Nutrients, Nitrogen (N) and Phosphorus (P), Removal using Aerobic Granulation Technology

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Introduction

Nutrient pollution

- **Definition:** Elevated concentration of N and P in water bodies;
- **Environmental issue:** Eutrophication (dense growth of aquatic plants and algal bloom) → Loss of aquatic habitats
- **Health issue:** Algal toxins – Example: cyanobacterial toxin microcystin, found in 246 water bodies in Canada [1];
- **Diagnosed Canadian water bodies:** Pigeon Lake in Alberta, Lake Winnipeg [1];
- **Overall River Water Quality Index of Alberta in terms of nutrients:** Marginal (Guidelines often exceeded) [2].

Conventional methods:

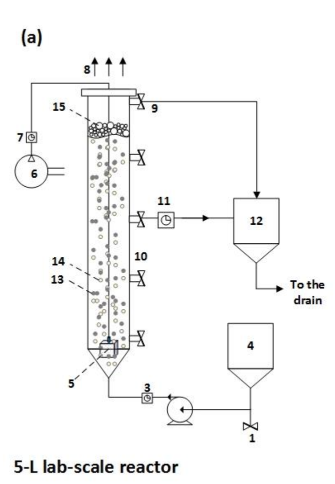
- **Physiochemical processes**
  - Costly
  - Rigorious control
  - Excess sludge buildup
- **Biological processes**
  - Erratic efficiency
  - Large space requirement
  - High oxygen demand (high energy requirement)

Objectives & Methodology

Lab-scale study: Two 5-L bubble column reactors

Investigation of optimum engineering parameters for P removal :

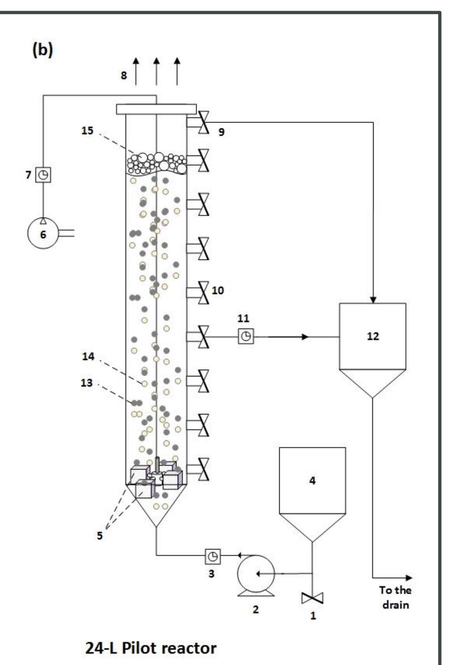
- Different concentrations of P (in the form of phosphate)
- Comparison of different operational conditions (aerobic, anaerobic/aerobic)



Pilot study: Two 24-L bubble column reactors

Insight into ammonia and phosphate removal pathways under aerobic and anaerobic/aerobic/anoxic conditions:

- Focus on microbiology
- Determination of granulation mechanism in terms of microbial dynamics



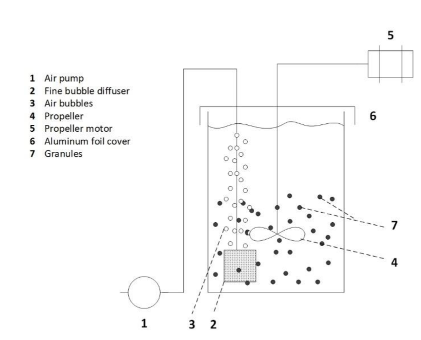
Batch studies

N removal pathways:

- Heterotrophic nitrification
- Autotrophic nitrification
- Anaerobic denitrification
- Aerobic denitrification

P removal pathways:

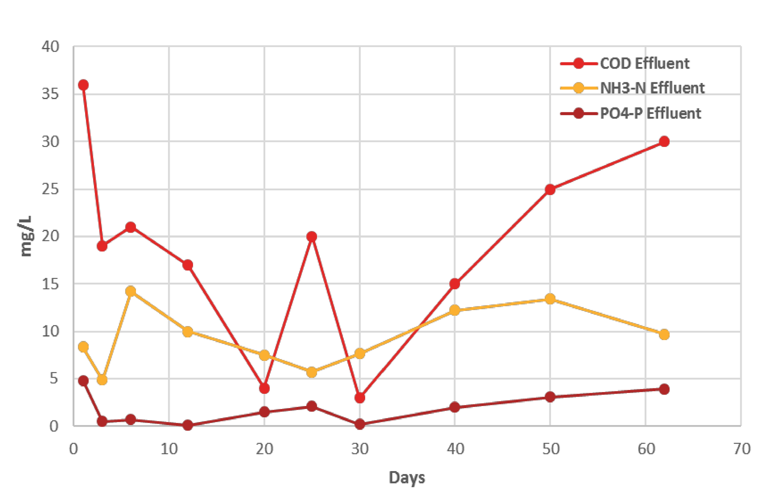
- Luxury accumulation (biological)
- Biologically-induced phosphate precipitation



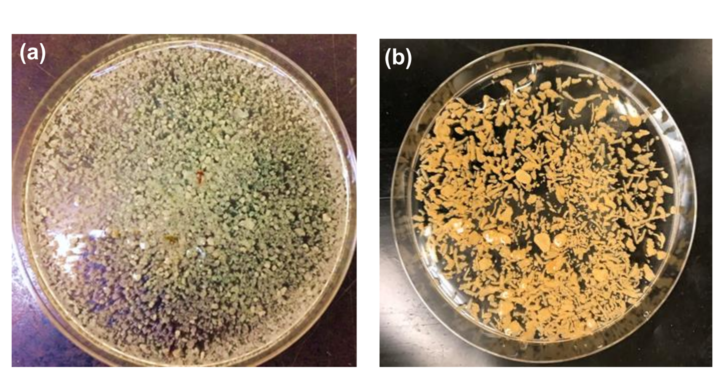
Results

Lab-scale study

- **Stable P-removing aerobic granules:** developed in 25 days, maintained over 150 days.
- **Alteration of P concentration in feed:** From municipal wastewater range (3 - 10 mg P/L) to industrial range (30 - 40 mg P/L) and assess the workability of granules.
- **Consistent P removal efficiency:** 98%
- **Optimized engineering parameters:** Superficial air velocity= 1.3 cm/sec (aeration rate = 5 LPM) , H/D ratio: 10:1, Volumetric exchange ratio= 40%, Temp. = 20-23°C, pH= 7.0 - 7.5.
- **Characteristics of granules:** Morphology: Flaky rod like, SVI_5= 50 mL/g, MLSS = 17.89 g/L, MLVSS = 9.39 g/L, mean size = 0.8mm



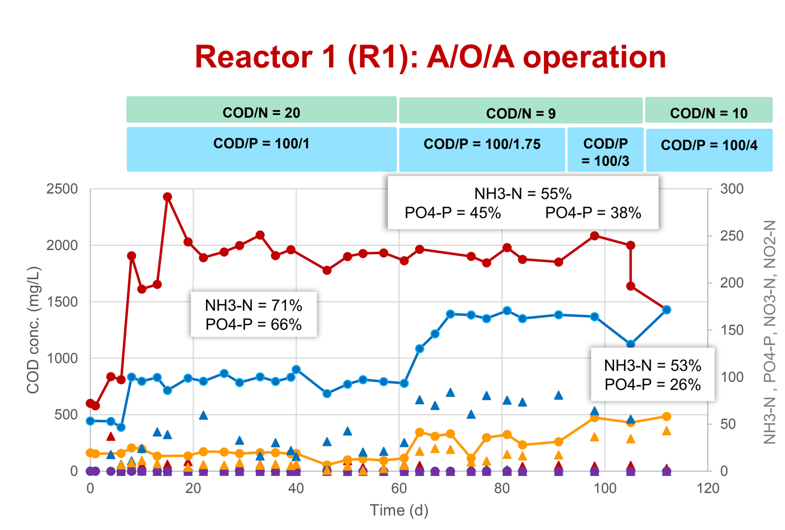
Effluent concentrations of COD, NH_3-H, PO_4^{3-}

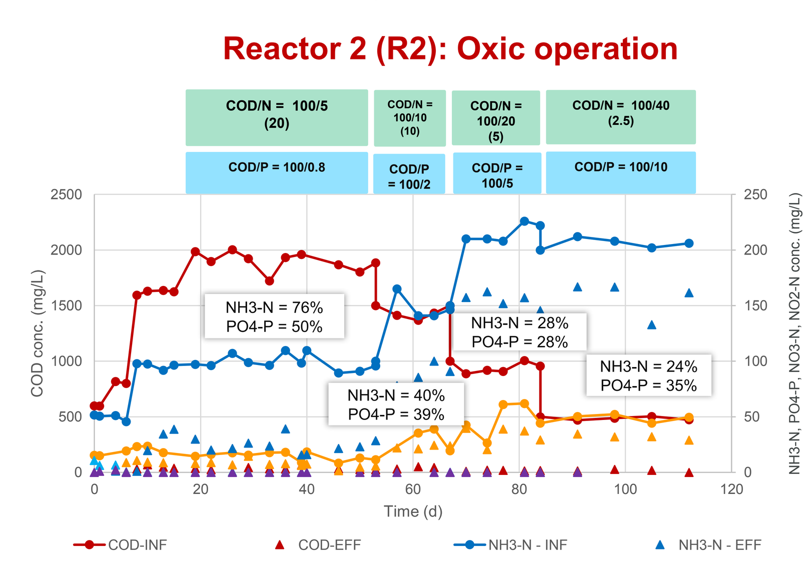


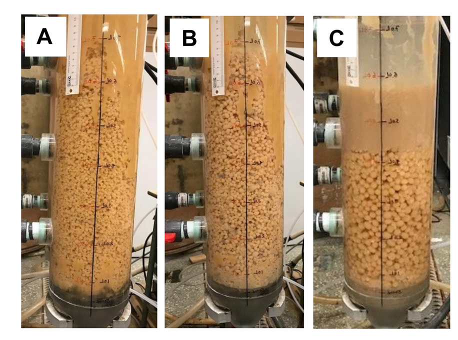
Aerobic granules at (a) day 18, and (b) day 60

Pilot study

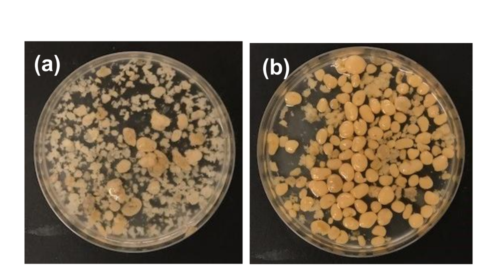
- **NH_3-N and PO_4-P removal efficiencies under merely aerobic (Oxic), and anaerobic/aerobic/anoxic (A/O/A) operations**
- **Different COD/N/P ratios** corresponds to real wastewater compositions, including the compositions of domestic and nutrient-rich industrial effluents
- **Satisfactory NH_3-N and PO_4-P removal efficiencies under <u>merely aerobic</u> condition:** Why? How? Detailed study on the removal mechanisms and microbiology of the process is under investigation.







Settled granules in R2 during changes in COD/N/P ratio at day (A) 47, (B) 54, (C) 112. Settling time: <u>10 min</u>



Aerobic granules at day 50 in (a) R1, and (b) R2

Significance of the project

General advantages of aerobic granulation technology over activated sludge are: 1) low energy requirement; 2) reduced footprint; and 3) high biomass retention. Aerobic granulation can effectively remove N and P in a single reactor with substantially less suspended solids in the effluent, resulting in no or smaller secondary clarifiers. Simulatenous nitrification and denitrification (two essential biochemical pathways for ammonia removal) can be accomplished in a single tank, reducing the size of anoxic tank up to 50%. Anaerobic and aerobic conditions required for P removal can be provided in microzones inside the granules. However, the mechanism behind aerobic granulation for nutrient removal is not fully understood yet. Optimizing engineering parameters can increase the feasibility and cost-effeciveness of the process. Grasping a profound understanding of the microbiology and granule formation mechanism can increase the reliability of the technology, and hence, its applicability.

References

[1] Kathryn Weatherley, (2013). How blue-green algae is taking over Canadian lakes. CBCNews.

[2] Alberta River Water Quality Index, Alberta Environment and Parks, Updated: Jun 8, 2017, Accessed: Jun 8, 2017.