Bioelectrochemical Anaerobic Sewage Treatment (BEAST) Technology Offering Promising and Cost-Effective Results for Wastewater Systems

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Problem:

- Smaller, northern municipal wastewater lagoons are not effectively biodegrading sewage waste, causing human and ecological health concerns
- Waste effluent discharge often also contains large amounts of nutrients, causing eutrophication of downstream water bodies

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Lagoon 101: What Do We Do with Our Poo?

Purpose: To treat human waste to a degree safe for releasing the effluent into the environment.

How: BUGS

Waste treatment is a 100% biological process using microorganisms.

Biodegradation increases when food and living conditions are more favorable.

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Lagoon 101: What Do We Do with Our Poo?

Little activity when cold = insufficient treatment
Lots of activity when warm = good treatment!

Traditional Lagoons can vary from having one cell, two cells (usually anaerobic and facultative), or three cells (anaerobic, facultative, and a polishing/stabilization pond as the final treatment).

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Lagoon 101: What Do We Do with Our Poo?

Lagoon operation is regulated by
Code of Practice (AEP, 2003)
Standards and Guidelines (AEP, 2013)
Wastewater System Effluent Regulations (Env. Canada, 2012)

Although the exact requirements differ for each system

Overall a typical healthy lagoon's TSS and BOD effluent is under 25 mg/L

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Bezanson Lagoon History:

Current Bezanson Lagoon:

Single-celled Lagoon

Facultative Lagoon = aerobic (oxygen) + anaerobic (no oxygen)

One year retention (seasonal discharge of effluent)

Effluent is discharged annually and typically released in late spring until 2016

Analytical tests of BOD are completed 24 hours after discharge

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Bezanson Lagoon History:

Community grew to capacity of the lagoon (~25 m^3/day)
Development ceased in community due to lagoon at capacity
Lagoon expansion needed
Submitted grant application in 2012
Received grant in 2017

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Bezanson Lagoon History Continued – The rest of the story

Alternate mixing device installed May 2010
Authorization for a second release was expected with the new device installed but was subsequently not authorized by AEP.

Bezanson Lagoon History:

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Bezanson Lagoon History Continued – The rest of the story

Inspection conducted by AEP in 2015

Additionally, there were complaints of odour from lagoon

Relocation study completed 2015 (KWG Engineering)

- $500K for expansion
- $1.5M for new site
- forecasted community capacity to be ~40 m^3/day

Since 2015, new wetlands classifications make onsite expansion difficult and costly.

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Bezanson Lagoon History Continued – The rest of the story

Lagoon Assessment Study 2016 (Elkan Environmental Eng.)

The study determined the lagoon to be septic, have a water imbalance, and have compacted, deep sludge.

A non-compliant release was reported to AEP due to a muskrat that burrowed into the lagoon berm in August 2016.

Bezanson Lagoon History Continued – The rest of the story

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Bezanson Lagoon History Continued – The rest of the story

Second release granted by AEP as vermin did the first one.
It is suspected that this caused the water imbalance.
Sludge was removed summer 2017.
Sludge removal did not provide the predicted capacity.
Lagoon is at full design capacity and is underperforming due to poor effluent quality.

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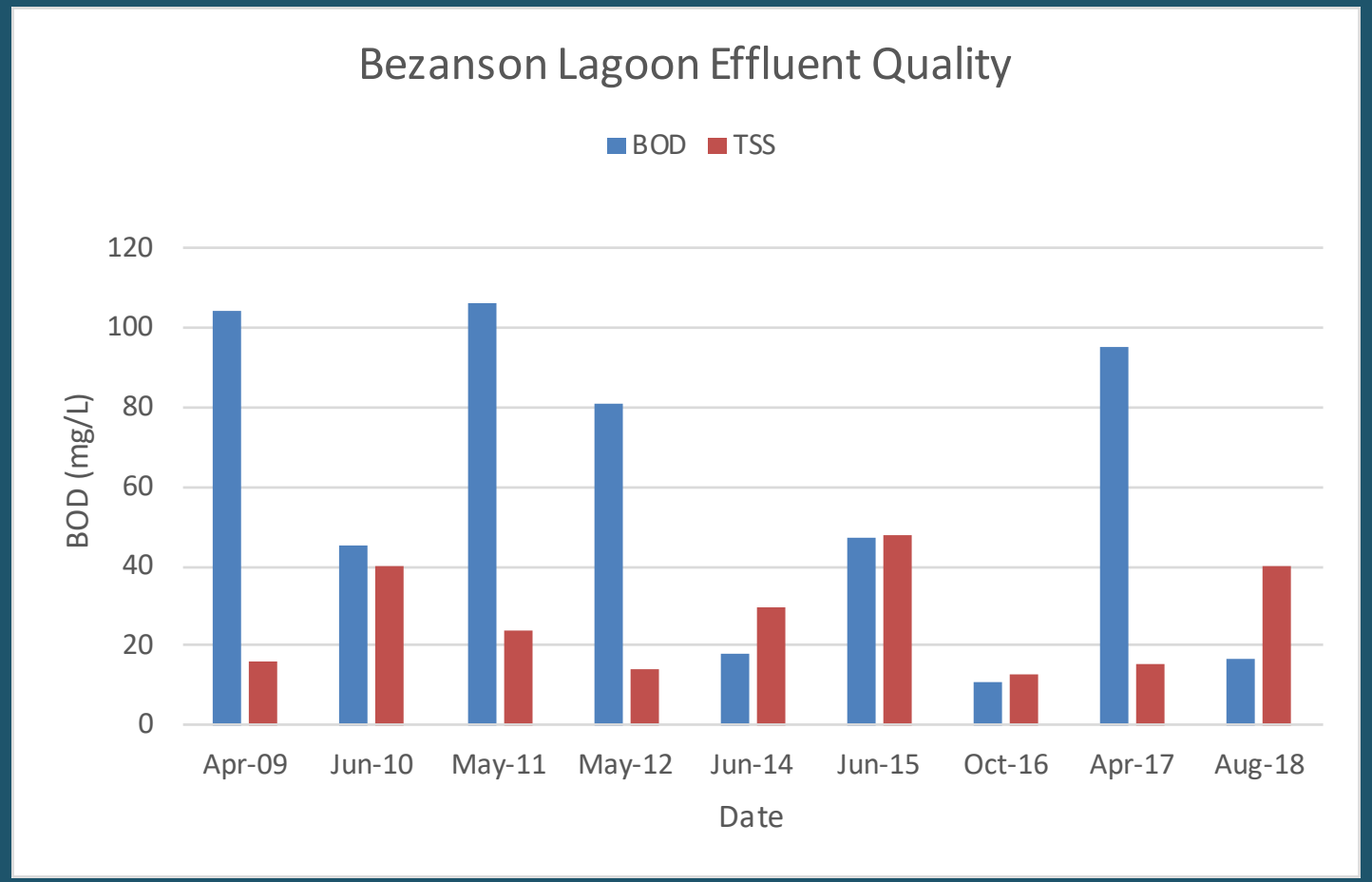

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Summary:

Lagoon is under-capacity and under-performing, so a new or additional system is needed.

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There is a system that can solve both capacity and quality issues:

NRC was looking for a location to pilot a new technology that solves both effluent quality and improves capacity.

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Solution:

- National Research Council (NRC) has developed a Bio-Electrochemical Anaerobic Sewage Treatment (BEAST) technology (US patent application number 15/875,511)
- Focused on energy efficiency and is based on a low-pressure flow (even gravitational) design to reduce energy consumption

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Solution:

- Combines Bioelectrochemical (novel) and Anaerobic (conventional) treatment to increase degradation rates
- Uses micro-aeration for reactor self-heating and ammonium removal
- NRC's technology achieves high effluent quality (BOD/TSS), while other technologies focus on high bio-methane production
- Biomethane recovery can be enabled, and it is economically feasible for larger communities

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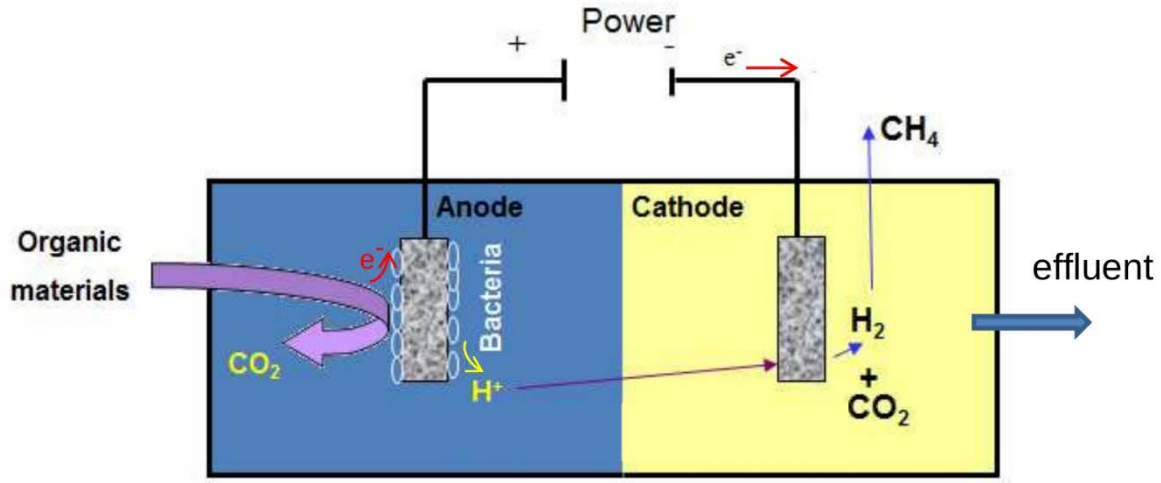
Concept: a low voltage (0.5 - 1.5 V) is applied to enable electron transfer (enhance biodegradation)

Anode reaction (bacteria): Organic materials + water → $CO_2 + n\ e^- + n\ H^+$

Cathode reactions: $8H^+ + 8e^- \rightarrow 4H_2$; $CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$



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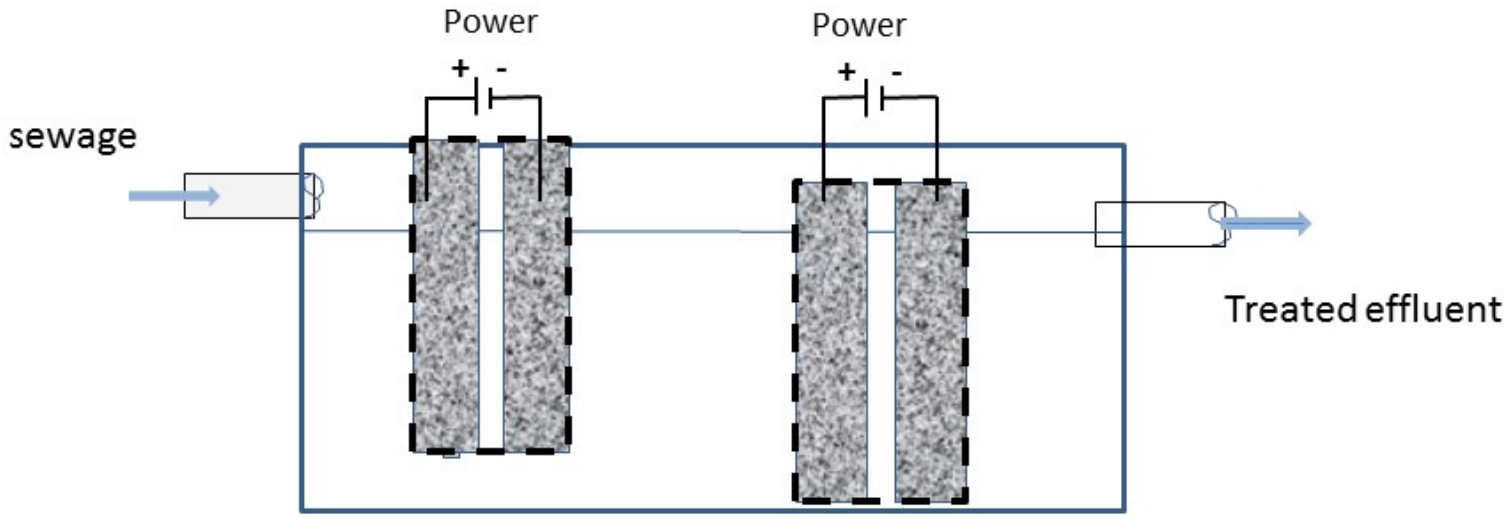

- Reactor design similar to septic tank (simple).
- Porous conductive electrodes.
- Low voltage power supply used to enhance anaerobic degradation of sewage.

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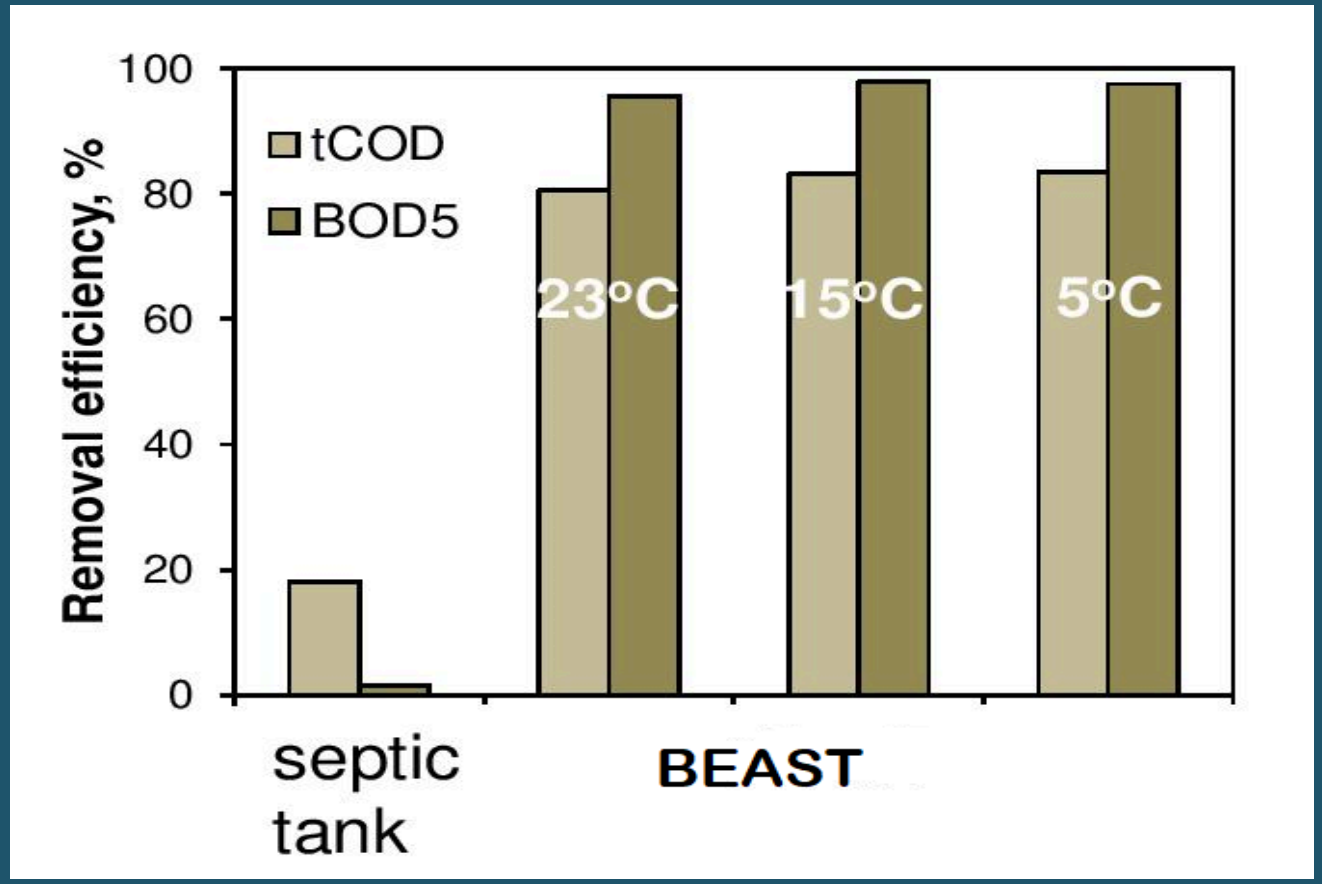

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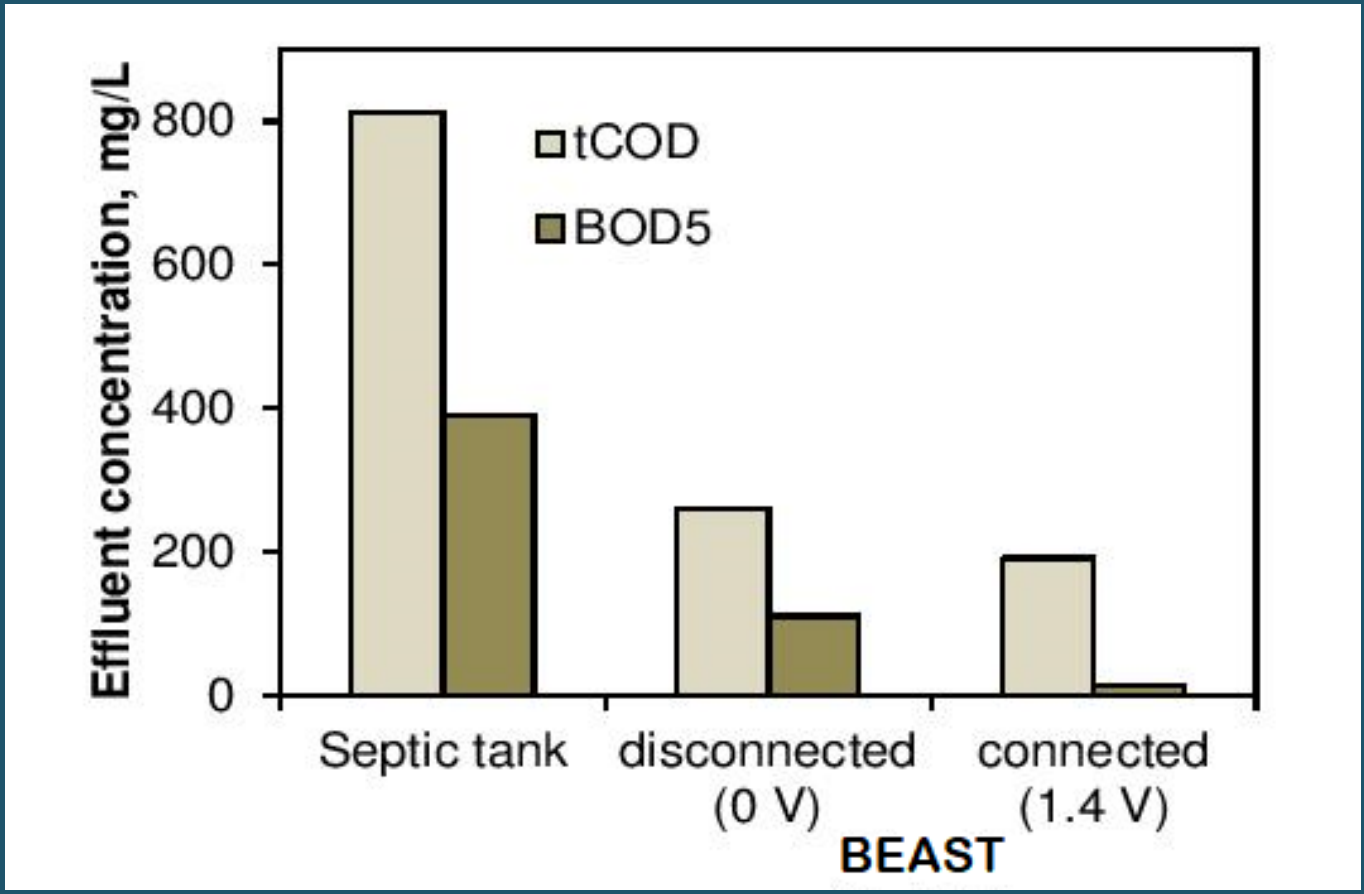

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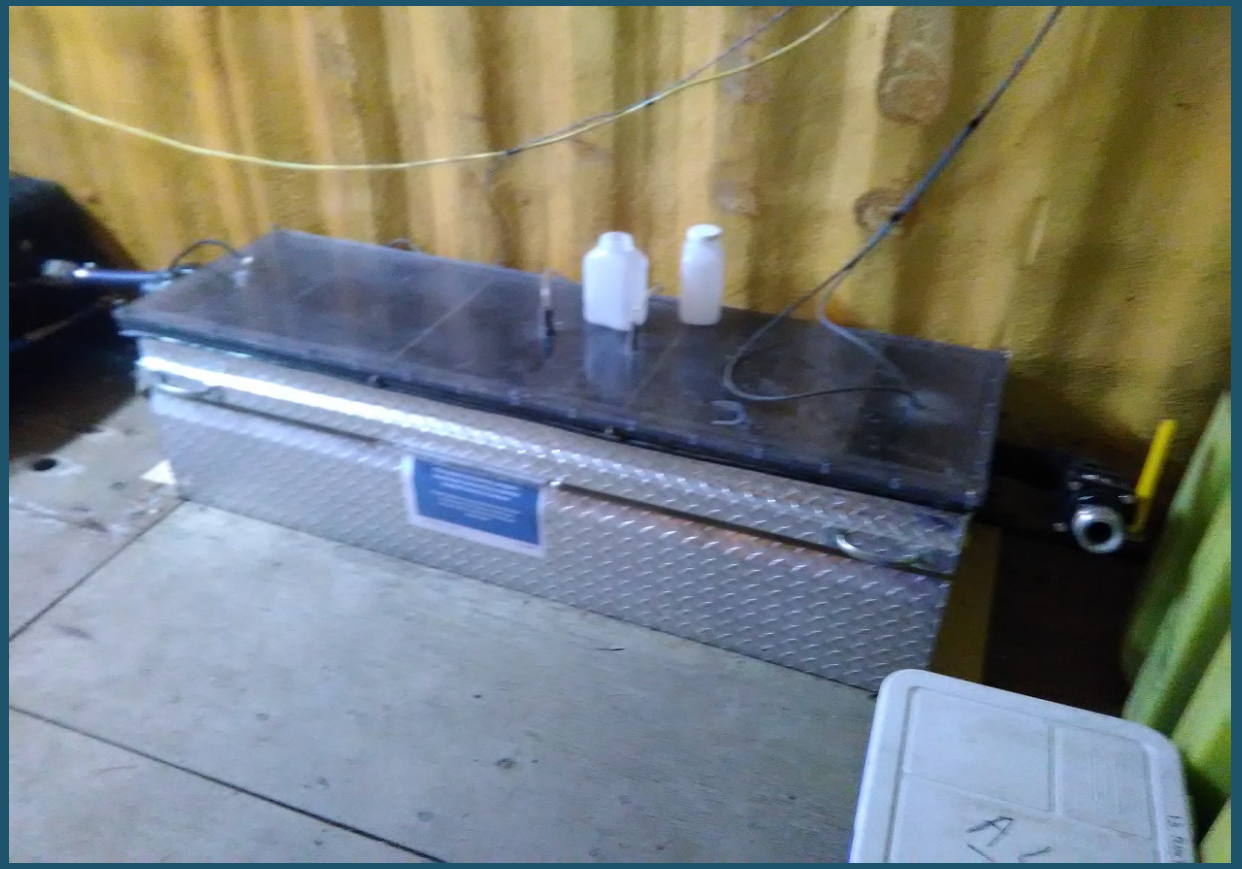
NRC BEAST 240 L Reactor (Bezanson, AB):



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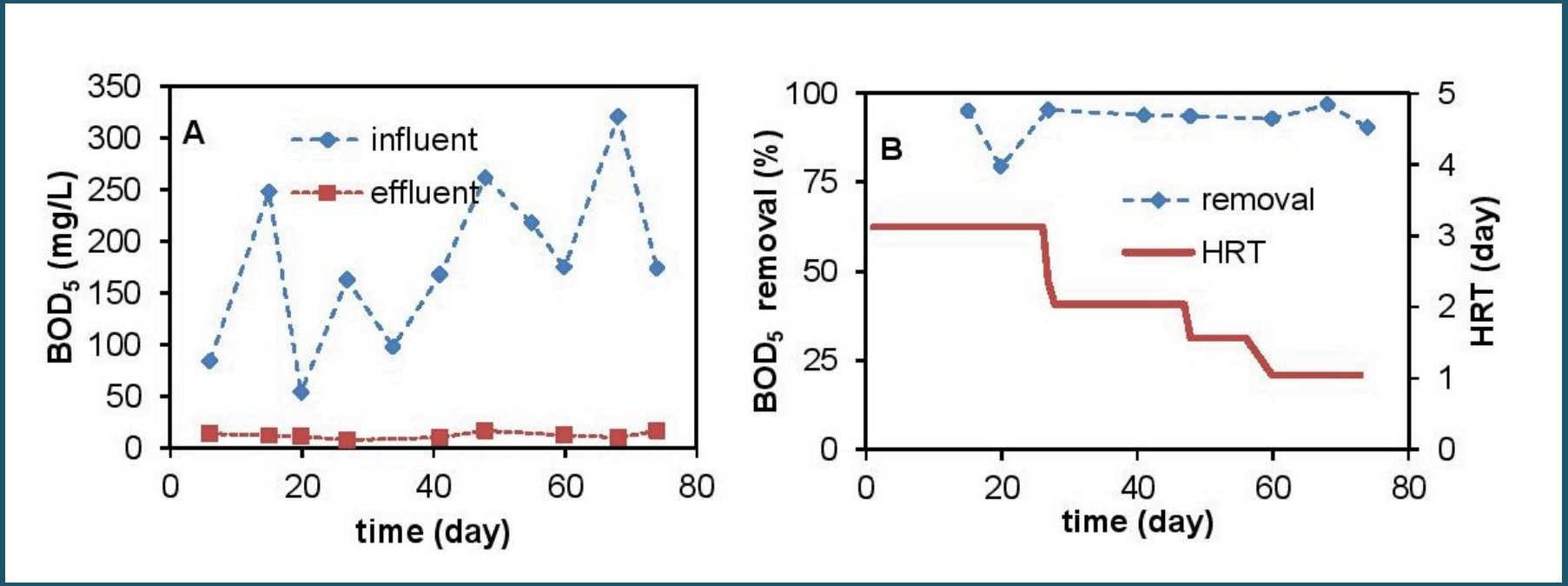

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Elkan-NRC BEAST 2500 L Reactor (Bezanson, AB):

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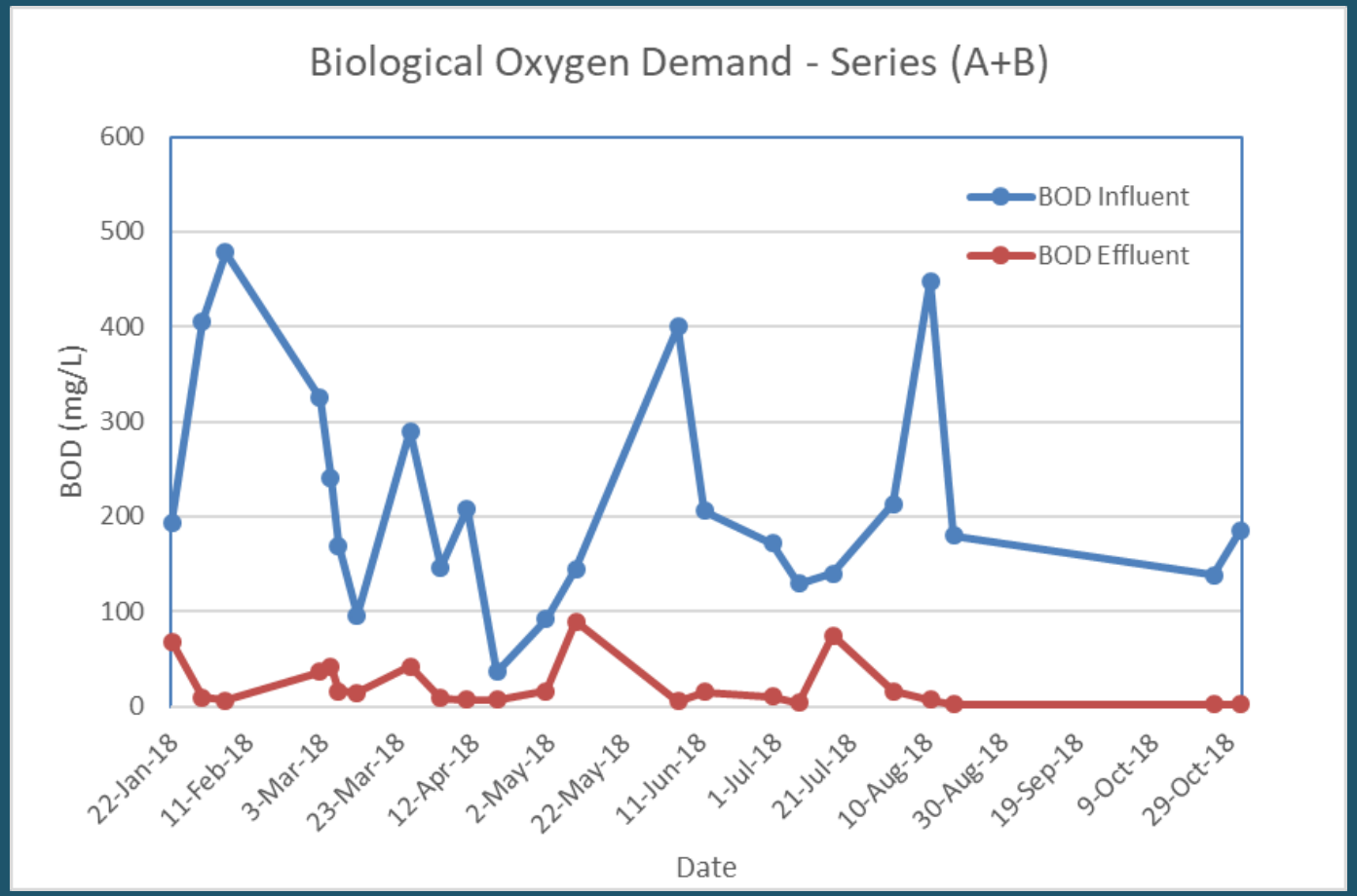

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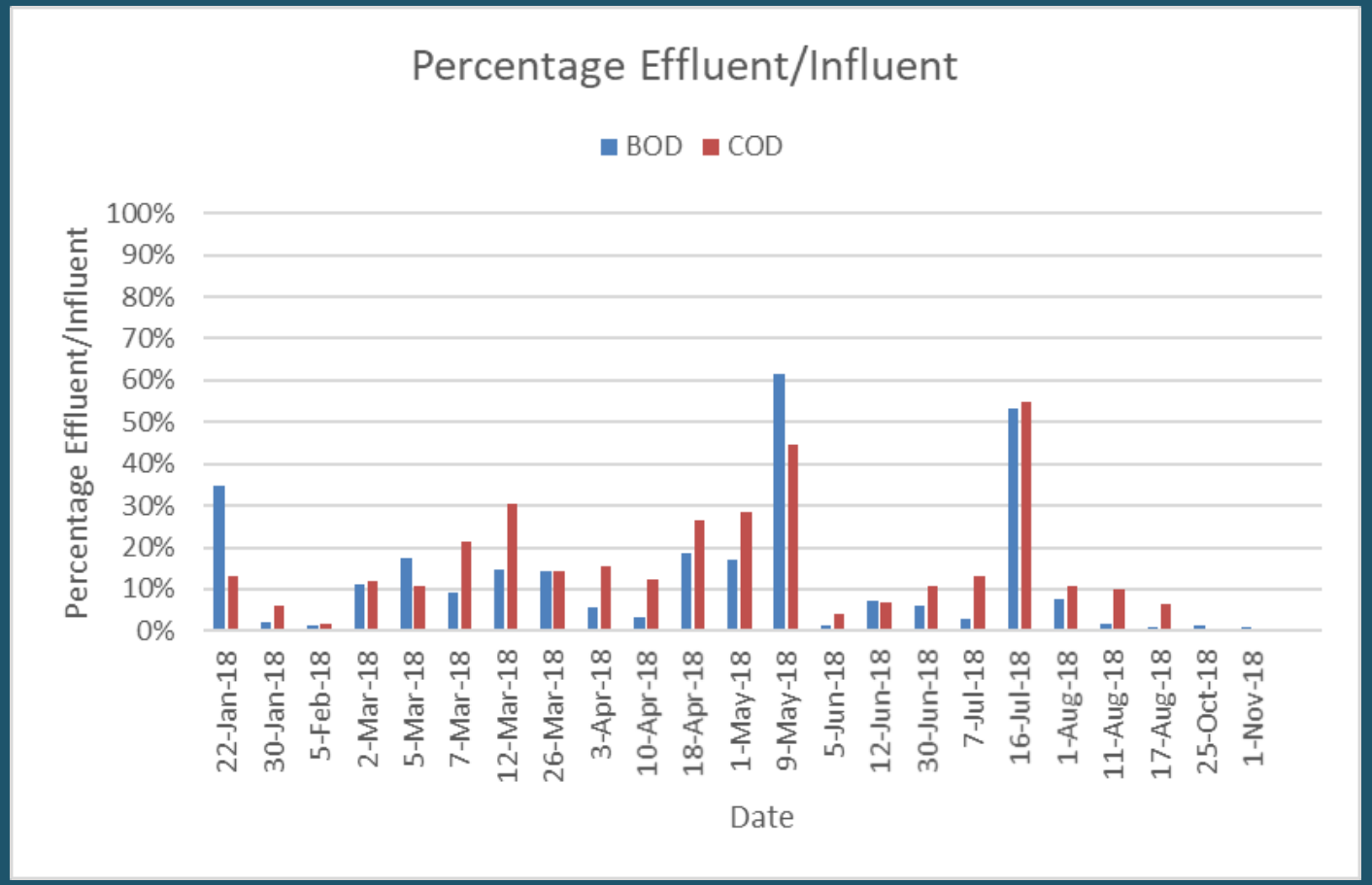

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Ongoing and Future Developments Relating to BEAST:

- Measure methane emissions to determine future use
- Expand System to 24 m^3 reactor; design and confirm pricing
- Install and commission system
- Apply for funding to test system at Canadian High Arctic Research Station (CHARS) in Cambridge Bay, NU
- Test 240 L Reactor in Work Camp environment with high-strength wastewater

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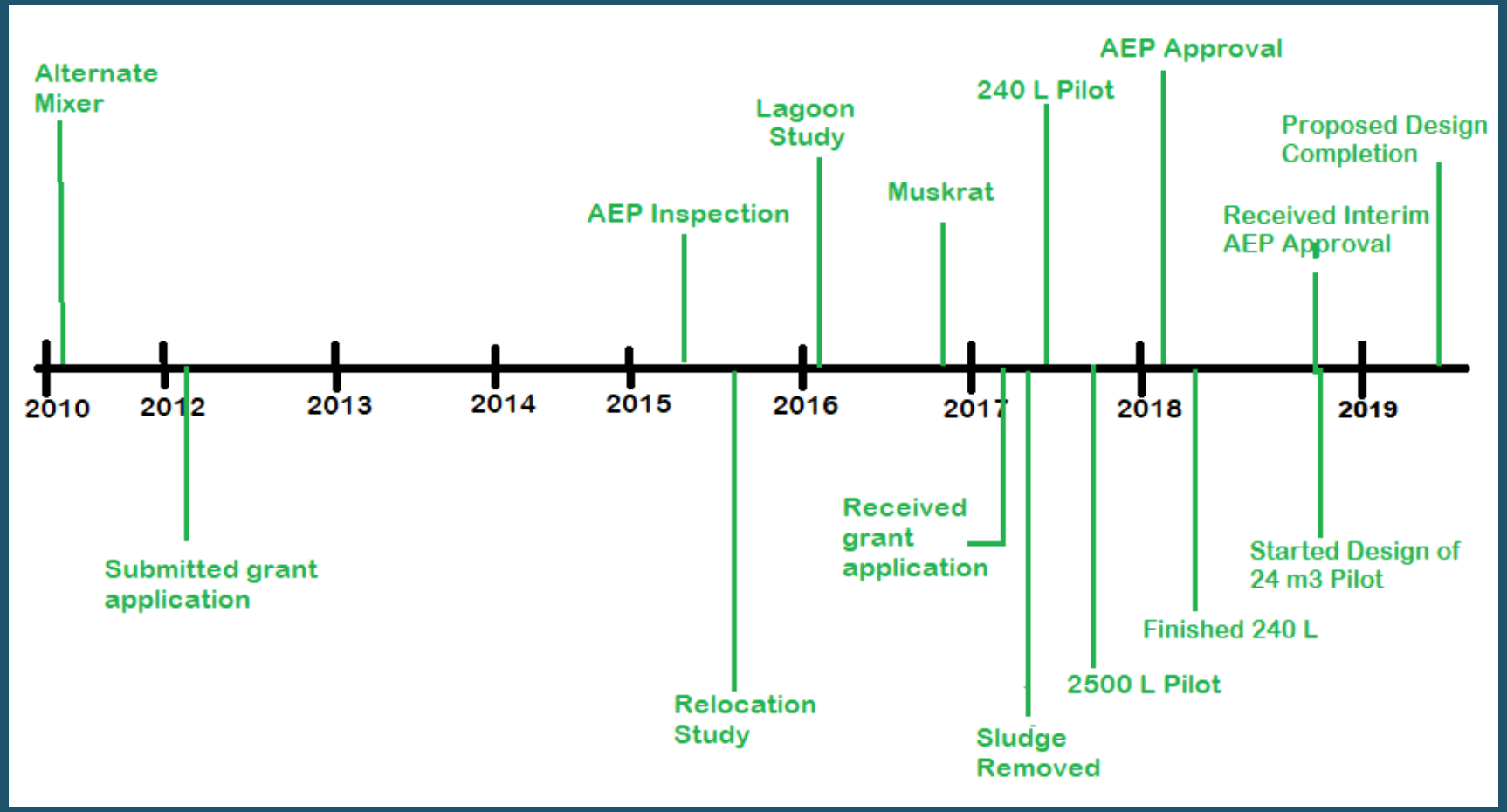
AEP Approval

- Involved in process and supportive from the beginning (December 2017)
- Received one-year interim approval from AEP for BEAST system
- Once successfully operated for one year, AEP will grant a permanent Approval



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Benefits of BEAST Technology:

- Can replace or enhance underperforming lagoons providing odor and visual problems in a cost-effective manner
- Low energy requirement with self-heating or net-positive energy balance
- Produces bio-methane that can be captured or used for reactor self-heating
- Simple, quiet, passive system

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Benefits of BEAST Technology:

- Easy to operate, works at low temperatures
- Uses small footprint
- Lower capital cost than mechanical systems
- The production of low quantities of sludge (~1/10th of aerobic systems)
- Eliminates high cost sludge removal events by managing sludge regularly prior to buildup

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Summary for Municipalities:

- Increased capacity with MUCH smaller footprint than lagoon
- Low capital costs, low operational costs
- System is modular and scalable with ~95% BOD/TSS removal
- System can be combined with existing lagoon or mechanical system to improve capacity and/or performance
- Small systems can reduce electricity costs (10% of activated sludge system)
- Large systems can capture methane (eg. self heating, GHG credits)

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