Presenters:

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Successes of The City of Calgary's Leachate Treatment Pilot Plant, and Use of Treated Leachate to Build a Greener Future

Background

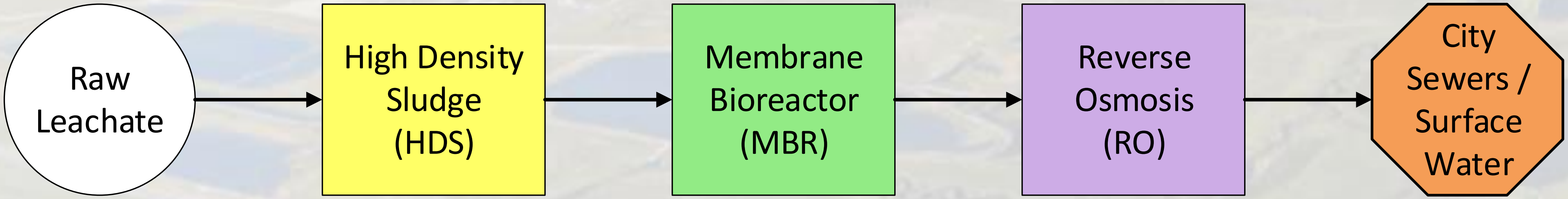
- In the late 1990s, the City of Calgary (the City) began managing leachate from its East Calgary Waste Management Facility (WMF) by collecting it and trucking it to the Bonnybrook wastewater treatment plant (WWTP)
- Leachate contains a wide array of contaminants:
  - Dissolved and colloidal solids,
  - Heavy metals
  - Organic and inorganic compounds

Background (continued)

- Leachate treatment technology evaluation
  - CH2M was retained by the City to develop a treatment process that could achieve compliance with City's Sewer Bylaw requirements
- Bench-scale testing:
  - CH2M design and completed bench-scale tests to evaluate treatment requirements and support treatment technology selection
- Bench test results:
  - Determined multiple technologies are required to achieve treatment requirements
- Field-scale pilot test:
  - Design a long-term pilot study to evaluate selected technologies

Treatment Process Overview

- Conceptual/preliminary design of pilot plant:
  - The treatment process consisted of three integrated technologies operating in sequence,
  - Each technology addresses a specific contaminant type of waste from the leachate



A High Density Sludge (HDS) Process

- Reduce heavy metal loading

Membrane Bioreactor (MBR) Process

- Reduce organic and nitrogen loading

Two-stage Reverse Osmosis (RO) Process

- Reduce Boron loading and final polishing
- Meet the City’s sewer bylaw discharge standards
- Meet surface water discharge limits

The City Identified three Objectives for the Pilot Plant

Objective #1: To determine the treatment effectiveness of the pilot plant treating various BOD/COD concentrations of raw leachate to meet:

- Environmental regulation for surface water discharge limits
- City of Calgary's sewer bylaw 9M2015 requirements

  (SCHEDULE "B", Amended Bylaw Number: 9M2015)

The City Identified three Objectives for the Pilot Plant

Objective #2: To determine the effectiveness of each treatment processes to achieve consistent compliance with discharge limitations under normal and through reasonable variations in raw leachate quality and quantity

Objective #3: To capture sufficient data from the study for preparing the conceptual design for a full-scale Leachate Treatment Plant (LTP)

Fabrication and Installation of the Pilot Plant

- Dynatec Systems, Inc. was contracted by The City to fabricate a trailer-mounted pilot system
- CH2M coordinated and provided construction management for the pilot plant, and connection to an existing Tank Farm

Fabrication and Installation of the Pilot Plant

- The three shipping containers, one for each of the treatment processes were installed next to an existing Tank Farm
- The Tank Farm was previously constructed to store raw leachate from the landfill, and was modified to act as raw leachate feed to and waste collection from the pilot plant
- Supporting facilities: office, lab, and a chemical shed
- Pilot plant was commissioned in March of 2014
- City staff operate the pilot plant; CH2M providing operations support and technical advice

Fabrication and Installation of the Pilot Plant

Operation of the Pilot Plant: General

- Pilot plant’s flow capacity: 10 L/min
- Daily volume of leachate treated by the pilot plant: 14 m^3
- Daily estimated volume of leachate generated at East Calgary WMF: 70 - 120 m^3
- There are 3 landfills in Calgary, with estimated daily leachate generation of: 250-300 m^3

Operation of the Pilot Plant: HDS Process

- Purpose of HDS:
  - To reduce heavy metal concentrations to meet the City's bylaw requirements
  - And/or reduce heavy metal concentrations that could be toxic or inhibitory to the microorganisms in the subsequent MBR process
- Why HDS method of chemical precipitation was selected?
  - Because preliminary characterization data indicated that the leachate contained sufficiently high concentrations of dissolved metals for sludge densification.
  - The HDS process is a modification of the conventional lime precipitation designed to densify the sludge, substantially reduce the volume of sludge requiring management, minimize equipment and pipeline scaling problems, and improve sludge dewaterability

Operation of the Pilot Plant: MBR Process

- Purpose of MBR:
  - To biologically degrade soluble, colloidal and particulate contaminants present in the pretreated leachate from the HDS system

- MBR bioreactor:
  - The vessel where microbial biomass treats (biodegrades) organic substances and nitrogen compounds
  - Divided into two reaction zones in series: a smaller anoxic zone and a larger aerobic zone
  - The mixed liquor in the anoxic zone is kept in suspension by a circulating pump, while the mixed liquor in the aerobic zone is oxygenated and kept in suspension by a fine-bubble aeration system

Operation of the Pilot Plant: RO Process

- Purpose of RO:
  - To remove boron, ions, dissolved solids, and non-volatile, non-degradable organics
  - The RO system may be required to meet regulatory requirements for direct discharge to surface water
- Process operation:
  - Consists of a two pass system, where the first pass permeate is fed to the second pass RO system
  - Concentrate from the second pass is recycled to the first pass feed
  - The concentrate from the first pass is discharged by gravity to a RO concentrate tank, and then pumped the waste tank
  - The second pass permeate represents LTPP final effluent.

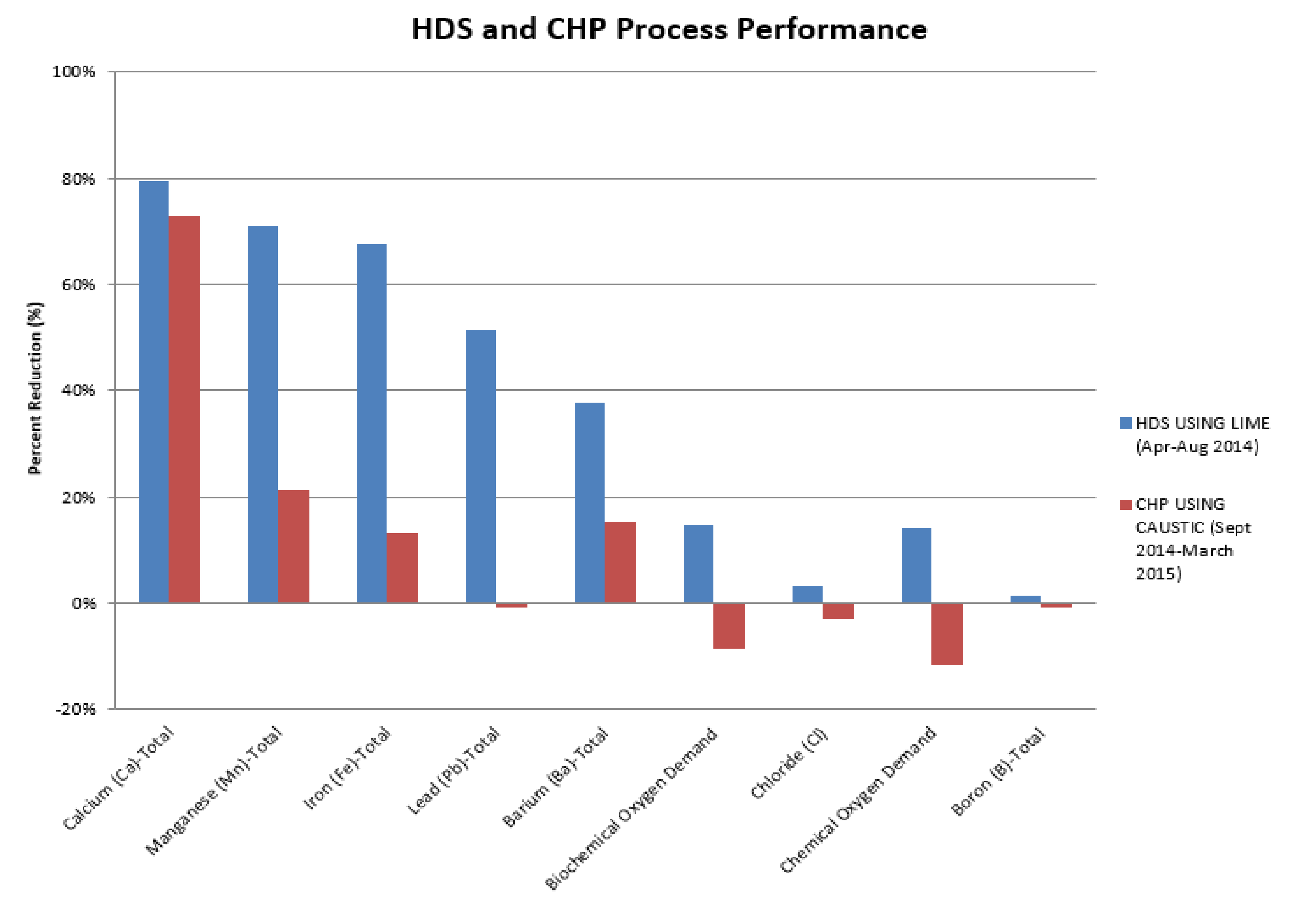
Results

- Chemical Precipitation (CP) Process:
  - Due to a number of clogging issues, spillage, and overflows from the process led to shutting down the treatment on several occasions
  - The ongoing clogging issues led to a decision to modify the HDS process to a conventional hydroxide precipitation (CHP) process
  - Difference between HDS and CHP process:
    - HDS configuration uses a small mixed reactor to contact the alkali reagent and recycled solids before blending the alkali-conditioned sludge with the influent leachate, whereas the CHP process involves adding the alkali directly to the influent in a reaction tank
  - After switching to the CHP process, the operation of the CP treatment proceeded more smoothly, and the operators continued to operate the CHP process for the remainder of the study

Results

- Chemical Precipitation Process - Results:
  - Overall, the HDS/CHP treatment process provided little value in terms of discharge limit compliance
  - This was due to the fact that the raw leachate metals concentrations were substantially lower than expected based on the previously available leachate characterization data, and the concentrations of most metals were low enough to not require treatment.

Results



HDS and CHP Process Performance
100%
80%
60%
40%
20%
0%
-20%
Percent Reduction (%)
Calcium (Ca)-Total
Manganese (Mn)-Total
Iron (Fe)-Total
Lead (Pb)-Total
Barium (Ba)-Total
Biochemical Oxygen Demand
Chloride (Cl)
Chemical Oxygen Demand
Boron (B)-Total
HDS USING LIME (Apr-Aug 2014)
CHP USING CAUSTIC (Sept 2014-March 2015)

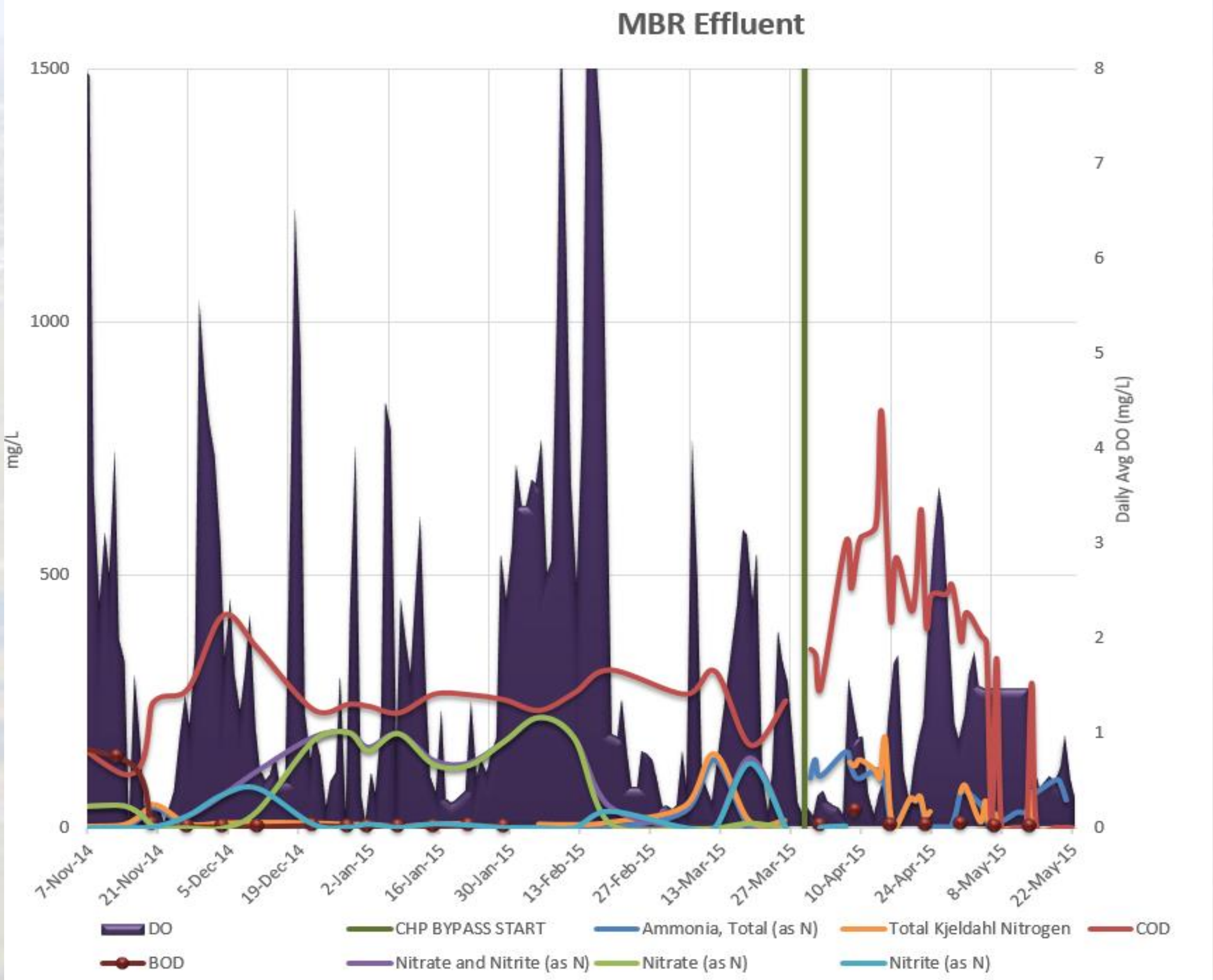
Results

- MBR Process:
  - Efficient removal of BOD and TSS, and nitrification were quickly established
  - However, stable MBR operation was delayed due to:
    - Nitrification failure,
    - Unstable HDS operation,
    - A high influent raw leachate COD,
    - And depressed dissolved oxygen (DO) concentrations.

Results

- MBR Process - Results:
  - MBR process performed reliably and consistently generated a high quality effluent, with low concentrations of the conventional secondary treatment effluent quality parameters – BOD, TSS, COD, and ammonia-nitrogen
  - Nitrification performance was hampered due to aeration deficiencies
  - Complete nitrification was achieved when DO concentrations were above 1.5 mg/L, and failed when DO concentrations were around 1.0 mg/L
  - In cases when nitrification failed because of inadequate aeration, it recovered quickly after adequate DO concentrations were restored in the bioreactor.

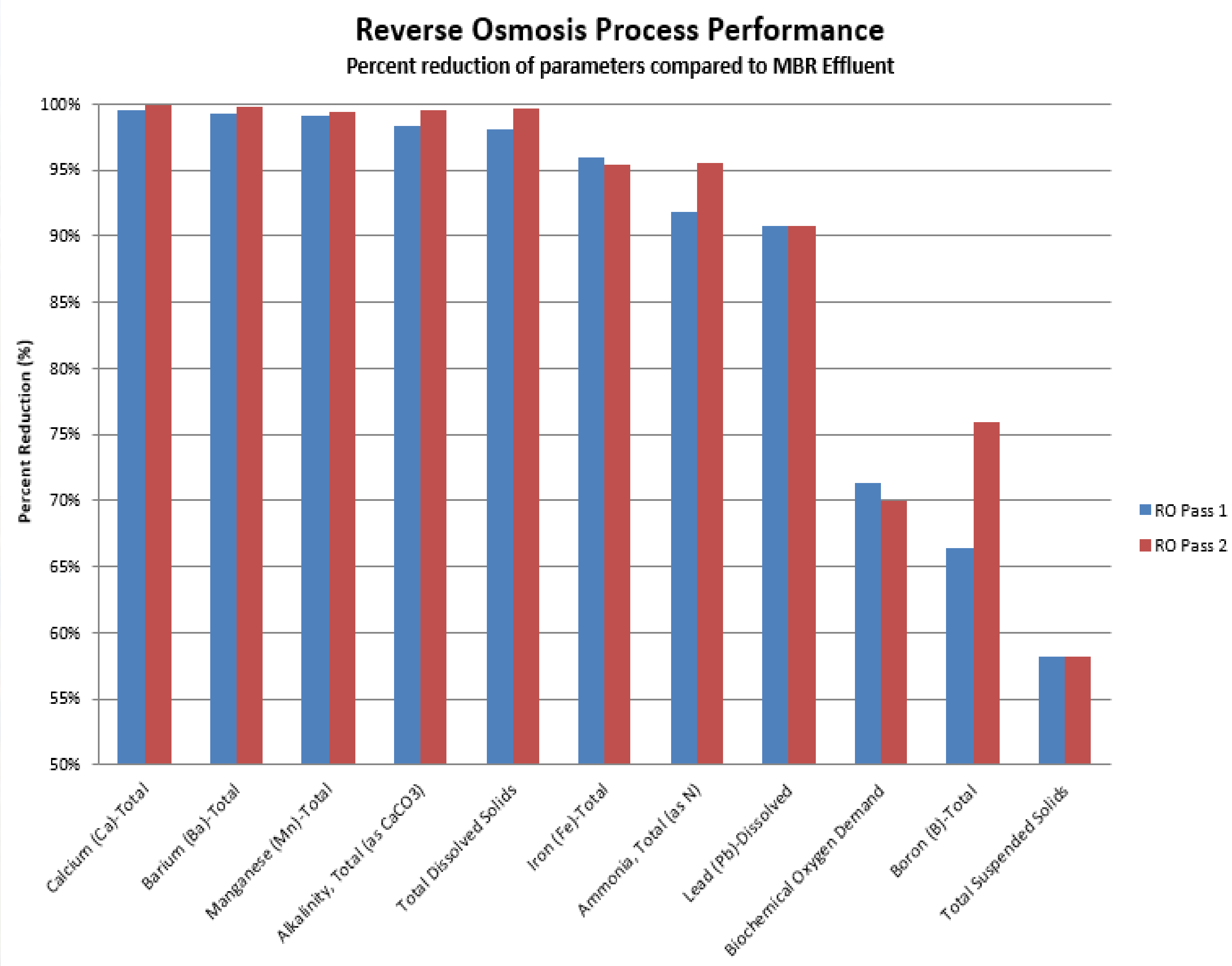
Results


MBR Effluent
1500
1000
500
0
mg/L
8
7
6
5
4
3
2
1
0
Daily Avg DO (mg/L)
7-Nov-14
21-Nov-14
5-Dec-14
19-Dec-14
2-Jan-15
16-Jan-15
30-Jan-15
13-Feb-15
27-Feb-15
13-Mar-15
27-Mar-15
10-Apr-15
24-Apr-15
8-May-15
22-May-15
DO
CHP BYPASS START
Ammonia, Total (as N)
Total Kjeldahl Nitrogen
COD
BOD
Nitrate and Nitrite (as N)
Nitrate (as N)
Nitrite (as N)

Results

- RO Process - Results:
  - The feed water to the RO process was leachate that had been treated by both the HDS and MBR processes.
  - RO's permeate was significantly better than the limits of The City's sewer bylaw requirements. And, on the average, other than for mercury, with a very small variance, the second pass permeate meet the surface water discharge limits
  - The overall recovery of the RO process was about 75% for the most part, indicating that approximately 25% of influent generated a concentrate solution.

Results



Reverse Osmosis Process Performance
Percent reduction of parameters compared to MBR Effluent
100%
95%
90%
85%
80%
75%
70%
65%
60%
55%
50%
Percent Reduction (%)
Calcium (Ca)-Total
Barium (Ba)-Total
Manganese (Mn)-Total
Alkalinity, Total (as CaCO3)
Total Dissolved Solids
Iron (Fe)-Total
Ammonia, Total (as N)
Lead (Pb)-Dissolved
Biochemical Oxygen Demand
Boron (B)-Total
Total Suspended Solids
RO Pass 1
RO Pass 2

Discussions

- Metals concentrations in raw leachate were considerably lower than anticipated based on data available prior to the study
- Therefore, a CP process designed for metals removal may not be needed for East Calgary's leachate treatment system
- Potential reasons for needing a CP process are
  - To meet discharge limits for metals
  - To protect the subsequent MBR system from toxic/inhibition
  - To protect the subsequent RO system from membrane scaling/fouling

However, the results of the LTPP study indicated that none of the potential reasons proved necessary

Discussions (continued)

- The MBR process performed well during the LTPP operation when the HDS/CHP process was offline, and it was concluded that the HDS/CHP process is not essential for pre-treatment to protect the MBR process if metals concentrations remain at the levels observed during this study
- A high quality of effluent was discharged from the MBR process with low concentrations of BOD, COD, TSS and ammonia-nitrogen
- Nitrification performance was contingent on having DO concentrations above 1.5 mg/L in the MBR aerobic tank
- Relatively high concentrations of nitrate/nitrate were observed in the MBR effluent during periods when nitrification was effective, an indication that denitrification was not particularly efficient

Discussions (continued)

- The RO process performed effectively when the HDS/CHP process was offline, however, this process must be preceded by the MBR process for the removal of the organics. The fouling of the RO membranes was expected to be more rapid than a typical system due to the high total organic carbon (TOC) concentrations.

Discussions

Table 1: Summary of LTPP Results - May 7, 2014 to May 28, 2015

Parameter	Average Concentration in mg/L						
	City of Calgary Sewer By-law[1] 9M2015	Surface Water Discharge Limits[2]	Raw Leachate	HDS Effluent	MBR Effluent	RO Effluent (First Pass)	RO Effluent (Second Pass)
Biochemical Oxygen Demand (BOD)	300		1051	1051	35.8	1.9	2.0
Chemical Oxygen Demand (COD)	600		1977	2035	374	10	15
Oil and Grease	100		12	26.4	2.9	1.1	1.1
Alkalinity, Total, as $CaCO_3$			3467	3463	2822	52.7	18
Ammonia, Total, as N (NH_3-N)		8.43	180	174	38	2.7	1.6
Chloride (Cl)	1,500	120	821	850	736	17.2	0.71
Fluoride (F)	10		0.43	0.36	0.667	0.1	0.027
Nitrate, as N (NO_3-N)		3	0.44	0.27	34.3	1.6	0.12
Nitrate and Nitrite, as N (NO_3+NO_2-N)			0.47	0.32	52.5	2.2	0.33
Nitrite, as N (NO_2-N)		0.20	0.13	0.17	18.4	0.6	0.20
Phosphorus, Total Dissolved (P)	10		1.6	1.0	8.2	0.025	0.005
Sulphate (SO_4)	1,500	429	623	581	647	4.0	0.30
Total Kjeldahl Nitrogen (TKN)	50		227	209	53	3.3	1.8
Total Nitrogen (TN)[3]	50		227	209	105.9	5.53	2.14
Total Dissolved Solids (TDS)			5280	5685	4891	104	21
Total Suspended Solids (TSS)	300		136	194	6.81	3.2	3.00
Dissolved Metals							
Aluminum (Al)	50	50	0.0777	0.0645	0.1222	0.0019	0.0018
Antimony (Sb)	5		0.0034	0.0037	0.0033	0.00015	0.0002
Arsenic (As)	1	0.005	0.0218	0.0199	0.0181	0.0002	0.0002
Beryllium (Be)	1		0.0058	0.0066	0.0059	0.0007	0.0006
Bismuth (Bi)	5		0.0007	0.0007	0.0007	0.0001	0.0001
Boron (B)	5	1.5	3.556	3.761	3.528	1.02	0.818
Cadmium (Cd)	0.7	0.00037	0.0001	0.0001	0.00016	0.000014	0.000015
Chromium (Cr)	3	0.0089	0.0327	0.0284	0.01495	0.00018	0.00015
Cobalt (Co)	5	0.0025	0.0074	0.0080	0.00595	0.00015	0.00016
Copper (Cu)	2	0.007	0.0015	0.0016	0.004967	0.0002	0.0002
Iron (Fe)	50	300	3.58	1.13	0.43	0.03	0.03
Lead (Pb)	0.7	0.007	0.000697	0.000690	0.000702	0.0001	0.00008
Manganese (Mn)	5		2.40	0.76	0.37	0.0059	0.0045
Mercury (Hg)	0.01	0.000005	0.000261	0.000139	0.000112	0.00002	0.0000097
Molybdenum (Mo)	5		0.0020	0.0023	0.0030	0.00007	0.0001
Nickel (Ni)	2	0.17	0.0707	0.0725	0.0615	0.0005	0.0002
Selenium (Se)	1	0.001	0.0022	0.00157	0.00167	0.00014	0.00015
Silver (Ag)	0.5	0.0001	0.000134	0.000136	0.000137	0.000015	0.000015
Thallium (Tl)	0.5	0.0008	0.000662	0.000706	0.000665	0.000071	0.000073
Zinc (Zn)	2	0.03	0.058	0.056	0.054	0.006	0.006

1 - According to City of Calgary (2015) Wastewater Bylaw, Bylaw Number 14M2015

2- Based on Alberta Environment (2014) Surface Water Quality Guidelines for Protection of Freshwater Aquatic Life (long-term [chronic] values)

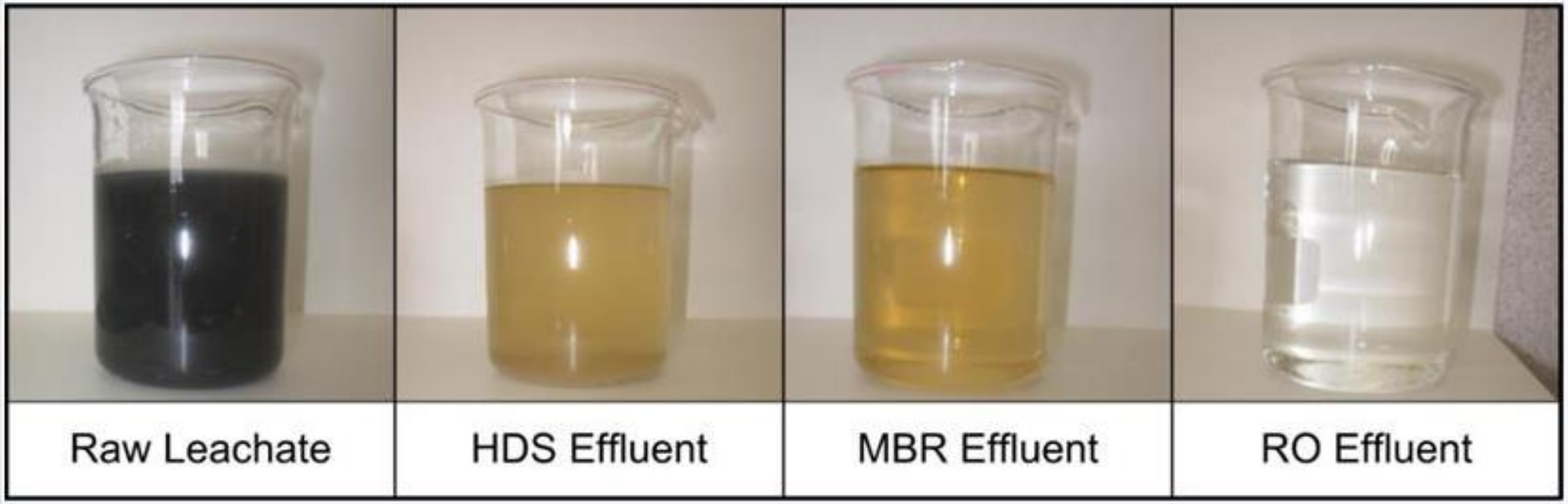
3 - Total Nitrogen (TN) = TKN + Nitrate (NO_3) + Nitrite (NO_2)

4 - Color coding reference:

1051	exceeding sewer by-law limits
180	exceeding surface water discharge limits
623	exceeding both sewer by-law and surface water discharge limits

Treatment effectiveness

- Effluent samples from each treatment process



Using treated leachate as a Resource

A small (2.4 m x 9 m) horticultural greenhouse was constructed in spring of 2015 from recycled materials:

- Glass from the demolition of an old hockey rink, and old television glass screens
- Diverted waste wood from the landfill
- Discarded household sinks serve as containers for tree saplings

Greenhouse Goal

To evaluate how horticultural plants and tree nursery stock respond to the different qualities of treated leachate

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To evaluate how horticultural plants and tree nursery stock respond to the different qualities of treated leachate

Plant Selection

- Drought, cold, heat, and/or salt tolerance,
- Native species and are typically grown or purchased by the City
- Included hardy dusty miller, begonias, petunias, pansies, and snapdragons

Greenhouse Findings

- Plants fed with MBR effluent water survived but did not flourish
- MBR effluent contains high concentrations of TDS, as high as 7,000 mg/L, and an average alkalinity in the range of 3,000 mg/L

Greenhouse Findings

- Plants fed with RO effluent flourished: TDS ~ 20 mg/L on average; alkalinity averaged 18 mg/L
- For the first year of greenhouse operation, the goal was meet by having it up and running and testing horticultural plants
- The plants provided a quick, visual gauge of our successes and failures with the various effluents

Greenhouse Findings

Growing trees:

- Requires a longer-term commitment: the evergreen saplings now growing in salvaged kitchen sinks can be the key to the eventual greening of Calgary’s landfills

Conclusions

- Meet objective #1: To determine the treatment effectiveness of the pilot plant treating various BOD/COD concentrations of raw leachate to meet:
    - Environmental regulation for surface water discharge limits
    - City of Calgary's sewer bylaw 9M2015 requirements
- Meet objective #2: To determine the effectiveness of each treatment processes to achieve consistent compliance with discharge limitations under normal and through reasonable variations in raw leachate quality and quantity
- Meet objective #3: To capture sufficient data from the study for preparing the conceptual design for a full-scale Leachate Treatment Plant (LTP)

Conclusions: Value of the Greenhouse

The greenhouse at the pilot plant has opened the door for exploring opportunities for using treated leachate as a potential resources. It may be one of the first facilities in Canada studying use of treated leachate by:

- Demonstrating how the treated leachate can be used for “greening up” the landfill
- Determining the level of treatment required to produce a useable effluent that is cost effective by determining which treatment processes are required
- Identifying the species of plants and trees that will thrive on treated leachate water

Conclusions: Value of the Greenhouse

- Promoting the use of innovative approaches to handle treated leachate
- Studying the use of treated leachate as a resource rather than a waste
- Reducing the use of The City's fresh water supply as process water
- Reducing the impact and costs to The City, including capital costs, utilities, and operating costs

An invitation:

- Do you manage landfill leachate?
- Are you involved with leachate treatment?
- How do you handle treated leachate from your landfill?

Let's get the discourse going ….

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