Minimising sludge production by long SRT, trash and grit removal from sludge

Yves Comeau[1], Peter L. Dold[2],
Alain Gadbois[3], Stéphane Déléris[4], Majdala M.-Geoffrion[1],
Abdellah Ramdani[1], Marc-André Labelle[1]

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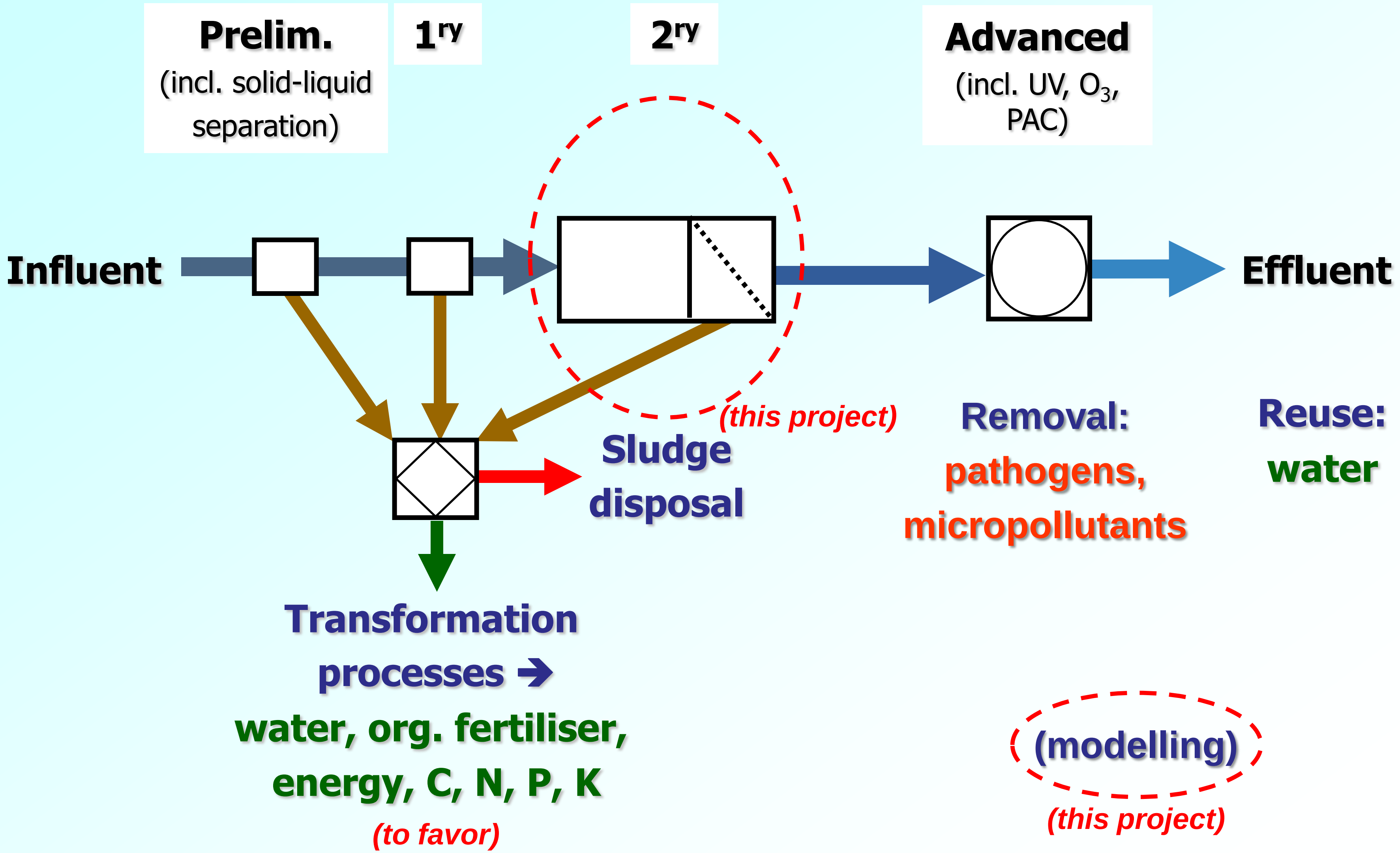
Outline

- WWT & sludge production
- Modelling sludge production
- Objectives
- Experimental units
- Trash and grit removal
- Biodegradation of « unbiodegradables »
- Conclusions and Perspectives

Wastewater Treatment
(or WW Resource Management)



Costs of WWT

Effect (+: positive/-: negative) of reducing sludge production

- **Capital costs:**
  - + size of bioreactors, settling tanks, sludge treatment units
- **Operating costs:**
  - – aeration
  - + sludge treatment & disposal
    - - increasing sludge disposal costs
      - - Quebec: from 20 to >80 $/wet t. from 2000 to 2009

Reducing sludge production

- Chemical: ozonation, uncoupling
- Thermal: thermal disruption
- Physical: mechanical disruption, ultrasounds, pressure drop, **microscreening, hydrocycloning**
- Biological: predation, anaerobic digestion, **fermentation, endogenous respiration (SRT)**

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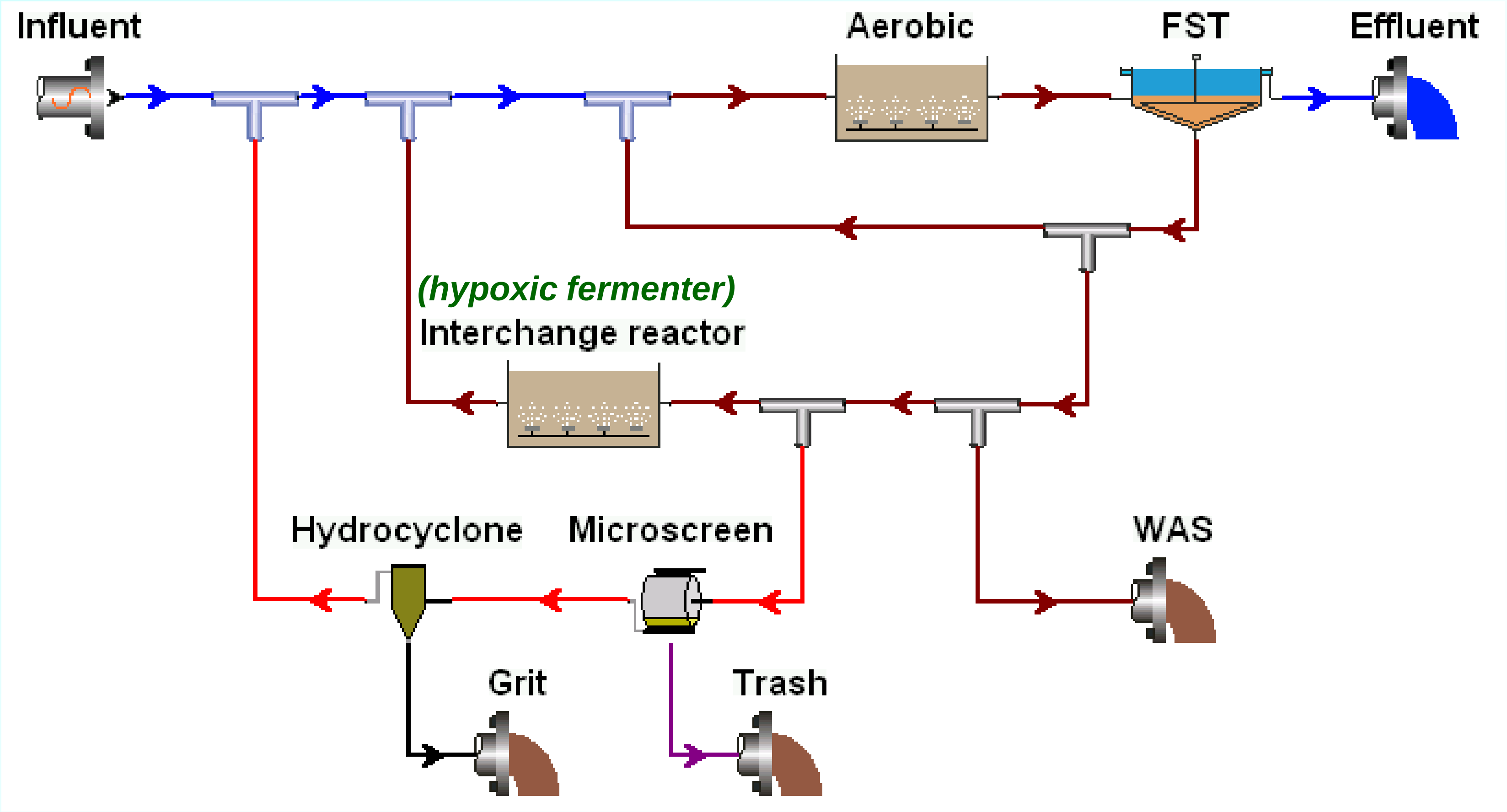
- **Claims of « no » or minimal sludge production**
- **Limited data available – How does it work?**

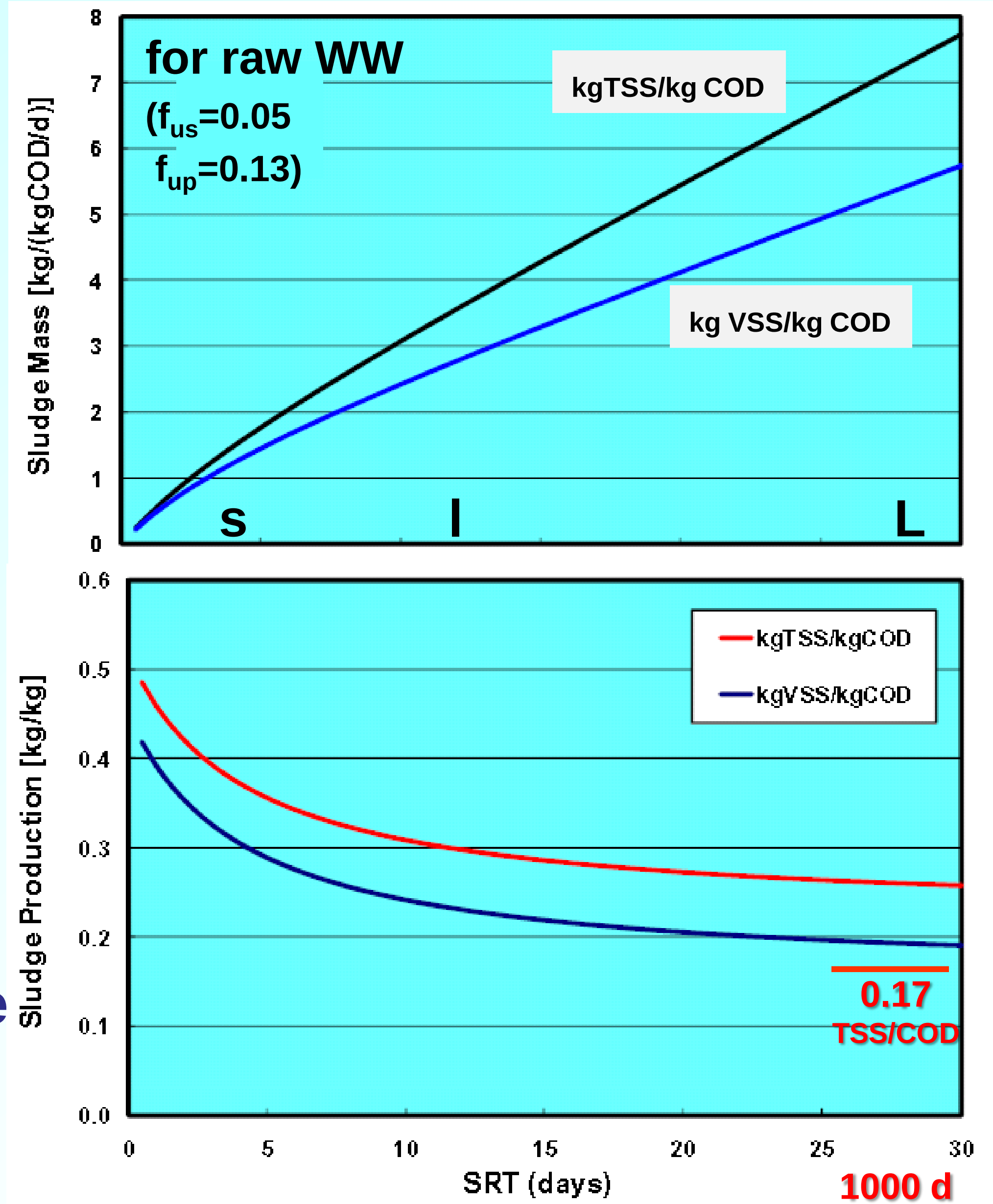


Sludge reduction: Effect of SRT

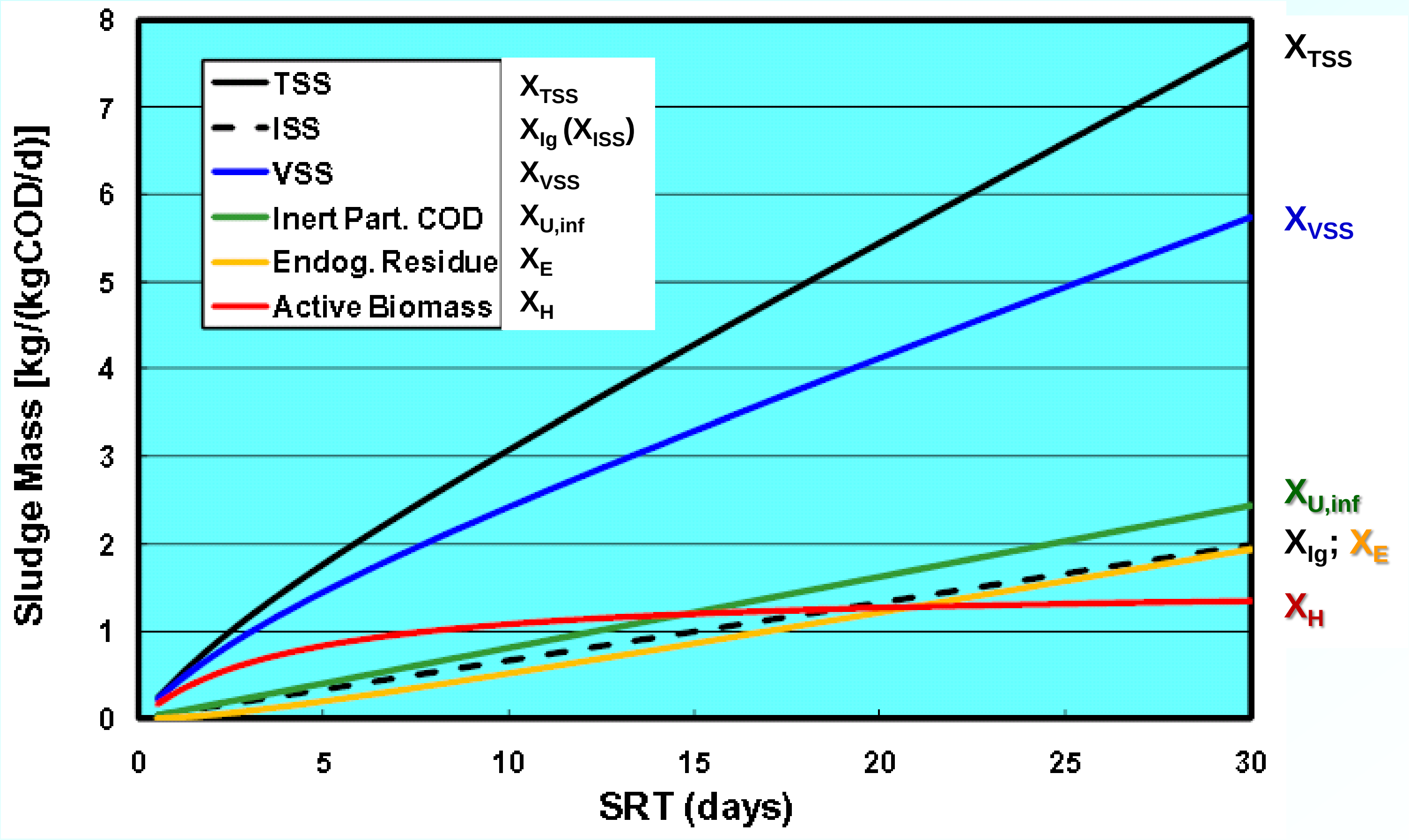
- **<u>Short SRT</u> for BOD removal**
- **<u>Longer SRT</u> for N and P removal at cold temperature**
- **<u>Longest SRT</u> for small-medium WWTPs to minimize sludge production (but increased costs of aeration)**

e.g. SRT 5 d to 30 d ➔
25% less kg TSS/kg COD

- **Thus, long SRT ➔ low sludge production (WAS + effluent) (nothing magical)**



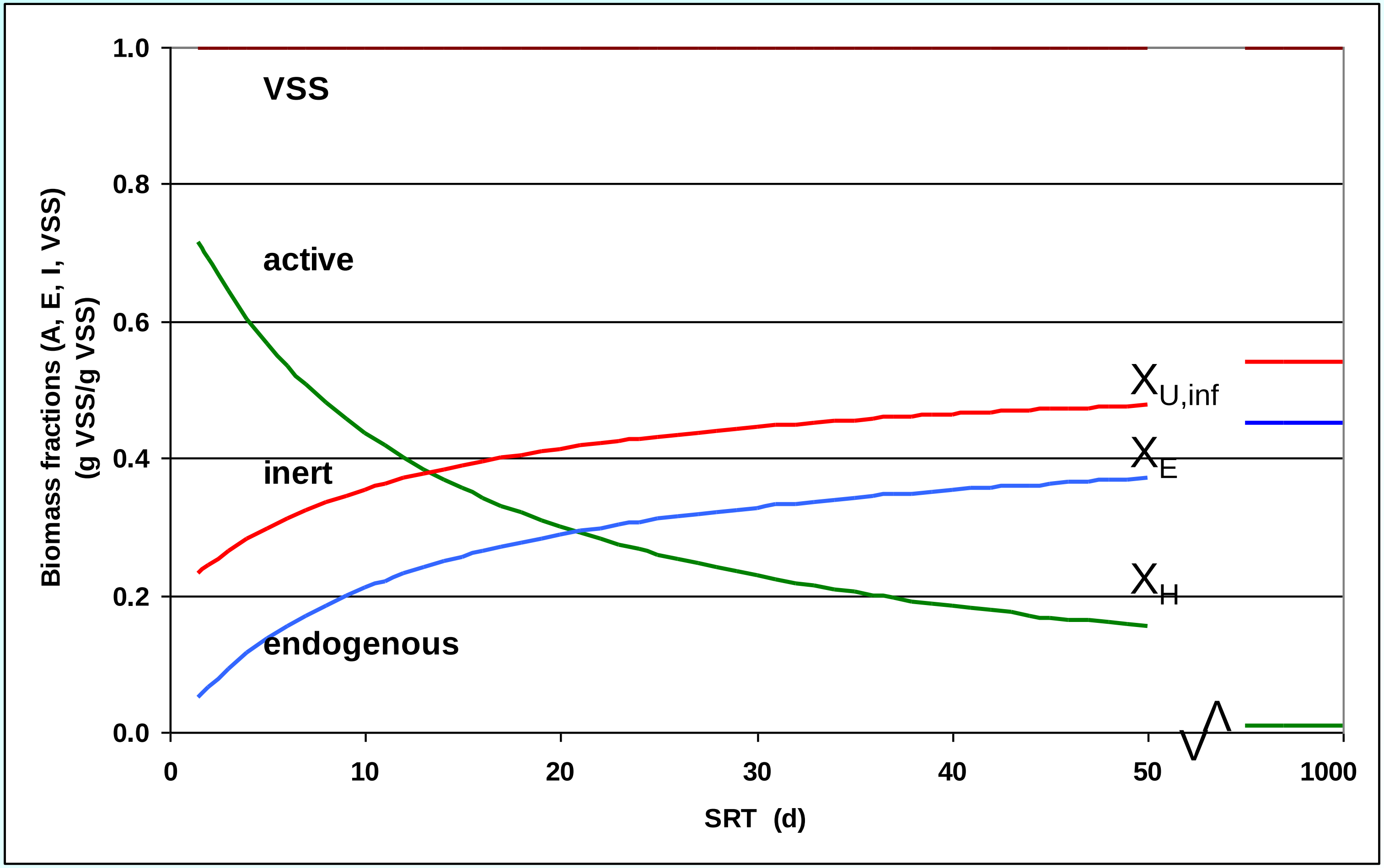
Mixed liquor components vs SRT



with increasing SRT, leveling of X_H

but continuous increase in X_{Ig}, $X_{U,inf}$, X_E

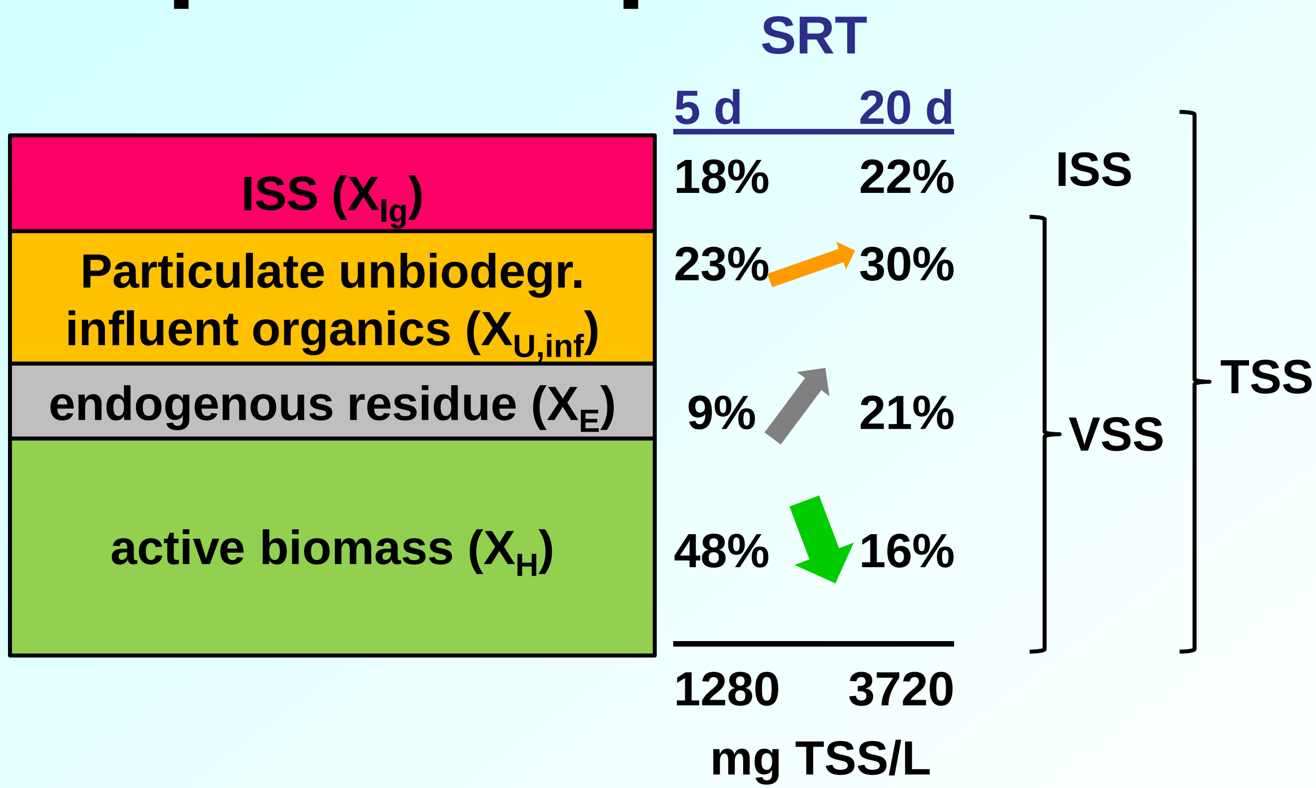
MLVSS fractions vs SRT



• at very high SRTs, the active biomass fraction becomes minimal and the VSS are essentially composed of $X_{U,inf}$ and X_E

Mixed liquor composition

Example:
raw WW: 280 mg COD/L
aerobic AS, 20°C, 8 h HRT



→from 5 to 20 d SRT, 2.9 times more sludge (but 3x less X_H)

→if 33% removal of grit (in X_{Ig}) and of trash (in $X_{U,inf}$) can be removed from sludge at an SRT of 20 d, the capacity can be increased by 17% (7+10)

➔treatment capacity increased or reduced reactor size

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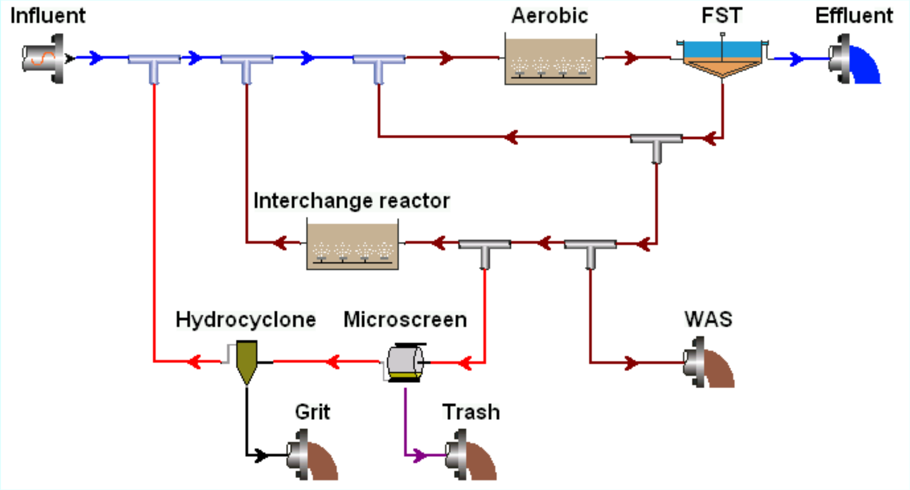
Research questions



- **Can grit (X_{Ig}) and trash ($X_{U,inf}$) removal from the mixed liquor be efficiently removed enough to increase significantly the treatment plant capacity?**
  - **what is the effect on sludge settleability?**
- **Can « unbiodegradable » X_E (endog. residue) and $X_{U,inf}$ (infl. partic. unbiodeg. org.) be biodegraded at long SRTs and in the AN/^{ox} fermentation reactor?**
  - **can the lower sludge production savings compensate the extra aeration costs?**

Objectives

« Explain » the Cannibal® process by:

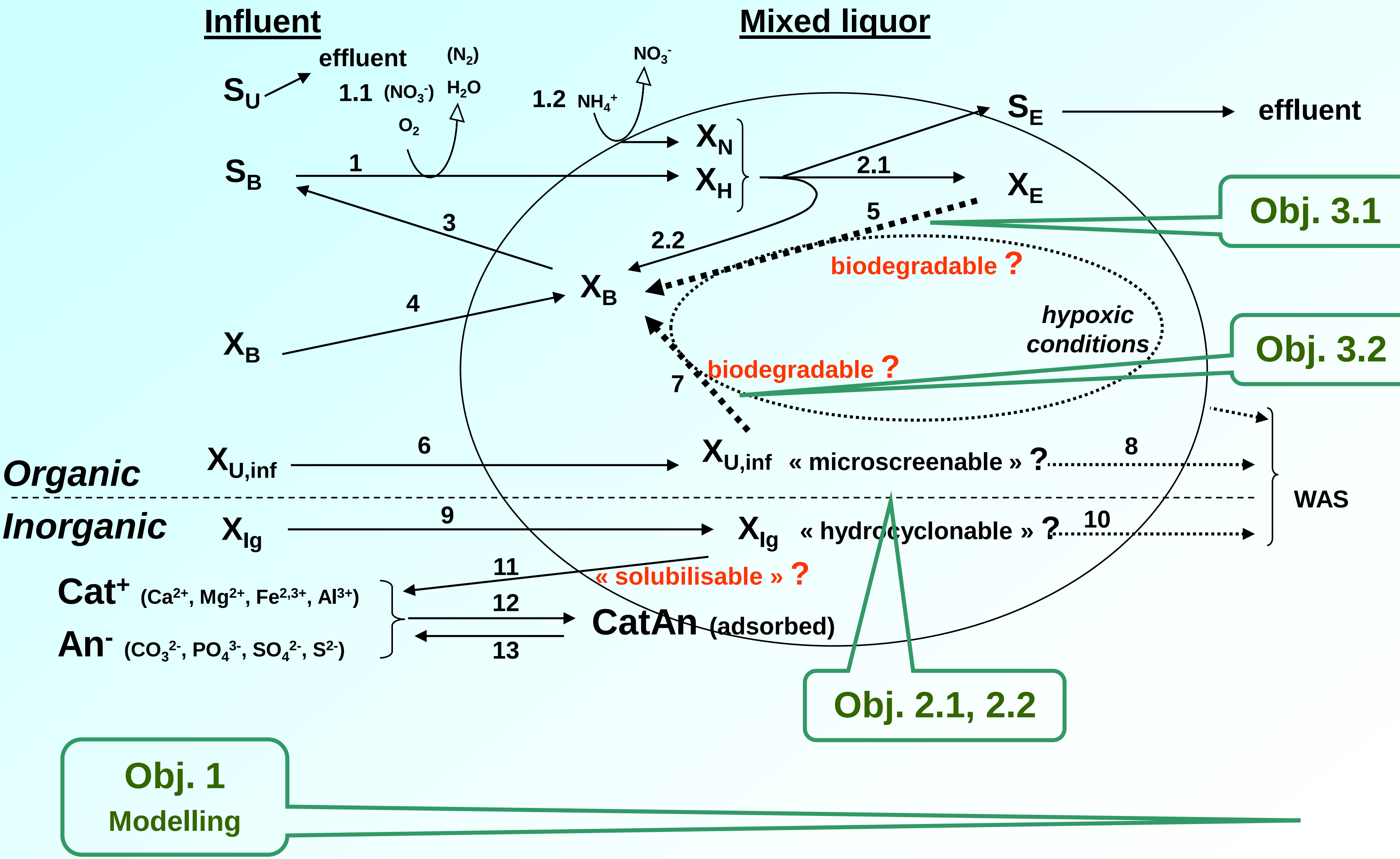
1) **Modelling biological and unit processes**

Characterizing the efficiency of:

2) **physical removal from mixed liquor (or RAS) by:**
   - **2.1 microscreening (MS) of trash ($X_{U,inf}$)**
   - **2.2 hydrocycloning (HC) of grit (X_{Ig})**

3) **biodegradation of the mixed liquor components:**
   - **3.1 endogenous residue (X_E)**
   - **3.2 influent « unbiodegrad. » partic. organics ($X_{U,inf}$)**

Processes & objectives

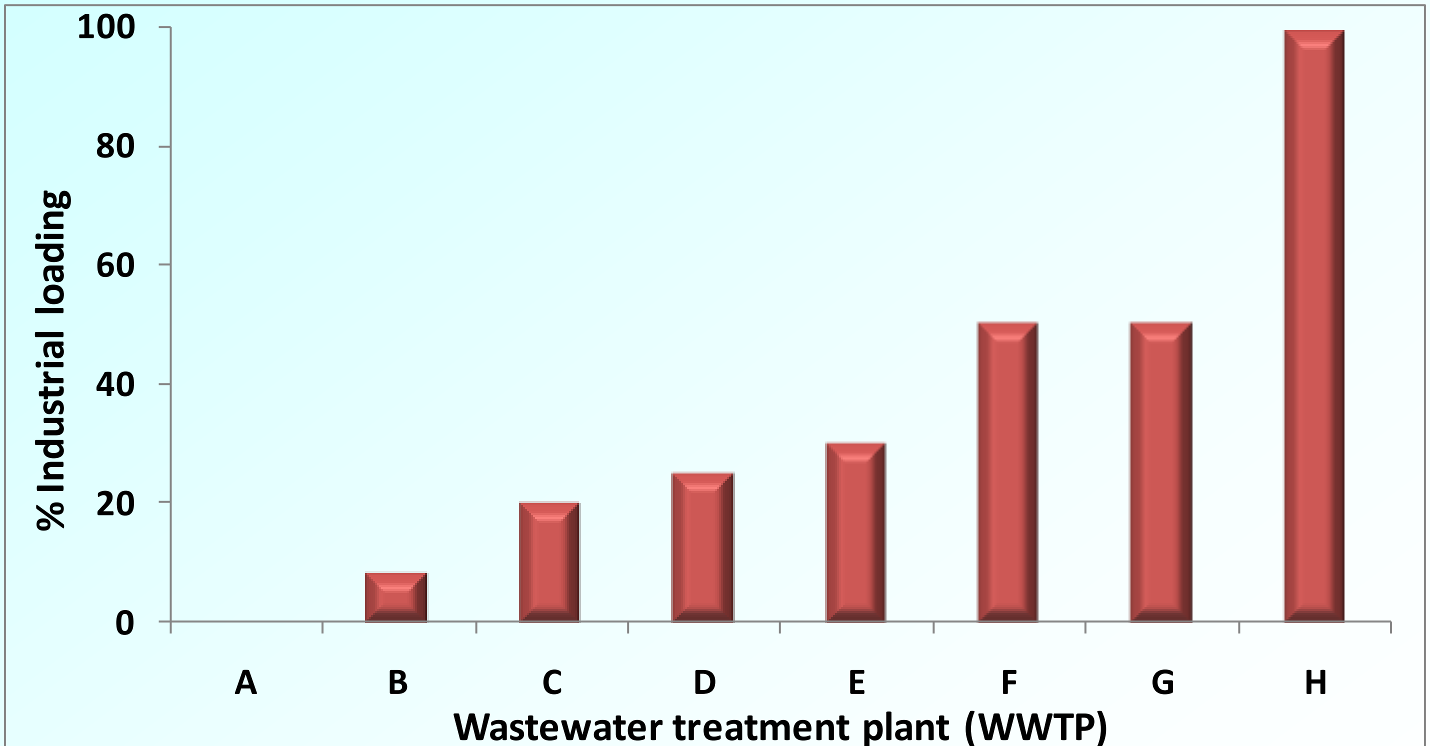


Methodology

- **Lab tests**
  - **MS and HC**
  - **Biodegradation of X_E**
- **Modelling**
- **Pilot testing**

MS & HC: ML & RAS samples

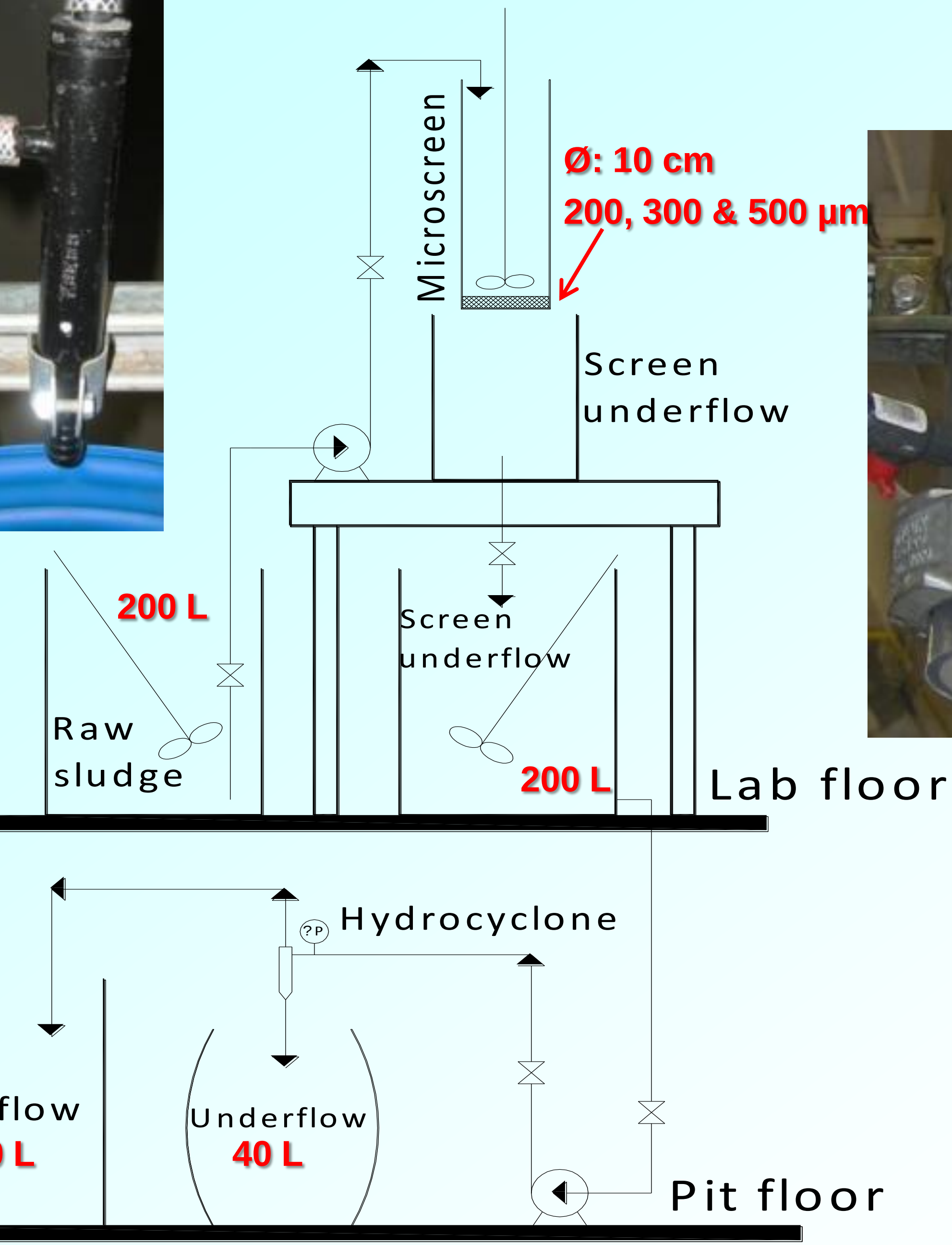
from 8 WWTPs near Montreal



Preliminary tr.	Coarse screening	✓	✓	✓	✓	✓	✓	✓	✓	8
	Grit removal		✓				✓	✓	✓	4
Primary tr.	Clarifier					✓		✓		2

Lab scale HC and MS

HC



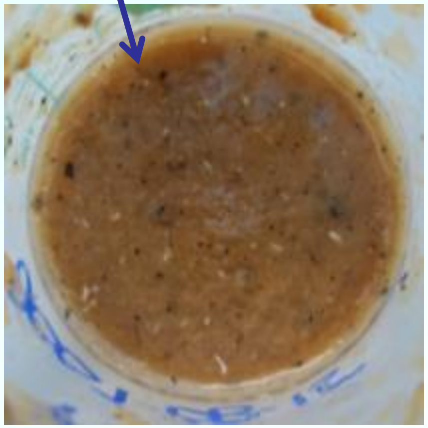
Microscreen

mixer above MS

Lab microscreening (MS) of mixed liquor and RAS

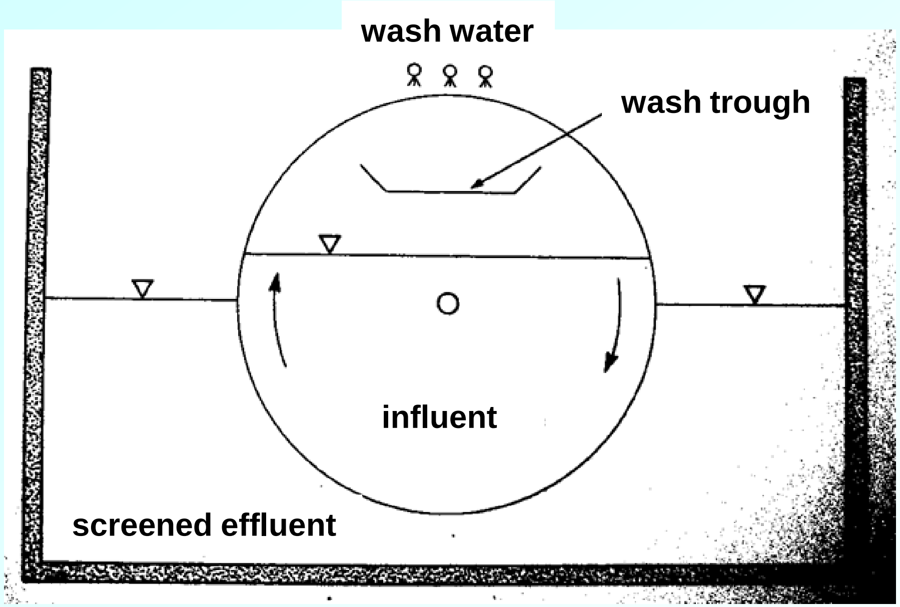
Trash (organic) retained by MS:
hygienic paper, vegetal (plants, wood) residues, hair, large filamentous flocs, etc.

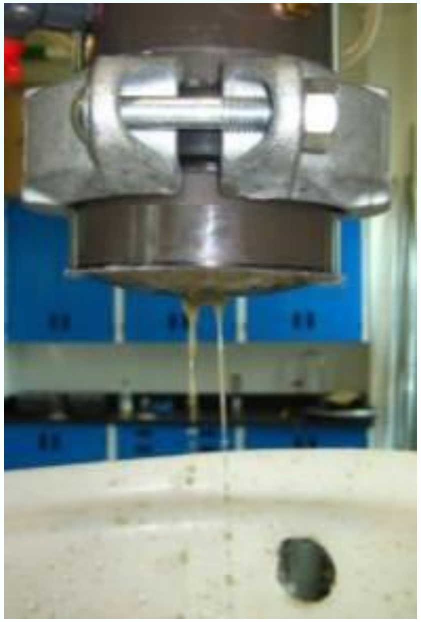
(+ sand)



Microscreen

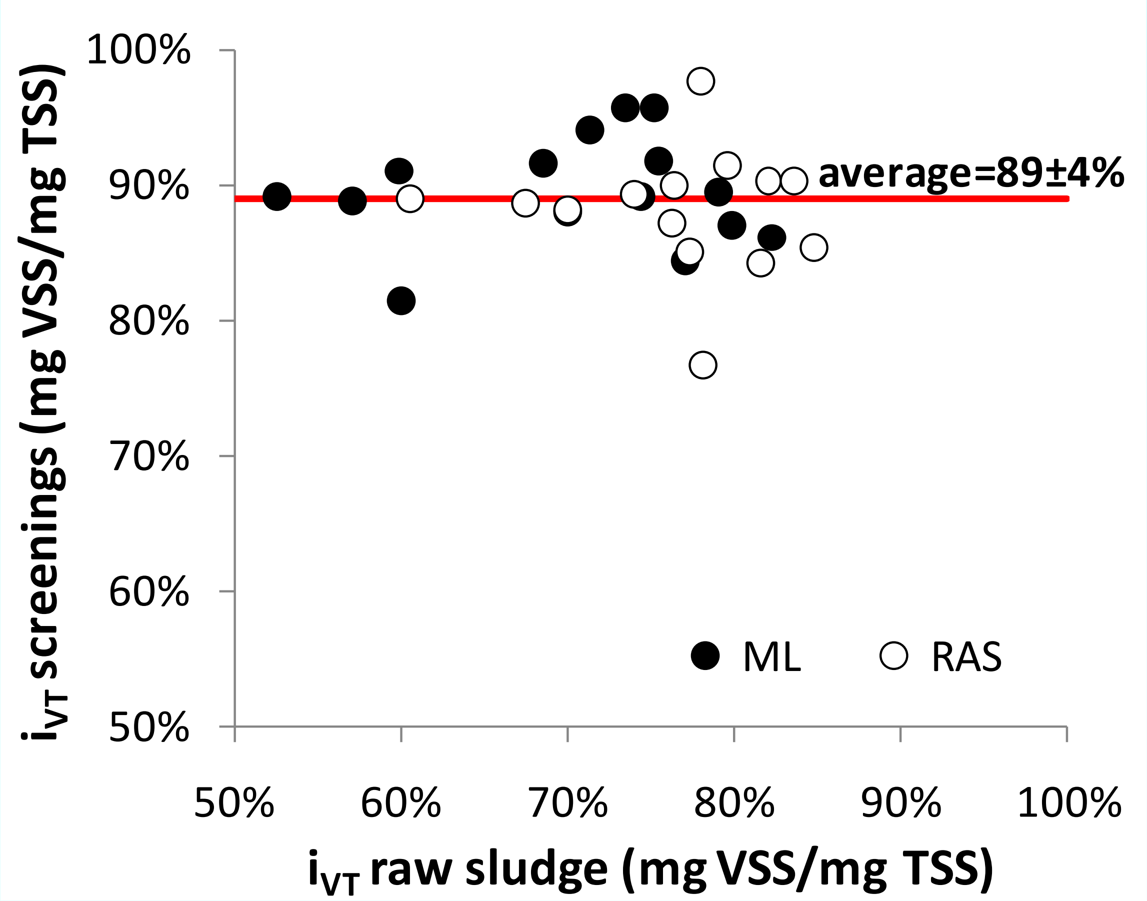
- Direct removal: by size
- Indirect removal: by dynamic filtration





Microscreen - results

Effect of raw sludge i_{VT} on screenings i_{VT}

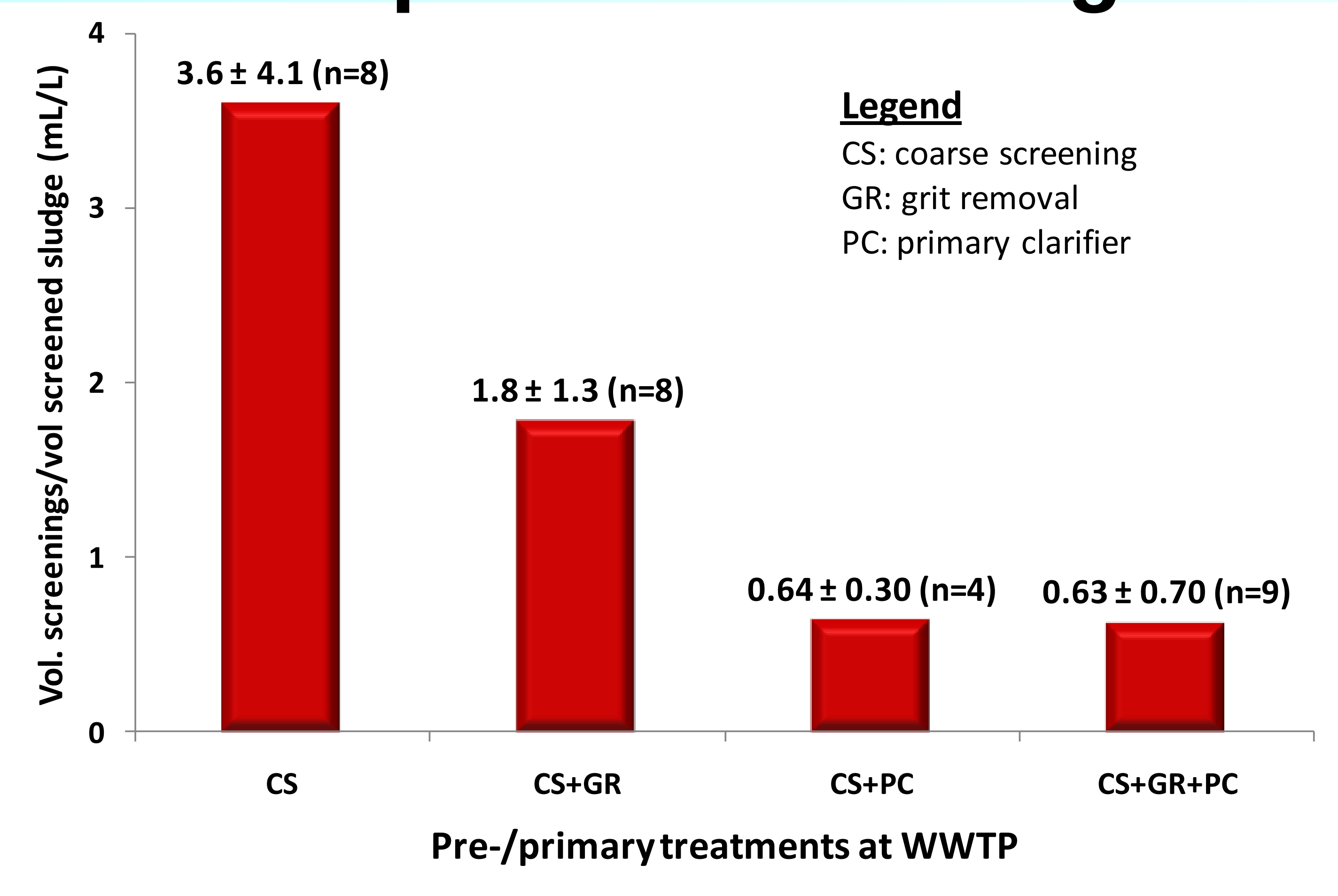


vs 99±1% for toilet paper, Kleenex, paper towel

screenings i_{VT} relatively constant (89 ± 4%) for ML and RAS

→ selective removal of organic matter of similar composition is possible

Effect of WWTP pretreatment on captured screenings



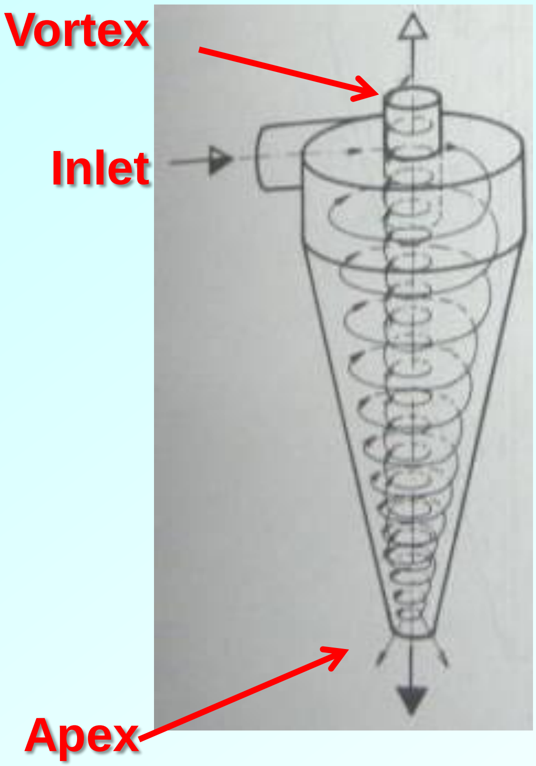
- Improved pretreatment results in less screenings that can be removed from the mixed liquor (or RAS) by MS
- ? g TSS/g COD & ? cost/kg TSS

Hydrocycloning: grit removal (X_{lg}) from mixed liquor and RAS

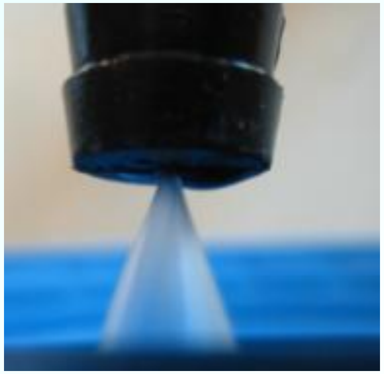
Composition of X_{lg}:

- **inorganics associated to X_H, X_E $X_{U,inf}$ (~9% VSS)**
- **precipitates (mainly with Al, Fe, Ca)**
- **fine sand, silt, egg shells, etc.**

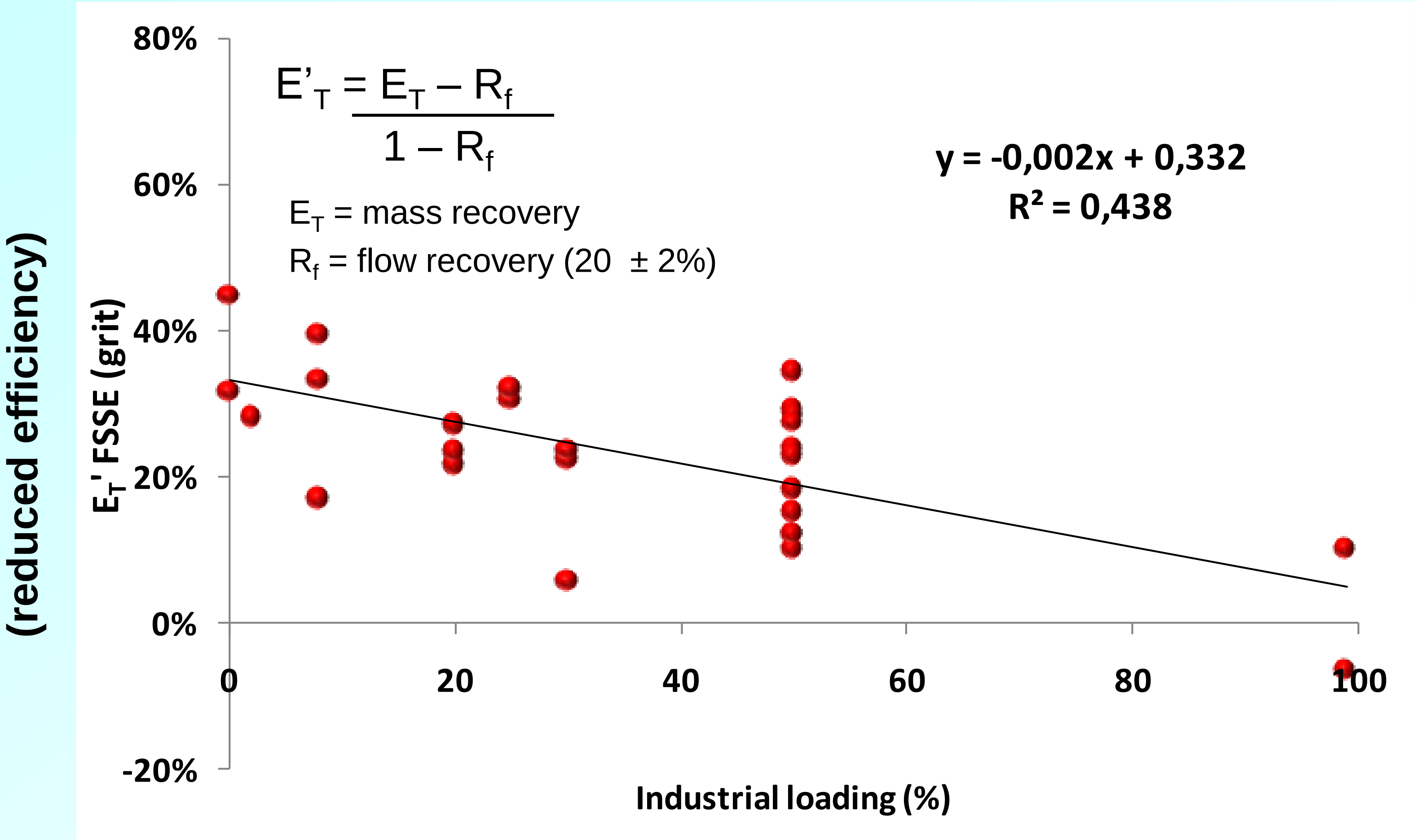
Hydrocyclone



(Svarovsky, 1984)



Effect of %industrial loading on $X_{ISS,Inf}$ (FSSE) removal by the HC



- **Higher efficiency with a smaller industrial loading: → sand from the municipality, not the industry**
- **About 25 ±10% of ISS can be removed by HC**

Endogenous residue (X_E) biodegradation

1. **Production of mixed liquor containing only (X_H + X_E) from a synthetic feed with acetate as sole carbon source in an MBR (200 L)**

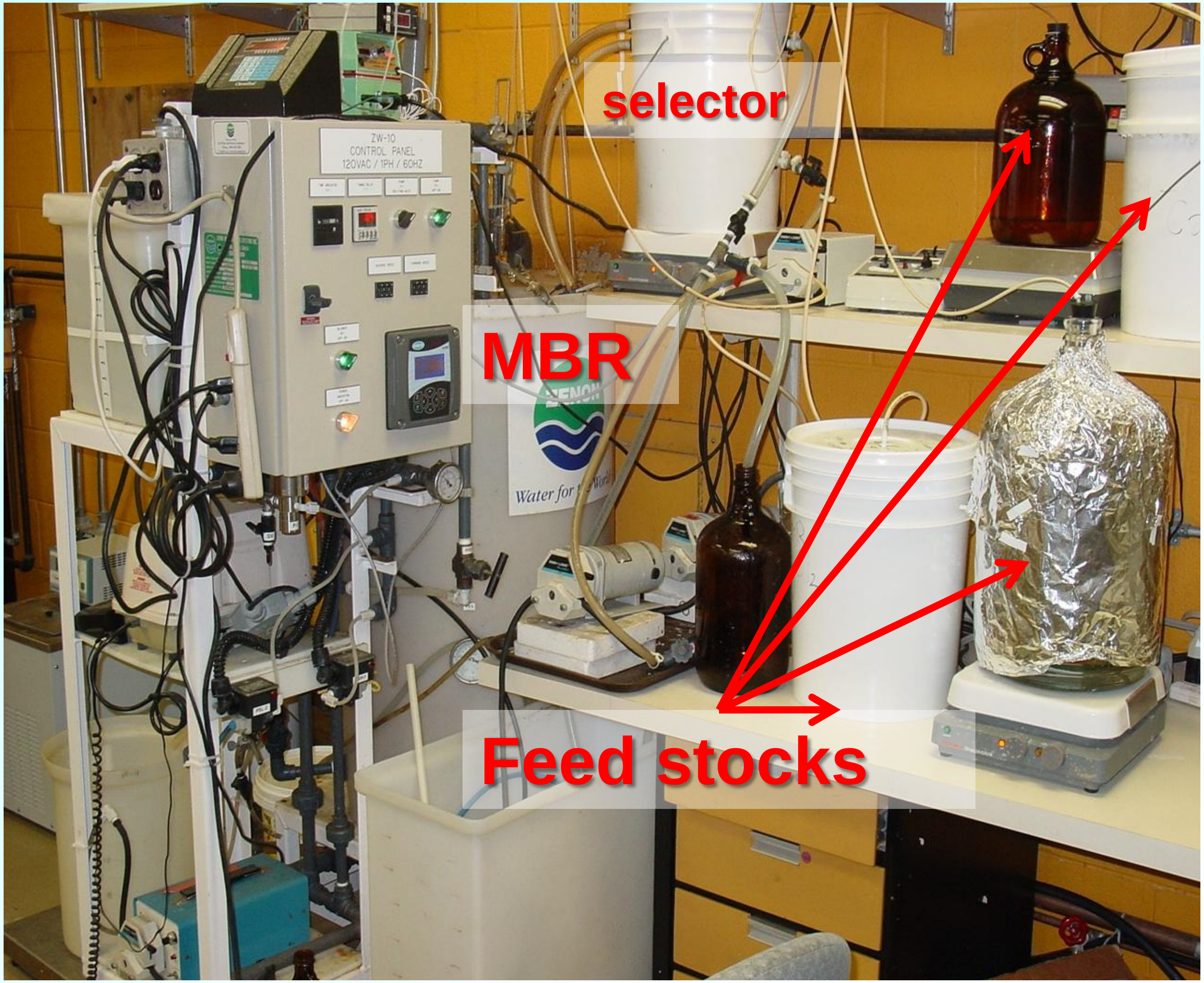
   - determination of the active fraction (F_A)

2. **Mixed liquor biodegradation under**

   2.1 anaerobic (AN) conditions

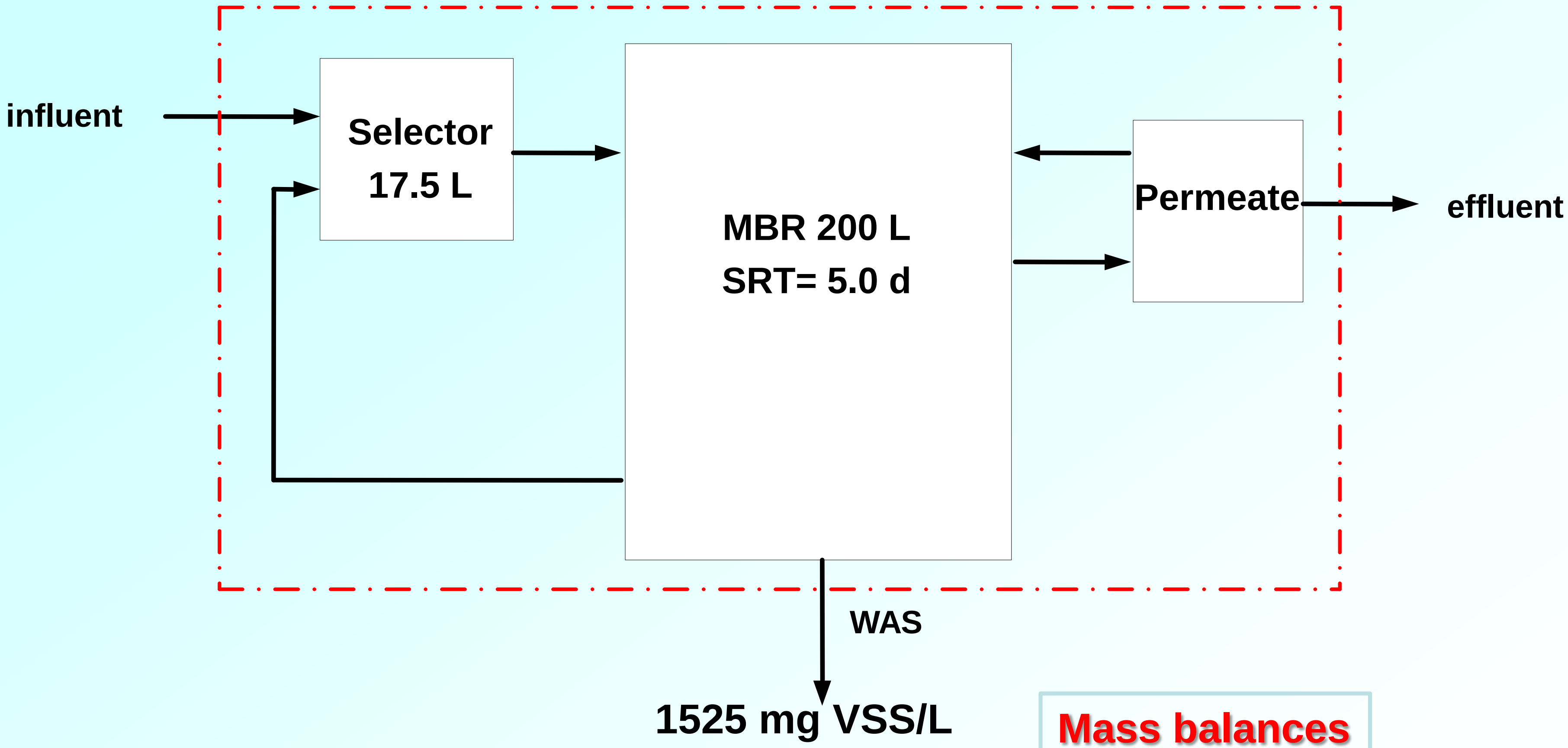
   2.2 anaerobic-aerobic (AN-OX) conditions

MBR setup



Zenon hollow fibers (ZW-10, 0.04 μm)

Removal efficiency and mass balances



Removal efficiency

COD: > 97%

TKN: > 96%

Mass balances

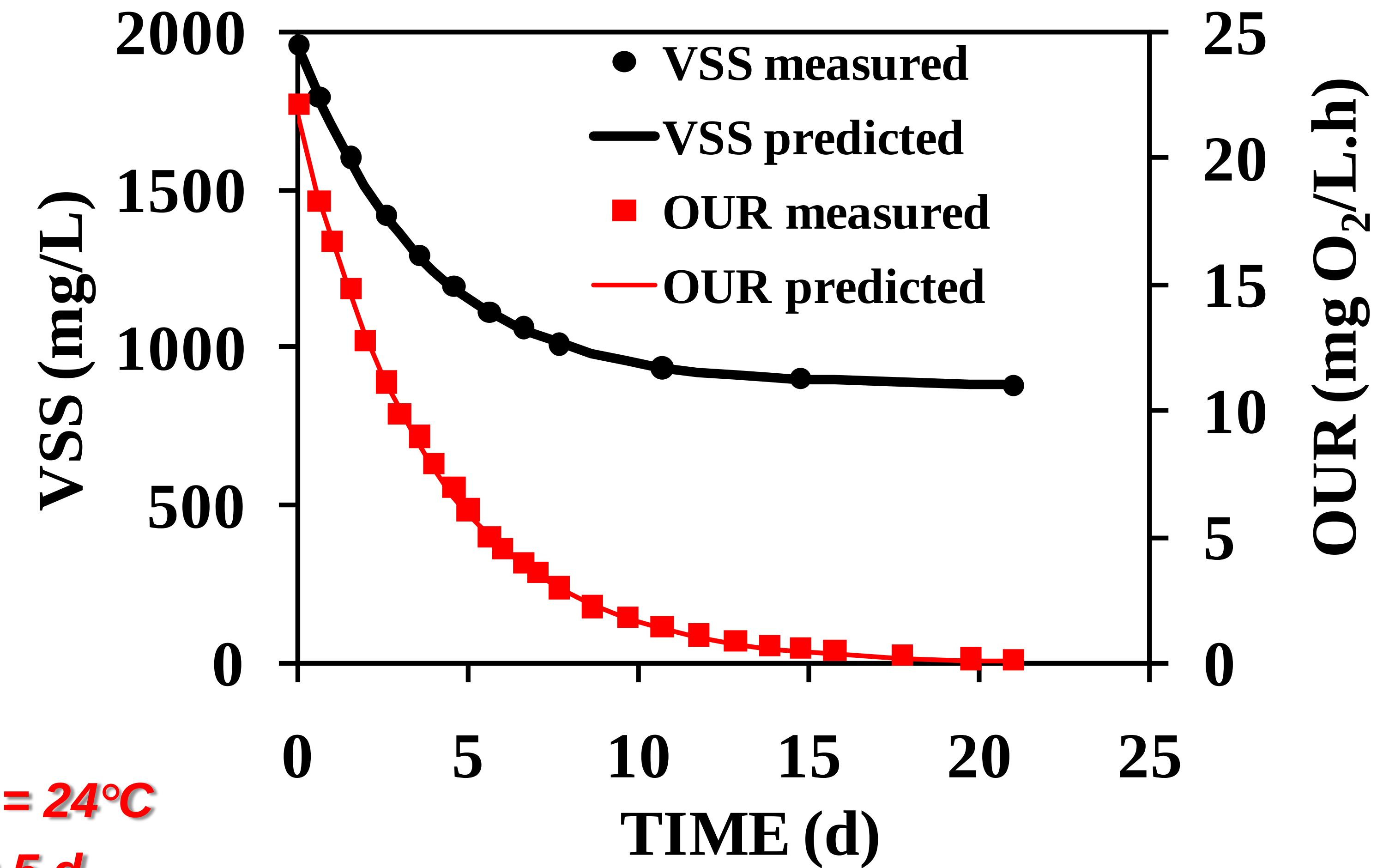
Hydraulic: 99.5 ± 0.4 (%)

COD: 98.4 ± 1.8 (%)

N: 101.9 ± 2.0 (%)

P: 102.8 ± 1.1 (%)

Active fraction (F_A) determination by 21 d endogenous respiration



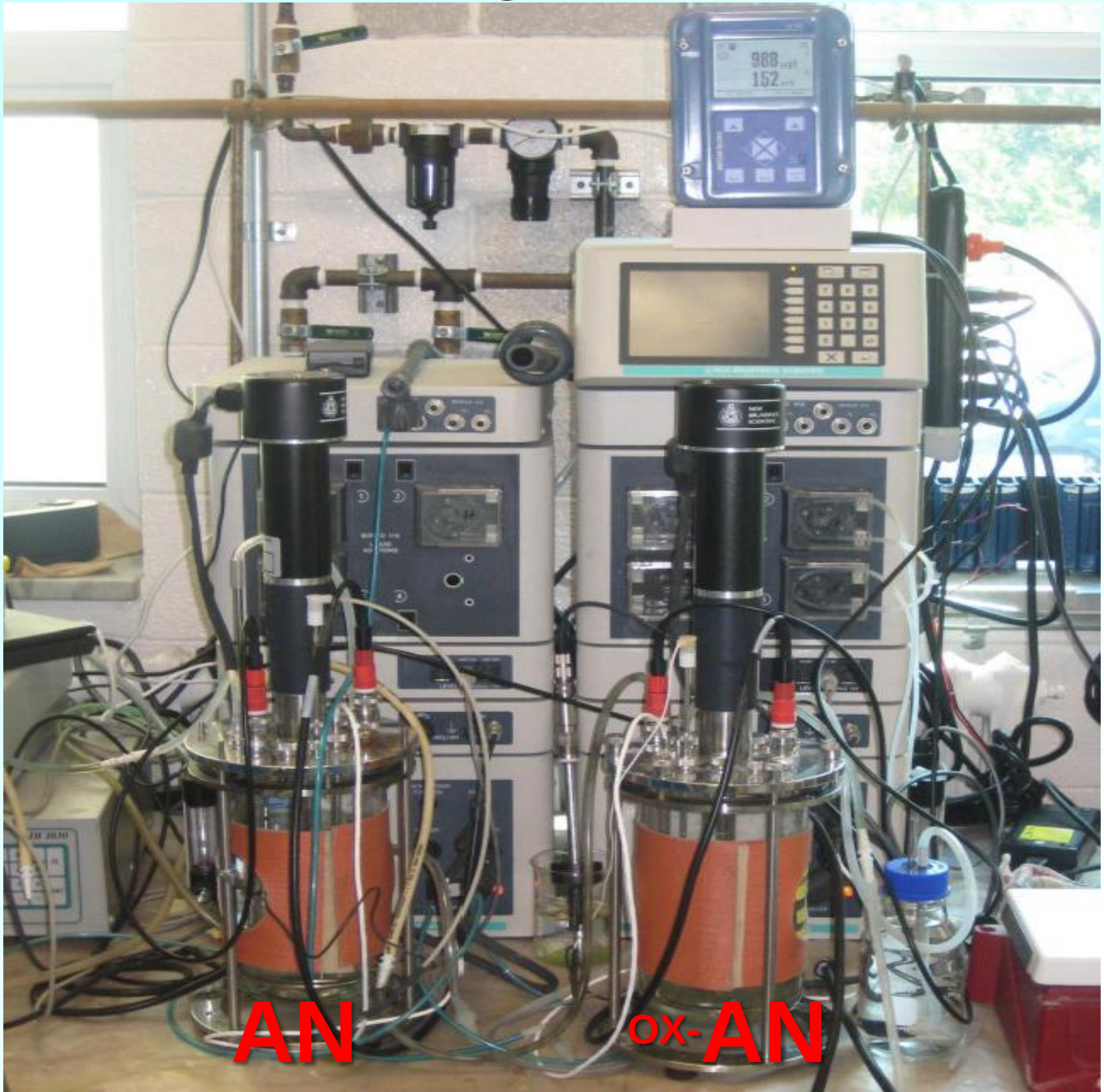
Temp = 24°C

SRT = 5 d

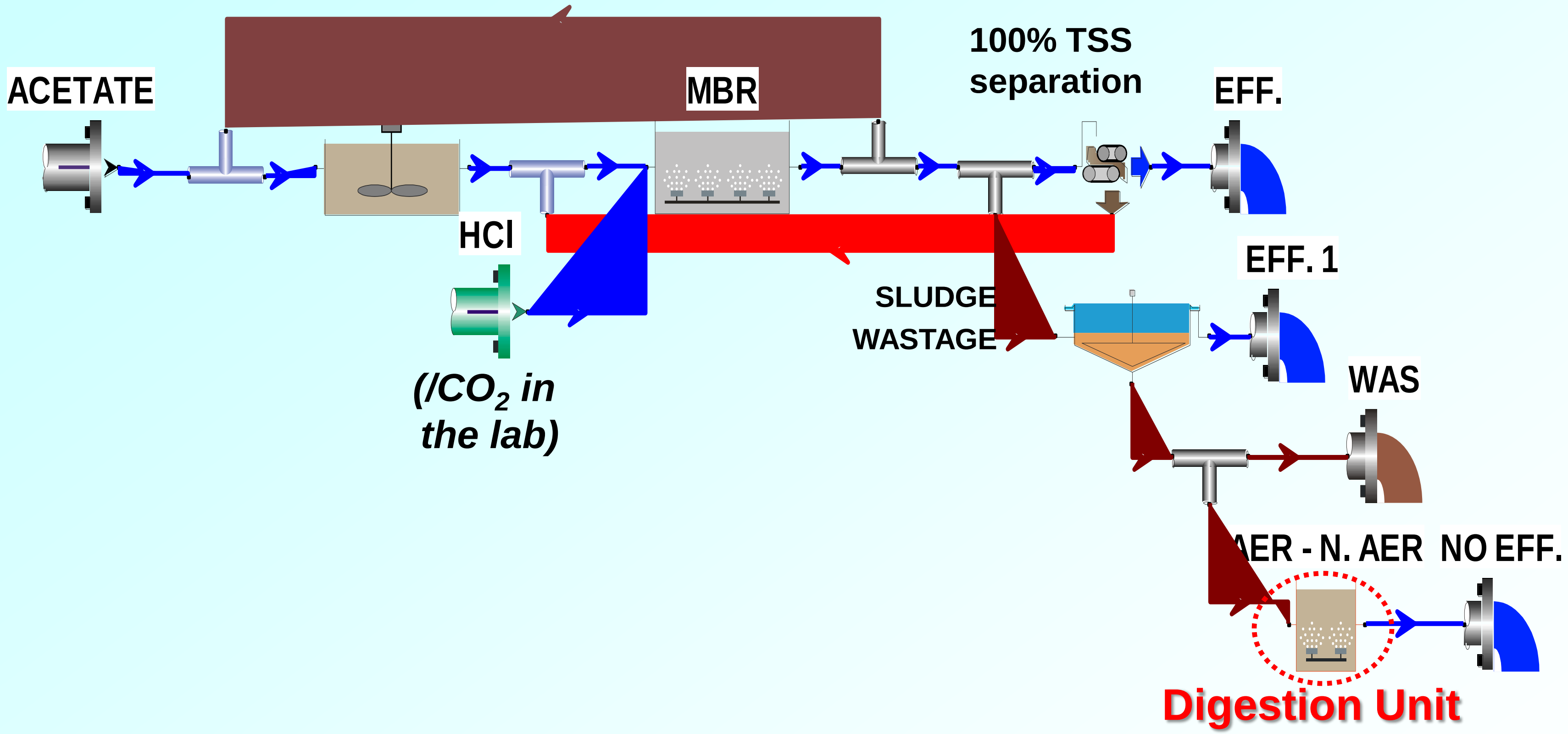
by VSS: b_T = 0.272 d^{-1} (0.243 d^{-1}@ 20°C); F_A = 0.685 g X_H/g VSS

by OUR.: b_T = 0.263 d^{-1} (0.235 d^{-1} @ 20°C); F_A = 0.683 g X_H/g VSS

Batch digestion units



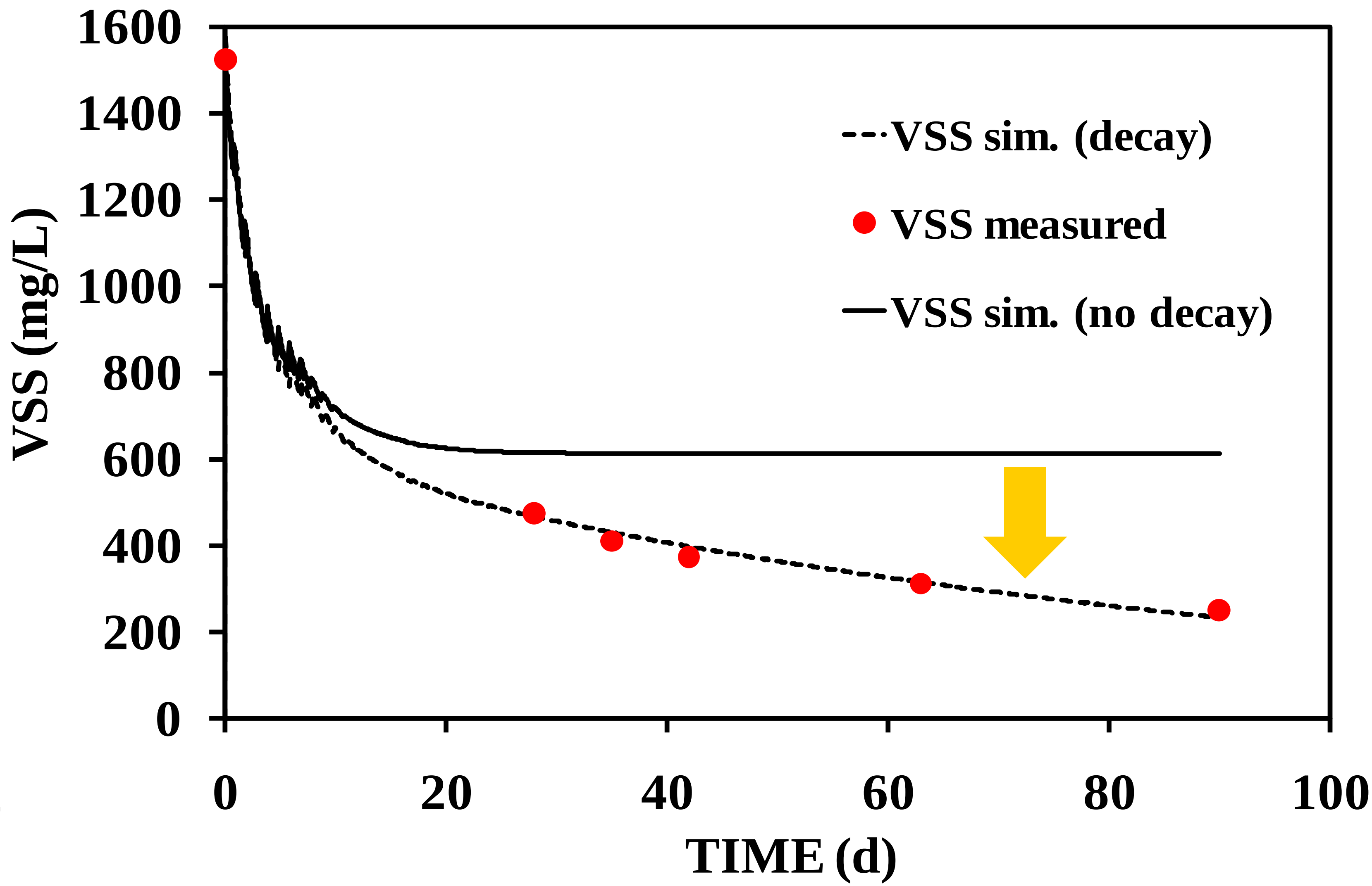
Modelling with BioWin
(OX-AN)



- Simulations consider or not the biodegradation of X_E

- Determination of the rate of X_E biodegradation: $k_{d,XE}$

ML biodegradation tests – AN-OX Results



pH 7.2

AN-OX: $k_{d,XE,35C,AN\text{-}OX} = 0.012\ d^{-1}$

(AN: $k_{d,XE,35C,AN} = 0.005\ d^{-1}$)

Biodegradation of « unbiodegradable » organics

- X_E is very slowly biodegradable
  - more rapid under AN-OX (0.012 d^{-1}) than AN (0.005 d^{-1}) conditions at pH 7.2 and 35°C
  - Arrhenius coefficient to determine

- $X_{U,Inf}$ is probably also similarly « slowly biodegradable »

Demo scale MBR with MS and HC

➢ **Mobile WWTP unit (16 m long) at St-Hyacinthe WWTP**


MS

HC

- **Activated sludge basins (1, 3, 5 m^3 + FST)**
- **MBR (membrane bioreactor – hollow fibers)**

•(option: SBR or media for MBBR or IFFAS)

(Observation: essentially no grit and trash in sludge fed from a primary effluent)

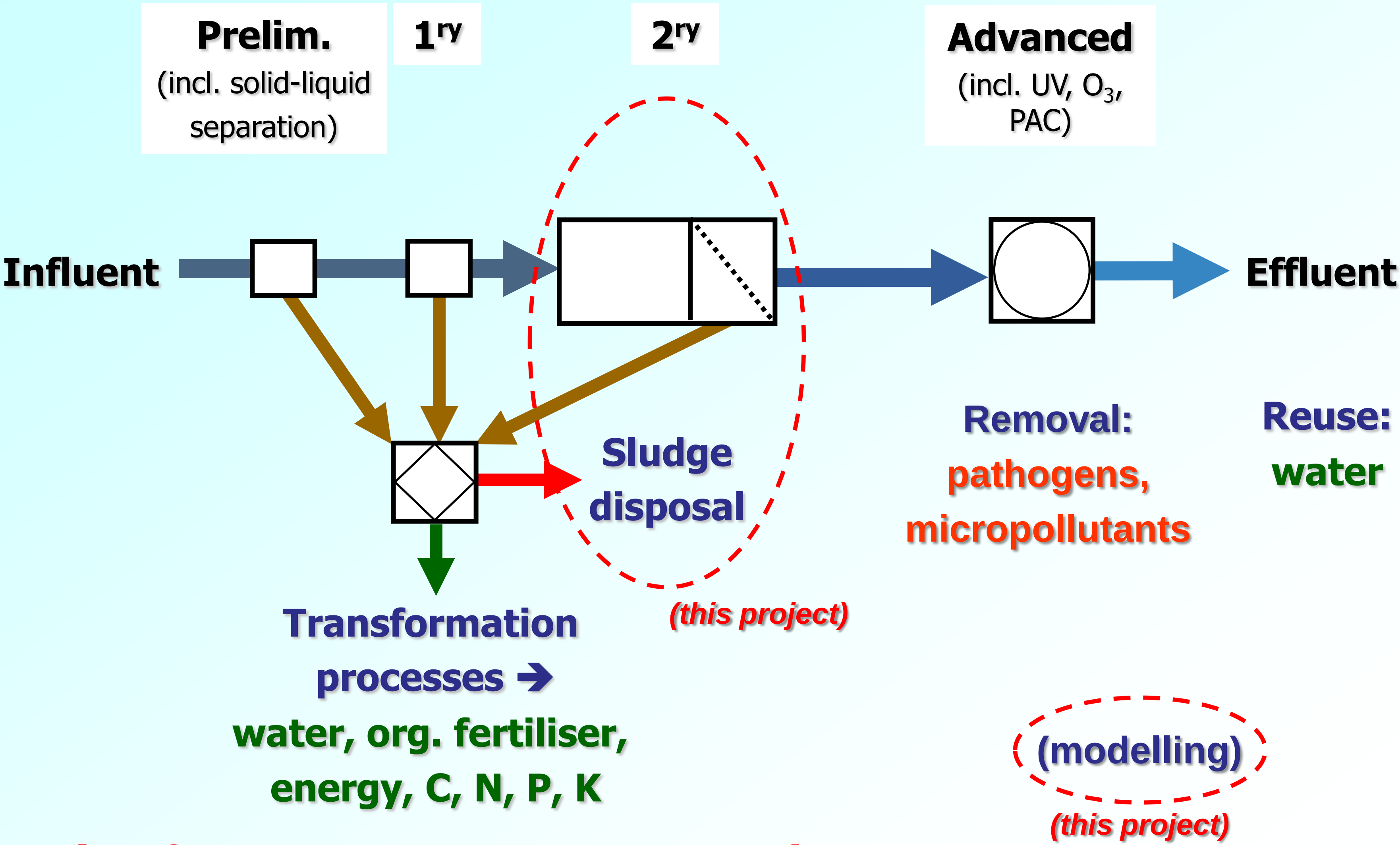
Conclusions

- **Grit & Trash can be removed from mixed liquor and RAS by <u>hydrocycloning</u> and <u>microscreening</u>, respectively**
  - ➔ **increased treatment capacity or smaller reactor size**
  - – **effect on settling to determine**
  - – **cost?**
- **X_E (and probably also $X_{U,Inf}$) is very slowly <u>biodegradable</u> under AN-OX or AN conditions**

Conclusions

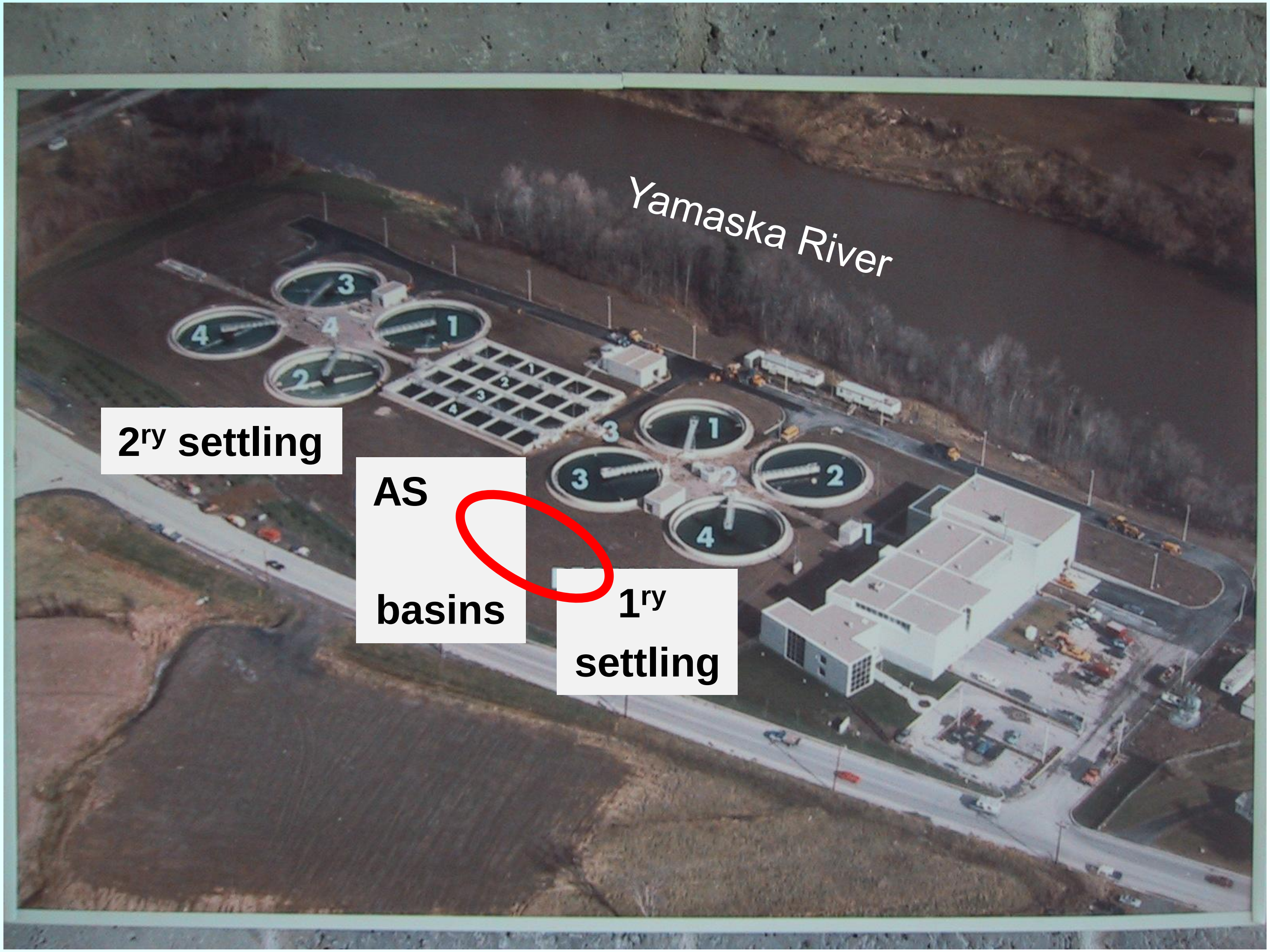
- **Cannibal®: proposed mechanisms of low sludge production:**
  - **main factor: long SRT (e.g. 0.40, 0.27, 0.17 g TSS/g COD at 3, 30 and 300 d SRT, respectively)**
    - **extra aeration costs to evaluate**
  - **other factors:**
    - **grit and trash removal by MS and HC feasible**
      - **MS screenings i_{VT} = 89 ± 4%**
      - **about 25 ± 15% grit removal by HC**
      - **not useful if there is primary treatment**
      - **effect on settling to determine**
    - **very slow biodegradation of « unbiodegradable » X_E and $X_{U,Inf}$ in the bioreactor and the hypoxic fermenter (0.005 to 0.012 d^{-1} for X_E at 35°C)**

Wastewater Treatment
(or WW Resource Management)



(to favor: energy via AD @ St-Hyac.)

St-Hyacinthe WWTP
Conventional activated sludge



St-Hyacinthe WWTP

La Presse, Feb 8, 2010

Completely mixed LIPP anaerobic digesters (german) & drying

- **+: energy from CH_4, sludge reduction**
- **-: odors, sludge disposal, transportation GHG**

Future: agrofood waste to digest in 2 extra units

➔ CH_4 for municipal vehicles

Future: maximize AD by bCOD recovery at 1^{ry} (CEPT) and 2^{ry} (high rate) treatment

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Thank you for your attention