Design of WTP Waste Residuals Treatment for Yellowknife, NWT

DALHOUSIE UNIVERSITY
FACULTY OF ENGINEERING

CITY OF YELLOWKNIFE

Department of Environmental Engineering

Thomas Bellows, Triston Hall, Tianyoumei Gao, Michael Neal & Tiannie Paul

Yellowknife Water Treatment Plant

Scope of Work

Background

- The Yellowknife Water Treatment Plant utilizes low-pressure microfiltration (MF) membranes to treat their drinking water.
- As the membranes filter raw water, foulants such as suspended particles, algae, pathogens and bacteria build up on the membrane surface.
- Backwashing clears out built up foulants on the microfiltration membrane surface. There are two types of backwashing: Clean-In-Place (CIP) and Chemically Enhanced Backwash (CEBW), which both use added chemicals.
- CIP and CEBW result in waste residual streams that require treatment of the concentrated foulants and cleaning chemicals.

Objective

- The aim of this project is to treat the waste residuals so that the backwash stream can be discharged into Yellowknife Bay while meeting the *Canadian Water Quality Guidelines for the Protection of Aquatic Life.*

Microfiltration Membranes

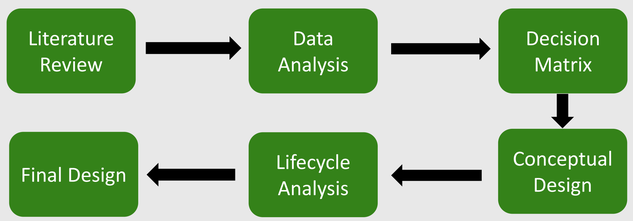
MF membranes remove particles with a pore size diameter greater than 0.1 microns. At the Yellowknife WTP, hollow membrane strands are packed into three racks of pressure vessels. Strained raw water is pumped into the vessels and filtrate is collected within the hollow strands. Foulants accumulate on membrane surface and are removed through backwash processes.

Initial Conditions

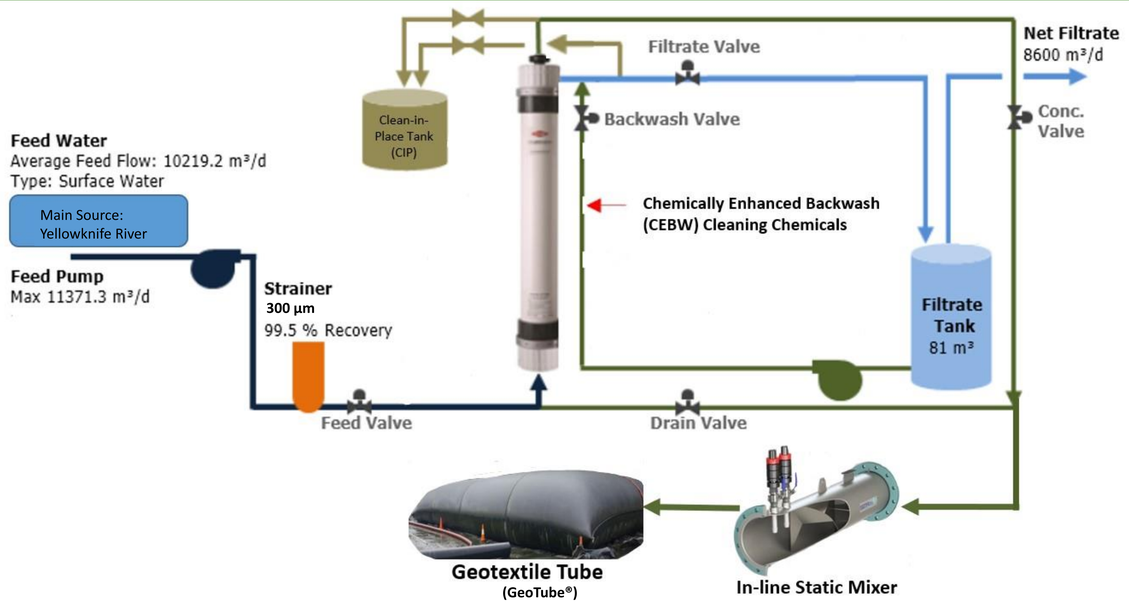
Backwash sampling from Yellowknife WTP, of 2017 and 2018, was taken and tested in lab. Results of main parameters in concern are compared to *Canadian Water Quality Guidelines for the Protection of Aquatic Life* set by Canadian Council of Ministers of the Environment (CCME). The values in red are exceeding the guidelines, and values in green are considered acceptable for discharge.

Parameter	2017 Sampling	2018 Sampling	CCME Guidelines
Aluminum	12.8 mg/L	60.4 mg/L	5 µg/L if pH<6.5 100 µg/L if pH≥6.5
Arsenic	2.2 µg/L	6.21 µg/L	5 µg/L
BOD	8 mg/L	2 mg/L	N/A but 20 mg/L for wastewater discharge regulatory
Iron	3.7 mg/L	14.8 mg/L	300 µg/L
Lead	2 µg/L	6.96 µg/L	1 µg/L when hardness is 0 to 60 mg/L
pH	7.26	5.56	6.5-9.0
TSS	65 mg/L	539 mg/L	Max increase of 5 mg/L from background level for long term

Design Process



Treatment Train for Waste Residuals Management



The WTP pulls water the Yellowknife River. Water is then pumped into wet wells before begin pushed through a screen mesh strainer and then through the microfiltration membranes. Clean water coming out of the membranes then goes through various fluoridation and chlorination steps before being distributed to the area. The residuals from the CIP & CEBW processes are then mixed with coagulant and flocculated in an in-line static mixer before being pumped into the geotextile tube.

GeoTube®

- Material is woven polypropylene yarn.
- Retains solids larger than 0.43 mm and allows water to pass through.
- As residuals are pumped into the geotextile tube, the number of solids captured increases.
- When the GeoTube is full, it is cut open, dredged, and hauled away.
- Produces dry solids (see figure).
- Produces high quality effluent.

https://bishopwater.ca/tag/geotube/

Solids Production

- The MF system occurs without coagulation and flocculation stages in the existing WTP, so there are not many solids in the backwash.
- Coagulant addition and in-line static mixing stage was designed to make particles stick together to increase contaminant removal.
- Aluminum sulphate (Alum) and polyaluminum chloride (PACl) were considered as coagulants.
- PACl was chosen as it is more efficient, is effective in a wide pH range, requires little alkalinity, and generates less solids.
- A PACl dose of 20mg/L would result in around 1000 kg of solids per year, which is about 3 m³ with 30% solids content after dewatering.

Water!Pro Modelling

- Water!Pro is a software that models various chemical water treatment processes.
- This software considers initial water characteristics such as flow rate, pH, total dissolved solids, water temperature, and many more.
- For the design, the initial backwash sampling data was used as an input in order to model how water quality characteristics would change with chemical addition.
- The main objective was to buffer the pH as it is quite low at 5.56, a more neutral pH allows for PACl to be more efficient.
- With the addition of caustic soda and lime a pH of 7.16 was achieved.

Backwash Water (pH)	Chemical Addition	Dose (mg/L)	Treated Water (pH)
5.56	Caustic Soda NaOH	150	7.16
	Lime $Ca(OH)_2$	150	

Decision Matrix

An options analysis was conducted using the **Analytical Hierarchy Process (AHP)** method in order to compare the different residual treatment technologies.

Evaluation Criteria

- Parameters deemed most important for the ideal residual treatment technology.

Evaluation Criteria	Description
Cost	Unit cost + O&M costs.
Energy Use	Energy used in day-to-day operation.
Maintenance	Frequency and complexity of required maintenance
Footprint	The amount of space required for operation.
Environmental Impact	Encompasses noise, air pollution, groundwater pollution.
Solids Concentration	Concentration of solids at the end of the dewatering/thickening process.

Evaluation Criteria Synthesis

- Comparison matrices and pairwise comparisons were evaluated on a 1 to 9 scale. 1 represents equally preferred options and 9 representing an option extremely preferred over another.
- Yellow indicates technology chosen at the end of AHP analysis.

	Cost	Energy Use	Maintenance	Footprint	Enviro Impact	Solids Concentration
Cost	1	7	7	7	3	1
Energy Use	1/7	1	5	9	1	1/7
Maintenance	1/7	1/5	1	3	1/9	1/9
Footprint	1/7	1/9	1/3	1	1/9	1/9
Enviro Impact	1/3	1	9	9	1	1
Solids Concentration	1	7	9	9	1	1

Lagoon	Plate/Tube	Gravity Thickener	Belt Thickener	Belt Filter Press	Wedgewire Bed	GeoTubes
0.625	0.348	0.425	0.448	0.347	0.569	0.712

Conclusions and Recommendations

- It can conclude that the method of treating waste residuals will result in sufficient effluent water quality. Through the use of GeoTubes, the retention of the contaminants of concern allow for the discharge of treated effluent back into the environment.
- Further recommendations include a more thorough monitoring system for the waste streams, field testing, and lab testing.
- The recommended GeoTube size of 4.5-meters in circumference and 15-meters in length will have a life-span of roughly 7 years.

Acknowledgements

- Dr. Margaret Walsh, P.Eng (Dalhousie University)
- Francois Gascon (Dalhousie University)

References

- Canadian Council of Ministers of the Environment. (2018). *Canadian Water Quality Guidelines for the Protection of Aquatic Life*.
- City of Yellowknife. (2020). Yellowknife Water Treatment Plant Operation and Maintenance Manual.
- Huang, H., Schwab, K., & Jacangelo, J. G. (2009). Pretreatment for low pressure membranes in water treatment: A review. In Environmental Science and Technology.
- Malmrosel, P., Lozier, J., Marie, J., Mickley, M., Reiss, R., Russel, J., Schaefer, J., Sethi, S., & Worley, J. (2003). Committee report: Residuals management for low-pressure membranes. Journal / American Water Works Association.
- Schlichter, B., Mavrov, V., & Chmiel, H. (2003). Study of a hybrid process combining ozonation and membrane filtration - Filtration of model solutions.