2022 Membrane Technology CONFERENCE & EXPOSITION
AMTA American Membrane Technology Association
American Water Works Association

HIGH-PRESSURE REVERSE OSMOSIS SYSTEM TREATING WASTEWATER FROM A PHARMACEUTICAL PRODUCTION FACILITY AS PART OF A ZLD PROJECT

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CROSSTEK

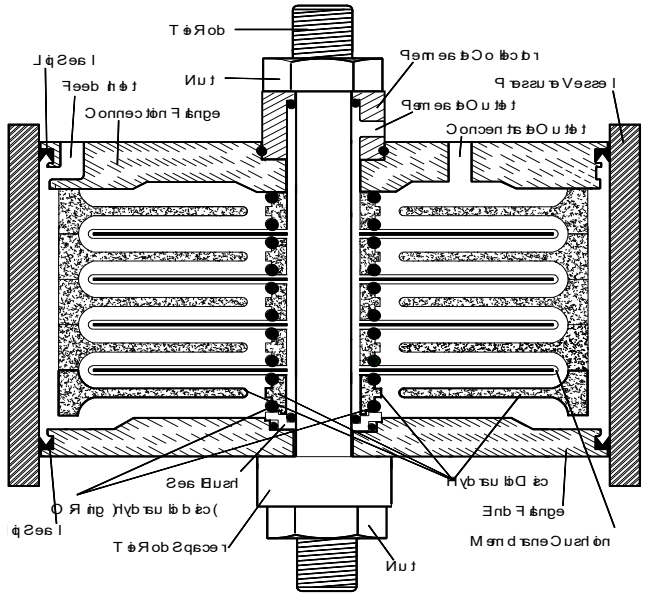
Introduction

- Crosstek is a supplier of water treatment equipment and services
- Client is major a multibillion pharmaceutical company with a 300 million USD pharmaceutical manufacturing plant in Massachusetts. The plant produces laboratory diagnostics equipment and supplies.
- The trial was performed as a requirement for a Zero Liquid Discharge (ZLD) system in a sister manufacturing plant under construction in Shanghai, China.
- Main sources of wastewater
  - An immense variety of pharmaceutical processes to manufacture the test supplies.
  - Water use in biological processes.
  - Laboratory sanitation and cleaning.
  - Process is extremely variable, and the wastewater characteristics vary based on production events. The feed SDI was out of range

Technology overview

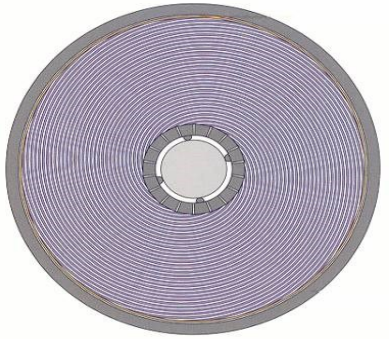
DTRO

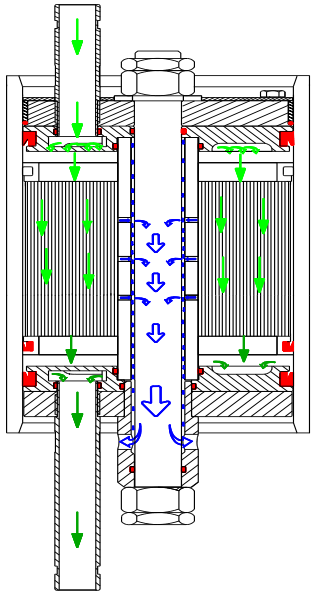
- 210 blue hydraulic discs forming stack with 209 white circular RO membrane cushions.
- 1.5 mm open feed channel and superior fluid ddynamics
- 105.4ft^2 / 9.8m^2 of membrane area



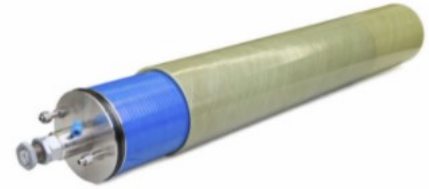
STRO

- ST+: 315.2ft^2 / 29.3m^2 of membrane area With proprietary feed spacer, ST+ can treat wastewater with potential for fouling and scaling, SDI (5min) > 5
- ST+ operates on feeds that conventional SWRO modules cannot without expensive pretreatment





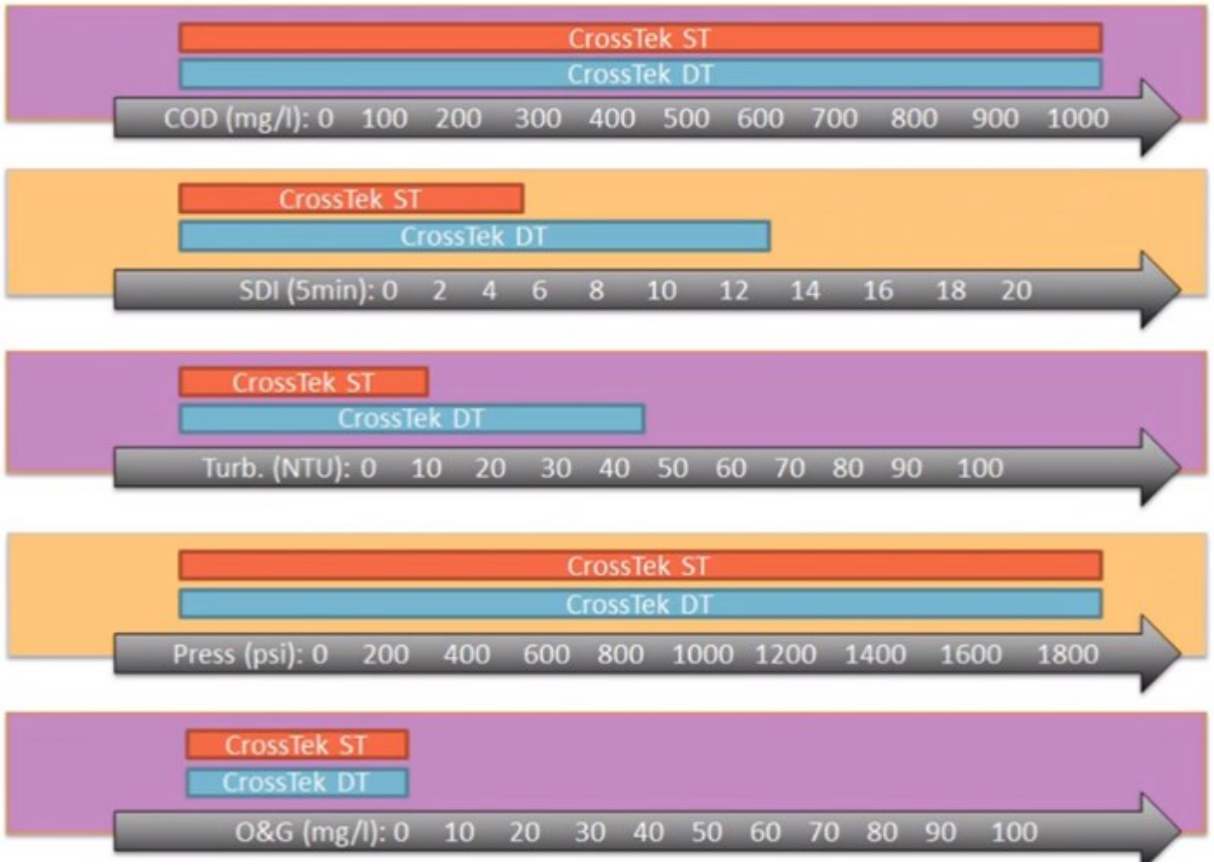
STRO/DTRO Membrane Module Configurations



AquaZoom® Disc Tube RO Membrane

AquaZoom® Spacer Tube RO Membrane

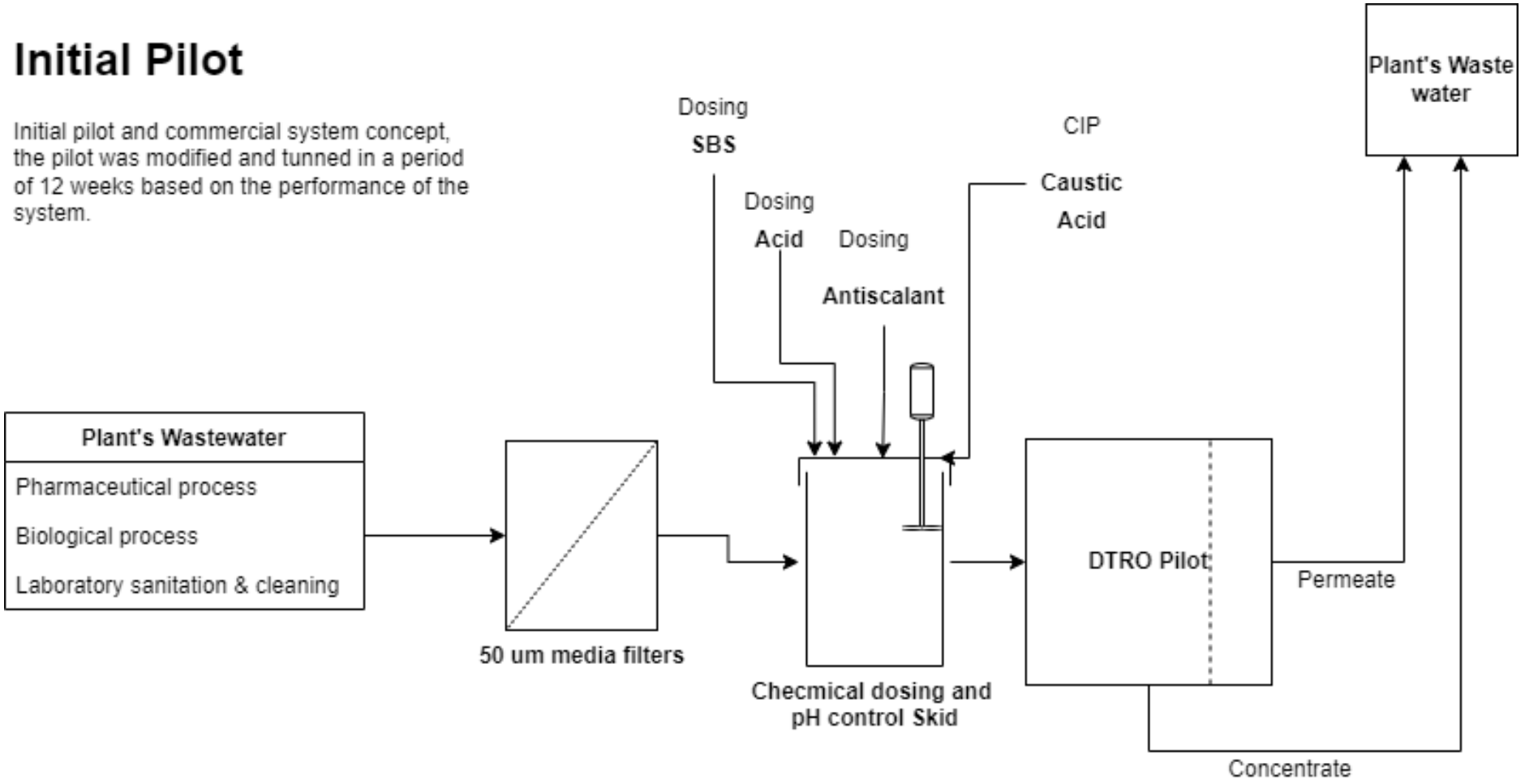
Membrane Skids with Double Length STRO modules



Initial pilot built

Initial Pilot

Initial pilot and commercial system concept, the pilot was modified and tunned in a period of 12 weeks based on the performance of the system.



Pilot trial objectives

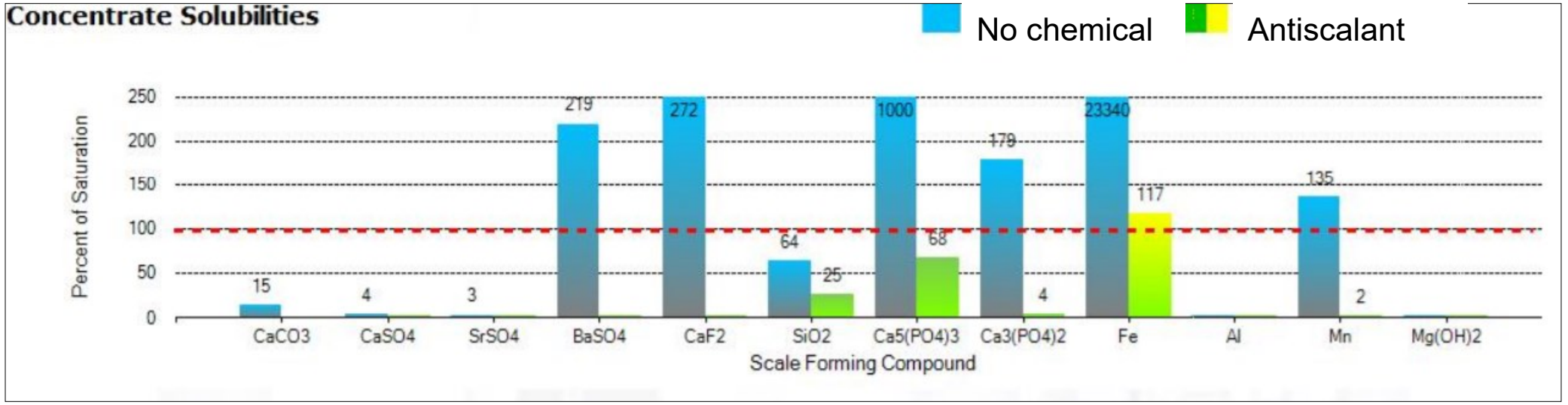
- Operate the Crosstek pilot system to collect hydraulic performance data for scale-up
- The pilot study is to be conducted over a 10-week testing period.
- Demonstrate permeate water quality suitable for the downstream discharge and that the STRO reject will be suitable for additional evaporation treatment
- Demonstrate design flux for the STRO membrane at the design recovery with design pretreatment
- Demonstrate an effective chemical cleaning regime and determine expected cleaning frequency and type of cleaning for the commercial plant.

Pretreatment and DTRO pilot unit

- DTRO4 5.17m^2membrane area, upgraded to 9.8m^2 later in the trial
- This membrane module is rated 90bar / 1,305psig as per the commercial project design requirements
- Pretreatment unit, containing chemical dosing with pH control, Antiscalant, and SBS dosing.

Scaling projection

- CaPO4 was the main supersaturated scale former to be managed
- The supersaturation with and without a dose of antiscalant is shown in the projection. This projection was used to develop the antiscalant dose concentration for the pilot and the acid dose / pH control.
- The iron was saturated and filtered out as a suspended solid in the pretreatment, hence not a real risk for the RO process.



Pretreatment unit capabilities

Pretreatment	Characteristic	Design Basis	Performance
Raw feed strainer 1	10 microns	2.65 GPM/square foot	Added upstream the 5 um to the system to avoid rapid plugging
Raw feed strainer 2	5 microns	5.7 GPM/square foot	It was replaced after plunging without a 10 um filter upstream
SBS dose	Dose on ORP measurement	Destroys residual bleach	Found very little residual bleach in the typical wastewater
Acid dose	H_2SO_4 dosed to control pH	pH set at nominally pH6 to 6.4 in the feed to manage $CaPO_4$ scale	pH control was not always easy as spikes occurred where feed pH went up to over pH 10 and was highly buffered
Antiscalant dose	SG300 dosed per scale projection (Figure 2)	Dosed at 2.5 mg/l into feed to manage $CaPO_4$ scale	Along with pH control, it appeared to work well as most fouling appeared to be related to organics (high pH cleaning was most critical)

Trial and sampling methodology

- The wastewater feed was treated to achieve a 95% recovery rate.
- The permeate and reject of the DTRO system were both returned to the wastewater discharge.
- The performance parameters of the reverse osmosis system are calculated mainly using data from on-site instrumentation included with the pilot plant, together with a multimeter to measure pH, Conductivity / TDS, and temperature.
- In addition to the on-site testing, weekly periodical samples for the pollutants of interest were sent to an external certified analytical laboratory.

Analytical Matrix

Raw wastewater feed

Total suspended solids (mg/l)	Silica (mg/l)	Potassium (mg/l)
Chloride (mg/l)	Carbonate alkalinity (mg caco3/l)	Zinc (mg/l)
Ammonia as N (mg/l)	Bicarbonate alkalinity (mg caco3/l)	BOD 5 (mg/l)
COD (mg/l)	Aluminum (mg/l)	TDS (mg/l)
Total Phosphorous as P (mg/l)	Barium (mg/l)	Nitrate as N (mg/l)
Sulfide (mg/l)	Calcium (mg/l)	Sodium (mg/l)
LAS Surfactants (MBAS) (mg/l)	Iron (mg/l)	Strontium (mg/l)
TPH GC/FID (ug/l)	Magnesium (mg/l)	Fluoride (mg/l)
Surrogate 2-Fluorobiphenyl (Range %)	Manganese (mg/l)	Sulfate (mg/l)

Concentrate		**Permeate**
Chloride (mg/l)	LAS Surfactants (MBAS) (mg/l)	Total suspended solids (mg/l)
Total suspended solids (mg/l)	TPH GC/FID (ug/l)	Total Phosphorous as P (mg/l)
Ammonia as N (mg/l)	Surrogate 2-Fluorobiphenyl (Range %)	Total Phosphorous rejection
COD (mg/l)	BOD 5 (mg/l)	COD (mg/l)
Total Phosphorous as P (mg/l)	TDS (mg/l)	TDS (mg/l)
Sulfide (mg/l)		

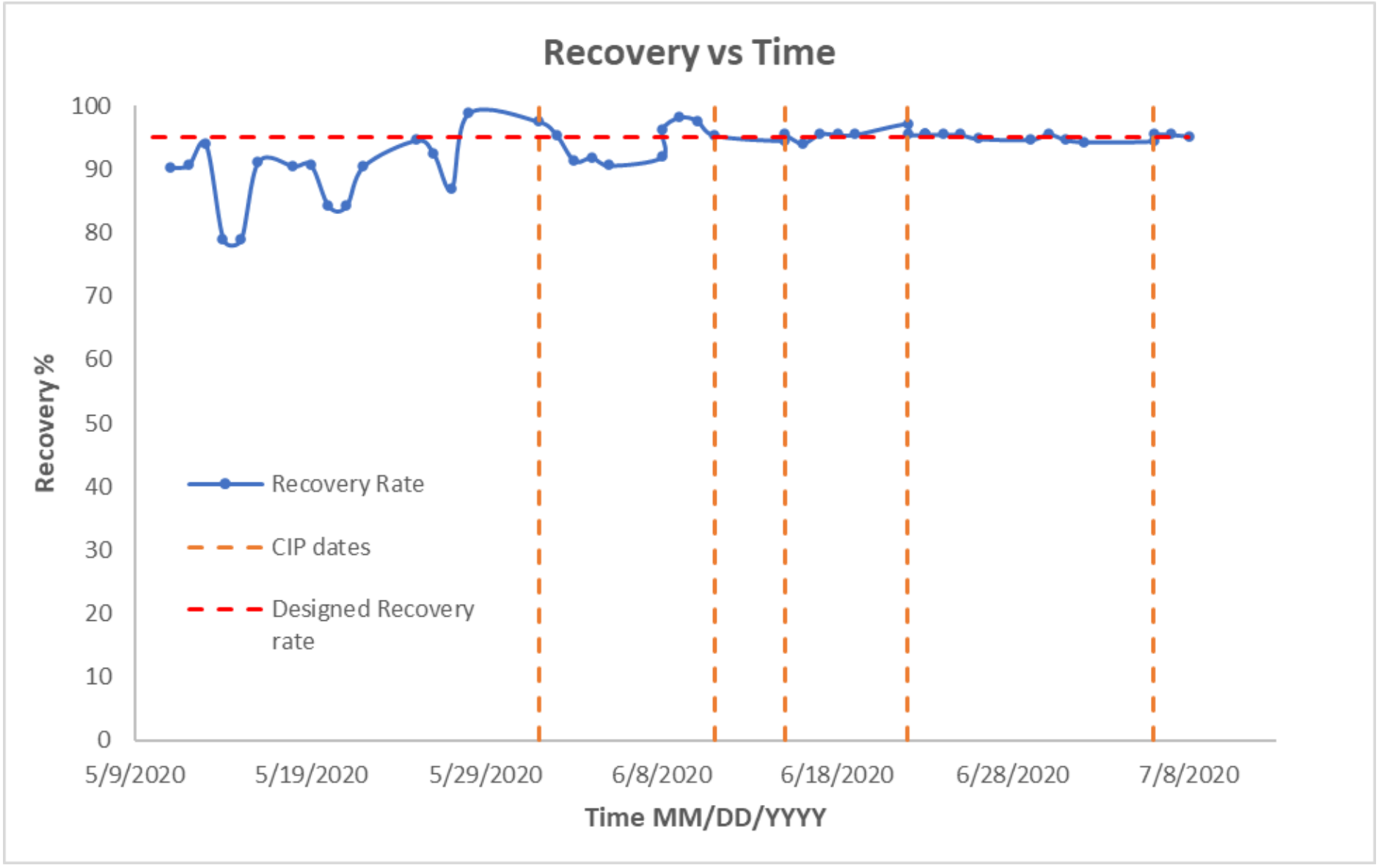
Results and discussion: Feed quality

Summarized Feed Conditions

	pH	TSS	TDS	BOD5	COD
		ppm	ppm	ppm	ppm
Average	7.2	39.5	4327	284	716
Max	10.5	55	11900	510	380
Min	6.9	23	1779	150	110

	Total Orthophosphates	Total phosphates	Surfactants (M.B.A.S)	Total Calcium	Temperature
	ppm	ppm	ppm	ppm	Deg. Celsius
Average	1158	760	0.9	13.25	27
Max	2040	1200	1.2	16.6	39
Min	530	396	0.5	11.6	21

Results and discussion: DTRO Pilot Results



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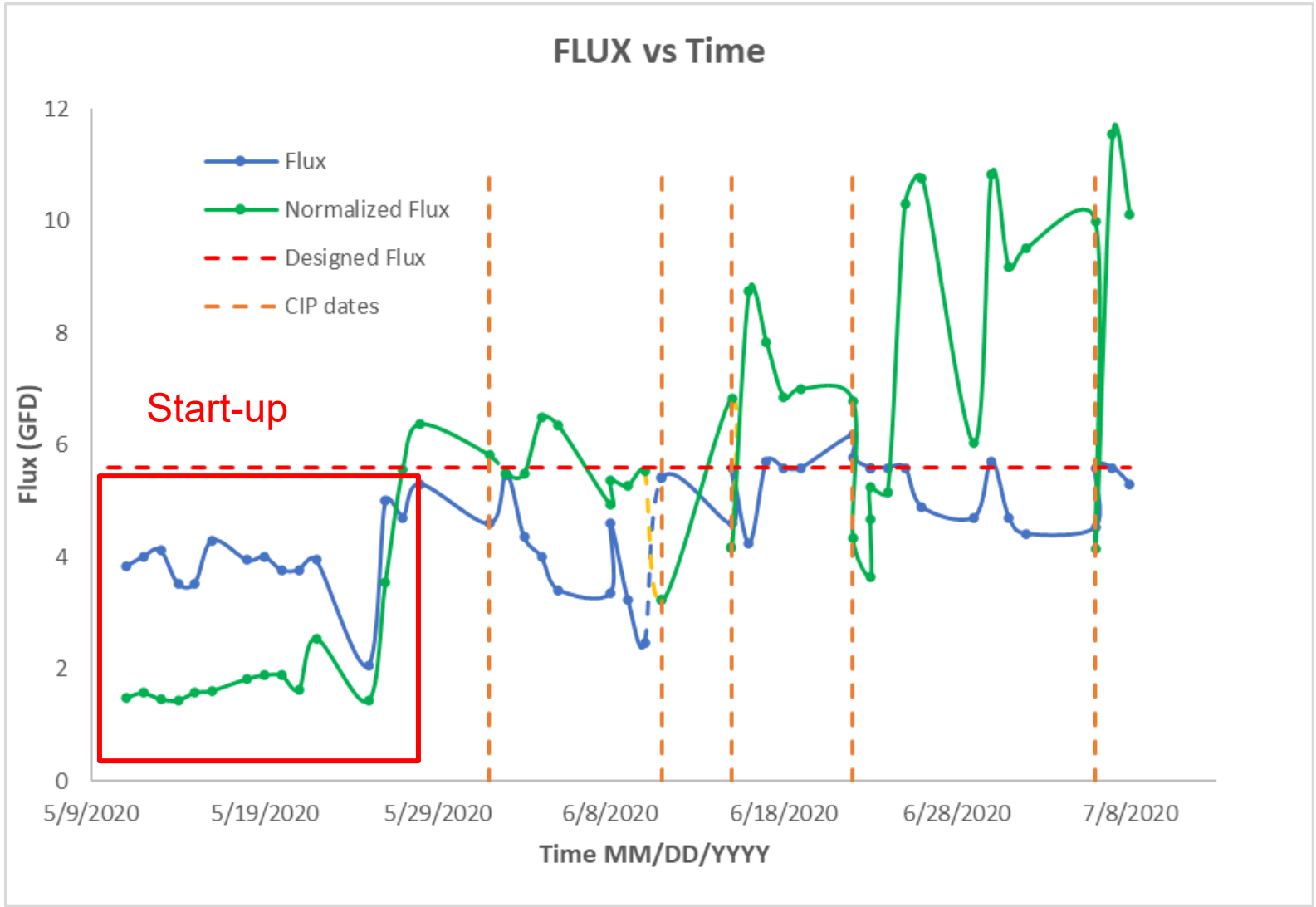

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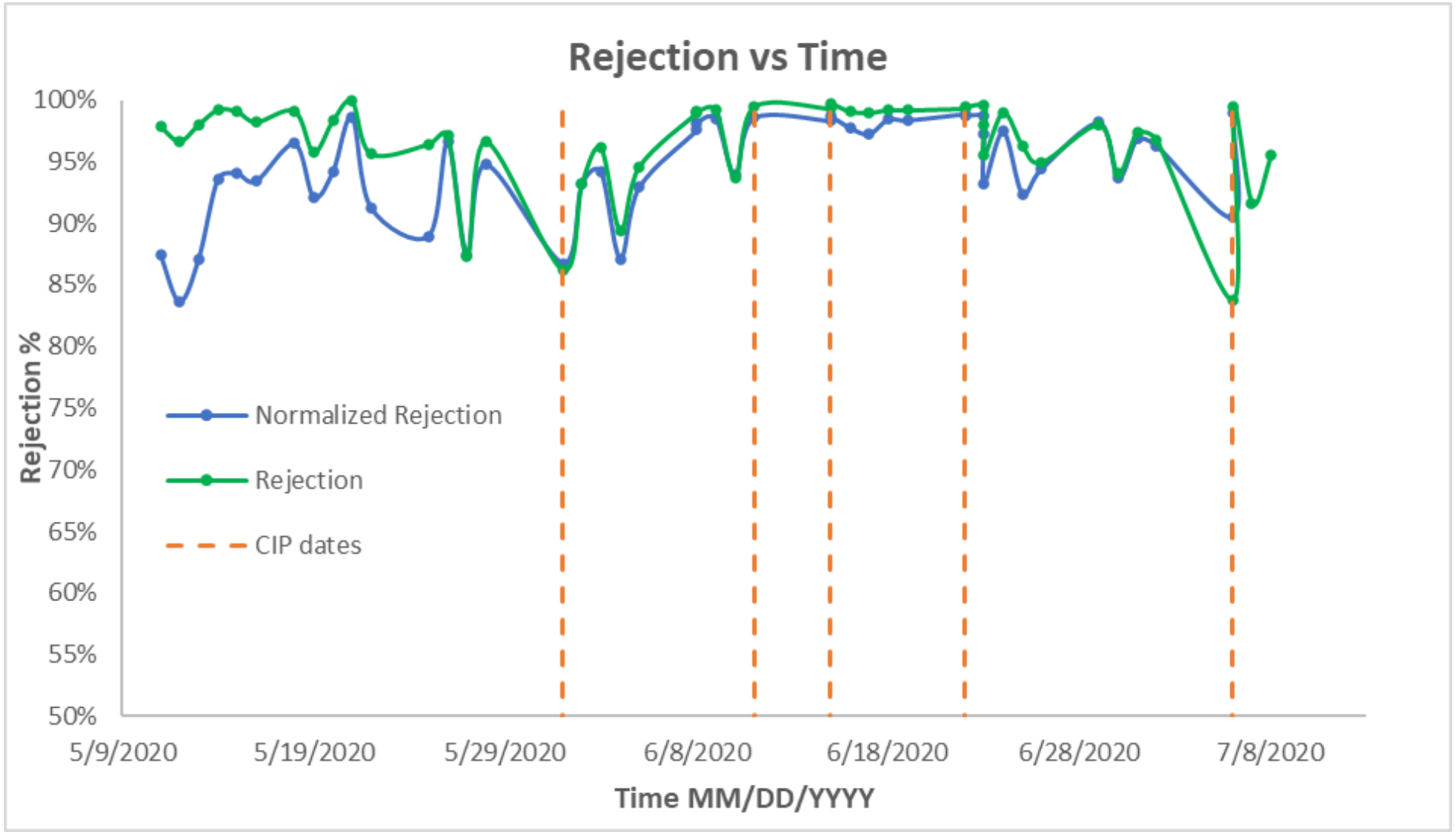

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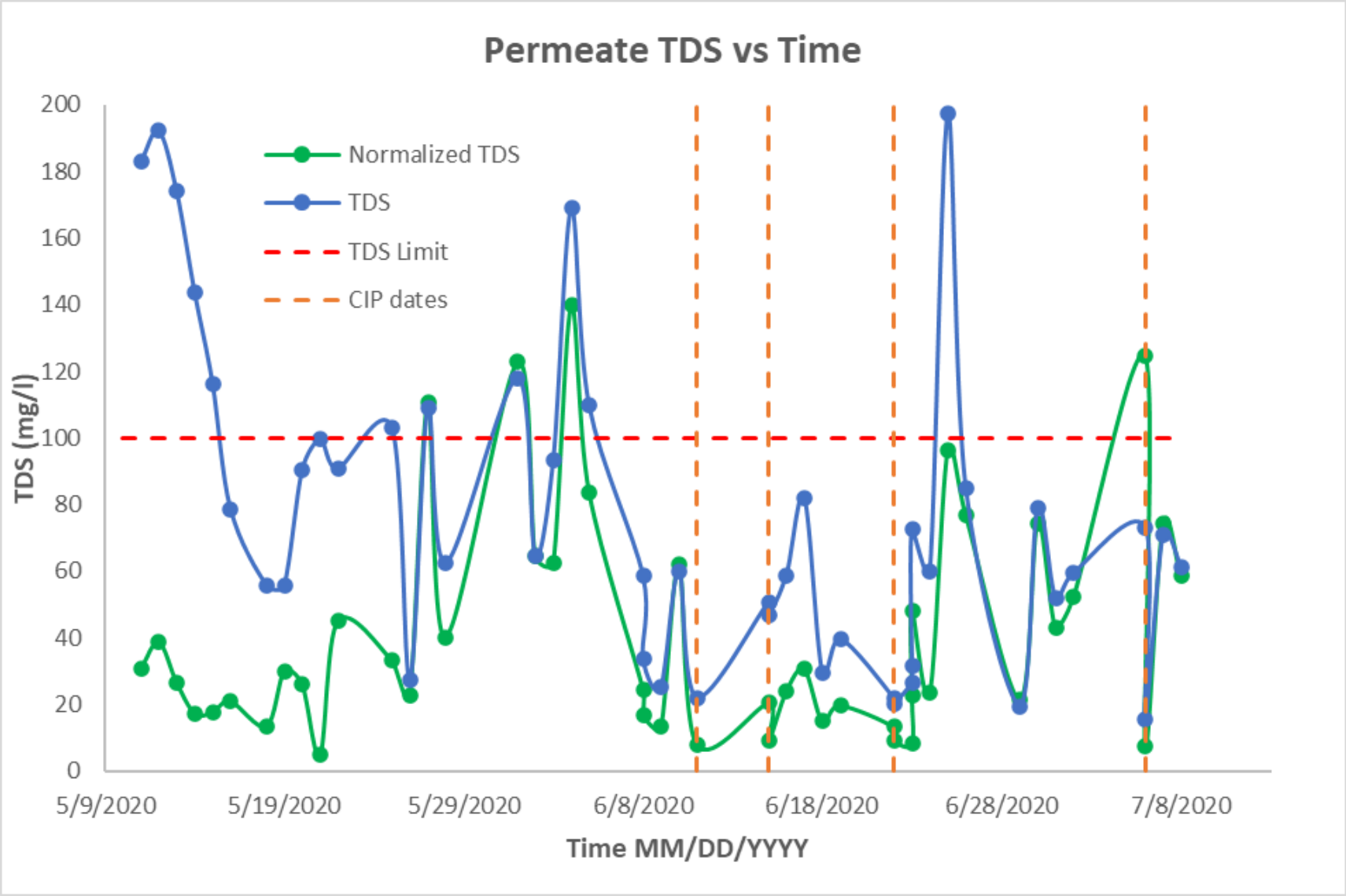

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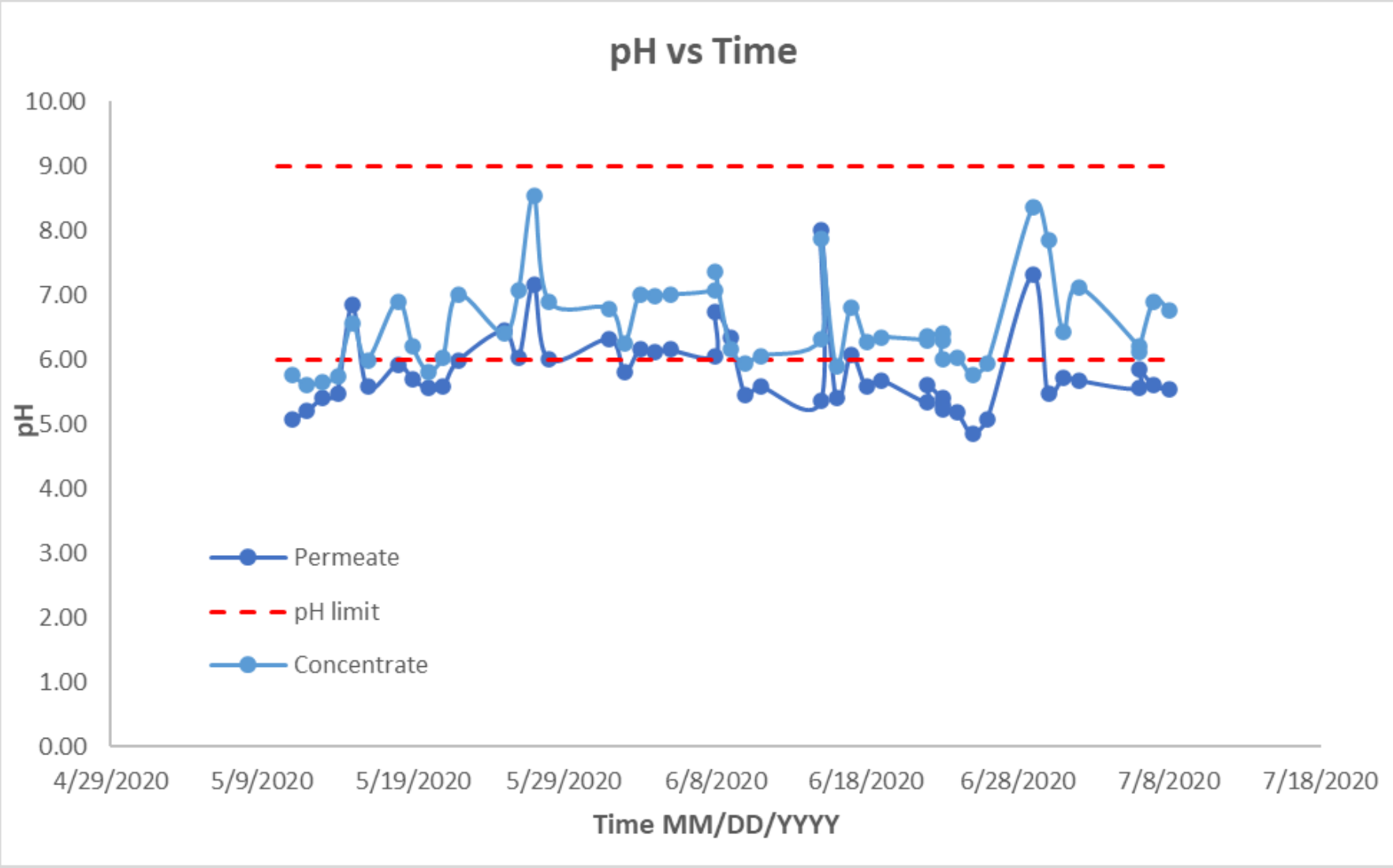


Pilot Results: Permeate quality

Permeate /discharge parameters

	Total Phosphates	COD (mg/l)	TDS (mg/l) Normalized/Standard
Average mg/L	13.95	27.2	41.2/76.4
STD	14	16	33.9/37.4
Desired effluent Limits mg/L	5	100	100
Rejection% Average	96.81%	87.57%	97%

- The COD and phosphate analytical data was not normalized. The normalized values should be lower.
- Permeate quality (average) compliance with desired standards for COD and TDS but showed elevated phosphates.
- Phosphate rejection was 96.82%
- The permeate phosphate exceeded the desired 5 mg/l with an average of 9 mg/l and a polishing RO system will be required.

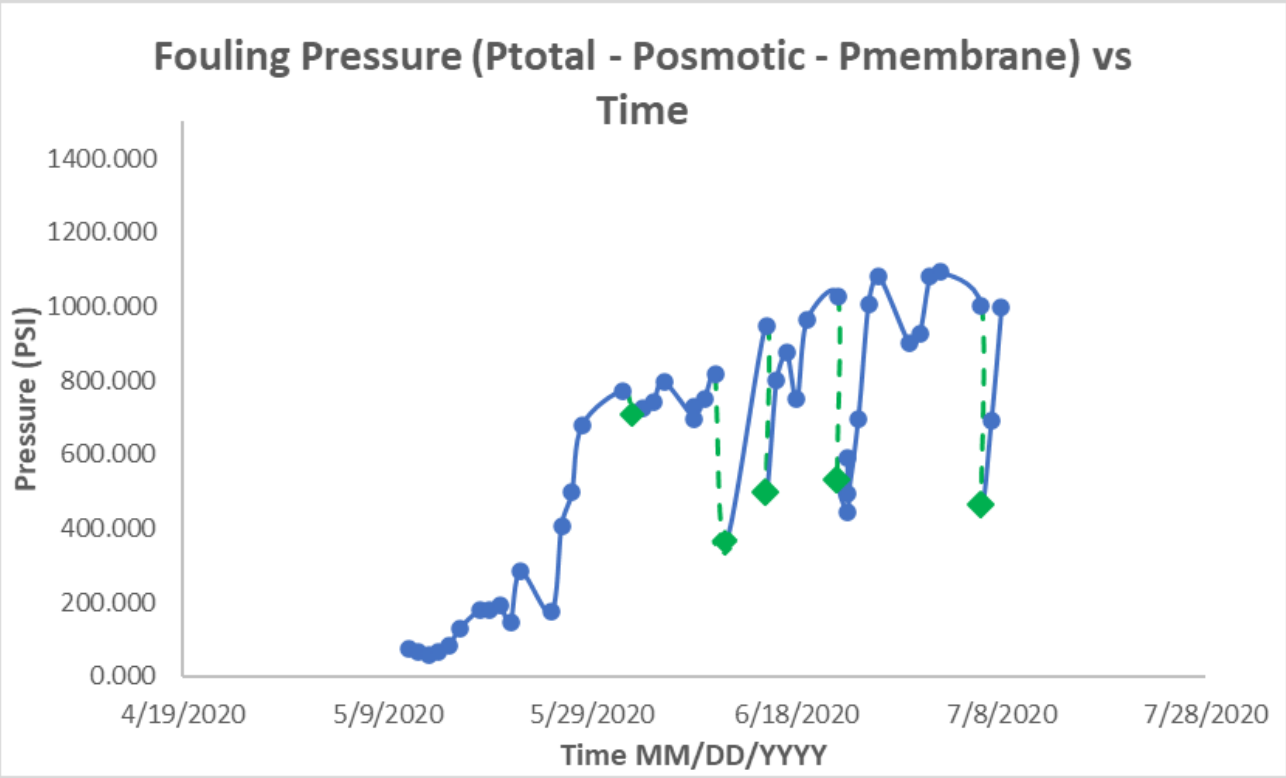
DTRO Pilot Results: Reject

- The reject quality is relevant to the project as it is to be the feed for an evaporator within the ZLD design.

Summarized Reject Conditions

	pH	TSS	TDS	BOD5	COD	Total Phosphorous	Surfactants (M.B.A.S)
		ppm	ppm	ppm	ppm	ppm	ppm
Average	6.8	300	60000	1900	4722	15625	4.8
Max	8.4	610	75000	2300	15000	29000	<1.2
Min	5.9	470	34000	1600	2200	12000	NA

DTRO Pilot Results: CIP and Fouling



CIP Conditions

Description	pH feed	pH reject	Temperature
Caustic: PWT Opticlean B	11.5-12	11-11.5	100 F
Acid: Citric acid	2.5-3.0	3.0-4.0	

Considerations: Biofouling

- Feed BOD data
- Observations of biofilm formation in the pilot system components, especially the filters.
- Observed membrane permeability decline when feed was left in contact with membranes over a weekend
- The fact that CIP primarily required caustic cleaning rather than acid cleaning for membrane permeability recovery
- The smell of anaerobic biofilm existence in the equipment

Conclusions

The pilot plant showed that it was possible to achieve the commercial design. The design for the commercial RO based on pilot results:

- Maintained 95% recovery so that the same evaporator system is installed as per the original design
- The design flux is achievable with 90bar/1340psi STRO4 modules
- This fouling rate would require at least one full CIP (caustic+acid step), possibly two CIP cycles per week. In the worst case, a short daily caustic flush could be required. As such, automated CIP should be incorporated into the STRO system
- Consider a blend tank for the RO concentrate to stabilize feed parameters for the evaporator.
- The antiscalant in the RO concentrate should be considered as it pertains to evaporator design.

Conclusions

- 1-micron disposable media filtration to remove TSS from the STRO feed and reduce biofouling.
- Bio growth is a risk with a 284 mg/l BOD in the RO feed. Bleach can be applied in a contact mix tank. A commercial biocide can be considered additionally for RO feed side dose.
- A highly caustic CIP is required to clean the membrane from organic and biofilm fouling.
- The high pH at high-temperature conditions, followed by an acid CIP, showed the best and most consistent results.
- The frequency of the caustic CIP should be considered to be twice a week depending on fouling conditions, and a daily acidic flush could be required.

Outcome

- The new plant in Shanghai is being constructed and the project is already contracted
- A similar plant is planned to be built in Europe.

Questions?

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- Job Omweno, (603-502-4052)

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