canadian Drinking Water Quality* (Health Canada, 2012). As such, Manitoba drinking water quality standards are periodically updated to address health risks caused by contaminants in the water supply.

The provincial regulations make a distinction in water quality criteria for surface water, groundwater and groundwater under the direct influence of surface water (GUDI), specifically with regards to disinfection requirements. A summary of existing disinfection requirements for public water systems using surface water is shown in **Table 2-2**.

Table 2-2: Summary of Microbial Standards for Surface Water and GUDI

Parameter	Treatment Standard
Cryptosporidium	3-log removal (99.9%)
Giardia lamblia	3-log removal (99.9%)
Viruses	4-log removal (99.99%)
Turbidity	≤ 0.3 NTU

Under regular operation, treatment processes based utilizing physical removal can be awarded log-removal credits noted in **Table 2-3**. In order to be awarded such credits, each treatment system must conform to specific operation and monitoring guidelines, as dictated by the ODW. Both ozonation and chlorination can provide additional log inactivation credits to supplement those outlined in **Table 2-3**.

Table 2-3: Log Removal Credits for Filtration Technologies, Abridged (Manitoba Water Stewardship, 2010)

Filtration Technology	Log Removal Credit *Cryptosporidium*	Log Removal Credit *Giardia*	Log Removal Credit Viruses
Conventional Treatment: Coagulation, flocculation, clarification, filtration	3.0	3.0	2.0

2.2.2 UV Disinfection Validation

In order to achieve a desired level of disinfection, a UV reactor must meet a required UV dose, measured in mJ/cm^2. A summary of required doses for various pathogens is presented in **Table 2-4**. These doses present ideal cases; from these, validated doses are determined.

Table 2-4: UV Dose Requirements (mJ/cm^2) (USEPA, 2006)

Target Pathogens	Log Inactivation							
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
Cryptosporidium	1.6	2.5	3.9	5.8	8.5	12	15	22
Giardia	1.5	2.1	3.0	5.2	7.7	11	15	22
Virus	39	58	79	100	121	143	163	186

A validation factor is always applied to UV disinfection installations to reflect the uncertainties of the water supply system such as varying flow rate, UVT level, lamp fouling and lamp age, as shown in **Equation 1**.

$$RED = VF \times D_{Req}$$

(**Equation 1**)

where RED is the reduction equivalent dose used by the reactor (mJ/cm^2), VF is the validation factor and D_{Req} is the required UV dose (mJ/cm^2). Validation factors applied are typically equal to or greater than the required dose stated in **Table 2-4**. The Office of Drinking Water recognizes that UV disinfection systems are typically validated by manufacturers (Office of Drinking Water, 2010).These validation protocols are created by independent regulatory bodies.

UV reactor validation tests can be conducted on-site (plant-specific) or off-site (validation test water). The method of validation may vary based on the type of facility, each offering advantages and disadvantages.

During operation, UV reactors can measure the applied UV dose in two ways, as recognized by the final UVDGM:

- **UV Intensity Setpoint Approach:** With this approach, the UV dose must exceed a given setpoint (or setpoints) to ensure the target dose is actually applied. During operation, the UV dose is measured directly, taking into account factors established during reactor validation that may affect the dose, such as flow rate and UV intensity. During operation a single, conservative UV dose can be determined to satisfy all pathogen reduction requirements. Alternatively, rigorous validation testing may also be used to determine variable setpoints based on varying system parameters (i.e. flow), which may be used to reduce the necessary UV dose and therefore reduce operating costs where possible. Water quality parameters such as UVT are not taken into account for this approach, as actual applied dosages are measured.
- **Calculated Dose Approach:** This approach relies purely on empirical equations to determine the applied UV dose with a given set of operating conditions. These equations may be determined by manufacturers and should take into account factors such as UV intensity, UVT and the reactor flow rate. This approach allows for variability in controlling the lamp power output in response to changing process conditions.

2.3 Treatment Objectives

The environmental assessment and licensing process controls sources of pollution and other environmental effects resulting from a wide variety of municipal, industrial, commercial, resource use and hazardous waste projects. Projects requiring environmental assessment and licensing under *The Environment Act* are listed on an inclusion list provided in Manitoba Regulation 164/88, the Classes of Development Regulation. Some projects require licensing under *The Dangerous Goods Handling and Transportation Act*. The regulatory process is in progress at the time of writing of this report.

This Technical Memorandum assumes that the expected treatment objectives include the removal of TSS and disinfection according to limits presented below. Additionally, chemicals aiding in the treatment process used commonly for coagulation and flocculation of solids are not allowed.

Table 2-5: Provincial Wastewater Effluent Limits

Parameter	Limit	Basis of Compliance
TSS	≤25 mg/L	monthly arithmetic mean
E. coli	≤200 CFU per 100 mL	monthly geometric mean
Fecal coliforms	≤200 CFU per 100 mL	monthly geometric mean

3. Water Characterization

The following sections present the available data and analyses for the wastewater produced during silica extraction.

3.1 Particle Size Analysis

A particle size analysis was conducted on samples taken form various wells.

Table 3-1: Particle Size Analysis

Sieves	Particle Size, µm	Big tank to little tank overflow	Fraction, %	Little tank dredge	Fraction, %
100	>150	1.25	21.3%	1.35	21.4%
120	>125	0.82	13.9%	0.97	15.4%
140	>106	0.64	10.9%	0.71	11.3%
200	>75	0.86	14.6%	0.95	15.1%
325	>45	1.21	20.6%	1.19	18.9%
400	>38	0.56	9.5%	0.50	7.9%
Pan		0.54	9.2%	0.64	10.1%
Total		**5.88**		**6.31**	

Particles 106 µm and larger (retained on the 140 mesh size) will be removed from the water, dewatered as salable sand and sent to the Processing Facility separately. Approximately 46% of sand and silt will be removed prior to treatment.

Of the remaining fraction of the particles around 30% will be retained on the 200 mesh which retains particles 75 µm or more. This fraction is expected to have relatively high specific gravity and settle out very well.

Only around 20% of the remaining particles are smaller that 38 µm. Those particles would settle relatively slower as they are representative of a very fine silt. The removal of the smallest fraction of the particles would most likely require coagulation and filtration system. **Table 3-2** summarizes the process water particle fractionation. The process water requiring treatment is expected to have effectively approximately 10,000 mg TSS/L.

Table 3-2: Summary of Process Water Particle Fractions and Solids Concentration

Particles		Raw Water			After Sand Removal	
Sieves	Size, µm	mass, g	Fraction, %	Concentration, mg/L	Fraction, %	Concentration, mg/L
100	150	1.30	21.3%	3,945	0%	-
120	125	0.90	14.7%	2,712	0%	-
140	106	0.68	11.1%	2,048	0%	-
200	75	0.91	14.8%	2,746	28%	2,746
325	45	1.20	19.7%	3,648	37%	3,648
400	38	0.53	8.7%	1,614	16%	1,614
Pan		0.59	9.7%	1,788	18%	1,788
Total			**100.0%**	**18,500**	**100.0%**	**9,795**

Figure 3-1 shows how the raw process wastewater looks visually. The wastewater is very milky with an exceedingly high concentration of solids. However, the sample settled completely after prolonged period of settling time.

Figure 3-1: Photographs of Raw Process Wastewater; Shaken vs Settled

Figure 3-2 shows photographs of a different sample. The photograph on the right was taken after 40 minutes of settling. Most of the solids had settled out; however, the supernatant was still very murky.

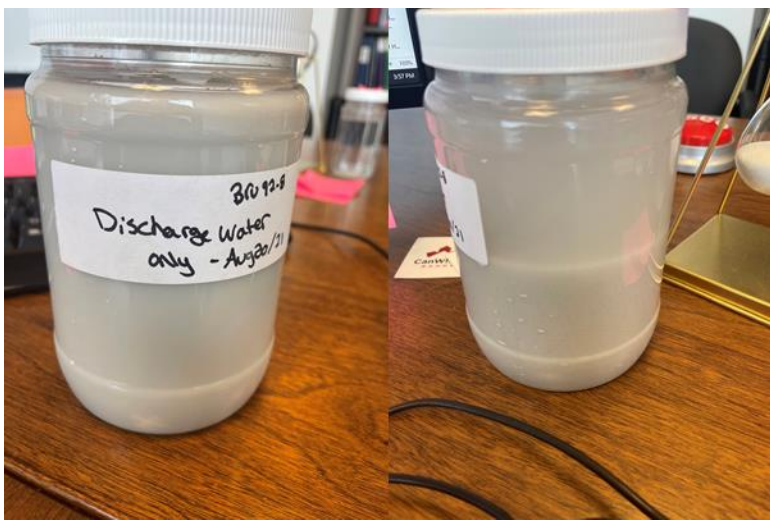

Figure 3-2: Photographs of Raw Process Wastewater Shaken and after 40 Minutes of Settling

3.2 Microbiological Analysis

Several microbiological analyses have been conducted at different sampling wells to investigate the presence of fecal coliforms and *E. Coli*. As expected from a deep groundwater source, none of the microbiological pathogens were present in the samples.

Table 3-3: Pathogens in Raw Process Wastewater

Well	Total Coliforms, MPN/100 ml	E. Coli, MPN/100 ml
92-1	0	0
92-2	0	0
92-7	0	0
92-8	0	0
96-1	0	0
96-2	0	0

3.3 Flows and Solids Loads

The raw process wastewater is expected to have a solids concentration of 18,500 mg TSS/L, which will then be reduced to approximately 10,000 mg/L and directed for treatment. This is a relatively high concentration. The flow is expected to range from 1,100 m^3/d to a peak of approximately 6,000 m^3/d. It is expected that only few wells will be operational at a specific location, so the treatment system is expected to have to be sized to treat only a fraction of the flow. A design flow of approximately 1,500 m^3/d (~250 gpm) was chosen at this stage. The resulting solids load is equal to 15,000 kg TSS/d at peak flow. **Table 3-4** summarizes the characteristics of the process wastewater.

Table 3-4: Characteristics of the Process Water

Parameter	Raw Water
Flow minimum, m^3/d	1,100
Flow peak, m^3/d	6,000
Design flow for a single system, m^3/d	1,500
TSS mg/L	10,000
Turbidity, NTU	>100,000[1]

[1] Turbidity exceeded upper limit of the nephelometric method. Minimum value reported.

4. Treatment Options Review

4.1 Equipment Mobility

The treatment equipment has to be as mobile as possible in order to drive it around to a designated well currently in operation in order to treat the produced water. Some of the proposed equipment comes as a pre-packaged mobile solution. Other equipment comes on skids that can be installed on mobile trailers, but the vendors do not provide already pre-packaged solutions and the necessary installation and retrofitting would need to be conducted by a third party.

The nature of the wastewater necessitates multistage treatment. Singe clarification or filtration step can not provide the level of treatment necessary to meet the expected effluent limits. A single mobile system would only provide one stage of the treatment, which would necessitate multiple trailers/shipping container skids combined in a single treatment train.

Ultimately, it is expected that each unit process would need to be conducted by a separate mobile system, some of them custom made, and connected to a single treatment train with all the necessary pumping and piping. From an operational and logistical perspective this might be challenging.

4.2 TSS Removal

The TSS in the wastewater is relatively high at a concentration of almost 10,000 mg TSS/L. It is therefore expected that a single filtration step is not feasible to reduce the solids concentration to 25 mg/L or lower. Depending on the settling velocity of the suspended solids it is possible that a gravity settler could remove majority of the solids. Filtration step should be preceded by a form of vortex solids/liquid separation pre-treatment step or a high rate gravity clarifier. The purpose of the pre-treatment step is to significantly lower the solids concentration so that the water quality is feasible for a filtration treatment step.

4.3 Pre-treatment

4.3.1 Vortex Grit Removal

The solids contained in the wastewater are similar to a very fine grit or silt. The bigger particles (>75 µm) are usually characterised by quite high specific gravity and fast settling. At the conceptual level for this report, a standard pre-treatment system for grit removal could be applied. Typical grit removal system will use a grit cell followed by grit classifying and dewatering units to dewater and remove the grit for disposal. Hydro International's GritKing® grit removal could be potentially used to pre-treat the wastewater and remove a bulk of solids leaving the smaller particle fractions for the second treatment step.

The Grit King® is a compact, unpowered advanced grit management system that removes 95% of 106 µm particles or larger, preventing costly downstream grit abrasion and deposits.

Flow is introduced tangentially to the Grit King® via a tangential inlet creating a rotational flow path around the outside of the dip plate. The flow gradually spirals around the perimeter allowing the grit and sand particles to settle out by gravity. The grit collects in the grit pot as the centre cone directs flow away from the base and up around the centre shaft into the inside of the dip plate. The upward flow rotates at a slower velocity than the outer downward flow. The resulting 'shear' zone scrubs out the finer particles. The concentrated grit underflow is pumped, or gravity fed to a grit classifier for dewatering.

According to the particle size analysis around 37% of total solids could be removed via this step for an effluent concentration of approximately 6,000 mg/L. The remaining solids would need to be removed in a secondary treatment step as the solids concentration is still too high for a filtration step.

The vendor does not offer premade mobile systems; however, the skid could be installed in a shipping container or on a trailer by third party.

Figure 4-1: Typical Grit Removal System (Figure Courtesy of Hydro International)

4.3.2 Hydrocyclone Solid Separation

Hydrocyclones use the centrifugal separation principle to remove or classify suspended solids in a slurry.

Slurry is fed into the hydrocyclone tangentially under a certain pressure. This creates a centrifugal movement, pushing the heavier phase outward and downward alongside the wall of the conical part. The decreasing diameter in the conical part increases the speed and so enhances the separation. Finally, the concentrated solids are discharged through the apex. The vortex finder in the overflow part creates a fast rotating upward spiral movement of the fluid in the centre of the conically shaped housing. The fluid is discharged through the overflow outlet.

The VorSpin Hydrocyclone is an example of a commercially available system. It features three improvements in hydrocyclone efficiency: 1) a volute feed inlet, 2) a fluted vortex finder ,and 3) a non-plugging discharge apex nozzle. The Volute feed inlet prevents the slurry from circulating back into the path of the incoming slurry, causing undesirable turbulence that will reduce separation efficiency. The fluted Vortex Finder shape increases the momentum as the incoming slurry swirls around the decreasing cross-sectional area, causing a more rapid separation of the suspended solids. This also prevents larger particles from "short circulating" and reporting out the Vortex Finder with the liquid phase.

The hydrocyclone units are primarily used for removal of sand-size and silt size particles from returned drilling fluids. Abrasion resistance polyurethane or stainless steel designs are available. The units can be standalone for use or assembled through pre-designed connectors. The number of hydrocyclone units is customizable according to the design flow and loads.

The hydrocyclones could potentially remove up to 100% of particles >5 microns. According to the particle size analysis at minimum 80% of solids could be removed via this step. The remaining solids would need to be removed in a secondary treatment step. The current particle size analysis shows that around 20% of solids are smaller than 38 microns and this was the smallest sieve used. It is recommended to analyse this group of particles in more detail to have a better understanding of a distribution of the smallest particle fraction. Potentially even higher removal rates could be achieved with hydrocyclones.

However, assuming a minimum removal of 80% would leave around 2,000 mg TSS/L in the effluent comprising of particles smaller than 36 microns.

The vendor does not offer premade mobile systems; however, the skid could be installed in a shipping container or on a trailer by third party. It is recommended to pilot a hydrocyclone system in order to estimate the actual removals.

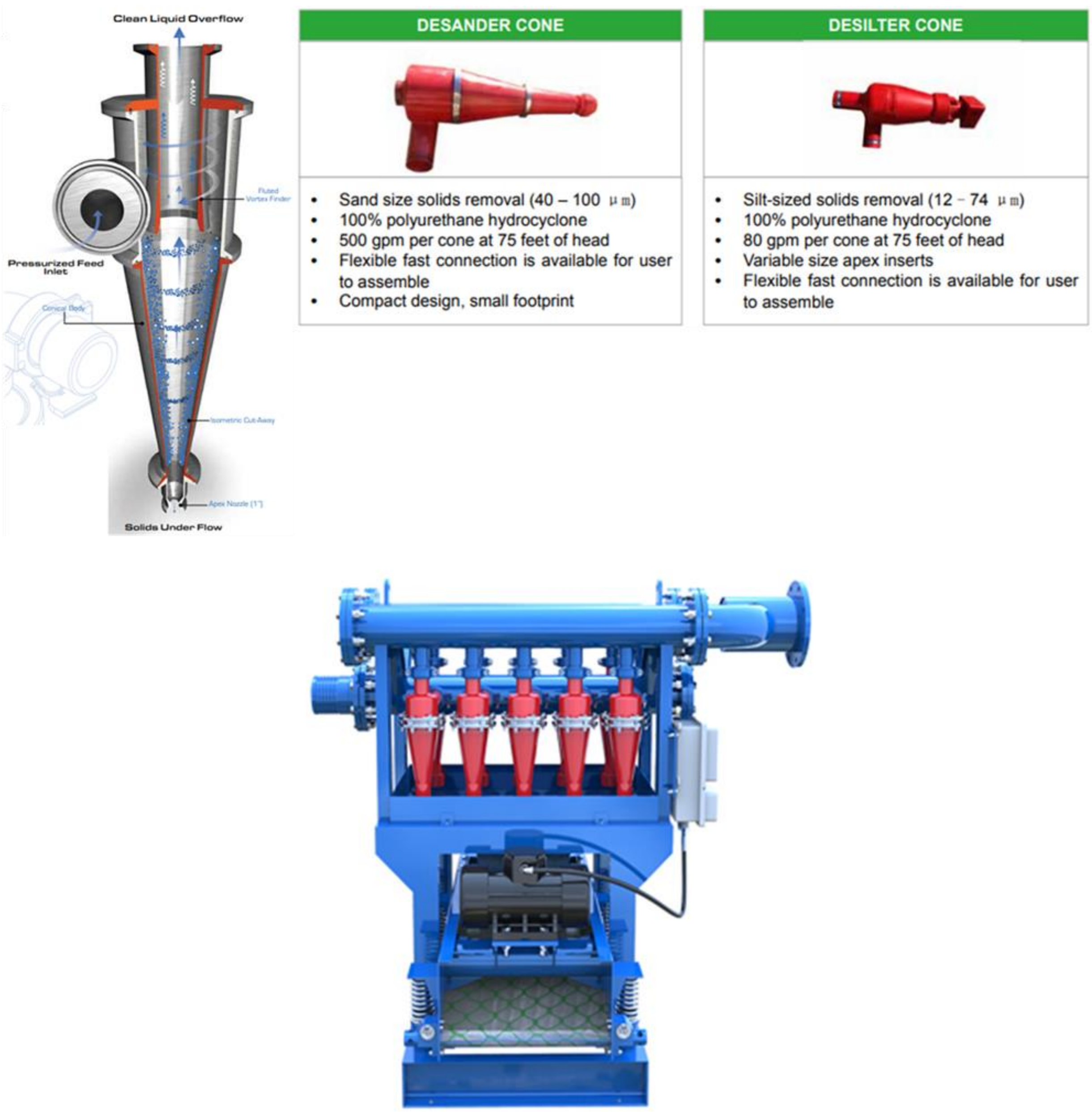

Figure 4-2: VorSpin Hydrocyclone (top) and KOSUN Desilter System (below)

4.3.3 Gravity Clarifier

Clarifiers are settling tanks built with mechanical means for continuous removal of solids being deposited by sedimentation. A clarifier is generally used to remove solid particulates or suspended solids from liquid for clarification and/or thickening. Inside the clarifier solid contaminants will settle down to the bottom of the tank where it is collected by a scraper mechanism. Concentrated impurities, discharged from the bottom of the tank are known as sludge, while the particles that float to the surface of the liquid are called scum. Clarifies are used for many applications including drinking water treatment, wastewater treatment and mining.

Assuming an inlet TSS concentration of 10,000 mg/L the gravity settling technologies are not expected to achieve full removal of solids but would act as a roughing treatment to reduce the solids concertation as much as possible. It is expected that an effluent concentration of approximately 2500 mg TSS/L depending on the settling velocity of the finest particles could be achieved.

It is recommended to measure settling velocity of each particle fraction before proceeding with the settler option or pilot a mobile clarifier unit in order to gauge the effectiveness of clarification.

An example of a mobile clarifier unit offered by Monroe Environmental is shown in **Figure 4-3**.

Figure 4-3: Mobile Clarifier Units by Monroe Environmental

4.3.4 Lamella Clarifier

A lamella clarifier or inclined plate settler (IPS) is a type of settler designed to remove particulates from liquids. The lamella plate vertical clarifier is designed to provide low cost, efficient solids removal from a wide range of waste and process liquids. The inclined plate design allows the total gravity settling area to be as much as ten times more than the actual floor space occupied by the conventional clarifier.

This unit is typically used to remove solids from industrial waste and process waters.

A vertical clarifier is designed to remove solids from wastewater and other process liquids. The optional flash mix and flocculation tanks allow for the addition of chemicals and polymers that will aid the settling process - adjusting pH to precipitate dissolved solids and/or enhancing the agglomeration of suspended particles into heavier, more settleable floc. The liquid is fed from these tanks into the clarifier through the inlet chamber, which directs flow into the separation section.

The liquid then enters the lower area of the laminar plates through side slots which distribute it across the entire width of the plates. Particulate settles onto the face of the plates and slides down to the clarifier bottom. The clarified liquid exits the plate sections through weirs at the top of the unit which are designed to develop and control adequate pressure drop, maintaining laminar flow through the plates. The clarified liquid then flows into the effluent chamber and out of the clarifier.

Settled solids collect at the bottom of the pyramid sludge hopper and are removed from the clarifier. A sludge thickener (optional) with rake mechanism may be utilized in place of the pyramid hopper when applicable.

Modular design of the lamella clarifiers allows for easy removal of individual laminar plate modules from the clarifier for inspection. The vendor does not offer premade mobile systems; however, the skid could be installed in a shipping container or on a trailer by third party. According to the manufacturer fully treating the raw water without any chemicals is not possible. For aggregate type applications which this is similar, it could be normally possible to reduce the TSS concentration to around 100 mg/l with coagulation chemicals.

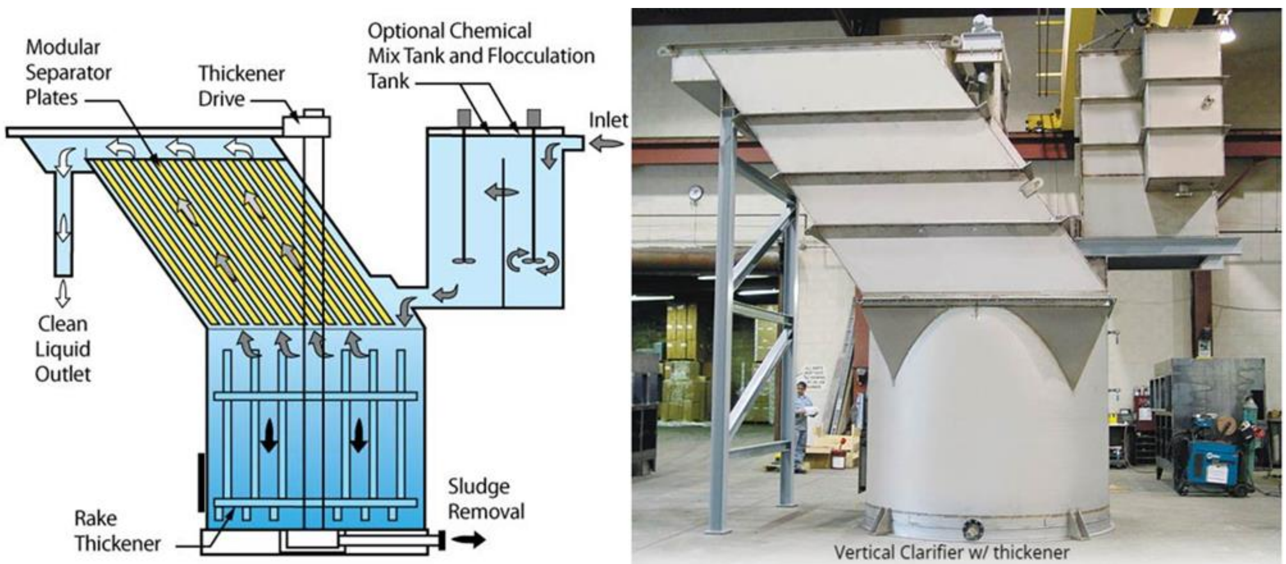

Figure 4-4: Typical Lamella Clarifier System (Figure Courtesy of Monroe Environmental)

4.4 Filtration

4.4.1 Chitosan Enhanced Sand Filtration

The gravity settling technologies are expected to achieve an effluent quality of approximately 25-100 mg/L depending on the settling velocity of the finest particles. From an effluent quality standard perspective this might be sufficient to achieve good UVT (>50%) and efficient UV treatment. However, at this stage there is no detail information on the settling velocity of the fine particle fraction. Visual observations of the process wastewater suggest that the finest particle fraction <38 µm does not settle readily. In this case a tertiary treatment step is necessary.

Depth filtration with a non-compressible filter medium or media is one of the oldest unit processes used in the treatment of potable water and is commonly used for the filtration of effluents from wastewater treatment processes, especially in water reuse applications. Depth filtration is used mostly to achieve supplemental removals of residual suspended solids, and as a conditioning step that will allow for the effective disinfection of the filtered effluent, especially with UV disinfection.

During filtration, wastewater containing suspended and colloidal material is applied to the filter bed. As the water passes through the filter bed, the suspended matter (measured as turbidity) in the wastewater is removed by a variety of removal mechanisms. With the passage of time, as material accumulates within the interstices of the granular medium, the headloss through the filter starts to build up beyond the initial value. After some period of time, the operating head loss or effluent turbidity reaches some predetermined headloss or turbidity value, and the filter must be cleaned.

SECURE offers mobile Chitosan Enhanced Sand Filtration (CESF) management systems. The active polymer, Chitosan, combines quickly with dirt, becomes insoluble, and is retained in the filter.

Chitosan is a linear polysaccharide. It is made by treating the chitin shells of shrimp and other crustaceans with an alkaline substance, like sodium hydroxide. Chitosan causes the fine sediment particles to bind together and is subsequently removed with the sediment during sand filtration. It also removes heavy minerals, dyes, and oils from the water. As an additive in water filtration, chitosan combined with sand filtration removes up to 99% of turbidity.

CESF system consists of two parts: settling basin where the polymer precipitates the solids that settle out and a sand filter where the remaining solids are retained. It is equipped with automatic recirculation of non-compliant discharge water to keep water discharge in compliance and comes with an enclosed sand filter complete with automatic and manual backwash functions.

The CESF can only accommodate an influent of approximately 1,000 mg TSS/L. That necessitates an additional treatment step prior to CESF. SECURE offers additional clarification module equipped with turbidity curtain that could be installed prior to CESF and could treat the effluent coming from the hydrocyclones for example.

The effluent from CESF is expected to meet 75 mg TSS/L. A bag filter system with 5 or 1 micron filter bags would be able to remove the residual suspended solids from the water and meet the water quality goal needed for UV treatment.

Figure 4-5: Chitosan Enhanced Sand Filtration (CESF) Management Systems (Figure Courtesy of SECURE)

The complete CESF package would consist of:

- Circular clarifier tank with turbidity curtain
- CESF unit
- Sand filter
- Bag filter
- Plate clarifier
- Frac tanks
- Pumps

Figure 4-6 shows the process flow diagram for the CESF package from SECURE. The package should be able to treat the influent of approximately 3,000 mg TSS/L to less than 10 mg/L according to the supplier.

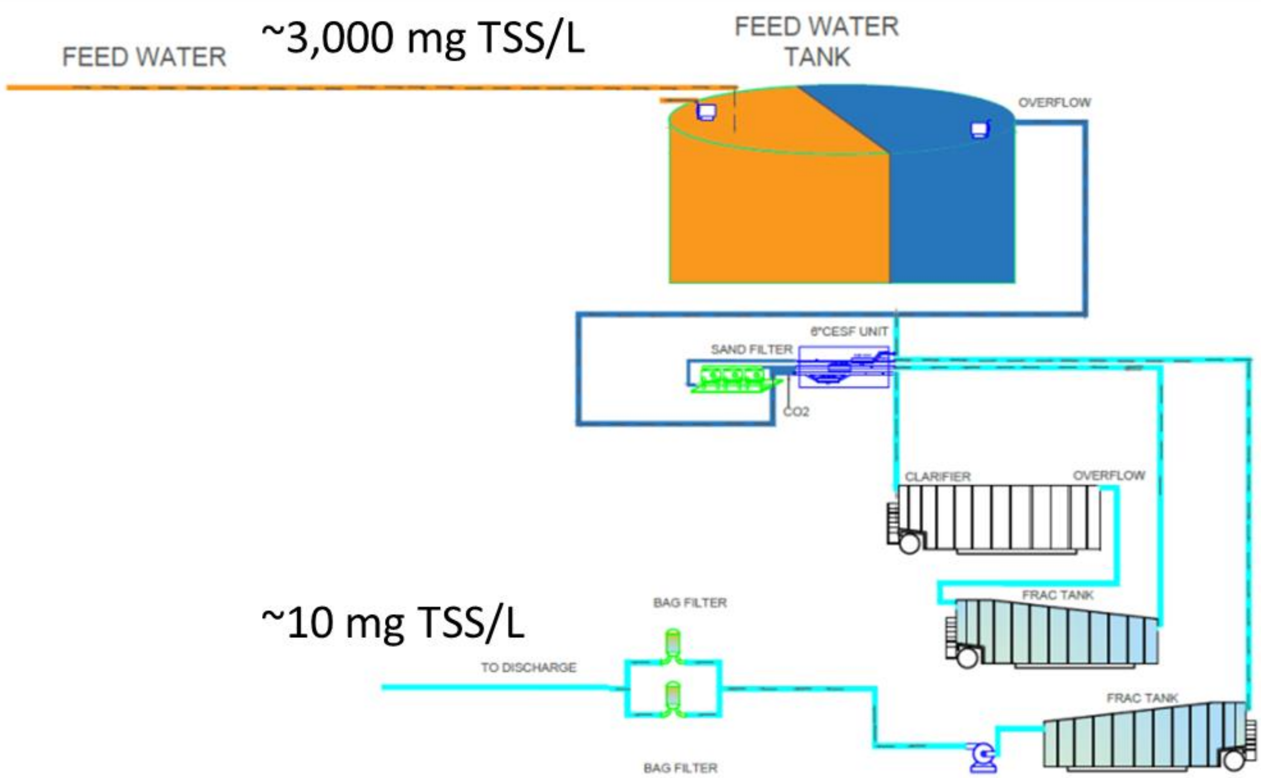

Figure 4-6: Water Treatment Process Flow Diagram for the Proposed CESF System

It is important to note that this equipment is not available for purchase. Renting the equipment is currently the only option.

4.4.2 Cloth Filtration

Pile cloth media filtration is commonly used for tertiary treatment. In these filters, the pile cloth uses depth filtration to provide solids-liquid separation to remove a wide range of particle sizes.

The Mita filter system offered by Nexom is designed for continuous filtration of solids and consists of the following processes and technologies:

- Turnkey Pile Cloth Filter system following coarse solids separation/clarification for Total Suspended Solids (TSS) polishing.
- Controls will be containerized and trailer-mounted allowing for 575 V connection to onboard power distribution.
- Filters are trailer-mounted with ANSI flanged terminal points to all customer provided process lines.

The maximum influent solids concentration the cloth filters can treat; however, is only 100 mg/L, which is relatively low. It is expected that the effluent from CESF system that includes a bag filter will remove enough solids so that the additional filtration before UV is not needed.

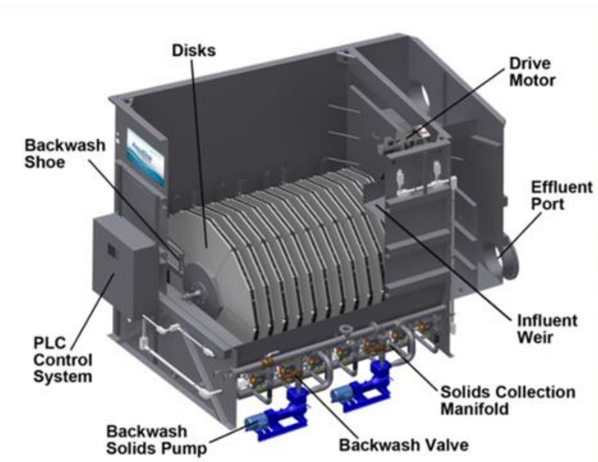

Figure 4-7: Cloth Disc Filtration System by Aqua-Aerobics

4.5 UV Treatment

Effluent disinfection is necessary to meet the effluent criteria for microbiological pathogens. UV lamps disinfect wastewater by affecting genetic material so that bacteria can no longer reproduce. In UV disinfection systems, germicidal lamps submerged in channels produce the UV light which imparts a damaging dose of UV radiation to the cells' DNA as the wastewater flows through the reactor.

There are several types of UV disinfection systems, with the main differences being the lamp intensity, the lamp pressure, and the lamp configuration. The systems currently available on the market are low pressure, low output (LPLO); low pressure, high output (LPHO); and medium pressure, high output (MPHO) and newer technologies which combine the features of low and medium pressure lamps. The other variable is based on configuration, or whether the lamps are set in an open channel or inside a closed vessel (i.e., pipe). An example of both styles of UV systems that could be considered (these specific solutions are not currently proposed, used for example purposes only) is shown in **Figure 4-8**.

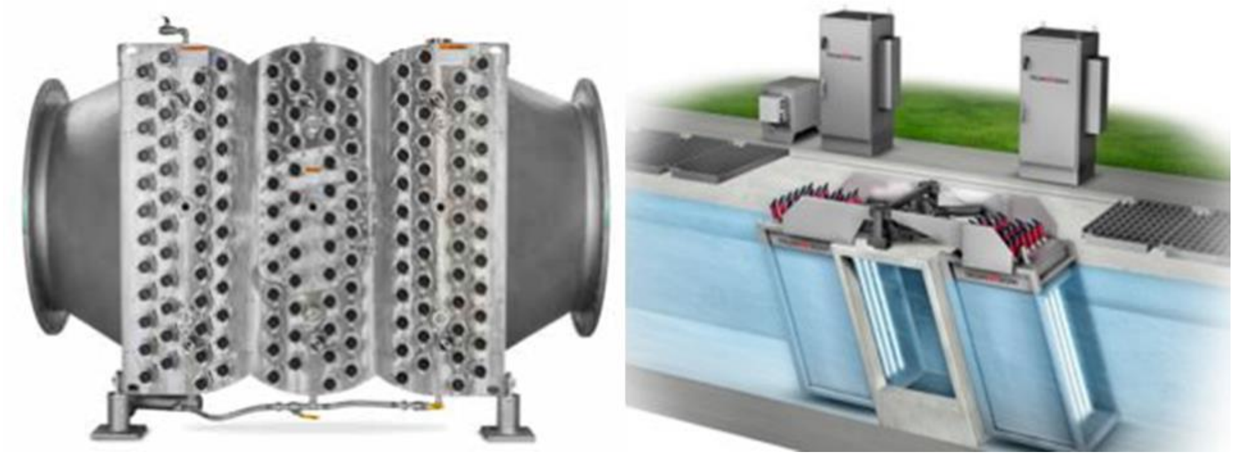

Figure 4-8: Example only of different styles of UV systems available, In-Vessel (left) Versus In-Channel (right) Configuration (Photo Courtesy of TrojanUV)

UV disinfection equipment sizing depends on the flows and the characteristics of the wastewater to be disinfected. The most important wastewater characteristic that influences UV disinfection is UV transmissivity, which is a measure of the “transparency” of the wastewater to the passage of UV light. Others include iron concentration, the presence of complex soluble organics, water hardness, TSS, turbidity, and particle size distribution. The TSS concentration may determine the level to which UV can disinfect; solids can shield organisms from the effects of the UV light allowing them to pass through the system unaffected.

The effluent characteristics have to be assumed or estimated when considering a new wastewater treatment facility. A UV transmissivity of minimum 55% has been assumed. The actual transmissivity in the wastewater will need to be measured and confirmed prior to final detailed design of the system. Experience in wastewater applications shows that UV disinfection is reliable under consistent effluent conditions at average effluent UVT > 55% at average TSS < 25 mg/L (maximum < 30 mg/L).

For the closed vessel systems like the TrojanUVFit from Trojan, the TSS needs to be lower than 10 mg/L. For an open channel configuration, the TSS can be slightly higher at 25-30 mg/L. Considering the need for a mobile UV system the open channel system is not recommended at this time.

The TrojanUVFit® offers an effective, compact, and energy-efficient solution for non-potable reuse with a streamlined hydraulic profile. The system is available in multiple configurations to treat a wide range of flow rates, up to 7 MGD per chamber.

UVpure offers a different design than TrojanUVFit system. UVpure offers a modular system, which utilizes mirrors to deliver a sterilizing dose of UV radiation from 360 degrees to overcome shadowing and reliably disinfect water with UVT as low as 35%, versus minimum 55% UVT for conventional systems. The lamps are not in contact with wastewater and the system has an easy-open chamber design with air-mounted lamps for fast lamp changes with no risk of breaking the quartz. The UV models are sized for up to 100 gpm, meaning that several units would need to be mounted together with a flow splitting between them.

Figure 4-9: The TrojanUVFit (top) and Hallett Multiplex UV (bottom) System for Wastewater Application from UVpure

Pre-treated influent needs to meet the following criteria for the Hallett Multiplex system:

- TSS – 20 mg/L max
- UVT – 35% min
- Turbidity – 4 NTU max

4.6 Sludge Management

All of the proposed solids separation technologies will produce concentrated sludge streams made up of all the removed solids. The sludge has to be managed accordingly. It is proposed that the sludge will be directed to the drying beds constructed on site.

Drying beds are devices used for the dewatering and drying of sludge and biosolids in which a semi-solid solution is spread over a porous (e.g., sand) or impervious medium and allowed to separate and air dry or decant.

Sand drying beds dewater primarily by gravity drainage of water from the sludge by placing the sludge on a sand medium. Loading rates are typically between 1.0 2.4 $kg/m^2$and 2.4 kg/m^2. Draining time is typically 3 to 4 days. Applied sludge depth should be 200 mm to 750 mm for coagulant sludges.

Sludge dewaters by gravity drainage through the sludge mass and supporting sand and by evaporation from the surface exposed to the air. Sludge can be removed from the drying bed after it has drained and dried sufficiently.

Most of the water leaves the sludge by drainage; thus the provision of an adequate underdrainage system is essential. Drying beds are equipped with lateral drainage lines (perforated plastic pipe or vitrified clay pipe laid with open joints), sloped at a minimum of 1% and spaced 2.5 m to 6 m apart.

Since one of the stipulated requirements is to disinfect all process water discharged back to the environment, it is expected that the drainage from the drying beds would need to be collected and returned to the treatment train.

4.7 Summary

At this stage it is expected that the full treatment would consist of several unit processes due to very high concentration of solids and uncertainty in the settling ability of the fine particles. **Table 4-1** summarizes all the described technologies and options that would be required to achieve the effluent limits.

Table 4-1: Sumamry of the Proposed Technologies

Treatment Stream	Technologies
Pre-treatment	Vortex Grit Removal
	Hydrocyclone
	Gravity Settler
	Lamella Clarifier
Filtration	CESF package
	Cloth Disc Filter
UV Treatment	Open channel UV module
	In-vessel UV module

Based on the currently available data and review of the available technologies a process train based around the package CESF system has been recommend as it maximizes the system mobility and reduces number of separate system providers. This option is also expected to produce good quality effluent. The recommended treatment train would consist of hydrocyclones to remove the majority of solids. It is expected that the TSS would be reduced from 10,000 mg TSS/L to around 2,000-3,000 mg TSS/L. In the second treatment step the process water would be treated in the CESF system that would include clarifier, sand filter, CESF unit, a plate clarifier and bag filters in a single system provided by SECURE. Finally, the effluent would be directed through a closed vessel UV treatment system such as one provided by UVpure.

Depending on the level of treatment and settleability of the solids alternative treatment train option was identified. Alternative 2 assumes that the solids are relatively easy to settle and uses hydrocyclones for pre-treatment. Lamella clarifier with coagulant dosing system would be required in the main treatment step and cloth disc filtration system for polishing. Finally, a UV system would provide disinfection.

Table 4-2: Summary of Potential Treatment Trains

Process	Pre-treatment	Main Treatment	UV Treatment	Effluent TSS	UVT	Fecal Coliforms
Alternative 1	Hydrocyclone	Full CESF package plant	Hallett Multiplex UV	10 mg/L	>70%	<200 MPN/100 ml
Alternative 2	Hydrocyclone	Lamella Clarifier (with coagulant) + Cloth Disc Filter	UVFit	10 mg/L	>70%	<200 MPN/100 ml

5. Recommendations

In order to achieve the anticipated effluent limits the raw process wastewater originating from the silica extraction process is expected to have to be treated in a series of several unit processes due to very high concentration of solids. Based on the currently available data and review of the available technologies a process train based around the package CESF system has been recommend as it maximizes the system mobility and reduces the number of separate system providers. However, the CESF system is only available on a rental basis and the cost are based on a monthly fee.

Due to uncertainty in the settling ability of the solids and unique characteristic of the wastewater it is recommended to pilot some of the recommended treatment options in order to assess the efficiency of the equipment treating the process water before proceeding with final equipment selection. It is especially recommended to pilot trial test the hydrocyclones and mobile/lamella clarifiers.

It is also recommended to conduct a particle size analysis of the particle fraction below 36 µm to have a better understanding of a distribution of the smallest particle fraction.

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