Energy savings in wastewater treatment plants: optimization and modelling

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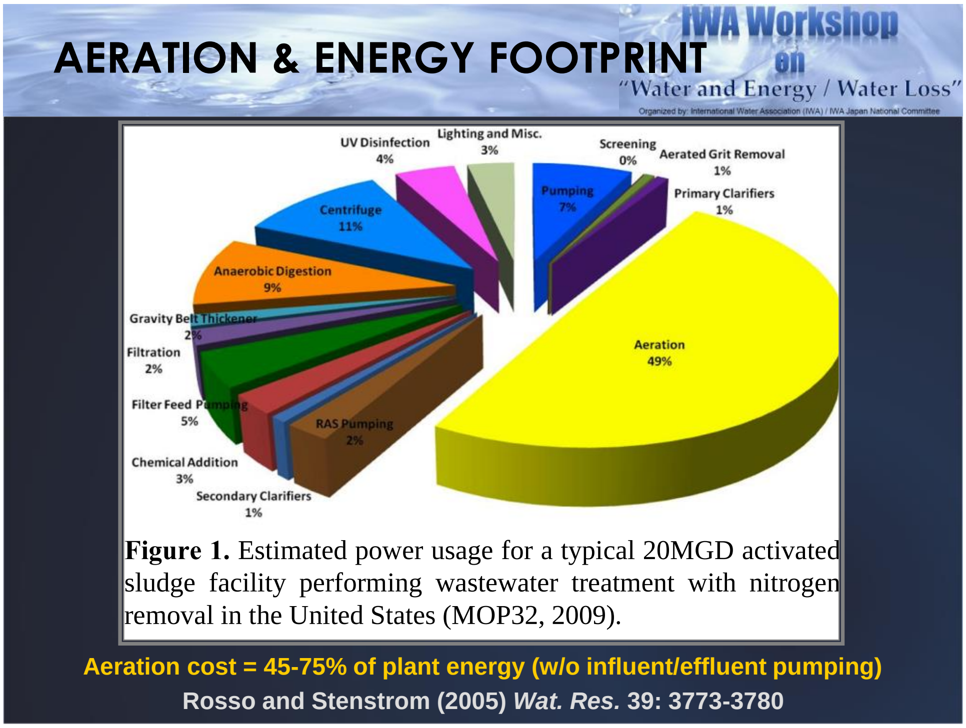
- Use of energy in wastewater treatment
- Energy modelling
- Energy recovery
- Optimization tools and technologies
- Conclusions


AERATION & ENERGY FOOTPRINT
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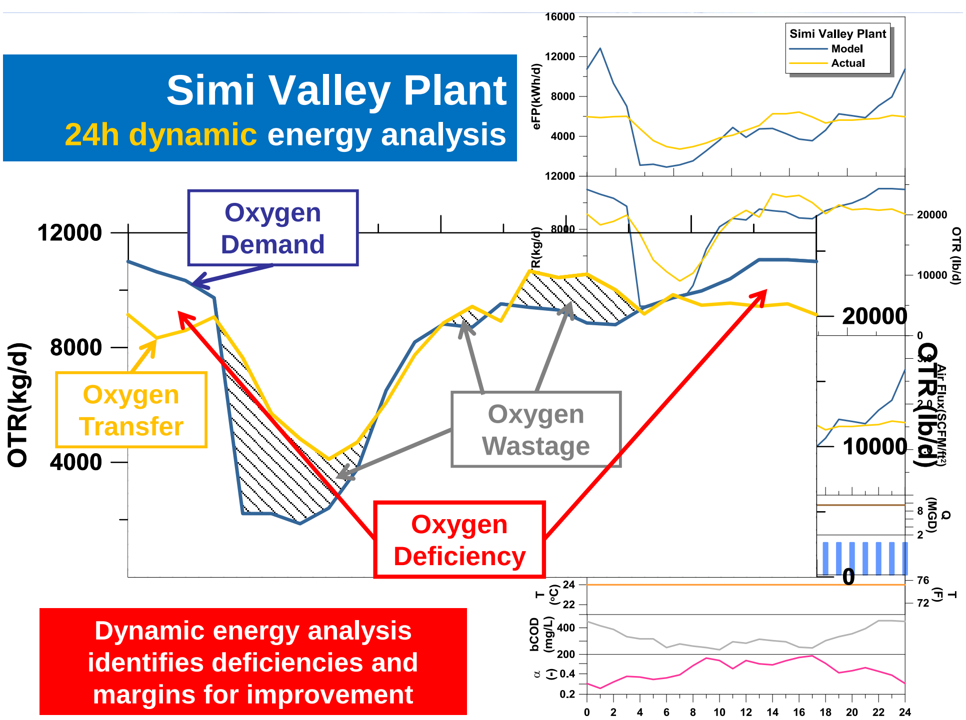
UV Disinfection 4%
Lighting and Misc. 3%
Screening 0%
Aerated Grit Removal 1%
Primary Clarifiers 1%
Pumping 7%
Centrifuge 11%
Anaerobic Digestion 9%
Gravity Belt Thickener 2%
Filtration 2%
Filter Feed Pumping 5%
RAS Pumping 2%
Chemical Addition 3%
Secondary Clarifiers 1%
Aeration 49%
Figure 1. Estimated power usage for a typical 20MGD activated sludge facility performing wastewater treatment with nitrogen removal in the United States (MOP32, 2009).
Aeration cost = 45-75% of plant energy (w/o influent/effluent pumping)
Rosso and Stenstrom (2005) *Wat. Res.* 39: 3773-3780


Simi Valley Plant
24h dynamic energy analysis
Oxygen Demand
Oxygen Transfer
Oxygen Wastage
Oxygen Deficiency
OTR(kg/d)
12000
8000
4000
20000
10000
0
OTR (lb/d)
Simi Valley Plant
Model
Actual
eFP(kWh/d)
16000
12000
8000
4000
OTR (lb/d)
Air Flux (SCFM/ft²)
Q (MGD)
T (°C)
24
22
T (F)
76
72
bCOD (mg/L)
400
200
α (-)
0.4
0.2
0 2 4 6 8 10 12 14 16 18 20 22 24
Hours
Dynamic energy analysis identifies deficiencies and margins for improvement

ENERGY MODELING

Information availability and capacity for improvement

Rosso et al (2012) Wat. Practice Technol.

$$eFP_{TOT} = \sum_{i=1}^{n} eFP_i = \sum_{i=1}^{n} \sum_{j=1}^{m} n_j \cdot p_j \cdot h_j \cdot t_j$$

#units power efficiency time in operation

eFP: Energy Footprint

Information Available	Modelling Nature	Difficulty to Gather	Margin for Improvement	Data Availability
Power bill	Cumulative	Easy	Small	Very common
Power by unit	Static	Moderate	Moderate	Rare
Power by Time-of-use (TOU)	Dynamic	Difficult	Large	Very rare

Energy vs. effluent quality

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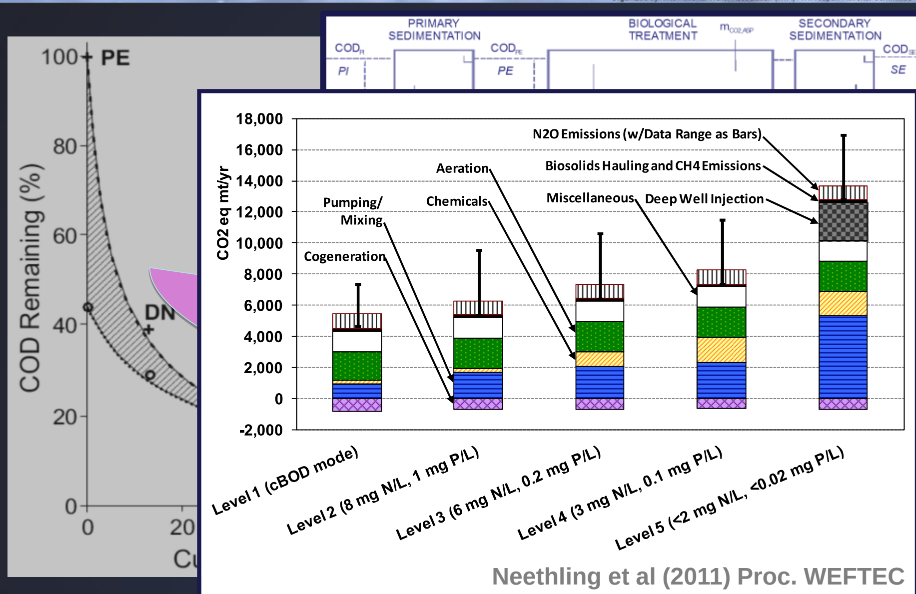

Case Study:
Energy Usage in Water Reuse

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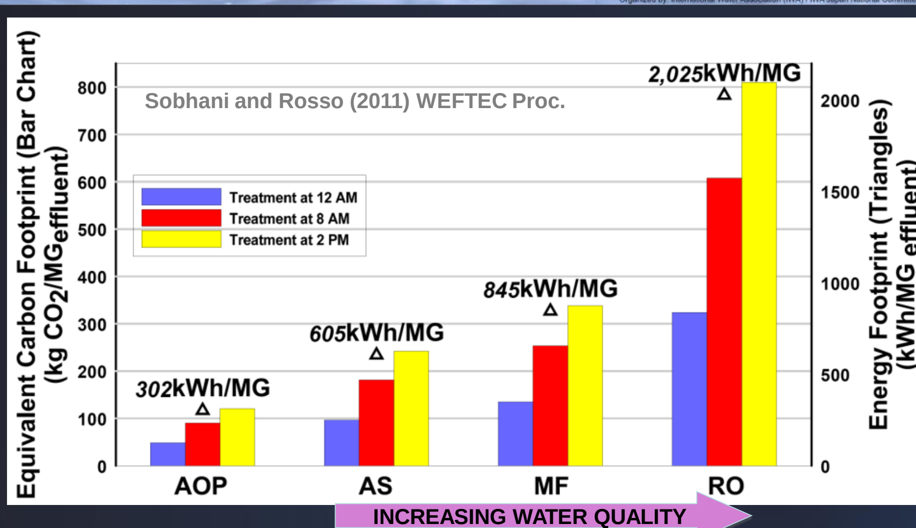
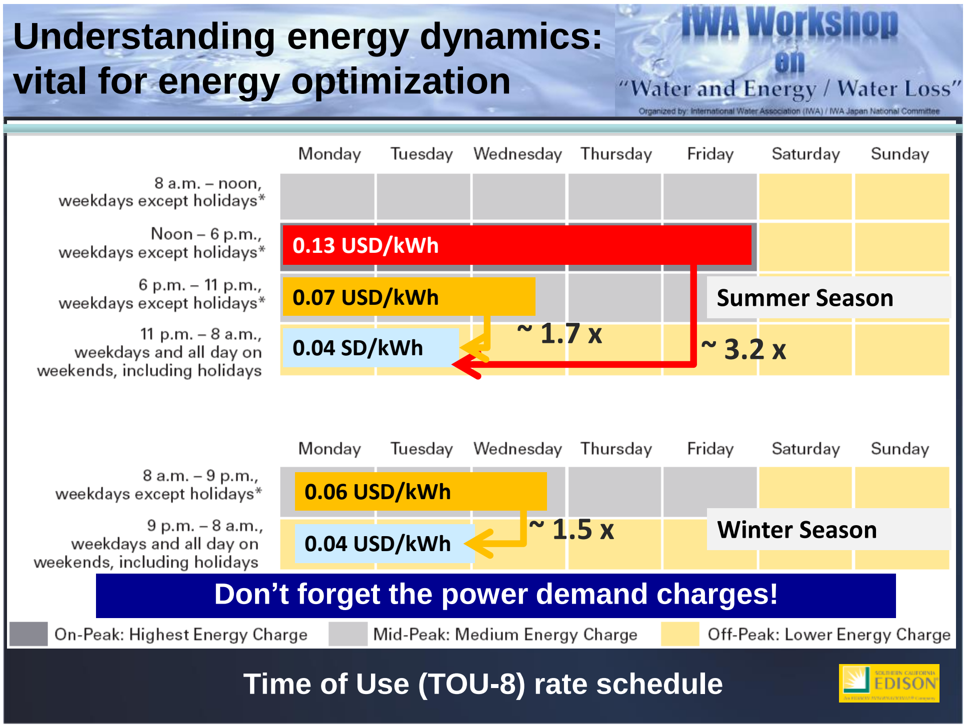
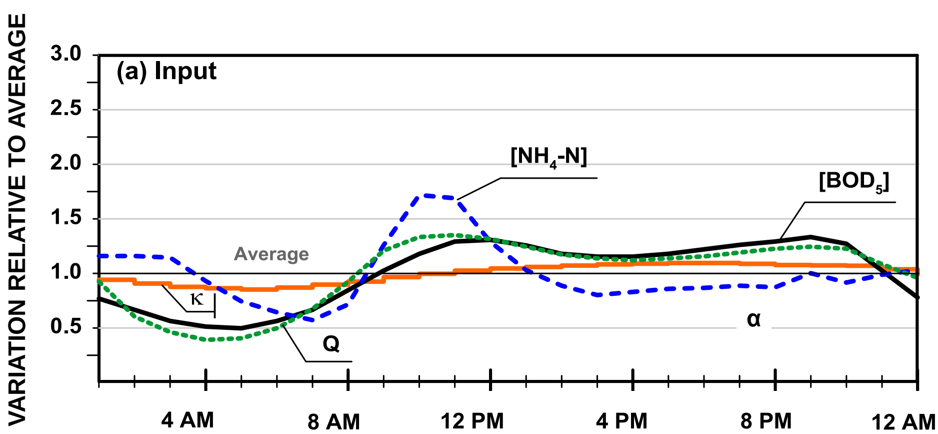


Local water reuse is a crucial component of the water portfolio and can substantially decrease utilities energy use by substituting water importation



Activated Sludge Process: Diurnal Dynamics



Flow equalization (when possible) does wonders

Sidestream loads (if not treated) should not be returned at peak hours

ENERGY RECOVERY

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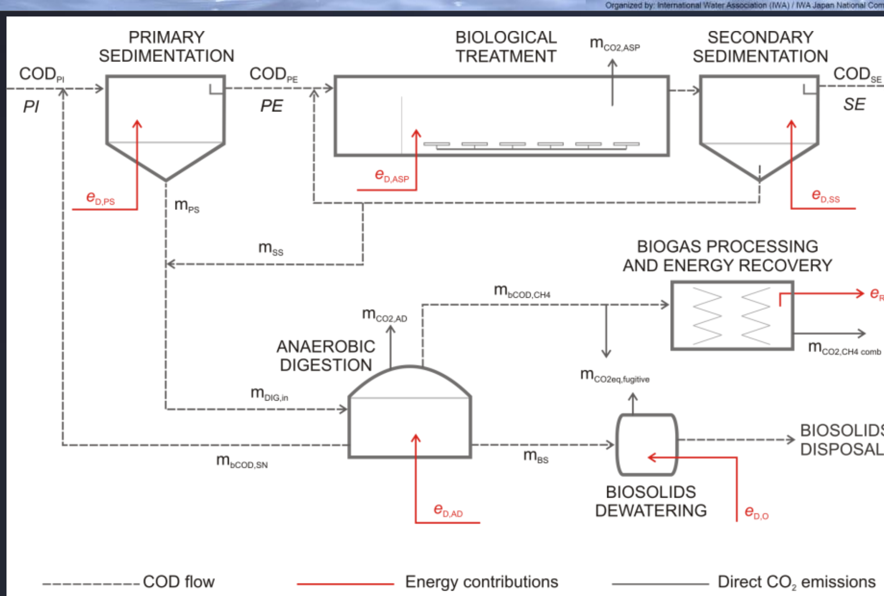
Typical treatment train



CFP/eFP effects of enhanced primaries

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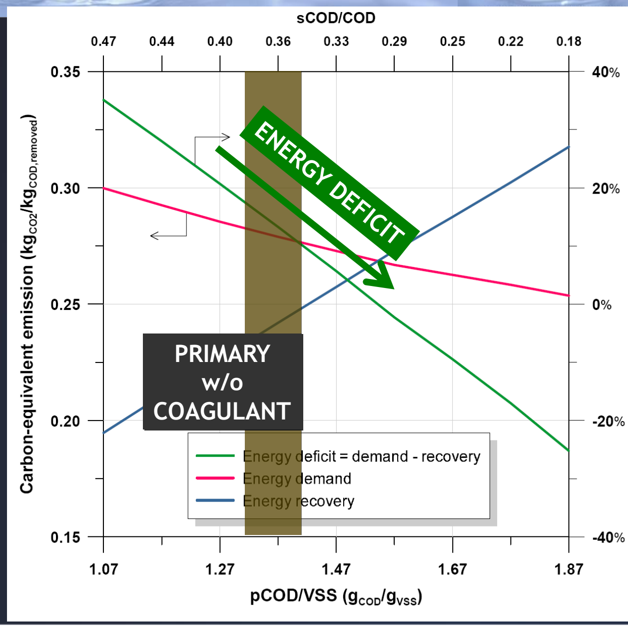

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Energy efficient units and practices

Aeration electrical efficiency for different systems over time

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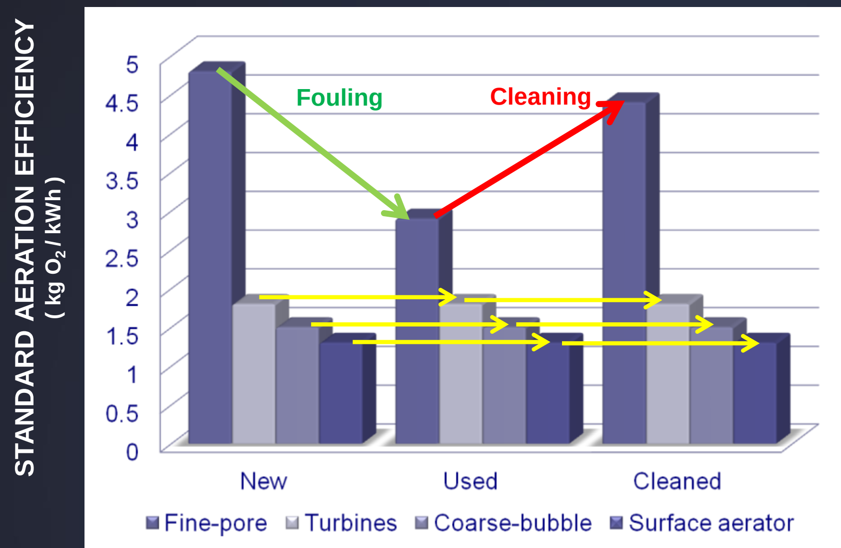

After Stenstrom and Rosso (2008)

HALF & HALF

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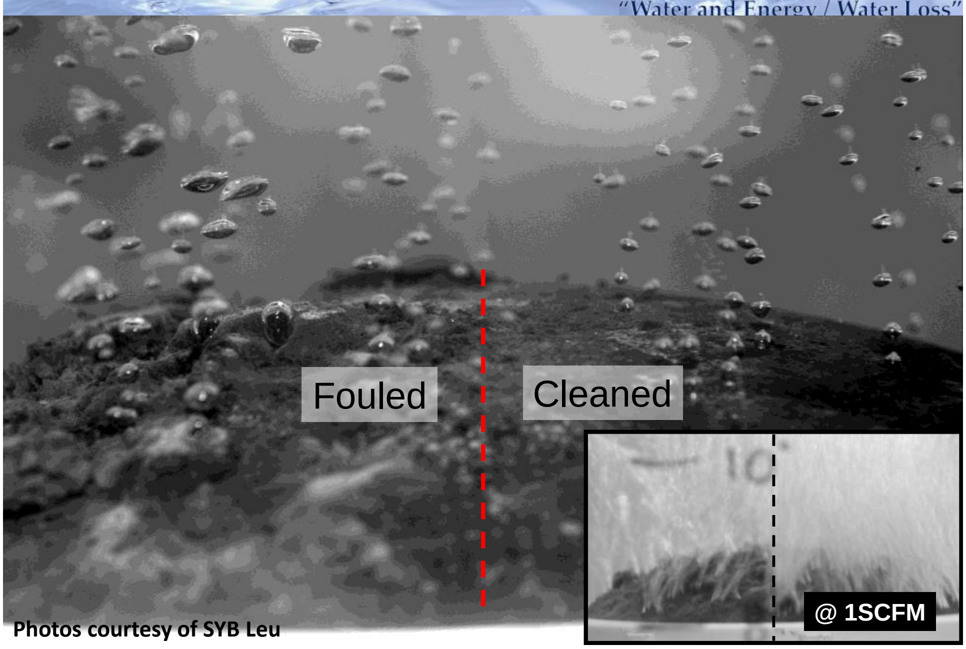

Photos courtesy of SYB Leu

Fine-pore diffusers:
clean them or don't buy them

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Oxygen transfer tests: e.g., off-gas testing

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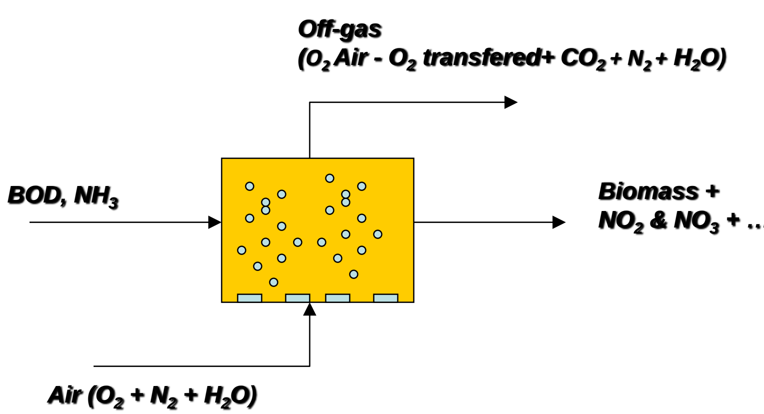

How efficient are my diffusers?: O_2 transfer tests

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O_2 transfer tests → O_2 transfer efficiency

OTE [%] = kg O_2 transf. / kg O_2 pumped

with OTE, k_La **can be obtained**

Optimization @Little River WWTP, Ontario, CANADA

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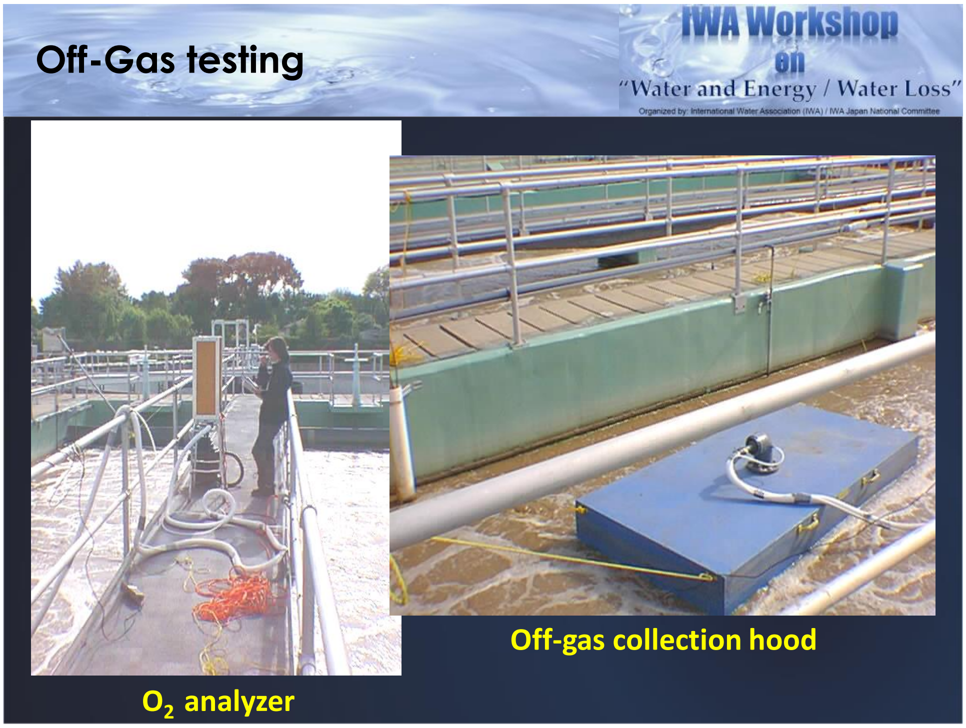
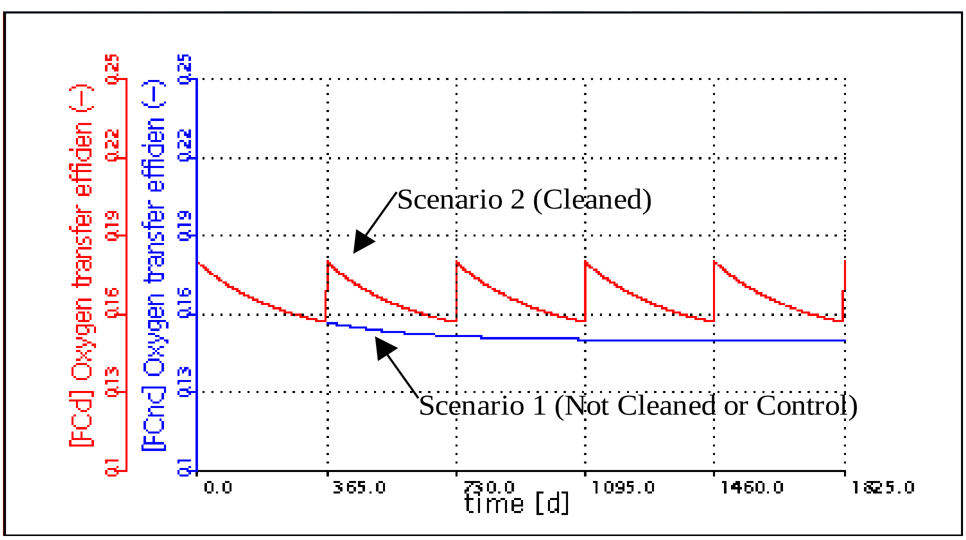
- 1 m^3/s
- Ceramic fine-pore diffusers
- Hydrochloric acid cleaning (HCL) system

Objectives:

1. Evaluate OTE before and after diffuser cleaning.
2. Determine optimal diffuser cleaning period





Taking into acccount diffuser cleaning cost and EE price (~0.05 u$s/kWh), optimal cleaning period was: 12 months.

Annual savings in EE ~ USD 50,000.-

Digester maintenance: key to optimize EE production and biosolids quality

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- Activated sludge plant in Ontario: 93.000 m3/d
- 2 anaerobic digesters + dewatering centrifuges → biosolids for agricultural use + biogas for EE generation
- VS destruction + biosolids quality + biogas production deteriorated over time
- Temperature?: OK
- Mixing? Not OK → CapEx for mixing system upgrade: US$4.5M
- Digester tracer studies using LiCl were proposed to evaluate cleaned vs. not cleaned digester

Li traces in digester effluent after a slug added at influent

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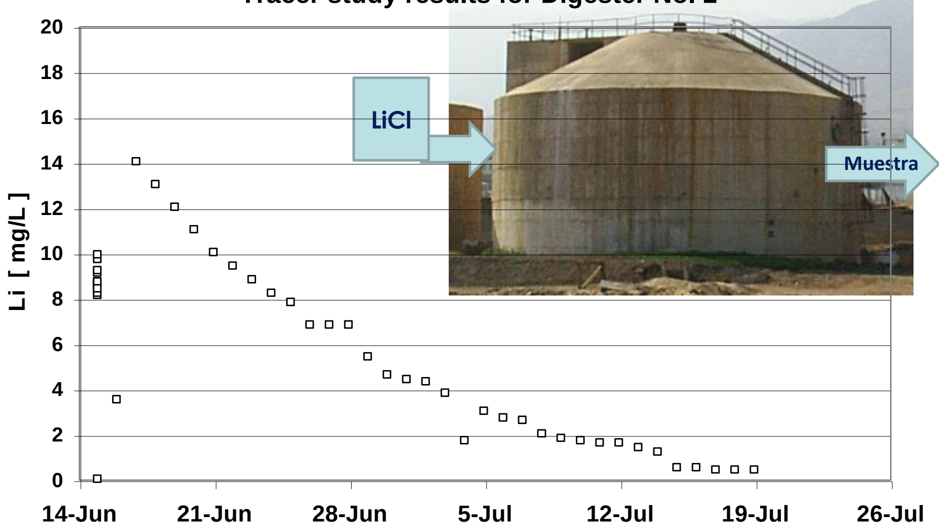
Figure 1
Tracer study results for Digester No. 2



Actual behaviour of digester?: model proposed

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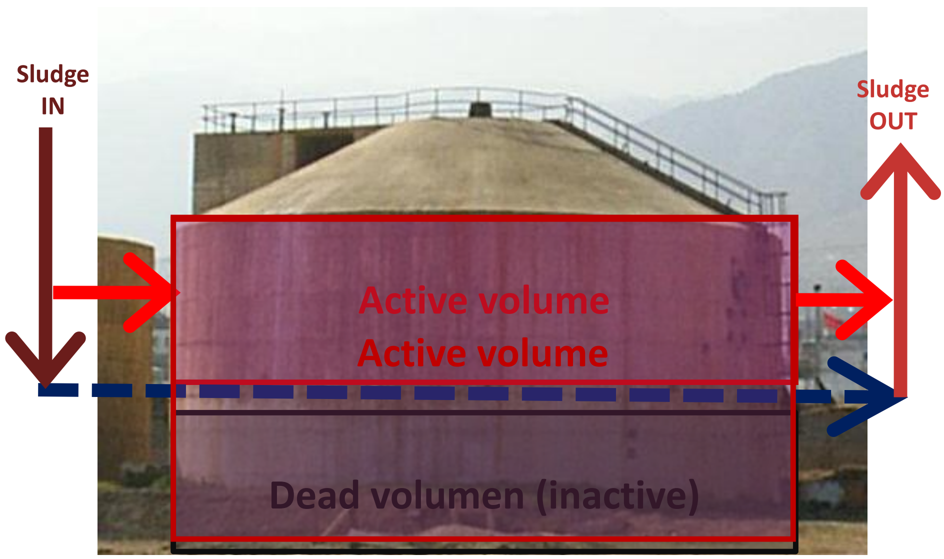

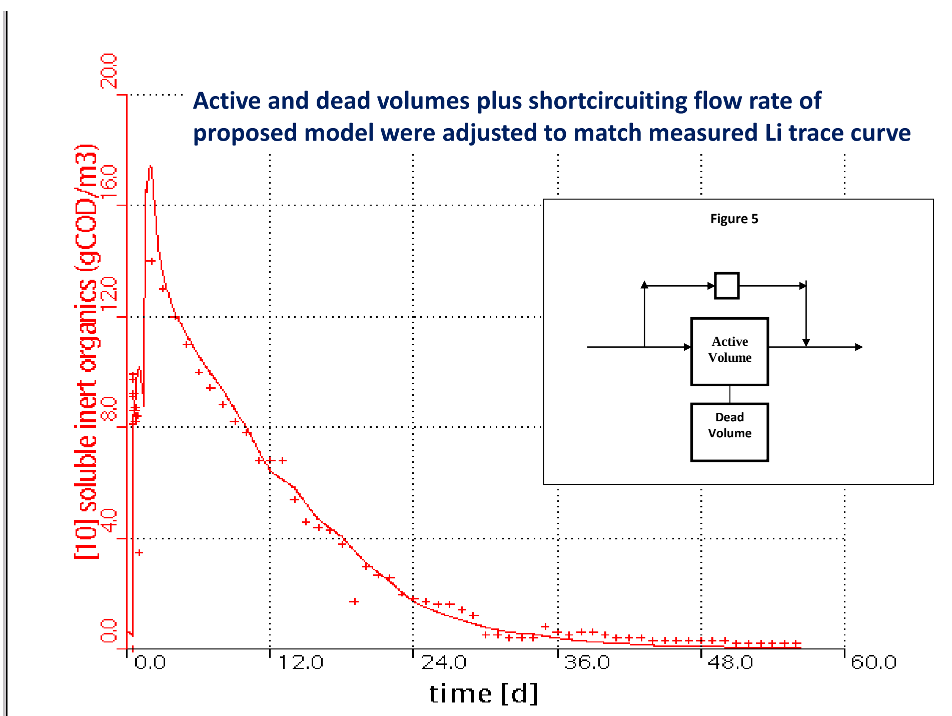

Case study conclusions

Impact on bioelectricity generation

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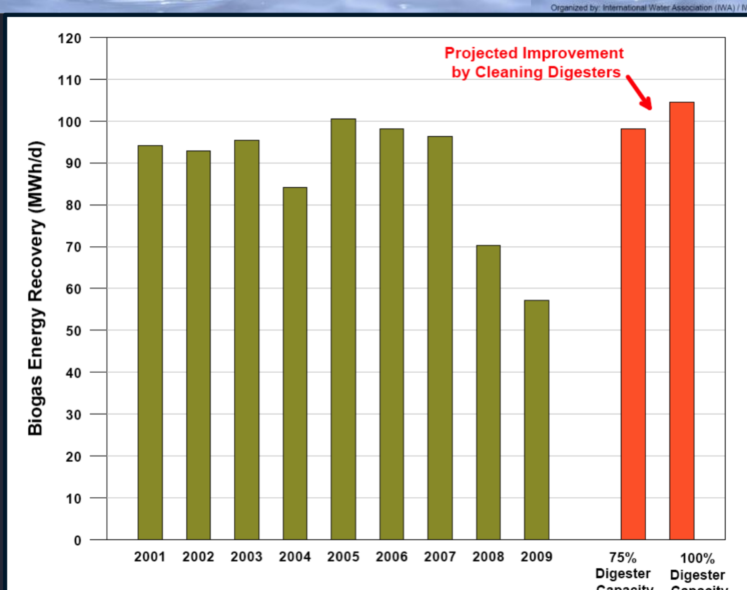


Co-digestion

Comparative increase in digester gas production with external FOG addition

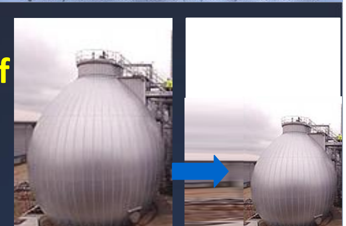
Multipliers for Digester Gas Production Rates

Year	Municipal Only	25% FOG Case	100% FOG Case
2010	1.00	1.30	1.69

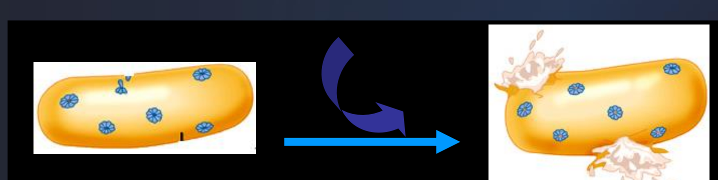
But keep in mind that:

- There is significant variability in FOG characterization
- Gross assumptions are used to develop design data
- There is a limited amount of data available on how digester performance changes with FOG addition

Thermal-hydrolysis (TH)



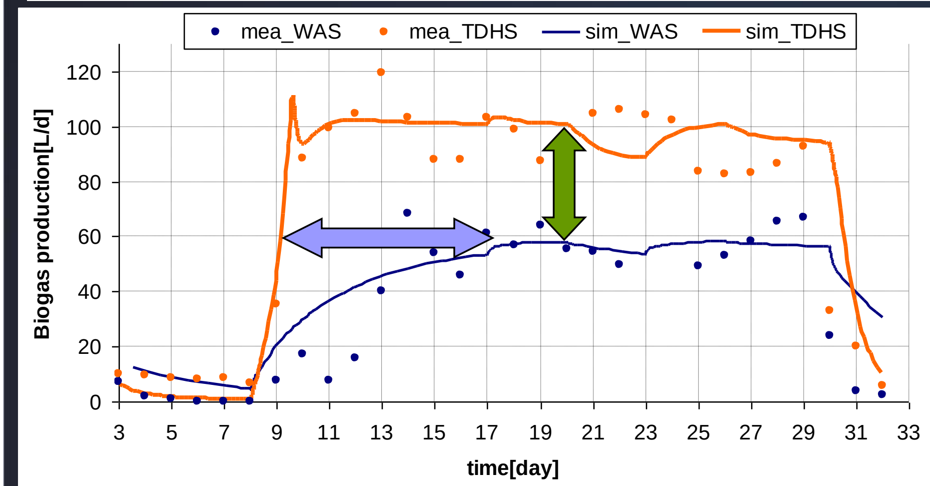
- Disruption of cell walls and release of degradable content
- Acceleration of digestion process
- High solids digestion
- Improved dewaterability
- Enhanced bioavailability of substrate



TDH Thermal-Pressure-Hydrolysis

Impact 1: Accelerated degradation – reduced HRT requirement

impact 2: Increased bioavailability – more complete digestion



DC WASA World's large Cambi installation now in construction phase

Full-scale Cambi dewatering (belt press)

- Thermal Hydrolysis minimizes the risk for a sustainable biosolids program compared to other process:
  - **Reduces digester volume**
  - **High solids content with a belt filter press**
  - **Odors are low and less offensive with belt filter press**
  - **Pathogen disinfection**

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Conclusions

CONCLUSIONS

- Compounding dynamics amplify energy consumption peaks: need to take into account tariff structure, C emissions, organic loading, recycle streams, α factor, equipment efficiency curves!!
- Smart primary treatment (e.g., CEPT), sludge enrichment (e.g., co-digesting sludge with FOG), sludge conditioning (thermal hydrolysis) may assist in reaching neutrality (both C & EE)
- Equipment evaluation and maintenance is key (diffuser and digester cleaning are good examples)
- Dynamic modelling: powerful tool to optimize

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Many thanks!

Dr. Hiroaki Furumai, University of Tokyo
Dr. Diego Rosso, U. of California @ Irvine
Dr. Suthir Murthy, DC WASA

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