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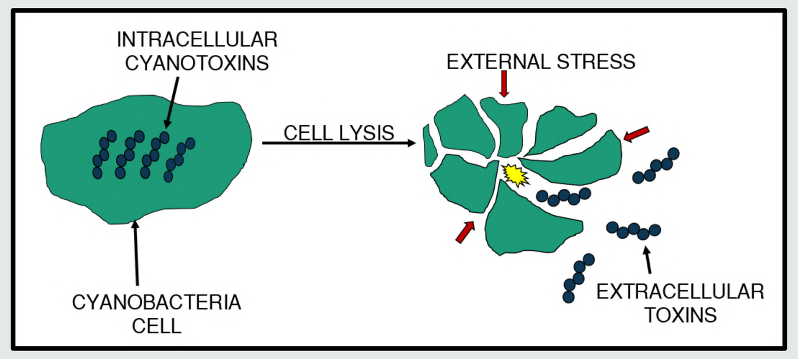
Design of Algae and Cyanotoxin Treatment for the City of Moncton, NB

INTRODUCTION

- In 2017, the City of Moncton Drinking Water Treatment Plant (WTP) experienced a toxic cyanobacterial bloom in two of its main reservoirs. No cyanobacteria or cyanotoxins entered the WTP.
- The City of Moncton would like to optimize its current conventional treatment process to ensure effective removal of future toxic cyanobacterial blooms.

CYANOBACTERIA AND CYANOTOXINS

- Cyanobacteria (also known as blue-green algae) are vigorous bacterial organisms that are capable of producing a variety of toxins (cyanotoxins).



Left: Cyanotoxins are produced in the cell (intracellular). During cell lysis, the toxins are released and become extracellular. Extracellular toxins dissolve in water.

Figure 1 Cyanotoxin release from cyanobacteria cell.

- Four main toxins include: *Microcystin* (MC), *Cylindrospermopsin* (CYN), *Anatoxin* (ANTX), and *Saxitoxin* (STX).
- Canadian Drinking Water Quality Guideline: Total Microcystin < 0.0015 mg/L.

DESIGN PROCESS

- Assessed the resilience of the current treatment plant against cyanobacteria and cyanotoxins.

Table 1 Removal by conventional water treatment.

	Potassium Permanganate	Coagulation/ Flocculation	Clarifier/ Filtration	Chlorine
CYANO	✗	✓	✓	✗
MC	✓	✗	✗	✓
CYN	✗	✗	✗	✗
ANTX	✓	✗	✗	✗
STX	✓	✗	✗	✓

- Conventional water treatment is vulnerable to dense populations of cyanobacteria and cyanotoxins.

Table 2 Removal by alternative water treatment mechanisms.

	UF	NF	DAF	AC	Ozone
CYANO	✓	✓	✓	✗	✗
MC	✗	✓	✗	✓	✓
CYN	✗	✓	✗	✓	✓
ANTX	✗	✓	✗	✓	✓
STX	✗	✓	✗	✓	✗

UF: Ultrafiltration
NF: Nanofiltration
DAF: Dissolved Air Flotation
AC: Activated Carbon

DECISION MATRIX

- Technologies were combined based on their ability to remove cyanobacteria and extracellular cyanotoxins.

Table 3 Decision Matrix of five potential technology options for WTP optimization.

FACTORS	EFFICIENCY OF REMOVAL					HEALTH & SAFETY	ENVIRONMENTAL SUSTAINABILITY	COST	TOTAL
	CYANO	MC	CYN	ANTX	STX				
Weight	**8**	**8**	**8**	**8**	**8**	**15**	**10**	**35**	**100**
UF/NF	7	10	10	10	10	8	3	1	59
DAF/NF	10	10	10	10	10	8	4	2	64
PAC/DAF	10	9	9	9	9	6	9	9	70
DAF/ GAC Filter	10	9	9	9	9	8	7	3	64
DAF/ GAC Column	10	9.5	9.5	9.5	9.5	7	8	2	65

WHY PAC AND DAF?

- PAC provides effective removal of dissolved extracellular cyanotoxins at a low cost (approximately $400,000).
- PAC can be applied only when required. Expected PAC application will occur during May-August.
- DAF is more effective at handling heavy cyanobacteria blooms than conventional clarification.
- PAC may form an explosive dust air-mixture, which can be ignited by heat or flame. With proper storage and handling, risks are mitigated.

PROCESS FLOW DIAGRAM

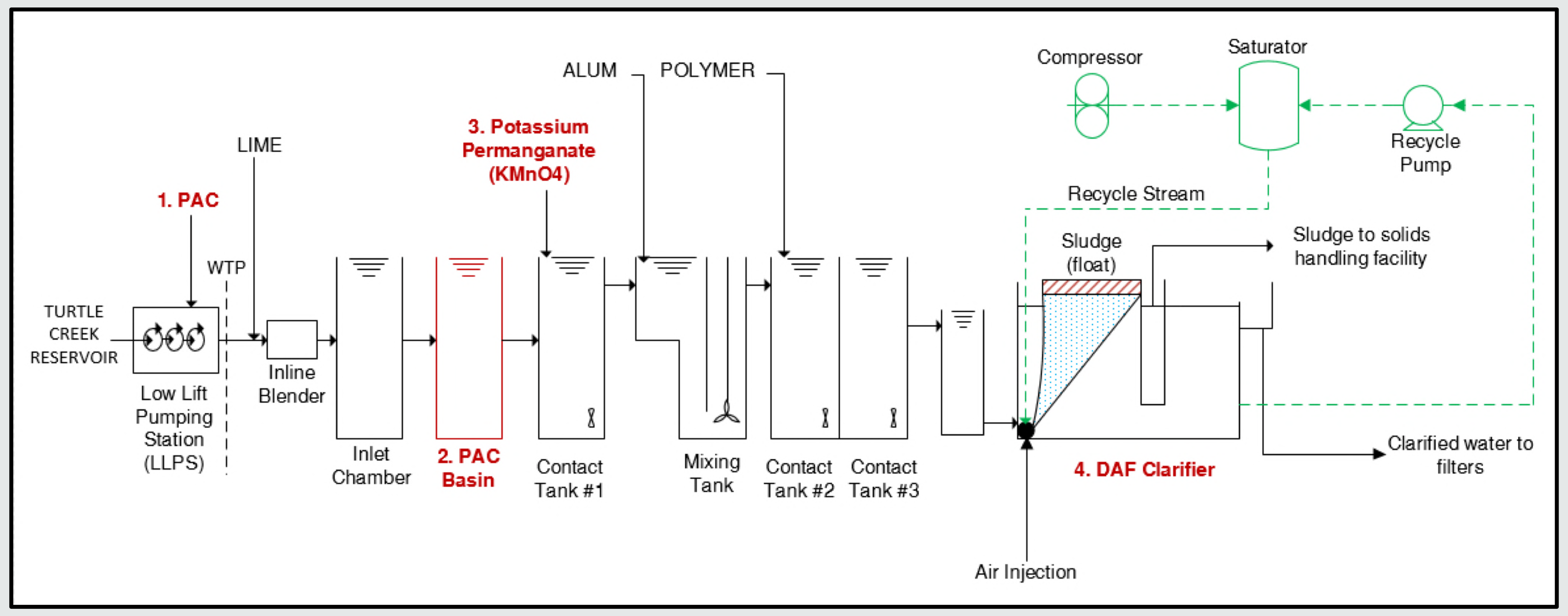


Figure 2 Unit Process Flow Diagram with addition of PAC and DAF.

Modifications to Current Process

1. PAC Feed System added at the LLPS.
2. PAC Basin added after inlet chamber for PAC mixing.
3. $KMnO_4$ moved from LLPS to Contact Tank 1.
4. High-rate Clarifiers retrofitted to DAF Clarifier.

CONSTRUCTION SCOPE FOR WATER TREATMENT PLANT

- Two clarifiers will be retrofitted to one DAF clarifier to allow for a greater hydraulic retention time.

LEGEND

C	Clarifier (x4)
F	Filter (x4)
	Footprint of Existing Plant
	Footprint of DAF Retrofit
	Extension to Plant for DAF Equipment
	Footprint of PAC Basin
---	Main Water Flow to Clarifiers

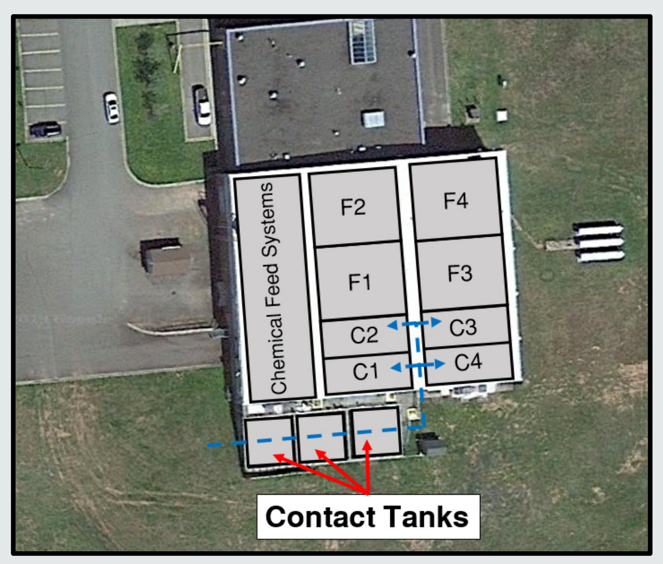


Figure 3 Current Water Treatment Plant Layout

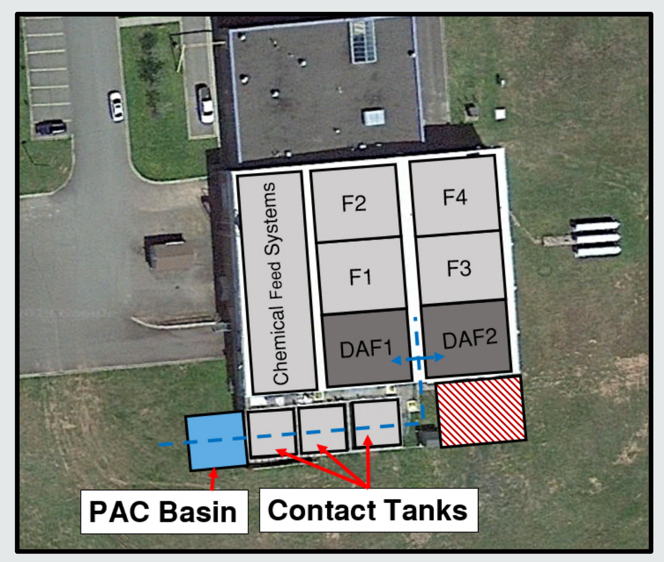


Figure 4 Proposed Plant Layout with DAF Clarifiers

DESIGN SPECIFICATIONS

Table 4 PAC Feed System at the Low Lift Pumping Station.

PAC FEED SYSTEM AND BASIN	
Parameter	Average
Average Flow Rate (m^3/hr)	57.8
PAC Basin Hydraulic Retention Time (min)	13
Total Contact Time of PAC (min)	40
Average Dose (mg/L)	10-15

- PAC should not be added concurrently with $KMnO_4$ or alum.
- Total recommended contact time is 15-30 minutes.
- Average dose was calculated using a factor of safety of 2 to account for competition with Natural Organic Matter.

Table 5 Design Specifications per DAF Clarifier.

DAF CLARIFIER	
Parameter	Average
Flow (m^3/day)	57, 800
Hydraulic Retention Time (min)	25
Hydraulic Loading Rate ($m^3/m^2/hr$)	19
Recycle Rate (%)	10
Saturator Pressure (psi)	60-90

RECOMMENDATIONS

PERFORM	INSTALL	APPLY
PAC Jar Testing	Monitoring Station at LLPS	Wood-based PAC

CONCLUSION

- The addition of PAC and DAF at the WTP will optimize the current treatment process.
- Cyanobacteria and cyanotoxin concentrations will be reduced to levels below the Canadian Drinking Water Quality Guidelines.

ACKNOWLEDGEMENTS

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