The Metropolitan

Water Reclamation District

of Greater Chicago

WELCOME

TO THE APRIL EDITION

OF THE 2015

M&R SEMINAR SERIES

BEFORE WE BEGIN

- PLEASE SILENCE CELL PHONES OR SMART PHONES
- QUESTION AND ANSWER SESSION WILL FOLLOW PRESENTATION
- PLEASE FILL EVALUATION FORM
- SEMINAR SLIDES WILL BE POSTED ON MWRD WEBSITE (www. MWRD.org: Home Page ⇒ Reports ⇒ M&R Data and Reports ⇒ M&R Seminar Series ⇒ 2015 Seminar Series)
- STREAM VIDEO WILL BE AVAILABLE ON MWRD WEBSITE (www.MWRD.org: Home Page ⇒ MWRDGC RSS Feeds)

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Publication: Over 70 publications in journals and conference proceedings; 3 patents

Award: Paul L. Busch Award, Water Environment Research Foundation (2013);

Oxygenic Biogranules: Aeration-free & Energy-recovery Wastewater treatment

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April 24th, 2015

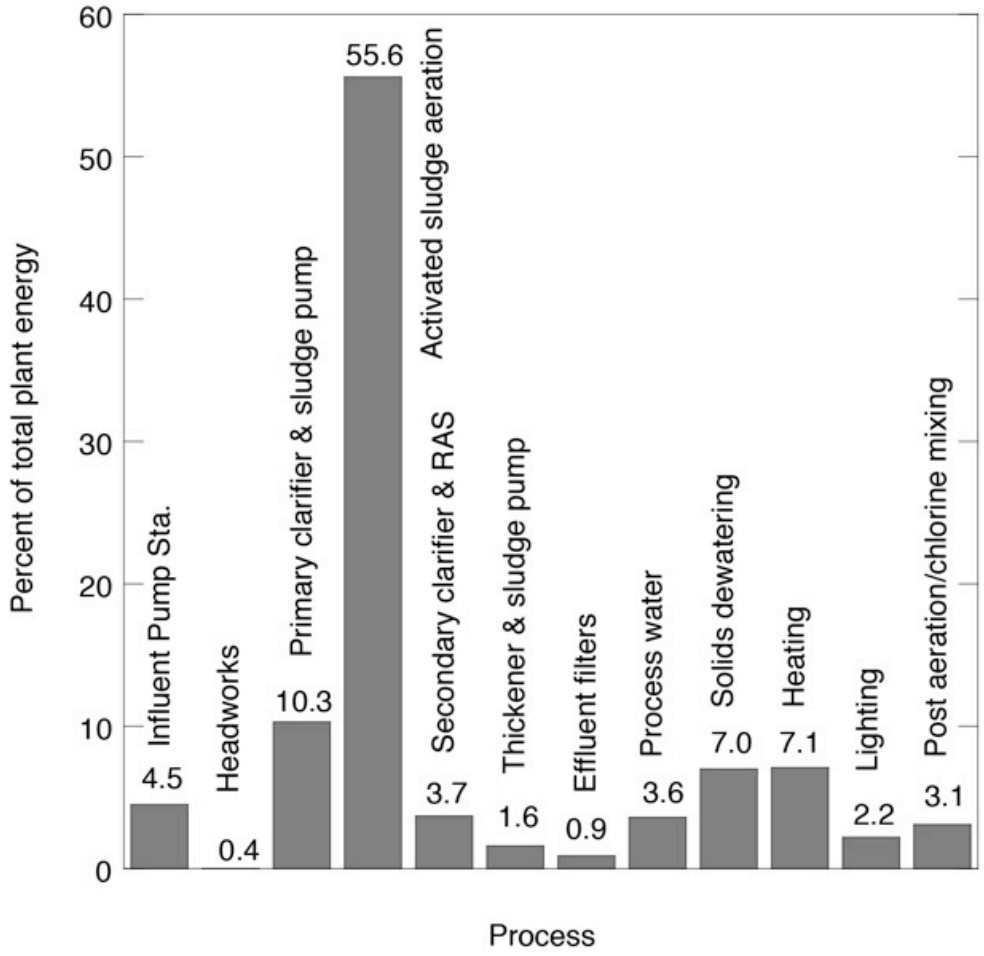
Melting Glaciers

Source: http://www.weather.com (USGS photos by Bruce Molnia)

Wastewater Treatment

- Our responsibility for
  - Sanitation and public health
  - Environmental health
- The process is not free
  - 1.2-2.4 MJ/m^3 wastewater (~2% of national E demands)
  - Up to 60% of this is for aeration (O_2)
- The carbon footprint
  - CO_2, CH_4, and N_2O
- More stringent regulations in future?

Energy Usage in the Activated Sludge Process



Adapted from:
Dr. George Tchobanoglous

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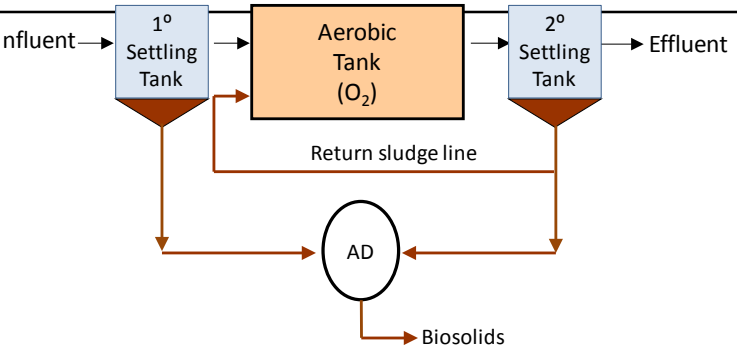
Wastewater Treatment: Opportunities

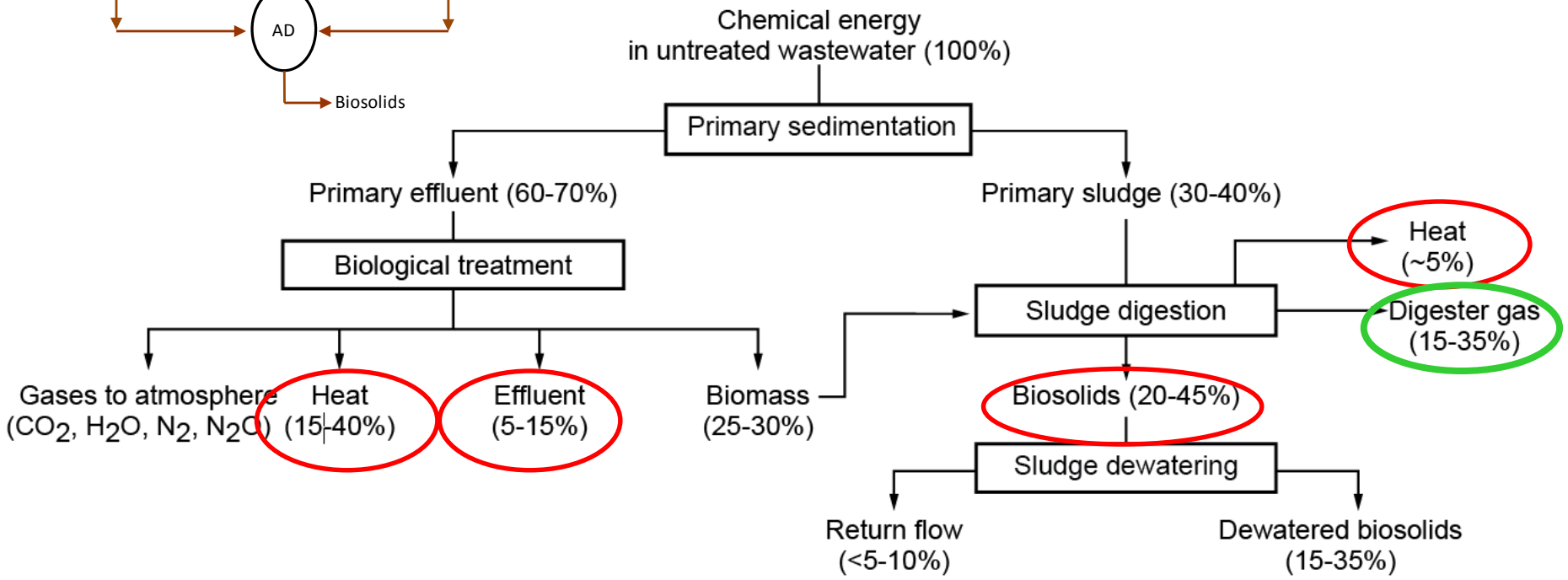
- Chemical (calorific) energy in wastewater
  - 6-8 MJ/m^3 wastewater (2.2 KWh/m^3)

    = (12-15 MJ/kg COD) (0.5kg COD/m^3)

    = 6-8 MJ/m^3 wastewater
  - 2-5 times the energy used to treat it
  - 3.2 x 10^{17} J per year ➔ 3-6% of national E
  - **This is renewable energy!!!**
- Stickney WWTP: 100~200 MW plant?
- *Dilemma: wastewater organic is dilute*

Energy Flow in the Activated Sludge Process





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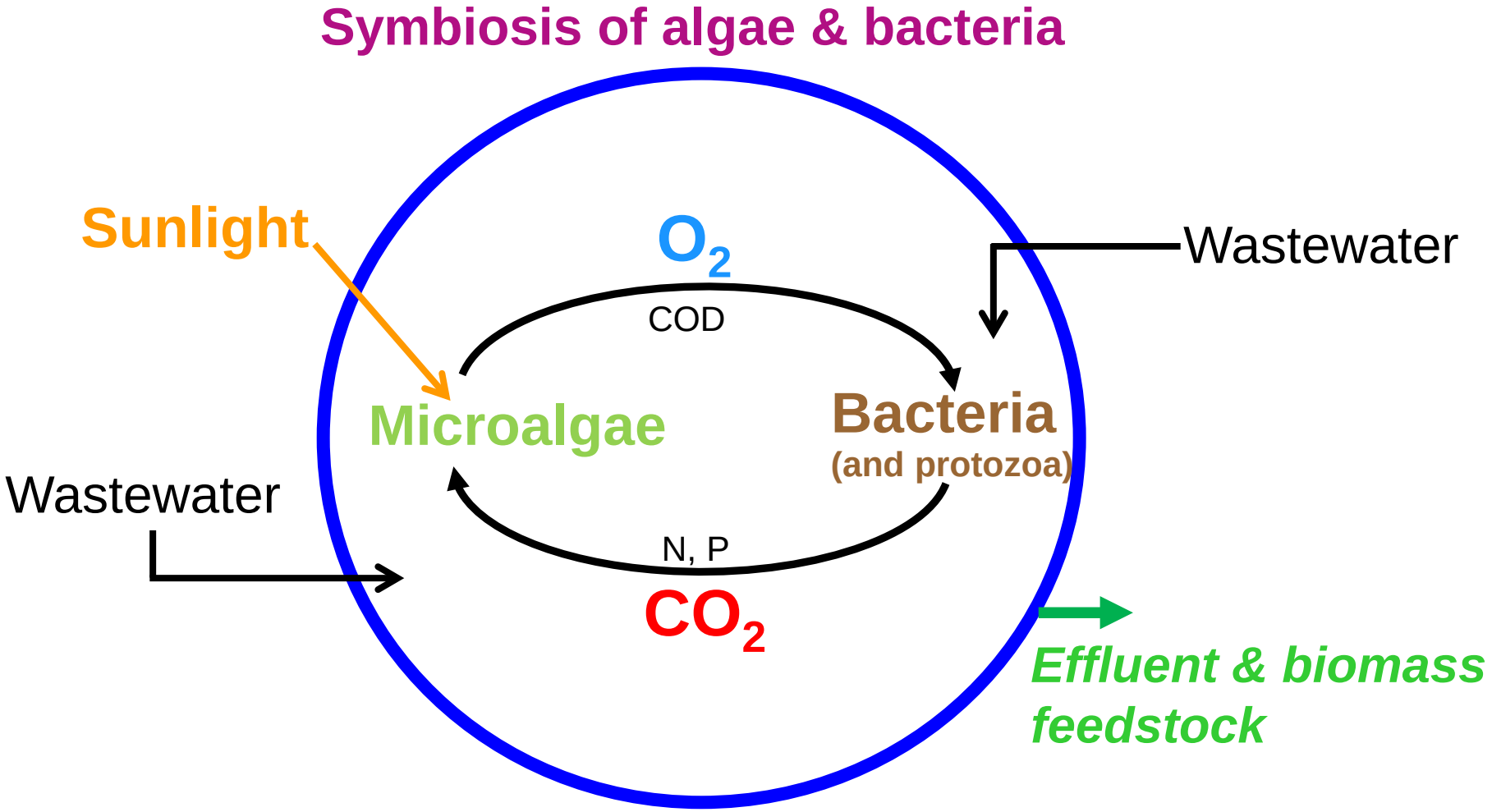
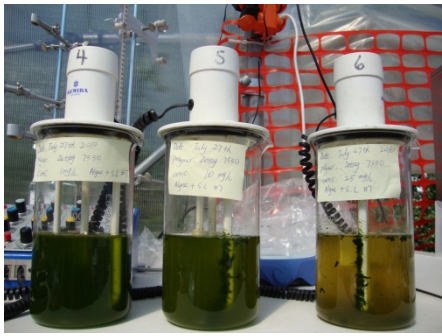
Microalgae-based Wastewater Treatment



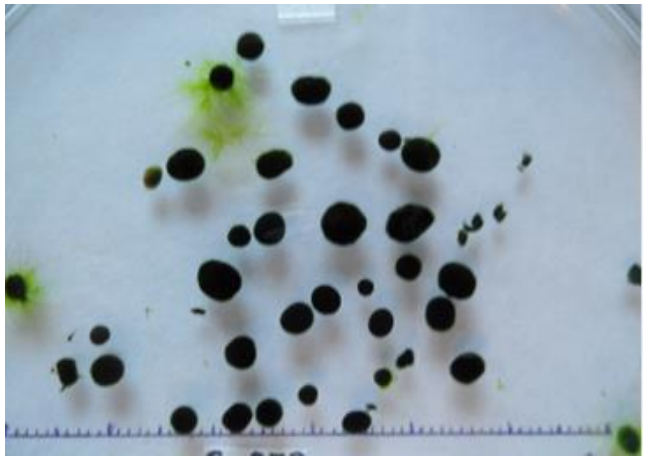
Challenges

- Algae do not usually aggregate
- Inability to bioflocculate results in ineffective separation of algae from water
  - Recycling of biomass
  - Harvesting (wastage) of biomass
- Needs light!
- Limited reactor configurations: e.g., open ponds
- High-rate algal ponds (still HRT ≈ SRT)
  - Activated sludge process (HRT ≈ 1/24 SRT)



Oxygenic Biogranules

- Bacteria and microalgae naturally form a granule under certain incubation conditions



Oxygenic Biogranules

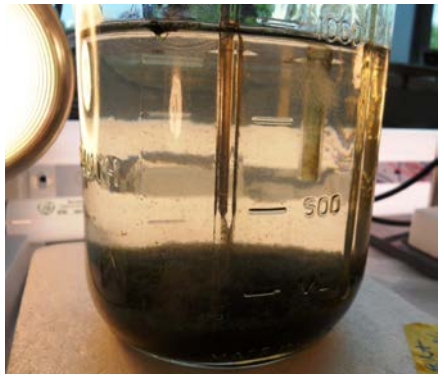
Activated sludge

Transformation

Novel algal granules

Seeding and reactor operation for WW TRT.

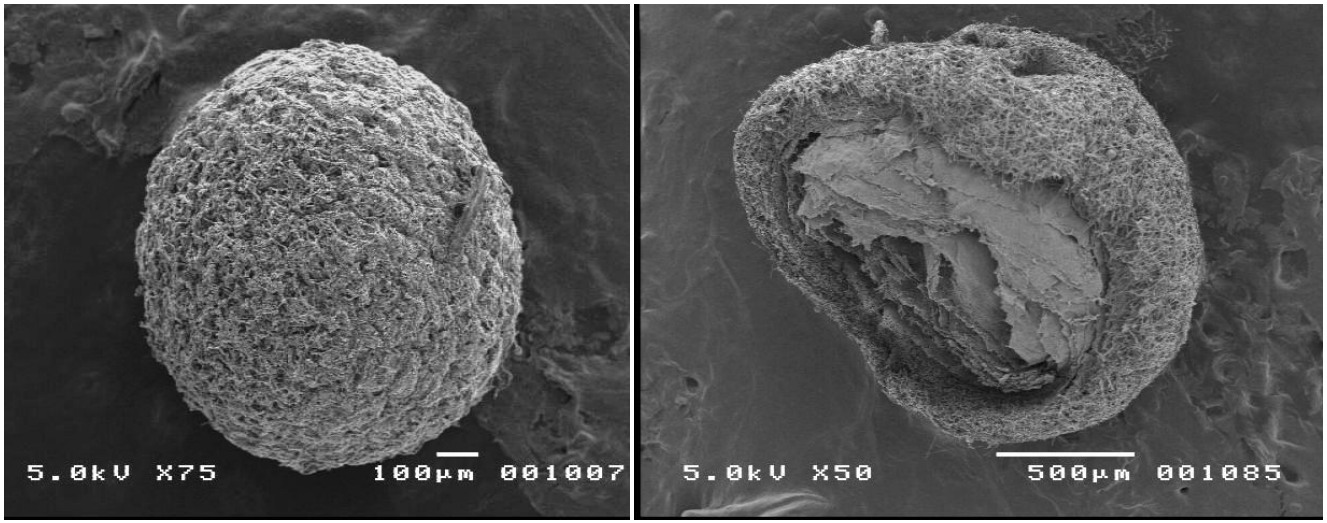
Biogranules mixing in an SBR during light reaction period.

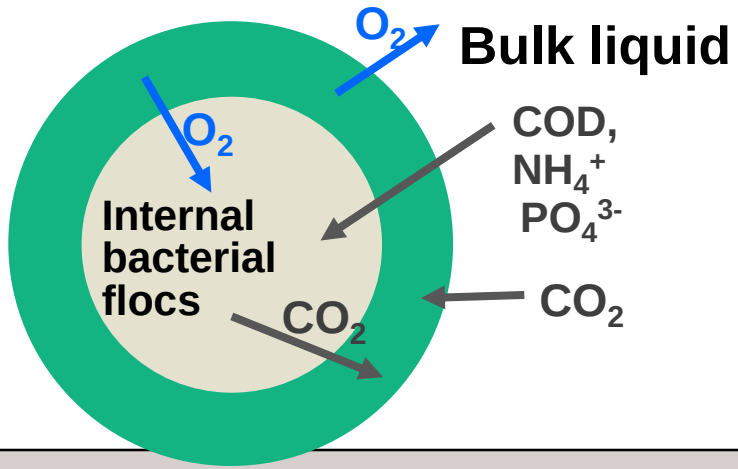


After 5 minute settling

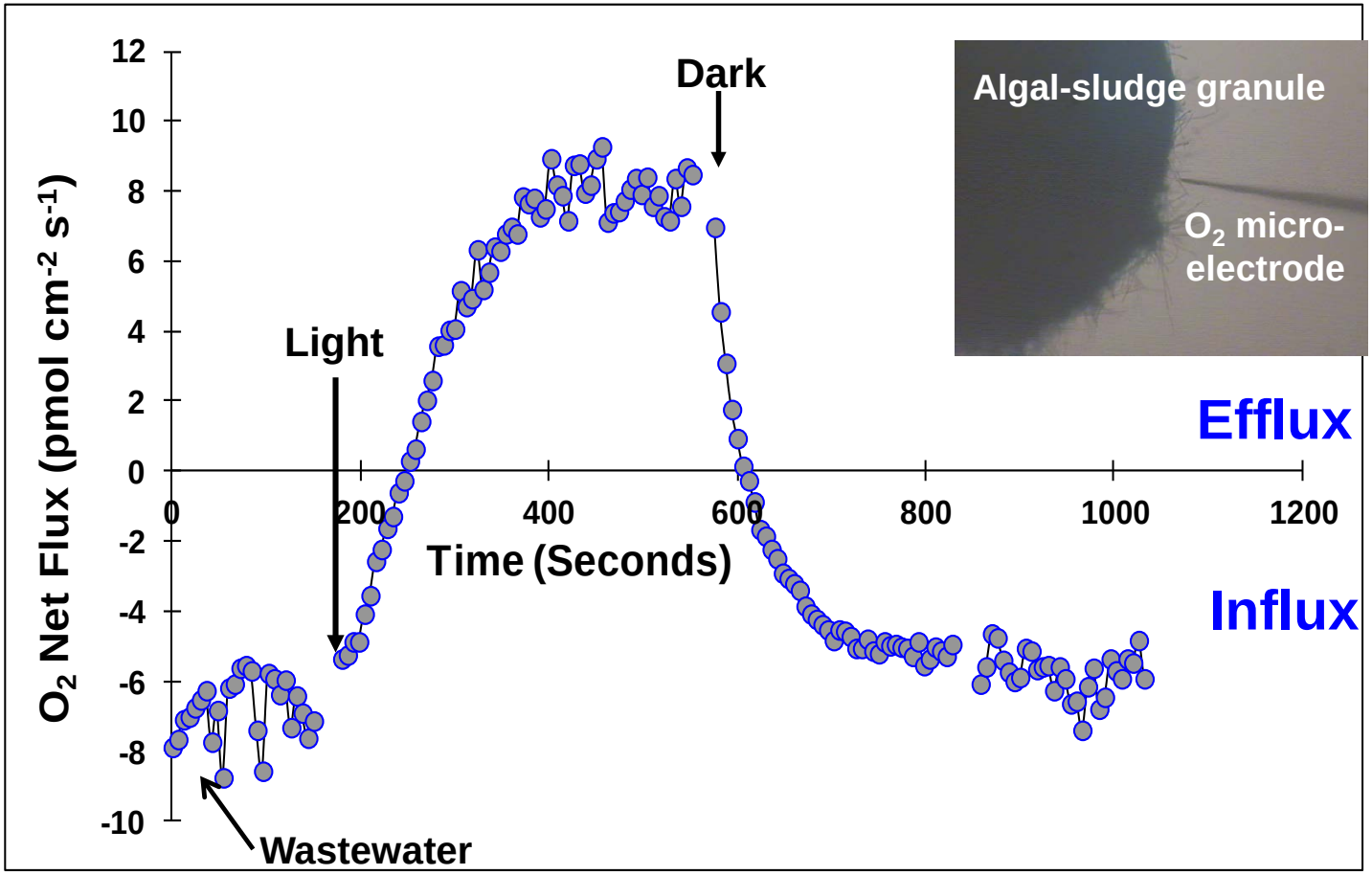
Harvesting
Anaerobic digestion

SEM Images of Oxygenic Biogranules





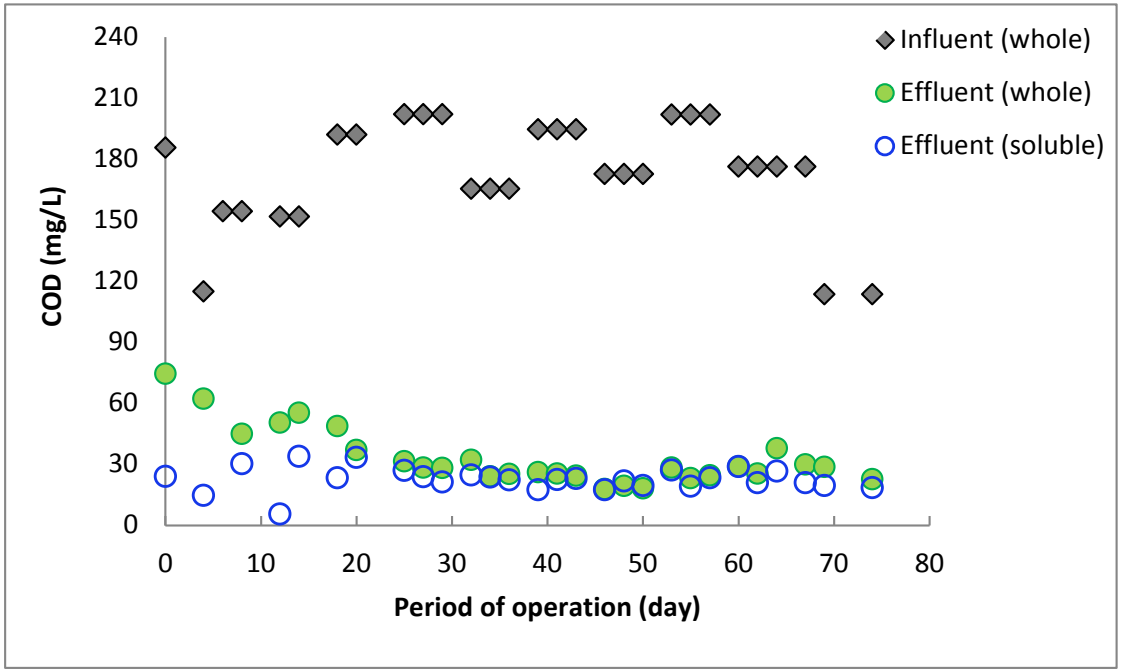
In-situ Oxygenation and COD Consumption



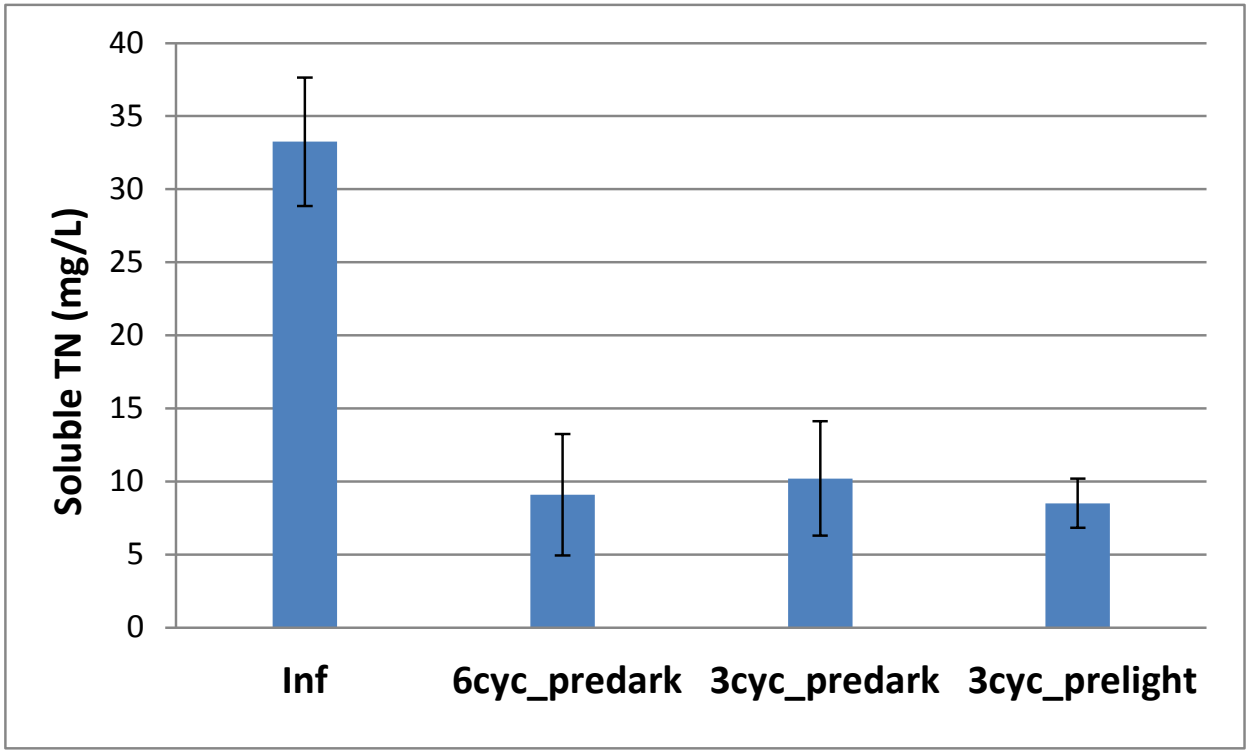
Operation of the 1st-generation Bioreactor

- Sequencing batch reactor (SBR)
- Light/Dark cycle
  - 2.5hr Dark + 3.5 hr Light (for one cycle)
- Primary effluent from the Amherst WWTP
- Seeding phase
- HRT: 18-24 hours
- SRT: 20-50 days
- Analysis
  - effluent quality, biomass characterization, biomass yield, etc

Effluent Quality

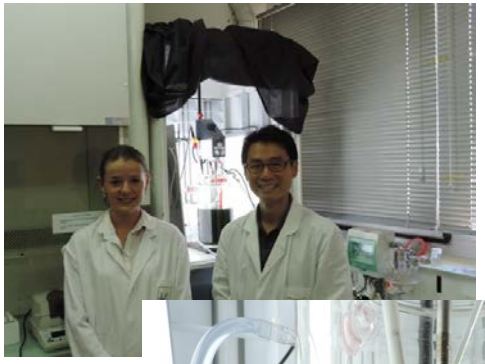


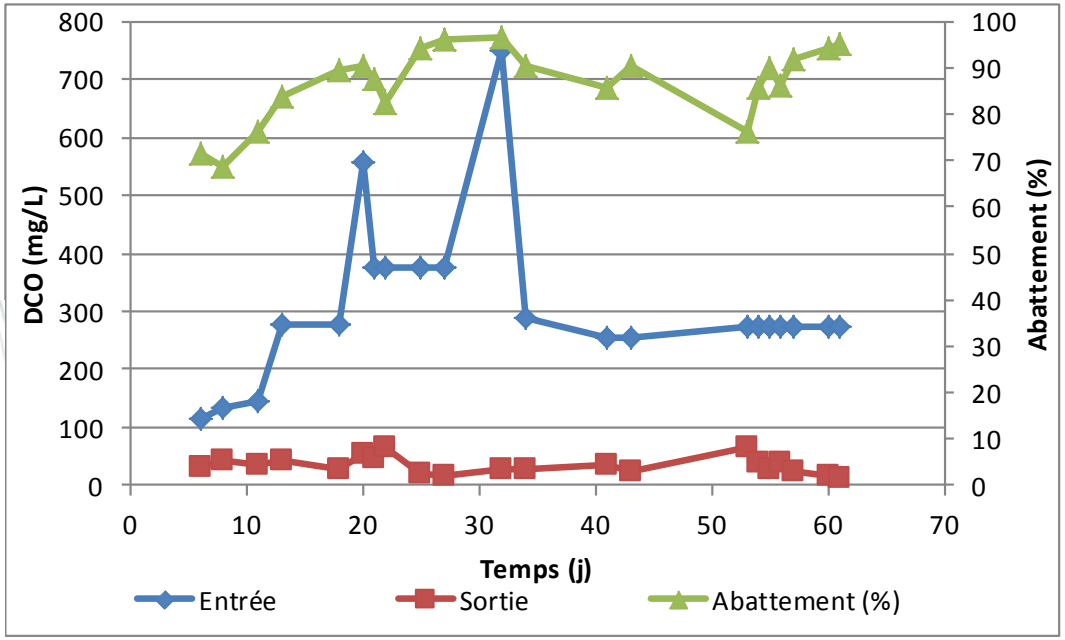
Effluent N Data



Study of Oxygenic Biogranules in France

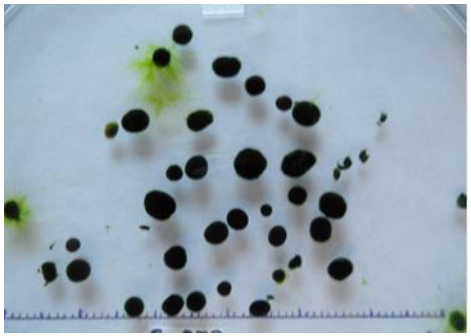
- Raw influent wastewater from Narbonne WWTP
- HRT = 1 day; volume of reactor (SBR) = 3 L
- SRT = 25 days





Conserving Energy in Biogranules

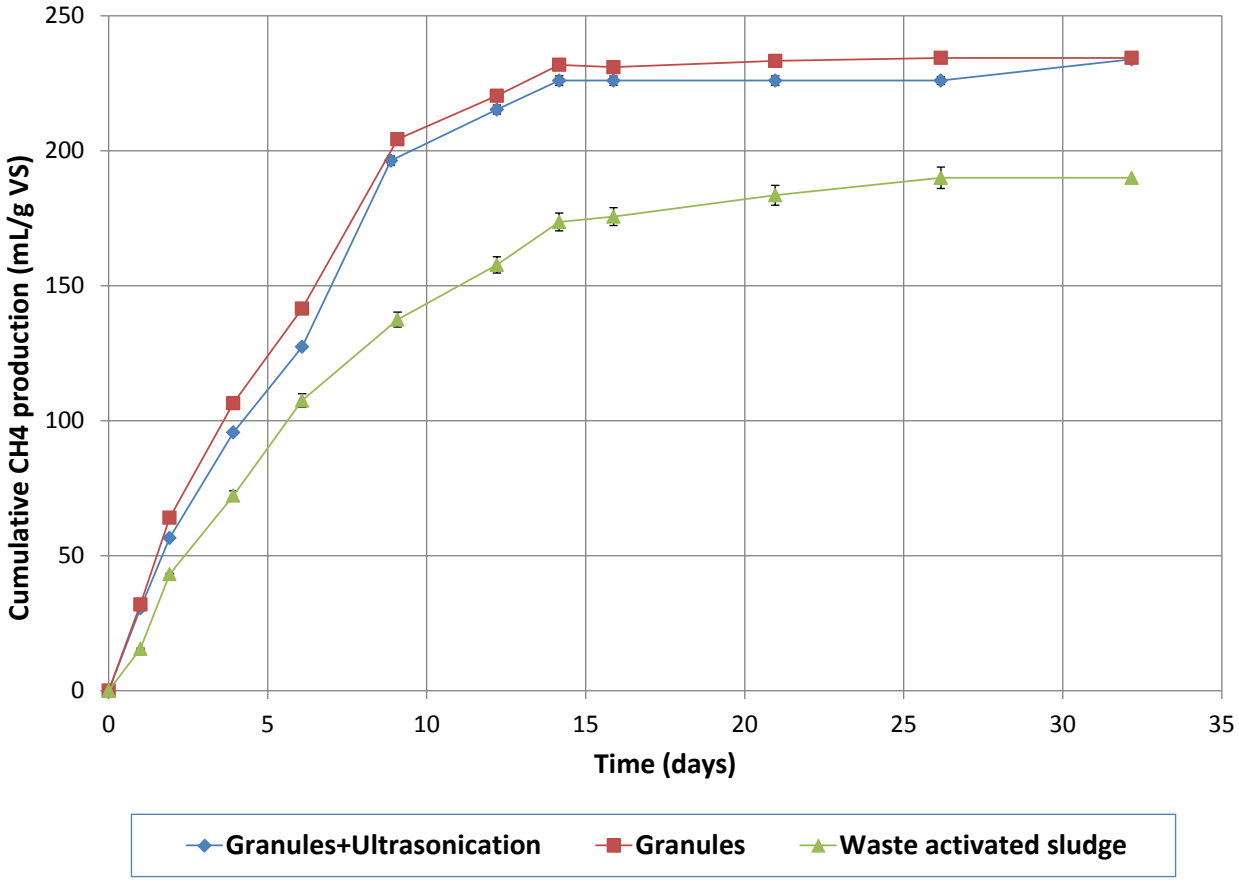
- Y_{obs} of activated sludge: 0.3-0.6 gCOD/gCOD
- Y_{obs} of oxygenic biogranules: ~1.5 gCOD/gCOD
- *What does this mean?*
  - 100% Recovery of COD energy into biomass: by fixing CO_2-COD
  - Fixing more CO_2/HCO_3^- from wastewater into biomass
- Biocoal or anaerobic digestion?



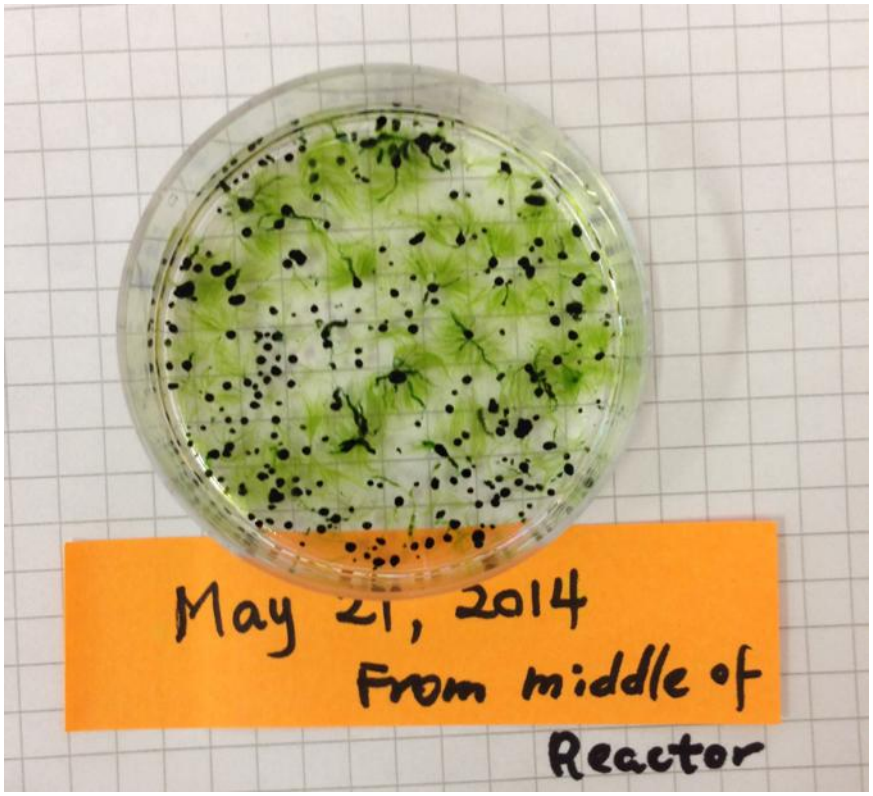
Anaerobic Digestion and Pretreatment of Granules

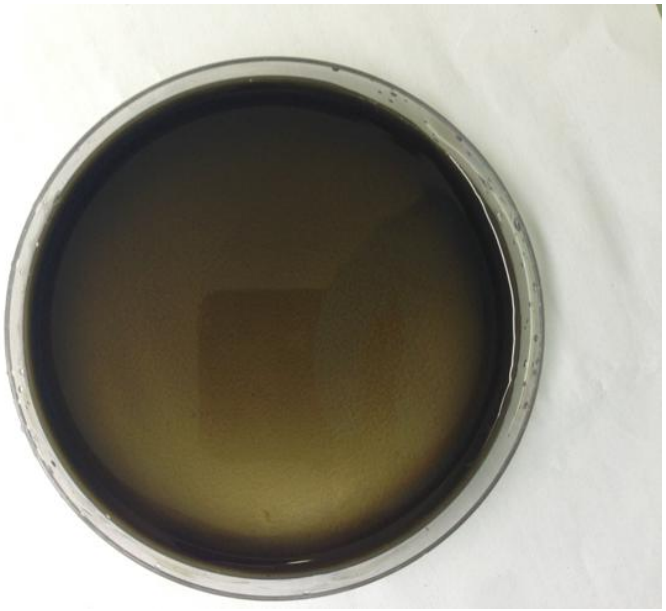
- BMP experiments (mesophilic)
  - Granule only (2-times)
  - Ultrasonic-treatment (2-times)
  - 90 °C treatment (1-time)
  - 170 °C treatment (1-time)

The First BMP Experiment

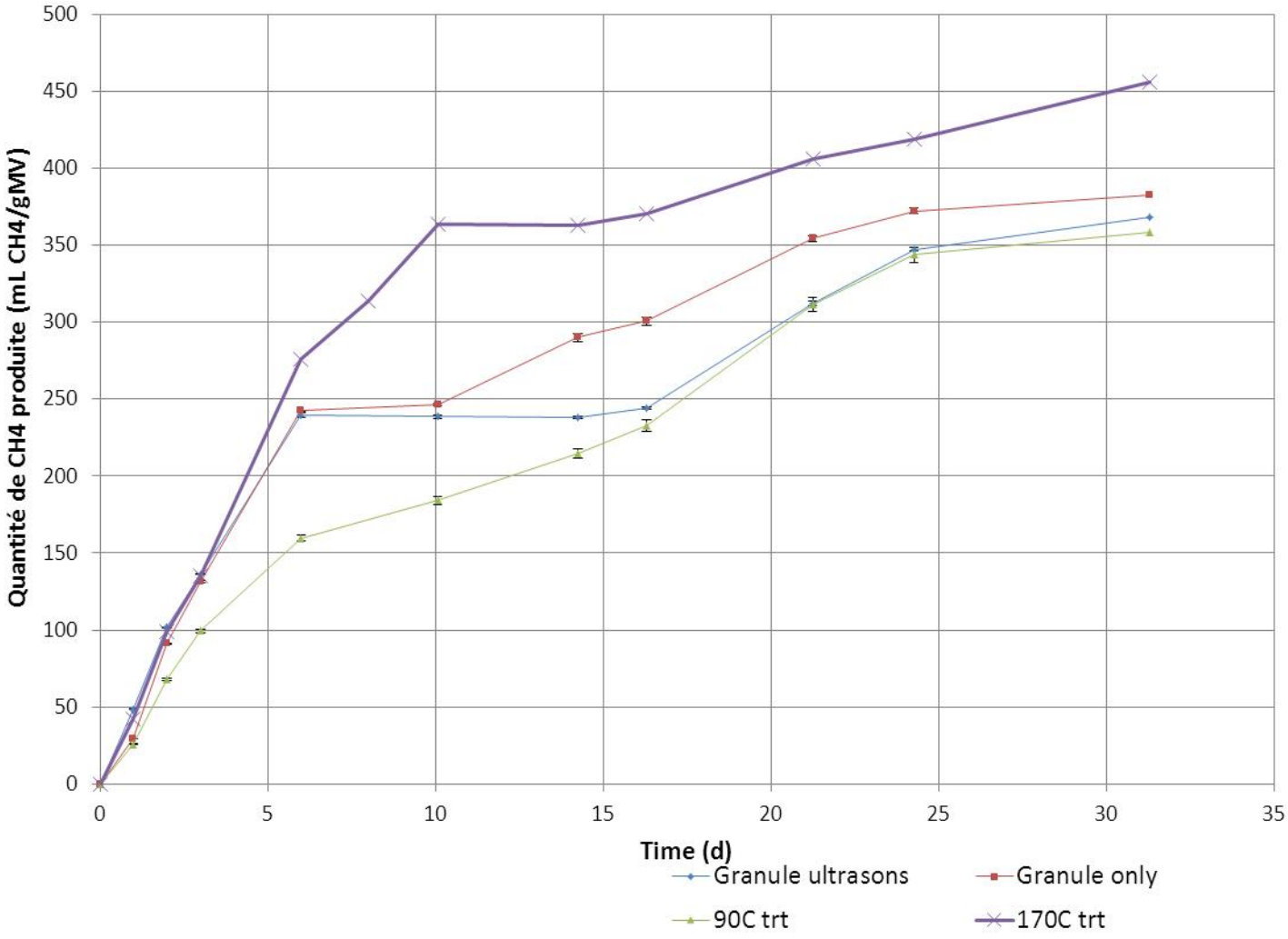


Before & After Anaerobic Digestion (no pre-treat.)





The Second BMP Experiment



Biomass and Energy Recovery

- Y_{obs} of activated sludge: 0.3-0.6 gCOD/gCOD
- Y_{obs} of oxygenic biogranules: ~1.5 gCOD/gCOD
- *Oxygenic biogranules showed 25% higher CH_4 yield than waste activated sludge*
- Need some economics analysis

Simple Economics (Energy Analysis)

(MJ/m^3 wastewater)	ASP	ASG
Potential energy in raw wastewater	7.4	7.4
Energy recovery as feedstock for AD	4.1	7.4-12.4*
Energy recovery as CH_4 from AD	1.2	2.9-5.1
Energy usage (Reference 2)	2**	1.1
Net energy recovery as CH_4	-0.8	1.8-4.0

ASP: activated sludge process; ASG: algal-sludge granule process; AD: Anaerobic digestion; *) 12.4: more recovery than the native energy due to the fixation of CO_2 in wastewater **) 60% of this is for aeration.

Conclusions

- Demonstrated the formation of oxygenic biogranules in different geography (7 WWTPs)
- The biogranules were oxygenic and degrade COD in the presence of light
- All chemical energy in wastewater was conserved in the biogranules
- Granules also digest better than activated sludge

Where are we going?

- Implementing in developing countries
  - Collaboration in Kenya
- The first pilot in USA
  - Amherst WWTP
  - Launch in July, 2015
  - Plan to go through winter in Massachusetts
- Investigation on several others
  - Pathogens
  - Heavy metals
  - Trace organics

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- Paul Busch Award, WERF

Conclusions

Melting glaciers

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