Carbon and Volatile Fatty Acids recovery in Reactive Primary Clarifier: A Pilot Case Study

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About me

Michele Ponzelli - MASc Civil Engineering

❑ Bachelor and master's degree in Civil and Environmental Engineering at UNIVPM (ITA)

Specializations:

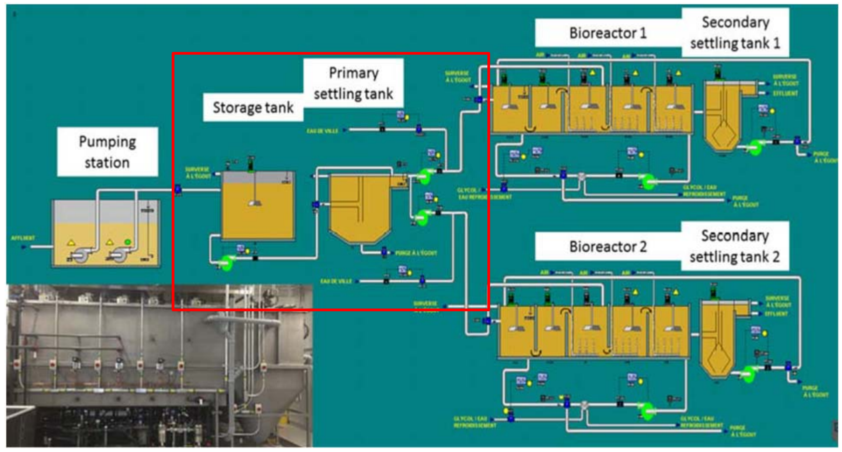
- Wastewater resource recovery
- Wastewater treatment process & design

Previous research interests:

- Combined sewer overflow (CSO) treatment
- Short-cut nitrogen removal in BNR.

Introduction – pil*EAU*te facility

- Domestic WW coming from the adjacent university's campus
- Two parallel biological line
- High process flexibility
- On-line monitored with sensors



Scheme of the pil*EAU*te facility (Université Laval)

Introduction

PRIMARY SEDIMENTATION – CHALLENGES

Primary clarifier: **physical reactor**

- Removing organic particles leads to lower C, or C:N ratio
- Bacteria utilize carbon as an energy source
- Denitrification and BioP need good, readily biodegradable COD (rbCOD)

lwbray.com/wp-content/Pickard-Environmental-Centre-Primary-Clarifier

➢ Supply external carbon (*methanol, glycerin, acetic acid*)

+ High substrate quality
- Bacteria acclimation
- Cost ($50-100M/y in N.A.)

➢ Take out primary clarifier

+ Take all the benefits from the raw incoming WW
- Shorter SRT
- Cost (sludge production)

➢ REACTIVE PRIMARY CLARIFIER

A **physical-biochemical reactor** (reactive primary clarifier) must:

1) remove particles
2) produce rbCOD (VFA)

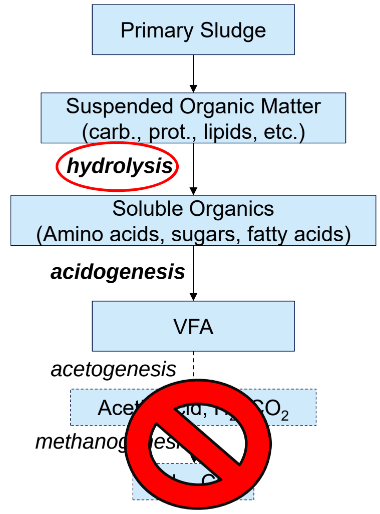
Objective

Use the primary clarifier as mainline fermenter

A **physical-biochemical reactor** (reactive primary clarifier) must:

1) remove particles
2) produce rbCOD (VFA)

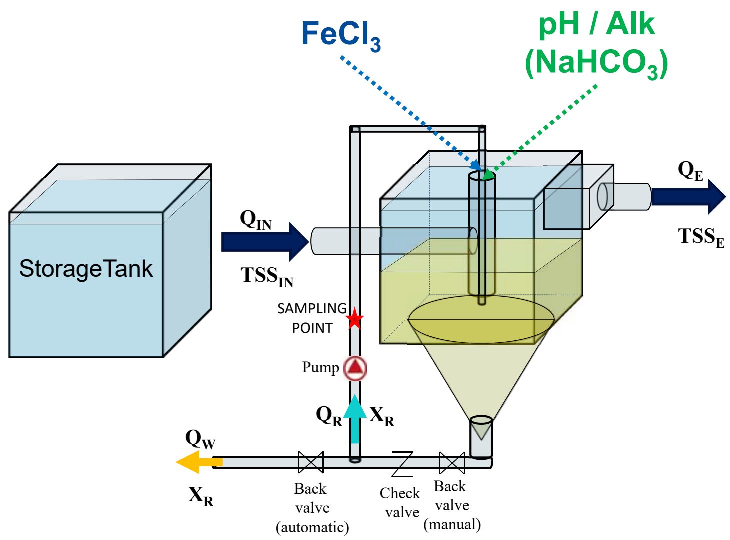
- **Hydrolysis** is a function of:
  - ❑ pH
  - ❑ Temperature
  - ❑ Particle size
  - ❑ Microbial biomass
  - ❑ Type of substrate



Objective

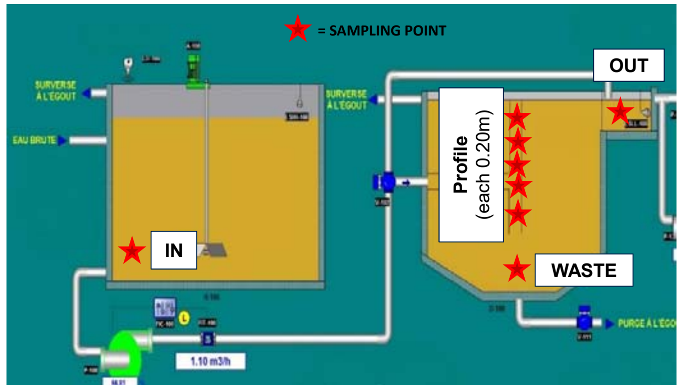
Operating and environmental parameters:

- Sludge retention time (SRT)
- Recirculation flowrate (Q_R)
- Coagulant addition ($FeCl_3$)
- pH conditioning / Alkalinity



Materials and methods – Sampling activity

- Sample: composite
- Location: In, Out, and Waste
- Profiles: TSS / VFA / pH / Alkalinity



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Materials and methods – Water quality and performance parameters

- Water quality characterization (probes values and lab measurements):

- Solids:	TSS, VSS
- Carbon:	T-COD, S-COD, VFA
- Nutrients:	Total-TN, Soluble-TN, NH_4-N, NO_3-N, TP, PO_4-P
- Other properties:	pH, Temperature, K concentration, Conductivity

A **physical-biochemical reactor** (reactive primary clarifier) must:

1) remove particles

2) produce rbCOD (VFA)

1) Solids removal efficiency (%):

$$E\%TSS = \frac{Q_{IN}TSS_{IN} - Q_{OUT}TSS_{OUT}}{Q_{IN}TSS_{IN}} \cdot 100 \text{ > 60\%}$$

2) VFAs yield (mgCH_3COOH / gVSS):

$$VFAs\ yield = \frac{VFA_{OUT} - VFA_{IN}}{VSS_{IN}} \text{ > ?}$$

Few literature data for continuous systems (mainly batch reactors)

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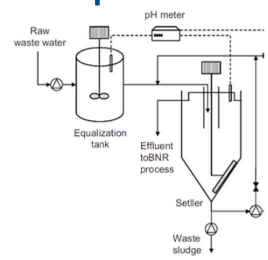
Materials and methods – Water quality and performance parameters

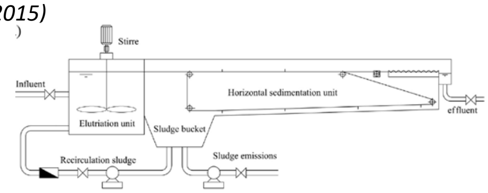
- Pilot-scale, primary clarifier (112 L) as in-line fermenter *(Bouzas et al., 2006)*

SRT (d)	7	7	8
VFAs yield (mg/g)	**98**	**110**	**166**
E%TSS	30%		



- Pilot-scale (0.5 m^3/h), primary clarifier as in-line fermenter *(Jin et al., 2015)*

SRT (d)	3	5	7
ΔVFAs (mg/L)	**12.3**	**18.8**	**19.9**



- Primary sludge, continuous-flow completely mixed reactor, HRT 1.25 d, SRT 10 d *(Maharaj et al., 2001)*

VFAs yield (mg/g)	**39**

Materials and methods

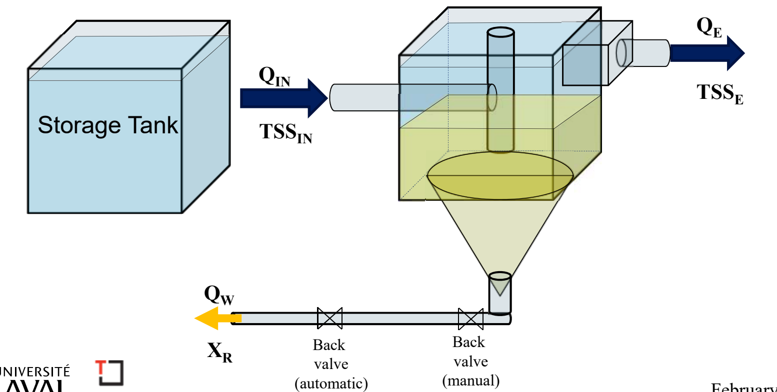
- **SRT** 1d, 3d
- **Q_R** no (0% Q_{IN}), low (15% Q_{IN}), high (50% Q_{IN})
- **$FeCl_3$** 0mg/L, 10mg/L, 20 mg/L
- **pH** uncontrolled, alkalinity addition

❖ Two or three levels for each parameter.

❖ **Implemented one by one.**

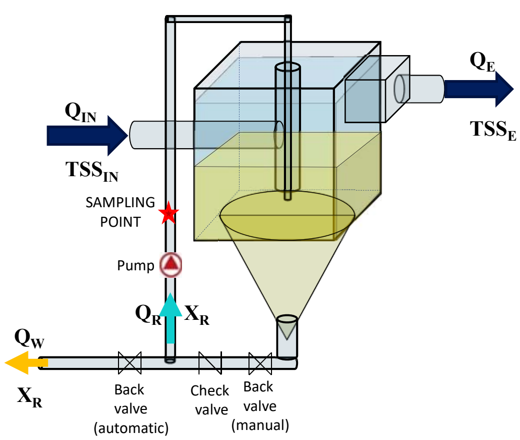
SRT

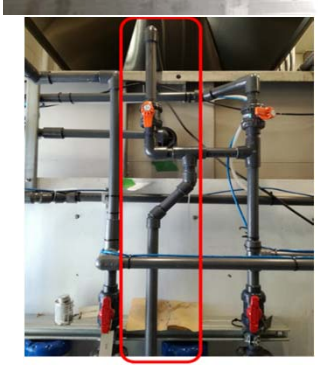
- **Three times SRT** must elapse for reaching steady-state. (e.g. SRT=1d → sampling after 3 days)
- Increasing/decreasing the **waste flow rate**.

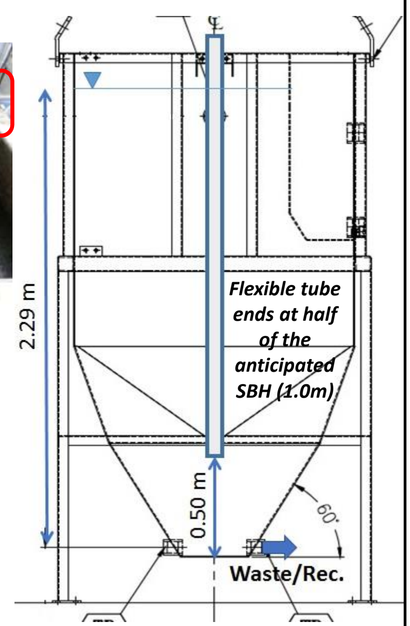


Return line (Q_R)

Return line set-up

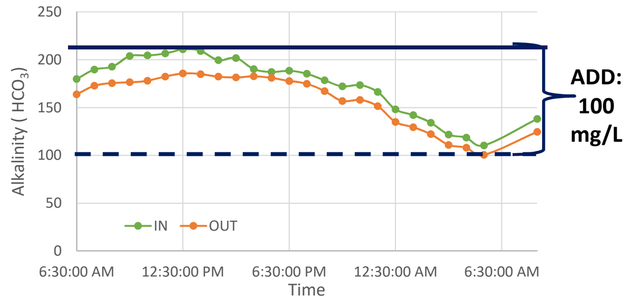




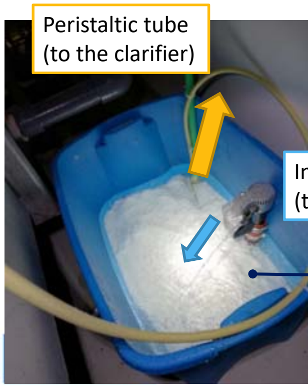


Alkalinity dosing

- 200mg/L as $CaCO_3$ needed for nitrification (Metcalf&Eddy).
- Dosage based on the pilot demand
- Build basin for feeding a saturated solution of baking soda ($NaHCO_3$)



Peristaltic tube (to the clarifier)

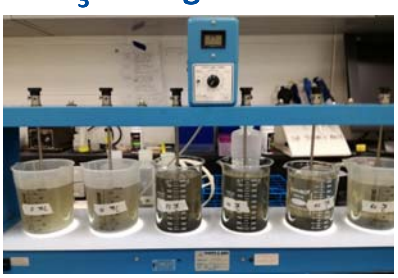


Inlet (tap water)

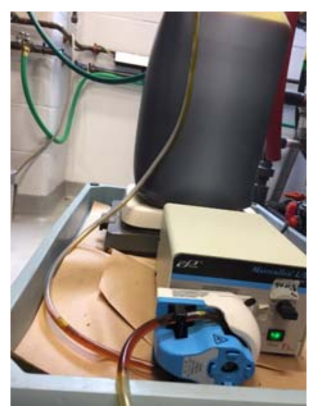
Total volume: **45-50 L**

15kg of $NaHCO_3$

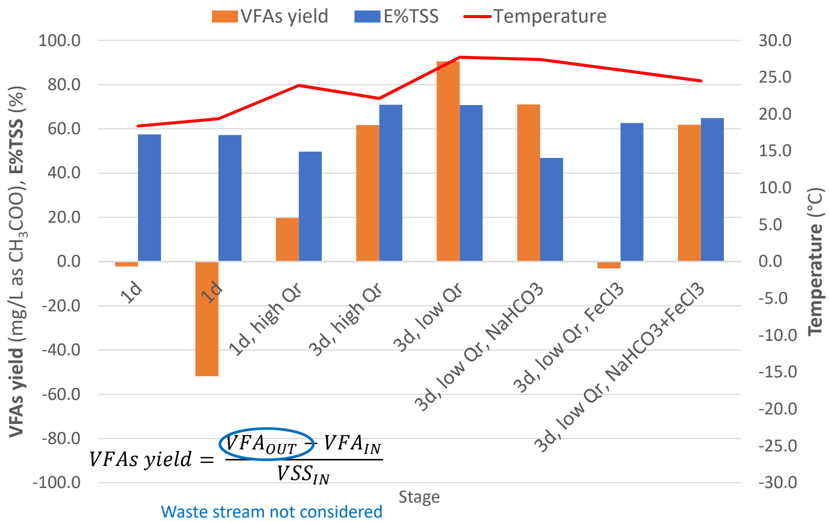
$FeCl_3$ dosing – Jar test



→ **20 mg/L** optimum



Results



- **SRT**
  - ✓ Minimum 1 day (establish fermentation)
- **Q_R**
  - ✓ bring SCOD to outlet.
  - ✓ Keep it low (power cost, material resuspension)
- **$FeCl_3$**
  - ✓ No E%TSS improvement (mixing conditions)
  - ✓ Fermentation seems negatively affected (but high sludge VFA conc.!)
  - → avoid PO_4^- and NH_4^+ release
- **pH / Alk**
  - ✓ $NaHCO_3$ dosing affects particle sedimentation
  - ✓ No effects on fermentation

Results

Data comparison

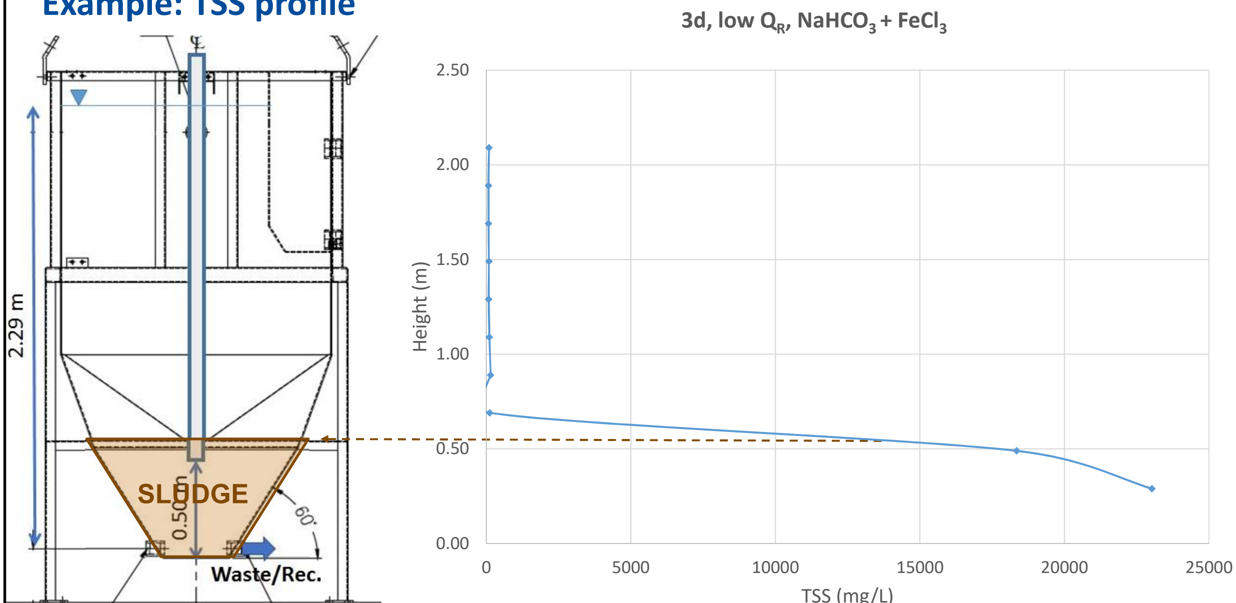
- SRT= 3 d, low Q_R, **<u>$FeCl_3$ & $NaHCO_3$ dosing</u>**

		IN	OUT	WASTE	E%
TSS	mg/L	380 ± 30	134 ± 12	16200 ± 2400	65%
VFAs	mg/L	61	83	452	-37%
NH_3-N	mg/L	**34.5** ± 0.1	**32.0** ± 0.4	**14.8** ± 0.1	7%
PO_4-P	mg/L	**11.8** ± 0.1	**10.4** ± 0.0	**14.5** ± 0.1	12%

- SRT= 3 d, low Q_R, **<u>NO CHEMICALS</u>**

		IN	OUT	WASTE	E%
TSS	mg/L	305 ± 15	89 ± 7	14200 ± 600	71%
VFAs	mg/L	64	90	286	-40%
NH_3-N	mg/L	**39.4** ± 1.6	**43.9** ± 0.7	**37.9** ± 0.4	-12%
PO_4-P	mg/L	**13.4** ± 0.0	**15.3** ± 0.0	**18.8** ± 0.1	-14%

Example: TSS profile



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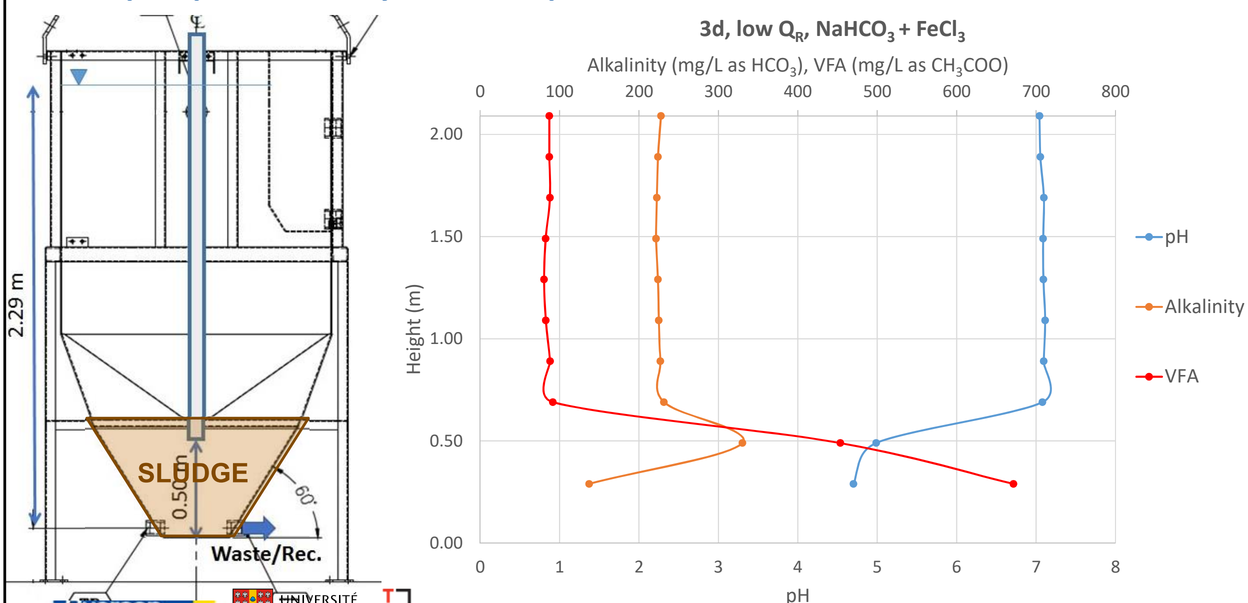
Example: pH, alkalinity, and VFA profiles



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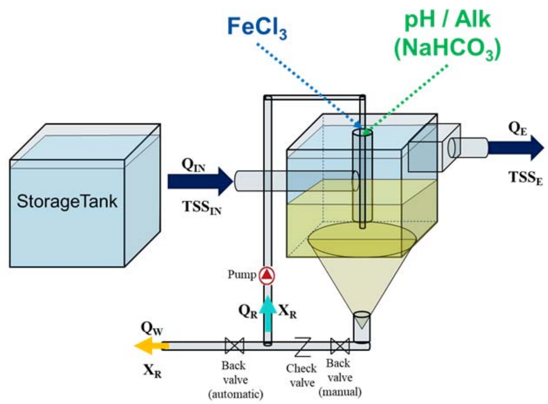
Conclusions

- Crucial parameters for VFAs production:
  - A **short SRT** (3 days)
  - A **low** internal recirculation **flow rate** (15%)
- Able to achieve up to **700mg/L VFAs** in the sludge blanket
- Clogging of the return line may occur



Room for further research:

- Develop and calibrate a reactive primary clarifier model;
- Identify types of microbial community involved;
- Run a cost benefit analysis (power, chemicals).

Acknowledgements

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