INSTRUMENTATION CONTROL AND AUTOMATION specialist group

22 NOVEMBER 2021

09:00 CET

IWA Specialist Group on Modelling and Integrated Assessment Webinar Series

State-of-the-art in anaerobic digestion modelling

Speakers

Ulf Jeppsson
Lund University

Raul Muñoz
Universidad de Valladolid

Xavier Flores Alsina
Technical University of Denmark

Damien Batstone
The University of Queensland

Jean-Philippe Steyer
INRAE-LBE

Ángel Robles
Universitat de València

The webinar is going to be recorded and shared on the MIA SG Youtube channel afterward.

A JOINT MIA AND ICA SG WEBINAR

This webinar is a joint venture between:

IWA SG on Modelling and Integrated Assessment

and

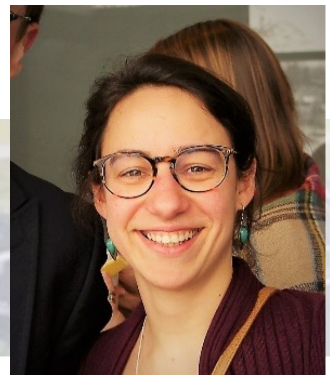
IWA SG on Instrumentation, Control and Automation

MIA Welcome Note

IWA Modelling and Integrated Assessment Specialist Group

Dr. Ulf Jeppsson (Chair of MIA SG)

Dr. Elena Torfs (Vice-chair of MIA SG)



inspiring change

LUND UNIVERSITY

GHENT UNIVERSITY

MODELLING AND INTEGRATED ASSESSMENT SPECIALIST GROUP (MIA SG)

“This group targets people from research, consulting companies, institutions and operators to think along ***the use of models and computing tools to support the understanding, management and optimization of water systems***.”

How to find us

Website: http://iwa-mia.org/

https://iwa-connect.org

PRIORITIES

- Interact with other IWA SGs and other professional organizations
- Organize specialized conferences, sessions and workshops
- Engage and activate YWPs in the domain.

CURRENTLY 1900 MEMBERS

MIA SG: ACTIVITIES

Task Groups (TGs)

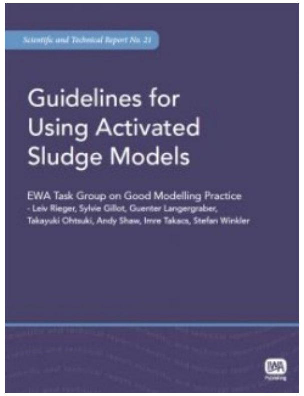
- Benchmarking of Control Strategies for WWTPs (BSM) AND Good Modelling Practice (GMP) (Both finished)
- Design and Operations Uncertainty (DOUT)
- Generalised Physicochemical Modelling (PCM)
- Use of Modelling for Minimizing GHG Emissions from Wastewater Systems (GHG)
- Membrane Bioreactor Modelling and Control (MBR)
- Good Modelling Practice in Water Resource Recovery Systems (New)

Working Groups (WGs)

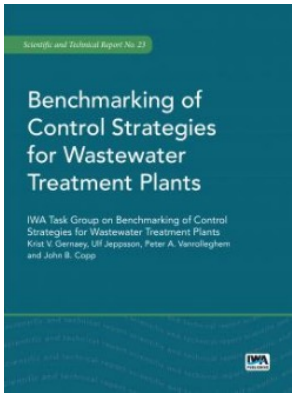
- Integrated Urban Water Systems (IUWS)
- Computational Fluid Dynamics (CFD)
- Good Modelling Practice (GMP)

Conferences / Events

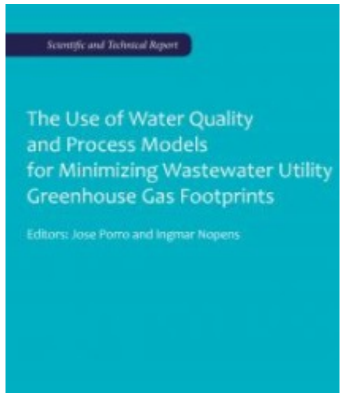
- WRRmod
- Watermatex



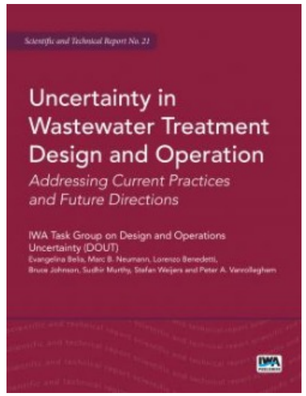
STR
(Sept. 2012)



STR
(Sept. 2014)



STR
(2021)



STR
(2021)

MIA SG: UPCOMING CONFERENCES

8th Water Resource Recovery Modelling seminar (WRRmod2022+)

- Location: Stellenbosch, South Africa, 15-18 January 2023
- Chair: Dr. David Ikumi (Univ. Cape Town)

11th Symposium on Modelling and Integrated Assessment (Watermatex2023)

- Location: Québec City, Canada, late summer 2023
- Chair/vice-chair: Prof. Peter Vanrolleghem (Univ. Laval)/Dr. Elena Torfs (Univ. Ghent)

FIND MIA SG ON SOCIAL MEDIA

Follow the Modelling and Integrated Assessment Specialist Group on:

- IWA Connect https://iwa-connect.org/group/modelling-and-integrated-assessment-mia/timeline
- https://www.linkedin.com/company/iwa-mia-specialist-group-on-modelling-and-integrated-assessment
- https://twitter.com/iwa_mia_sg
- **MIA SG open web site** http://iwa-mia.org

to get informed about our latest events, publications and news!

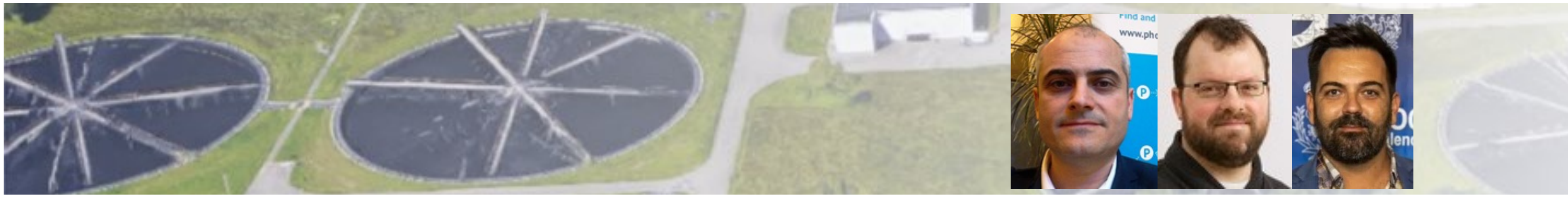
ICA Welcome Note

IWA Intrumentation, Control and Automation Specialist Group

Dr. Juan Antonio Baeza (CHAIR)

Dr. Kris Villez (VICE-CHAIR)

Dr. Ángel Robles (NL EDITOR AND AND PUBLIC RELATIONS COORDINATOR)



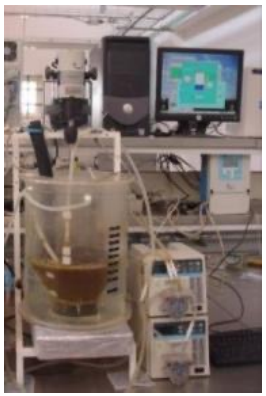
inspiring change

INTRODUCTION TO THE ICA SG

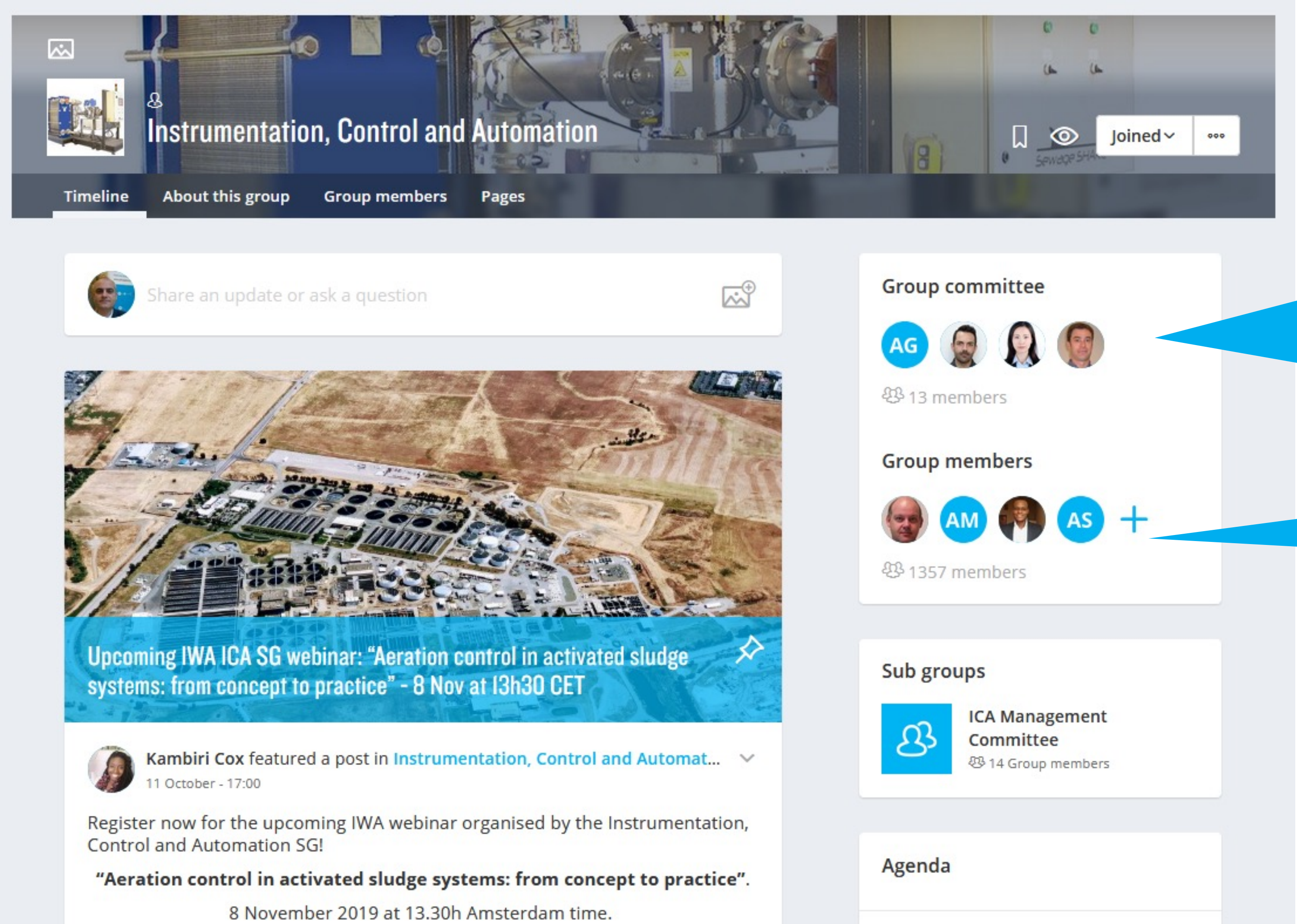
Objectives of the ICA SG

- International discussion forum
  collect and exchange methodologies and experience
  all aspects of instrumentation control and automation for water systems
- Collect, summarize and publish practical experience
  to support and promote the use of ICA in practice
- Highlight socio-economic and sustainability aspects of ICA
  e.g. management problems, operator aspects or incentive systems



INTRODUCTION TO THE ICA SG



14 MC members, including 5 affiliated YWP

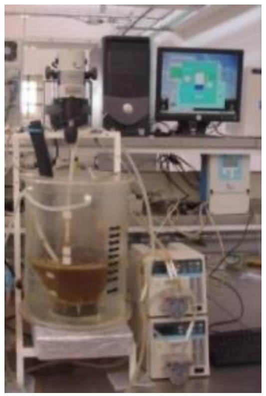
1402 SG members

INTRODUCTION TO THE ICA SG

INSTRUMENTATION CONTROL AND AUTOMATION

Key activities of the ICA SG

- Group newsletters (which can be found on the SG's IWA Connect page)
- Organizing and supporting Conferences & Workshops
- Supporting Task Groups & Working Groups & Clusters
- Organizing webinars
- Leveraging partnerships and relationships with industry organization with overlapping missions, such as the Smart Water Network Forum.



ICA SG: UPCOMING EVENTS

INSTRUMENTATION CONTROL AND AUTOMATION

13th IWA Conference on Instrumentation, Control and Automation, Beijing, China

- Beijing, China, October 2022
- TSINGHUA UNIVERSITY AND STATE KEY JOINT LAB ENVIRONMENTAL SIMULATION & POLLUTION CONTROL

WEBINAR Advanced biological nutrient removal control: developing novel strategies towards process optimization

WEBINAR Advanced nitrogen removal control: showcasing successful implementations at full-scale WRRFs

Follow the Instrumentation, Control and Automation Specialist Group on:

IWA Connect https://iwa-connect.org/group/instrumentation-control-and-automation/timeline

INTRODUCTION TO THE WEBINAR

IWA Specialist Group on Modelling and Integrated Assessment Webinar Series

State-of-the-art in anaerobic digestion modelling

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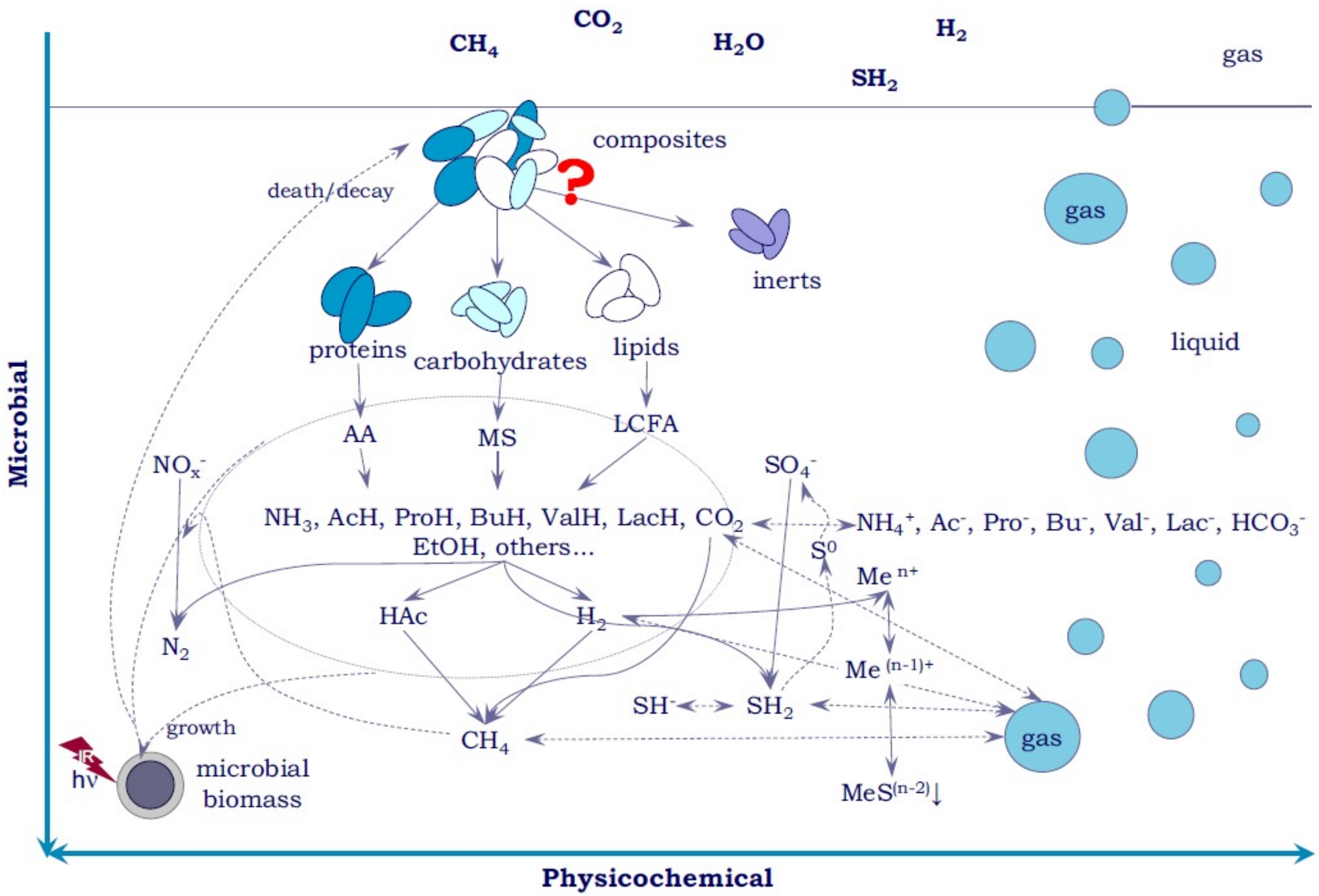
INTRODUCTION TO THE WEBINAR

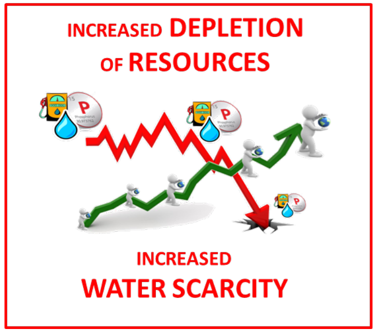
- Anaerobic Digestion



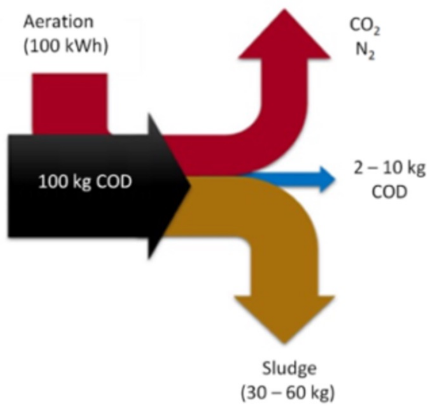
Batstone et al. (2015) Rev Environ Sci Biotechnol

INTRODUCTION TO THE WEBINAR

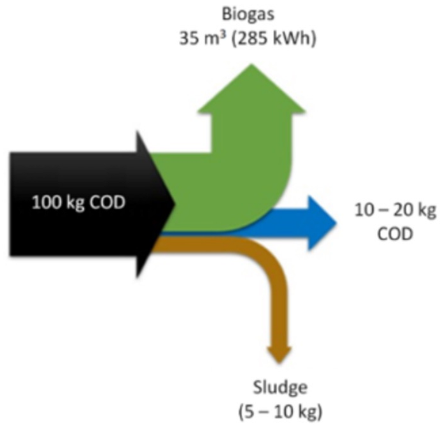
- Anaerobic Digestion: a key tecnology in Circular Economy



- *Sewage sludge*
- *Food waste*
- *OFMSW*
- *Manure*
- *Agri-industrial waste*
- *Industrial wastewater*
- *Urban wastewater*
- *Co-substrates*



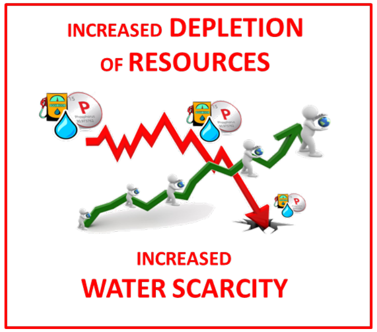
Aerobic process



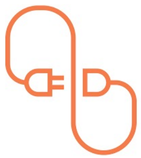
Anaerobic process

INTRODUCTION TO THE WEBINAR

- Anaerobic Digestion: a key tecnology in Circular Economy



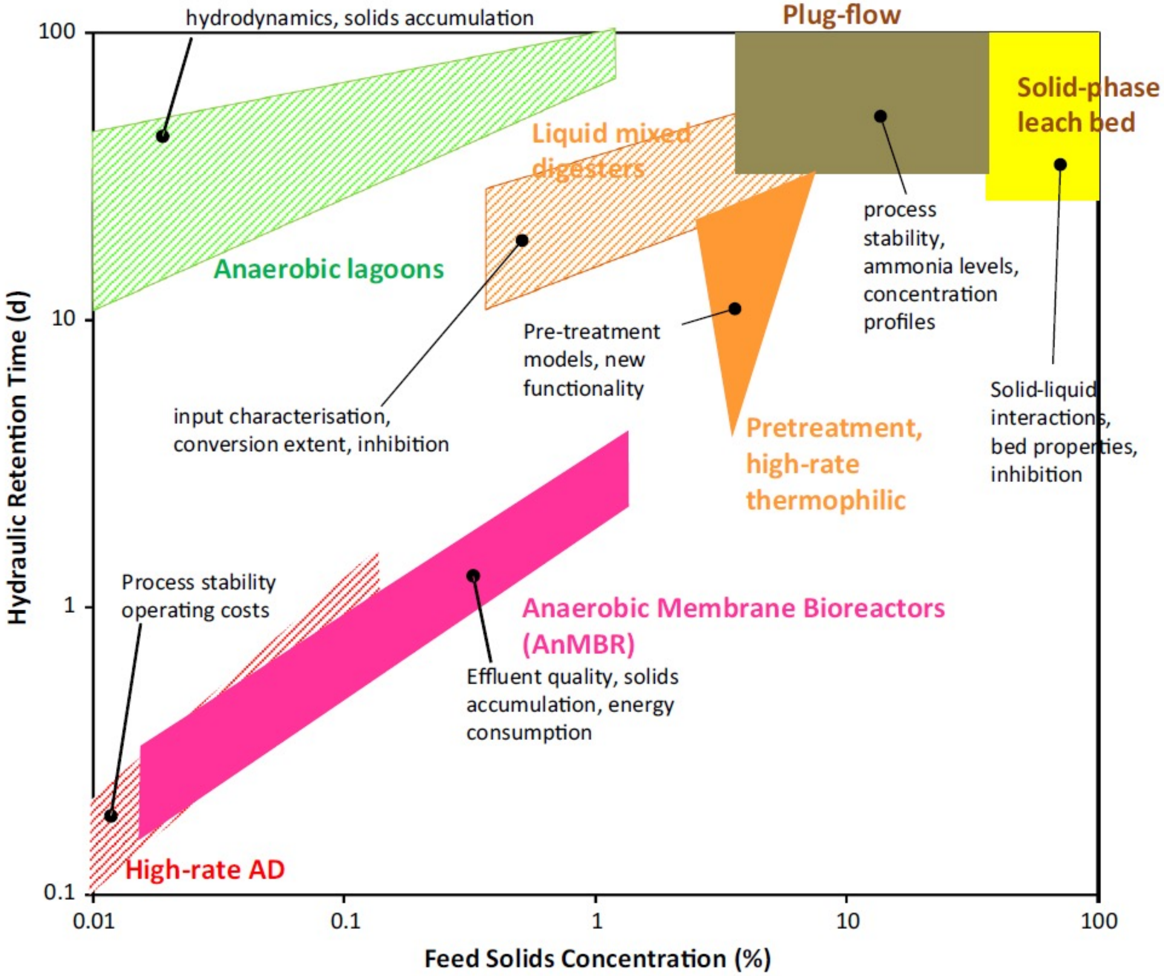
- *Default process for bio-conversion of organics to renewable energy and biofuel in the form of methane.*
- *Driver for nutrient conservation and recovery.*
- *Driver for value added chemicals production through mixed culture biotechnology.*
- *Low energy demand, GHG emissions and sludge production*



INTRODUCTION TO THE WEBINAR

- Anaerobic Digestion: from hatched existing to emerging processes

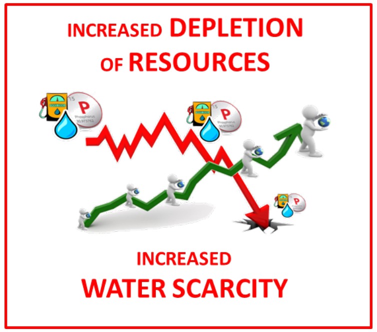
New technology, new processes, and the need to consider anaerobic processes in a much broader context of the wastewater cycle as a whole.



Batstone et al. (2015) Rev Environ Sci Biotechnol

INTRODUCTION TO THE WEBINAR

- Anaerobic Digestion modelling and control within CE: some challenges



- *Increased importance of phosphorous, sulfur, and metals as electron source*
- *Consider hydrogen and methane as potential electron sources*
- *Consider variable mass/volume contents during high-solids AD*
- *Consider other metabolic pathways for complex organics treatment (e.g. SAO)*
- *Consider trace element complexation and precipitation*
- *Account for non-ideal aqueous-phase chemistry*
- *Account for membrane interactions in high-rate membrane-based systems*
- *Enhance monitoring and control systems for AD optimization*

INTRODUCTION TO THE WEBINAR

IWA Connect

IWA https://iwa-network.org/all-events/

AGENDA AND HOUSEKEEPING

Speaker 1
Raul Muñoz (University of Valladolid, Spain)

Speaker 2
Damien Batstone (The University of Queensland, Australia)

Speaker 3
Xavier Flores-Alsina (Technical University of Denmark)

Speaker 4
Jean-Philippe Steyer (INRAE-LBE, France)

Q&A Session Moderator: *Ángel Robles (Universitat de València, Spain)*

- This session is being recorded;
- Microphones and cameras have been disabled due to the large number of attendees;
- The normal chat function is disabled;
- Please put any questions and comments you may have in the Q&A and we will do our best to answer them during the session (in writing or orally).

SUMMARY OF THE WORKSHOP

"ANAEROBIC DIGESTION: *QUO VADIS*?"

Raul Muñoz (mutora@iq.uva.es)
Institute of Sustainable Processes- University of Valladolid

INTRODUCTION TO THE WORKSHOP

Institute of Sustainable Processes
UNIVERSITY OF VALLADOLID

UVa

CRETUS

BioGroup
Group of Environmental Biotechnology

Workshop:
Anaerobic Digestion,
Quo vadis?

Sala Cardenal Mendoza. Palacio de Congresos Conde Ansúrez.
Calle Real de Burgos, s/n. Valladolid
October 21st 2021. 14:30 - 19:00

NOS IMPULSA Junta de Castilla y León

FONDO EUROPEO DE DESARROLLO REGIONAL
UNIÓN EUROPEA

Europa impulsa nuestro crecimiento

CONTEXT OF THE WORKSHOP

In September 1990 and with the sponsorship of the IWA, an International Workshop on Anaerobic Treatment Technology for Municipal and Industrial Wastewater was held in Valladolid (Spain).

In the last 30 years, the scope of application of anaerobic processes has expanded from a simple waste/wastewater treatment technology, to a platform capable of producing renewable electricity, and in the latest years AD is regarded as the core of a multiproduct biorefinery.

New tools and processes such as molecular biology, process automation and control, biogas upgrading, nutrient recovery, and organic acid generation have upgraded the potential of anaerobic digestion and increase its robustness.

INTRODUCTION TO THE WORKSHOP

Jules van Lier. Delft University of Technology

Anaerobic treatment of chemical wastewaters under extreme conditions: the role of membranes

Kornel Rabaey. Center for Microbial Ecology and Technology

Potential and limitations of fermentation and chain elongation

Ana Soares. Cranfield Water Science Institute

State of the art of nutrient management and recovery from digestate

Irini Angelidaki. Technical University of Denmark

Moving beyond biogas

Jean Phillipe Steyer. INRAE

Instrumentation, modeling and control of digesters : an old story for today and tomorrow

Lutgarde Raskin. University of Michigan

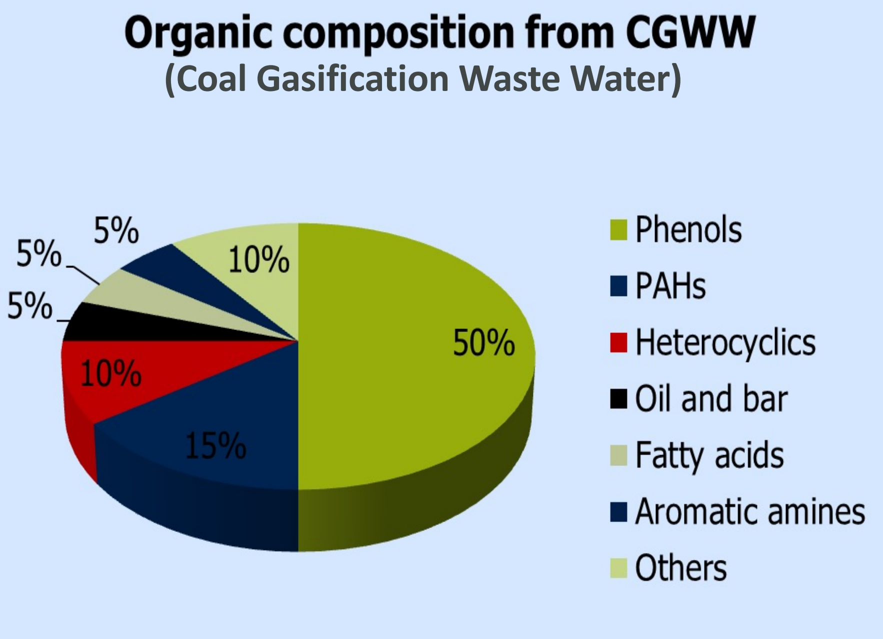
Potential of molecular biology tools in AD

ANAEROBIC TREATMENT OF CHEMICAL WASTEWATER UNDER EXTREME CONDITIONS: THE ROLE OF MEMBRANES

By Jules van Lier

CASE STUDY: TREATMENT OF COMPLEX CHEMICAL WASTEWATERS

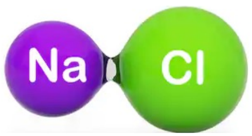
- Refractory / Toxic COD
- Aromatic compounds
- High salinity
- High temperature
- No nutrients (N, P, S)
- No trace metals

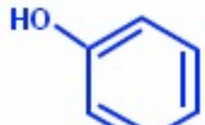


e.g. Coal Gasification Waste Water

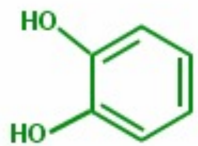
Technology: membrane anaerobic bioreactors

- Prevents wash-out of de-granulated/de-flocculated biomass (impact salt/ high temp.)
- Long SRT enhances specific catabolic conversions: adaption + bacterial growth
- In-situ bioaugmentation of specialized bacteria
- Effluent is solids free → UF pre-treatment for RO → process water reclamation!

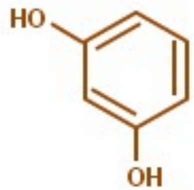




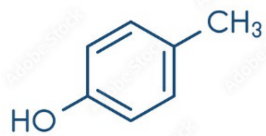
phenol



catechol



resorcinol



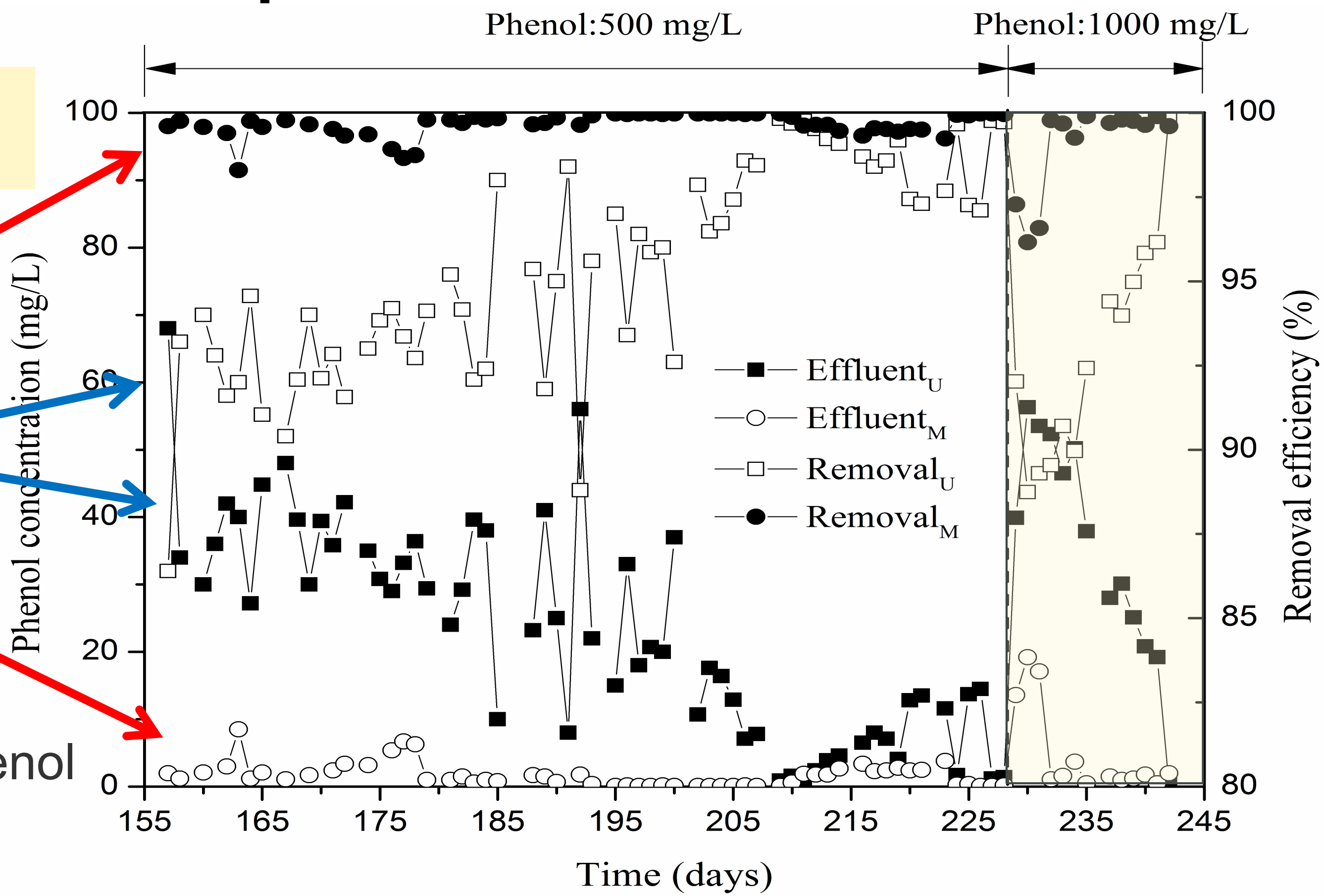
para-cresol

AnMBR – UASB comparison

- 16 g Na^{+}/L
- 0.5 – 1.0 g/L Phenol

AnMBR

UASB

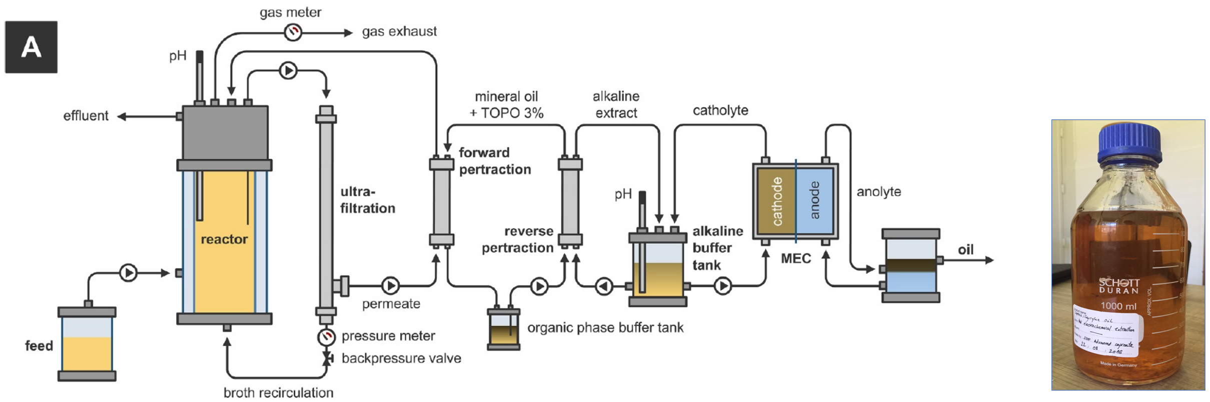


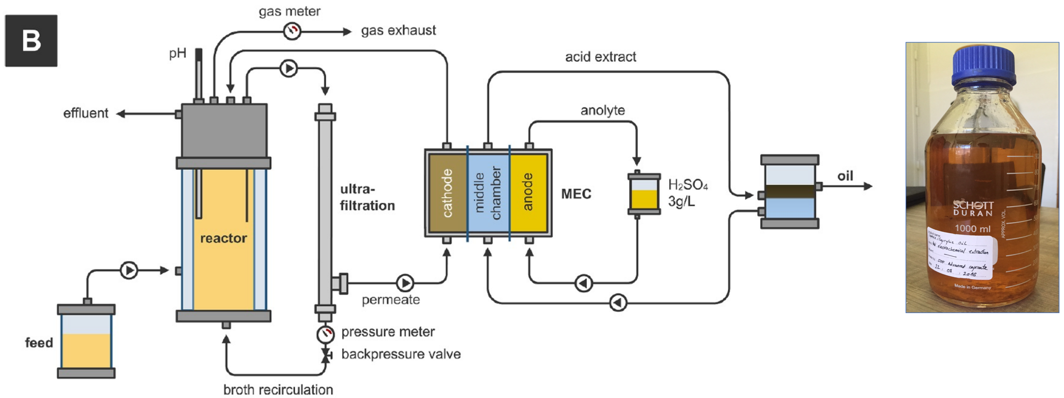
Effluent phenol and phenol removal efficiency

FROM AD TO BIOPRODUCTION
FROM LIMITATION TO POTENTIAL

By Korneel Rabaey
& Ramón Ganigué

CASE STUDY: CAPROIC ACID PRODUCTION FROM THIN STILLAGE





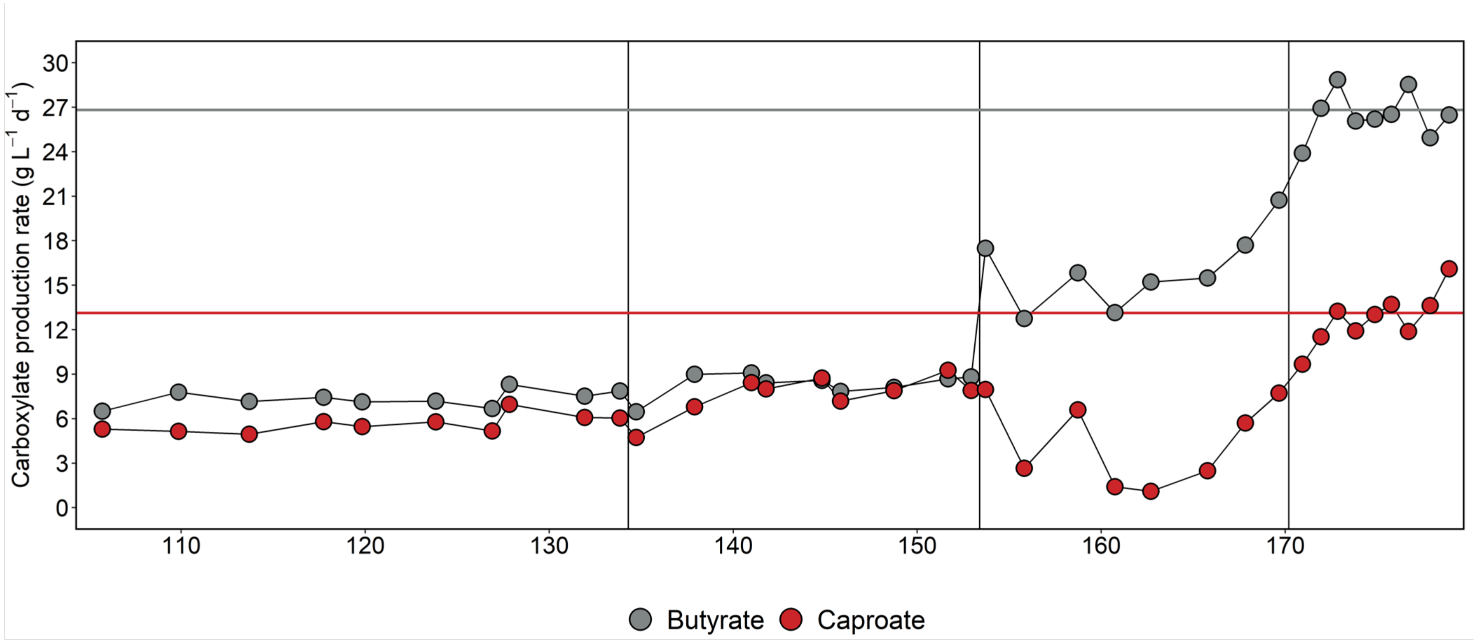
MAIN RESULT: PRODUCT STABILITY AND COMPOSITION OK,

BUT PRODUCTION RATES AND PRICE NOT COMPETITIVE

FROM AD TO BIOPRODUCTION
FROM LIMITATION TO POTENTIAL

By Korneel Rabaey
& Ramón Ganigué

The potential of granules: *uncoupling liquid and solid retention times, higher biomass concentrations and higher production rates*



FROM AD TO BIOPRODUCTION
FROM LIMITATION TO POTENTIAL

By Korneel Rabaey
& Ramón Ganigué

The potential of granules: Where are we now?

- Great science and engineering research!
- Rates >1 g L^{-1} h^{-1} achievable with granules
- Selectivity OK certainly with pure culture
- Extraction OK for technical solutions and certain applications

But… not all together. And market not strong.

STATE OF THE ART OF NUTRIENT MANAGEMENT AND RECOVERY FROM DIGESTATE

By Ana Soares

Advanced AD concepts increase solids hydrolysis: + increased biogas production and higher nutrient concentration in dewatering liquors

Characteristic	MAINSTREAM		SIDESTREAM	
	Raw WW	Settled WW	Conventional AD dewatering liquors	THP/AD dewatering liquors
Temperature, °C	10-20	10-20	**26-30**	**26-30**
Ammonia, mg N/L	10-100	10-100	**500-1,000**	**1,000-2,500**
Total phosphate	2-12	2-12	**20-100**	**80-200**
COD, mg/L	250-800	100-464	**1,000-3,000**	**2,500-3,500**
BOD, mg/L	110-350	64-203	**200-400**	**200-400**
Alkalinity, mg $CaCO_3$/L	74-200	74-200	**2,000-4,000**	**3,000-6,000**
pH	6.5-7.5	6.5-7.5	**7.2-8.5**	**8.0-8.7**

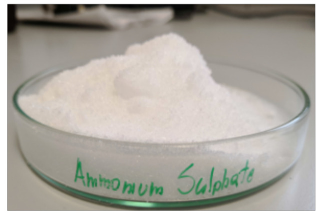
By Ana Soares

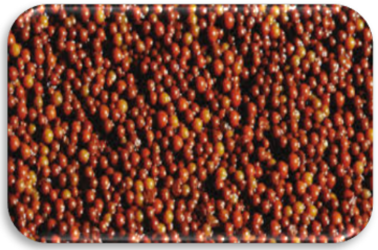
Ion exchange processes for N and P recovery

10 m^3/day
P removal 5 min contact time
N removal 10 min contact time

Ammonia removal: Zeolite-N
Exchange of ammonia with potassium or sodium

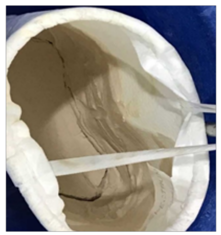
Recovered ammonia

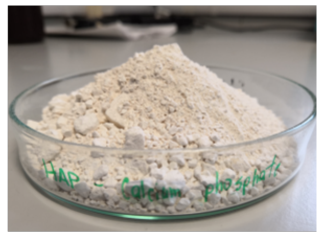




Phosphorus removal: hybrid anion exchange
Adsorption of P to iron nanoparticles. Can be reversed by an increase in pH

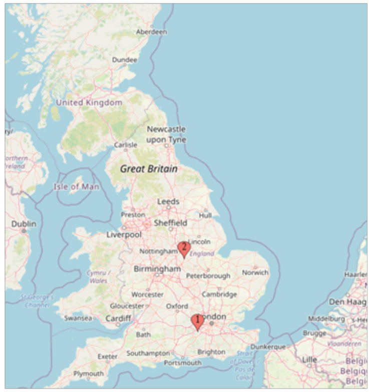
Recovered phosphate (CaP)





Absolutely TERRIBLE!!!!!

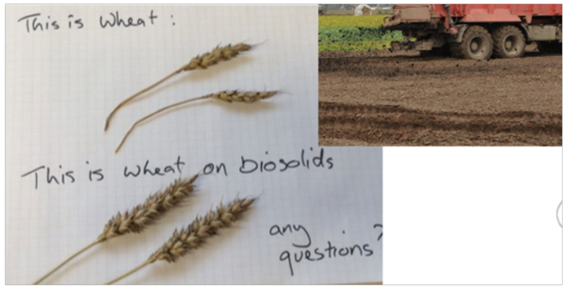
2 Struvite plants in the UK, none of them working



A few struvite plants in Europe but the exception

What next:

- Struvite related tech has high TRL but can only be applied at <10% EU WWTP (high enough P)
- Analyse what best to do with the recovered products at local level – including liaise with local communities and industries
- Increase TRL of technology by completing demonstration scale trials liquor treatment
- Clear business cases and LCA at large scale



MOVING BEYOND BIOGAS

By Irini Angelidaki

Manure

Biopul
p

Sludge

Indust. Waste

Electricity

Heat

AD

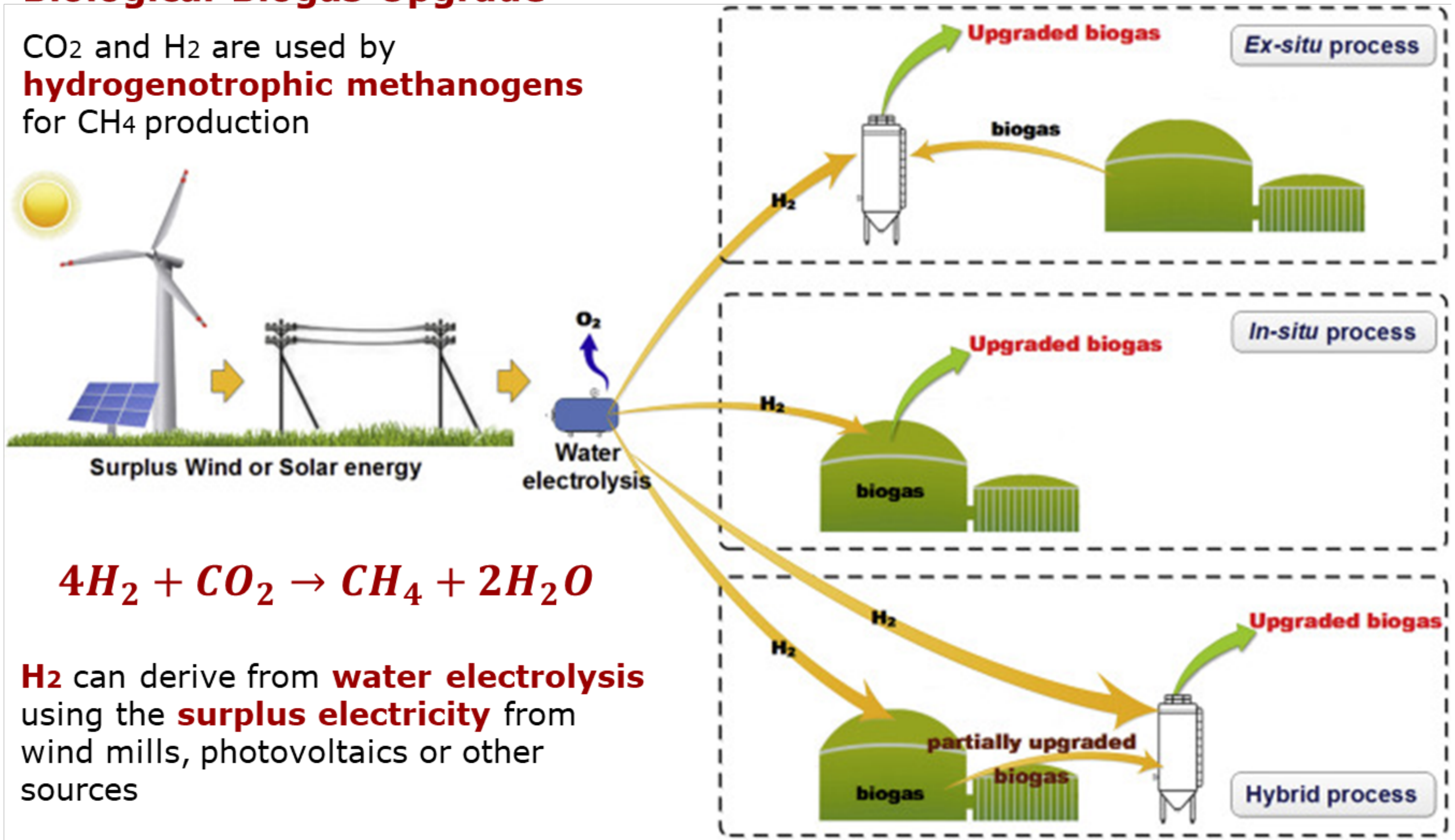
- SCP
- Biomethane
- PGP (HOB)
- Methanol
- Aviation Fuels
- Biodiesel
- Chemicals
- Algae
- Biodegradable plastic

MOVING BEYOND BIOGAS

By Irini Angelidaki

Biological Biogas Upgrade

CO_2 and H_2 are used by **hydrogenotrophic methanogens** for CH_4 production

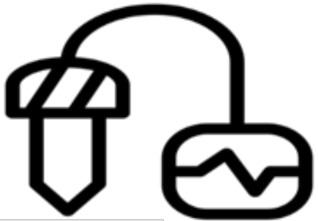


$$4H_2 + CO_2 \rightarrow CH_4 + 2H_2O$$

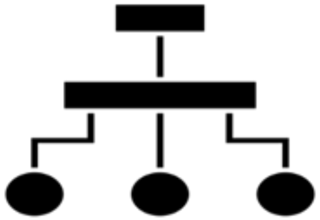
H_2 can derive from **water electrolysis** using the **surplus electricity** from wind mills, photovoltaics or other sources

INSTRUMENTATION, MODELING AND CONTROL OF DIGESTERS: AN OLD STORY FOR TODAY AND TOMORROW

By Jean Philippe Steyer



Instrumentation



Modeling

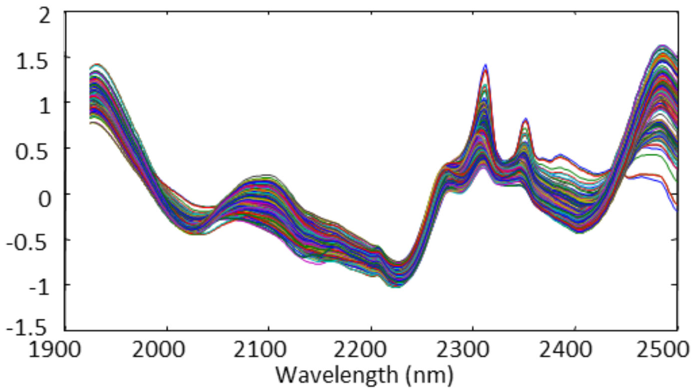
Control

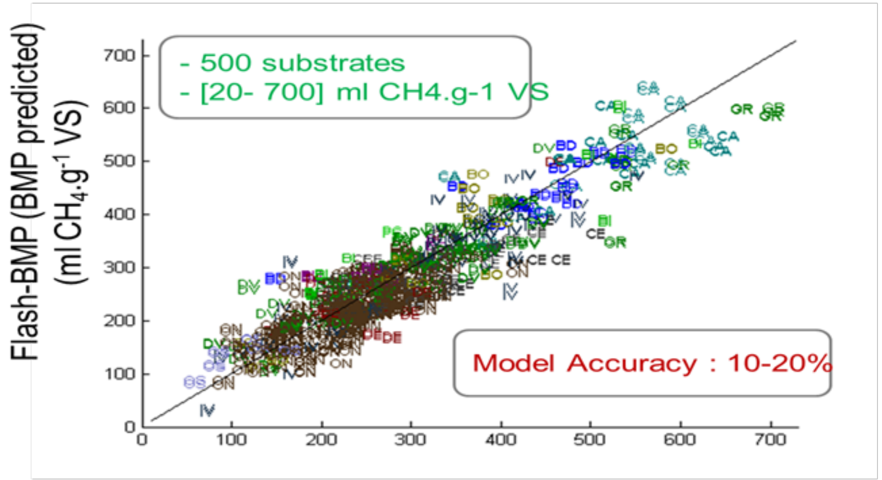
INSTRUMENTATION, MODELING AND CONTROL OF DIGESTERS: AN OLD STORY FOR TODAY AND TOMORROW

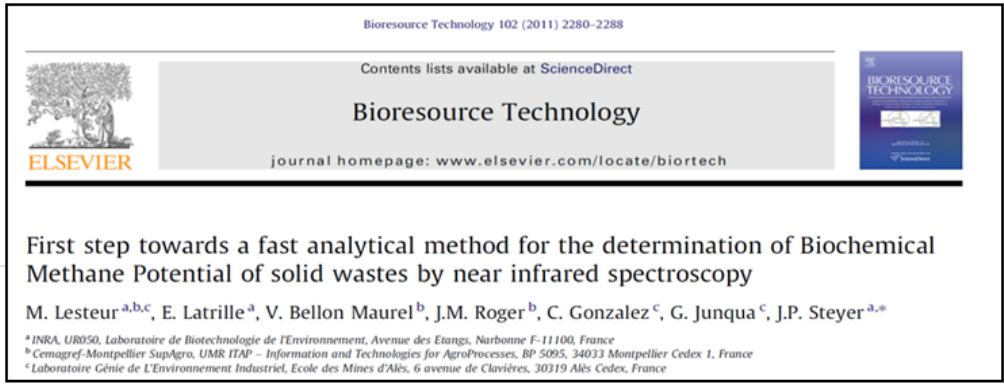
By Jean Philippe Steyer

Towards *smart* sensors

Near InfraRed Spectroscopy






Bioresource Technology 102 (2011) 2280–2288

Contents lists available at ScienceDirect

Bioresource Technology

journal homepage: www.elsevier.com/locate/biortech

ELSEVIER

First step towards a fast analytical method for the determination of Biochemical Methane Potential of solid wastes by near infrared spectroscopy

M. Lesteur [a,b,c], E. Latrille [a], V. Bellon Maurel [b], J.M. Roger [b], C. Gonzalez [c], G. Junqua [c], J.P. Steyer [a,*]

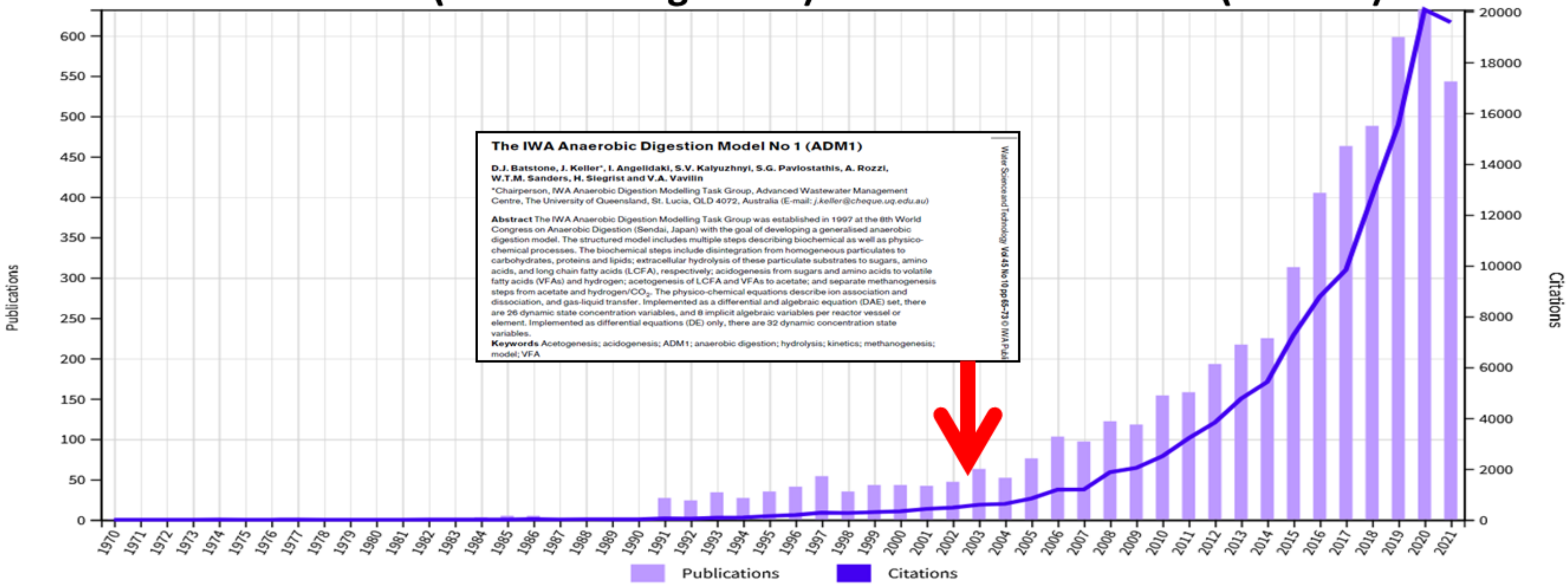
[a] INRA, UR050, Laboratoire de Biotechnologie de l'Environnement, Avenue des Etangs, Narbonne F-11100, France
[b] Cemagref-Montpellier SupAgro, UMR ITAP – Information and Technologies for AgroProcesses, BP 5095, 34033 Montpellier Cedex 1, France
[c] Laboratoire Génie de L'Environnement Industriel, Ecole des Mines d'Alès, 6 avenue de Clavières, 30319 Alès Cedex, France

INSTRUMENTATION, MODELING AND CONTROL OF DIGESTERS: AN OLD STORY FOR TODAY AND TOMORROW

By Jean Philippe Steyer

Evolution of the field of AD modelling

TITLE-ABSTR-KEY(anaerobic digestion) and TITLE-ABSTR-KEY(model*)



From Jean-Phillipe's experience in control of digesters

Water Science & Technology **Vol 53 No 4–5 pp 25–33** © IWA Publishing 2006

Lessons learnt from 15 years of ICA in anaerobic digesters

J.P. Steyer*, O. Bernard, D.J. Batstone*** and I. Angelidaki*****

*Laboratoire de Biotechnologie de l'Environnement, LBE-INRA, Av. des Etangs, 11100 Narbonne, France (E-mail: *steyer@ensam.inra.fr*)

**INRIA-COMORE, 2004 Avenue des lucioles, BP93, 06902 Sophia-Antipolis, France (E-mail: *obernard@sophia.inria.fr*)

***Environment & Resources, DTU, Bygningstorvet Building 113, Lyngby 2800 DK, Denmark (E-mail: *djb@er.dtu.dk*; *ria@er.dtu.dk*)

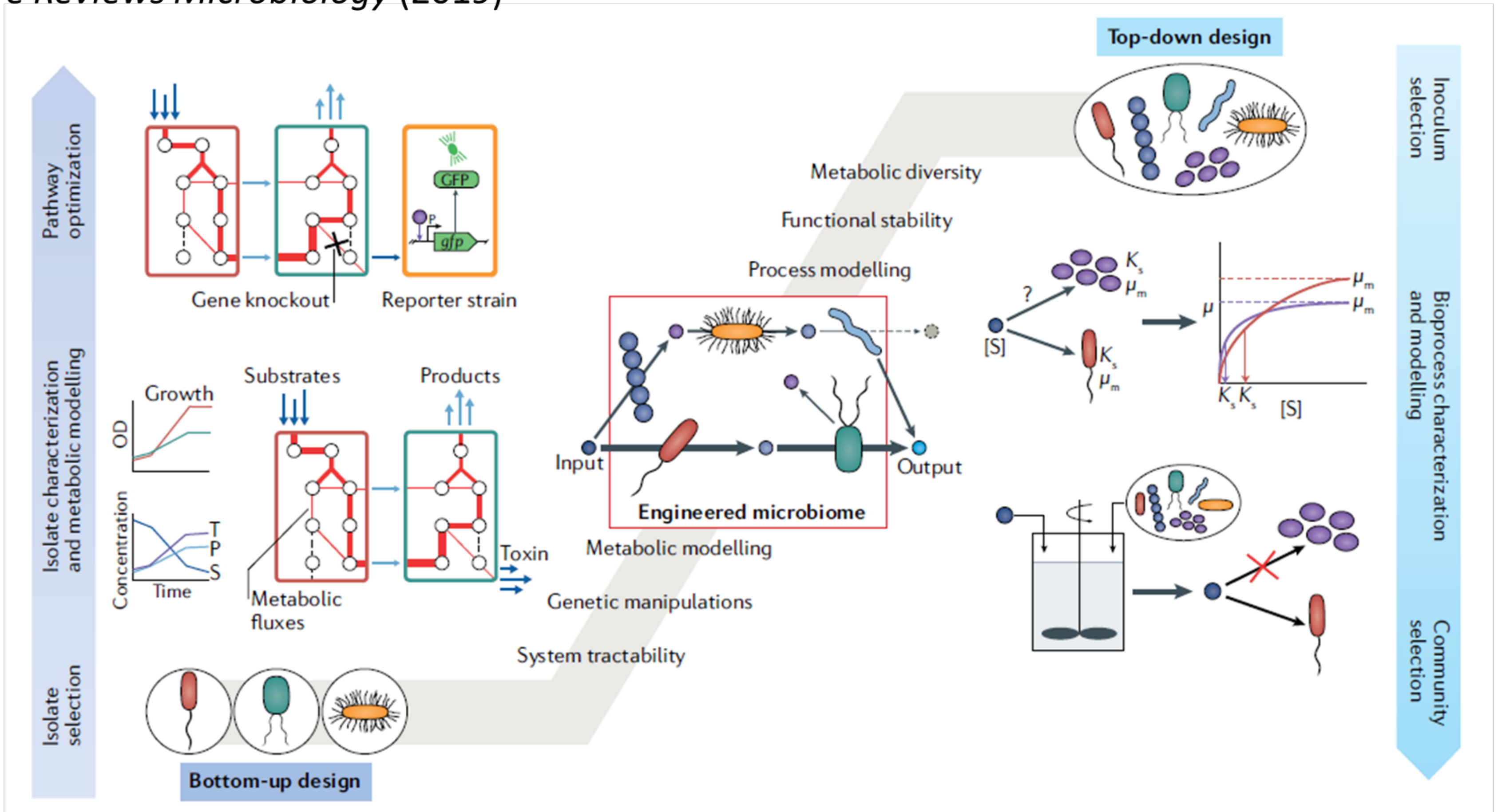
	Performances	Mathematical Complexity	Instrument Complexity
PID	☹	☺	☺
Fuzzy Logic	☺ ☺ ☺	☺	😐 😐
Neural Networks	😐 😐	😐 😐	☹ ☹ ☹
Adaptive Control	☺ ☺ ☺	😐 😐	☺
Linear Optimal Control	😐 😐	😐 😐	😐 😐
Non Linear Robust Control	☺ ☺ ☺	☹ ☹ ☹	☹ ☹ ☹

POTENTIAL OF MOLECULAR BIOLOGY TOOLS IN AD

By Lutgarde Raskin

Reflections on engineering microbial communities

Lawson, ..., Noguera, McMahon, Common principles and best practices for engineering microbiomes. *Nature Reviews Microbiology* (2019)

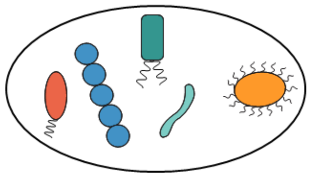


POTENTIAL OF MOLECULAR BIOLOGY TOOLS IN AD

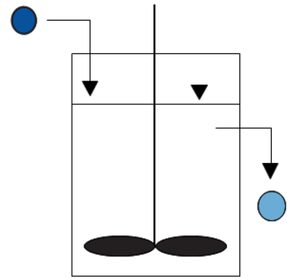
By Lutgarde Raskin

Engineering microbiomes – “Top-down approach”

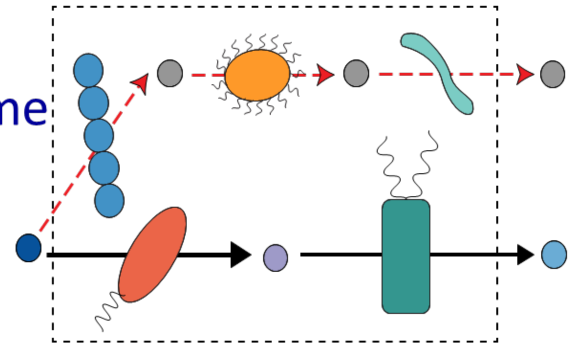
1. Use complex microbiome as inoculum



2. Select bioreactor operating conditions to obtain desired outcomes



3. Apply process modeling and adjust process variables to influence function and obtain engineered microbiome



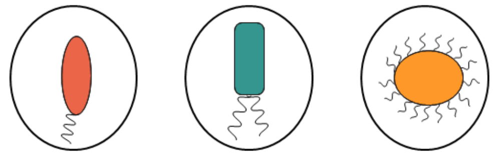
ITERATE

Evaluate economic feasibility and environmental impacts

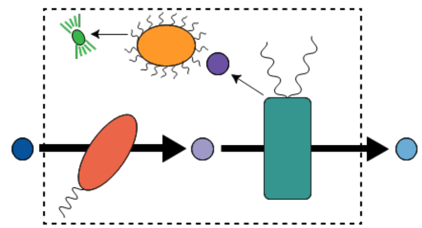
Lawson, ..., Noguera, McMahon, Common principles and best practices for engineering microbiomes. *Nature Reviews Microbiology* (2019)

By Lutgarde Raskin

Engineering microbiomes – “Bottom-up approach”



1. Obtain isolates and genomes of desired microbes
2. Use metabolic modeling to obtain desired outcomes
3. Use gene editing and synthetic biology to optimize pathways
4. Combine microbes to obtain engineered microbiome



ITERATE

Evaluate economic feasibility and environmental impacts

Lawson, ..., Noguera, McMahon, Common principles and best practices for engineering microbiomes. *Nature Reviews Microbiology* (2019)

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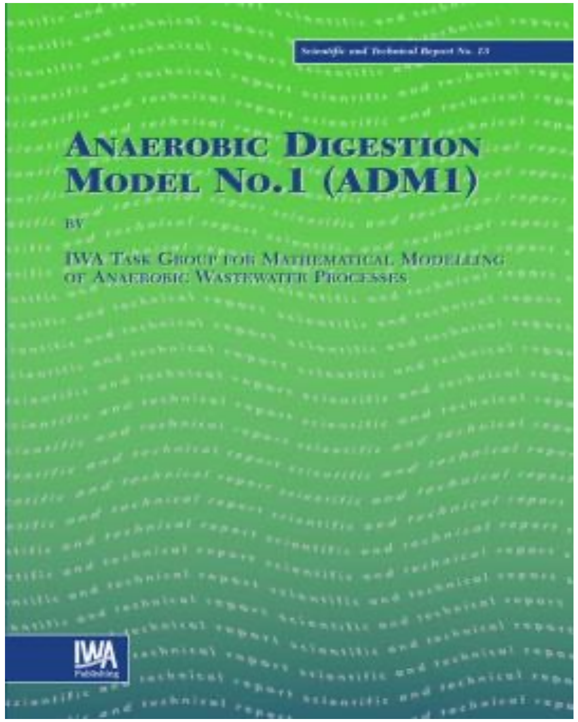
INTRODUCTION TO THE IWA ADM1 MODEL

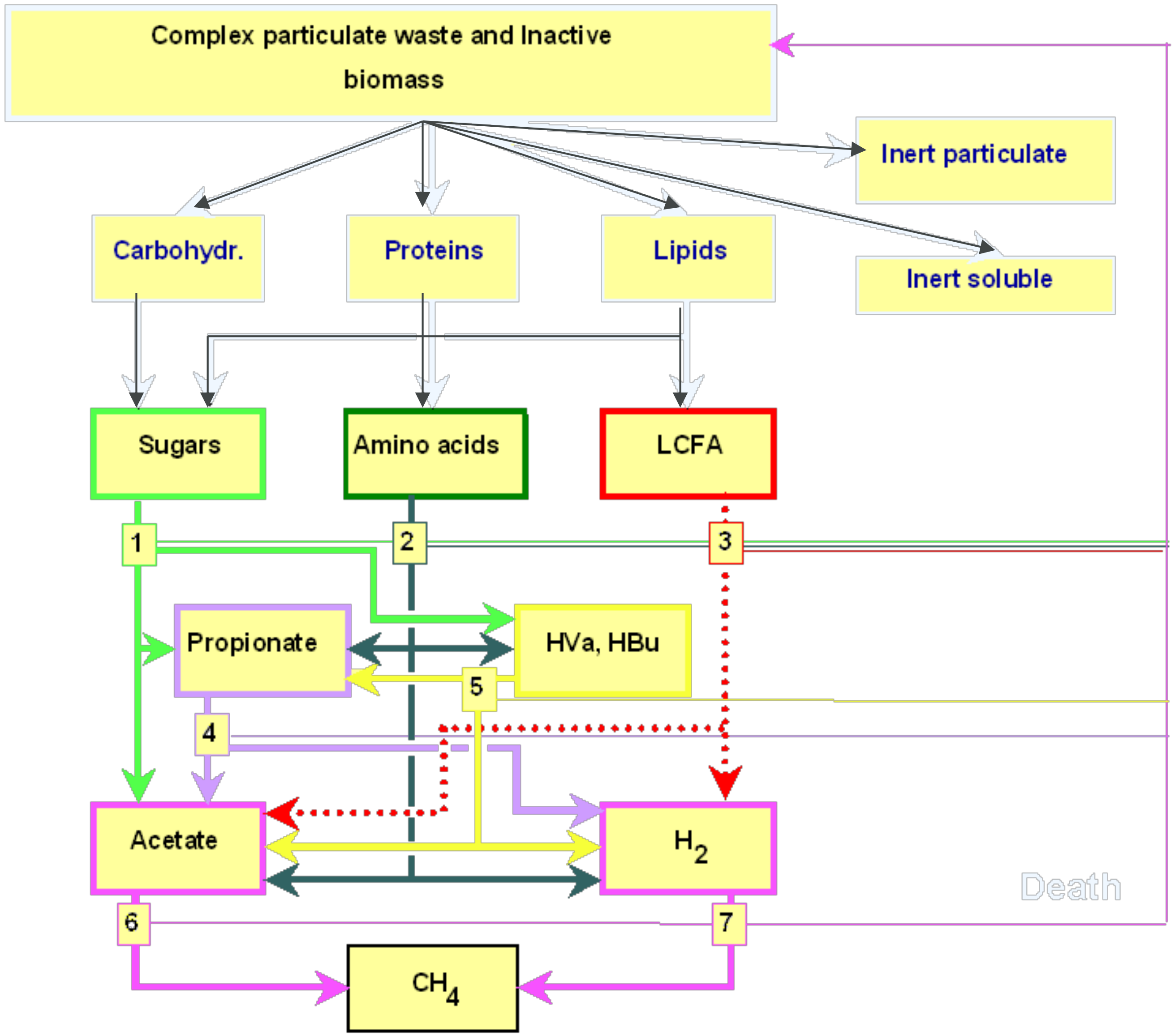
Damien Batstone
The University of Queensland, Australia

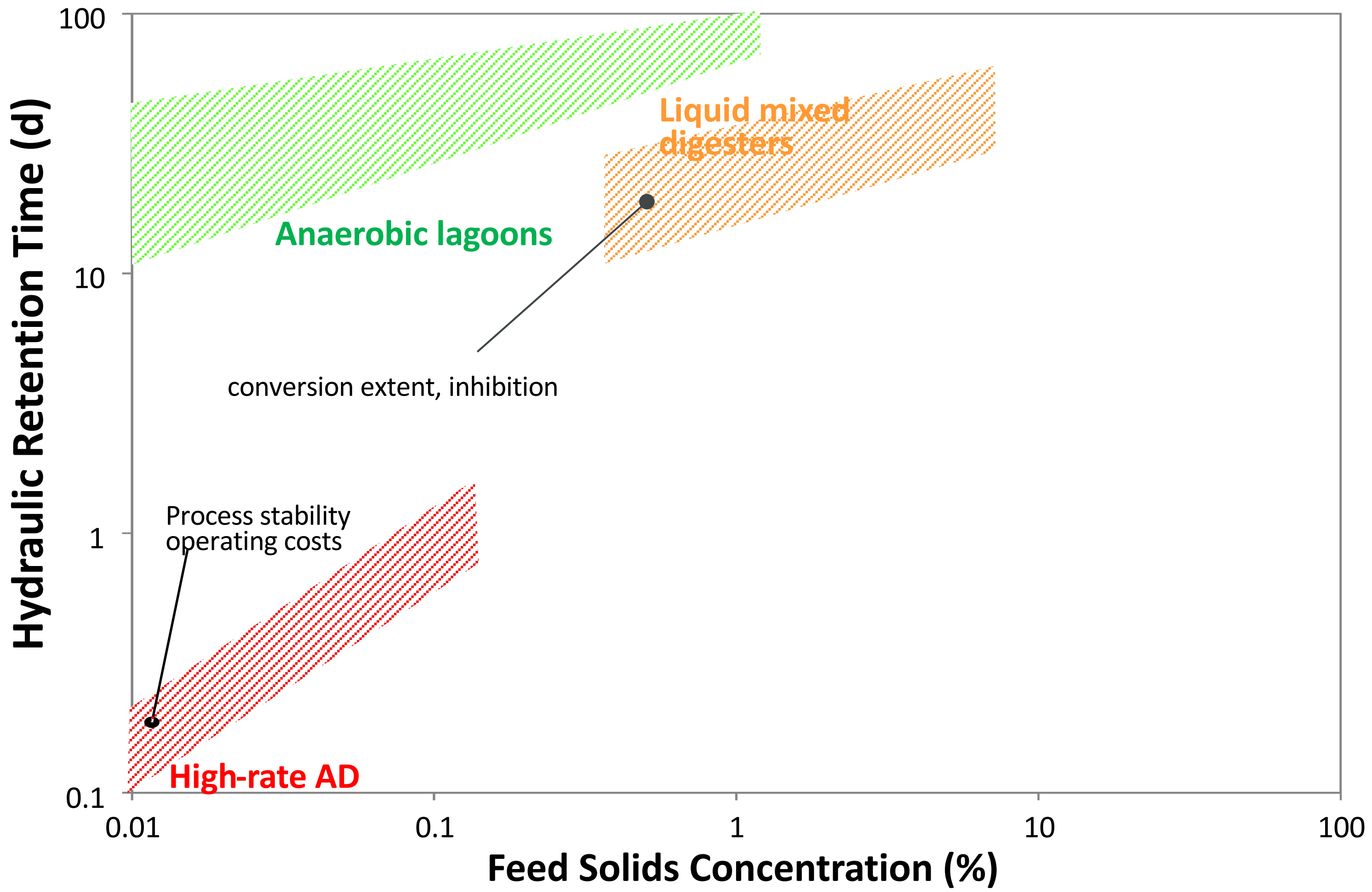
ADM1

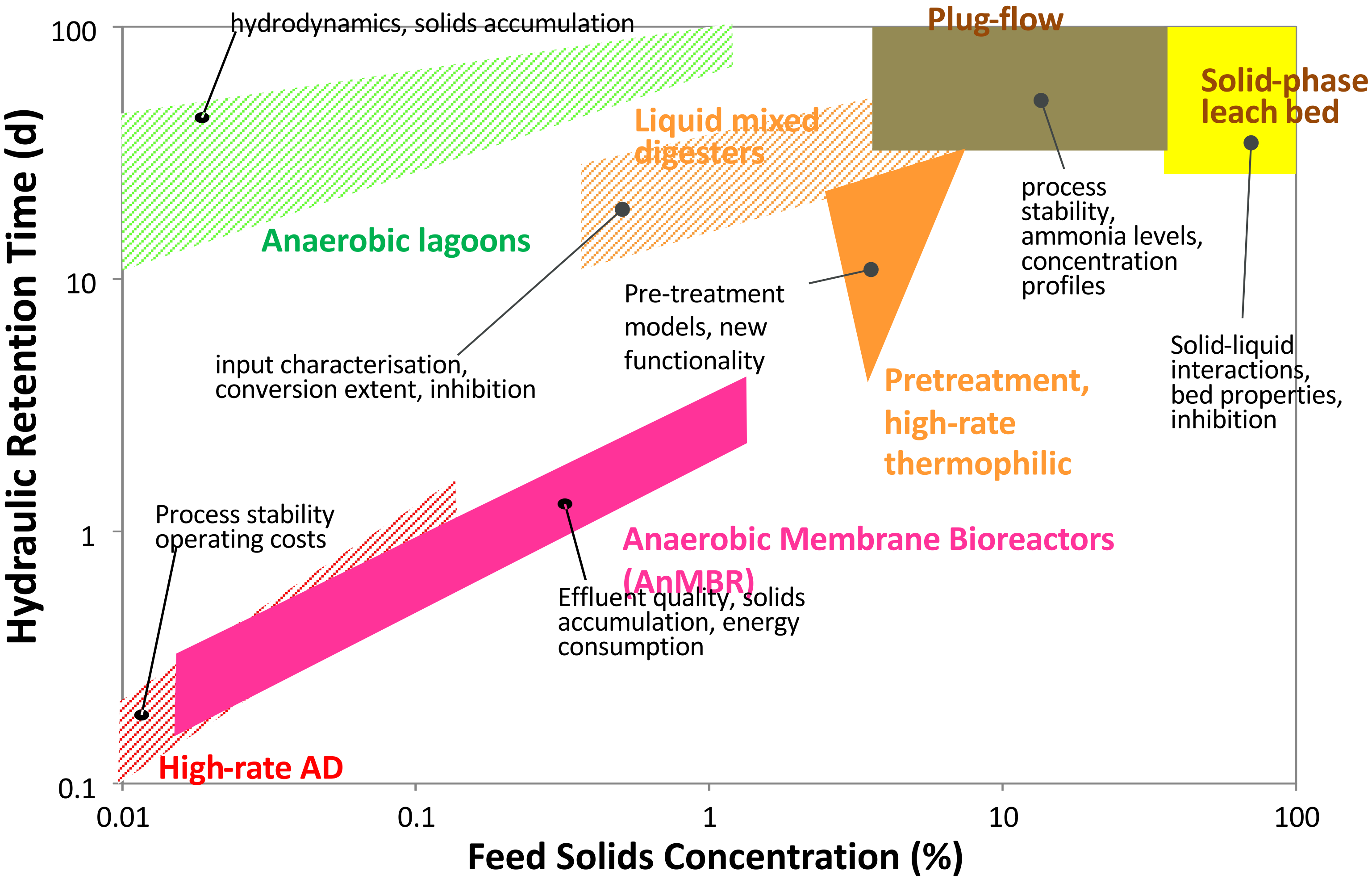
- Published 2002 (presented AD9)
- Aggregation of previous approaches
- Generalised model
- Cited >2000 times
- Over 500 sold
- Widely available
- Cited in >60% of AD modelling papers



MODEL STRUCTURE




100
10
1
0.1
0.01
0.1
1
10
100
Hydraulic Retention Time (d)
Feed Solids Concentration (%)
Liquid mixed digesters
Anaerobic lagoons
conversion extent, inhibition
Process stability
operating costs
High-rate AD

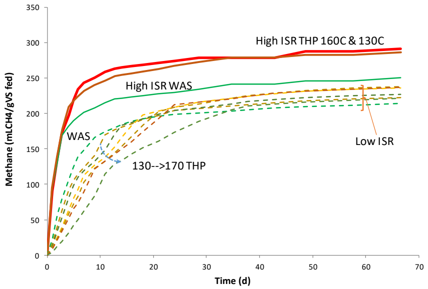


Hydraulic Retention Time (d)
100
10
1
0.1
0.01
0.1
1
10
100
Feed Solids Concentration (%)
hydrodynamics, solids accumulation
Anaerobic lagoons
Liquid mixed digesters
input characterisation, conversion extent, inhibition
Pre-treatment models, new functionality
Plug-flow
process stability, ammonia levels, concentration profiles
Solid-phase leach bed
Solid-liquid interactions, bed properties, inhibition
Pretreatment, high-rate thermophilic
Anaerobic Membrane Bioreactors (AnMBR)
Effluent quality, solids accumulation, energy consumption
Process stability operating costs
High-rate AD

INPUT CHARACTERISATION

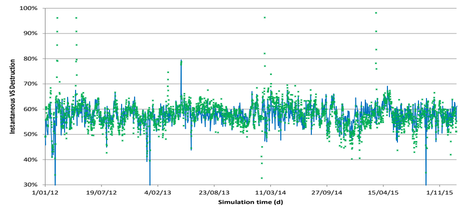
- Base on experience/knowledge/fitting
- Reduce to key parameters (k_{hyd}, f_d)
  - Measure with B_0 and VS or COD
- Mixed substrates (manure/primary)
  - Estimate X_{pr} based on N
  - X_{LI}/X_{CH} based on COD:VS or B_0
- Activated sludge
  - Use B_0 data if available, or
  - Use Nopens – includes impact of sludge age, catchment etc (if no ASM1, estimate f_d from Gossett)

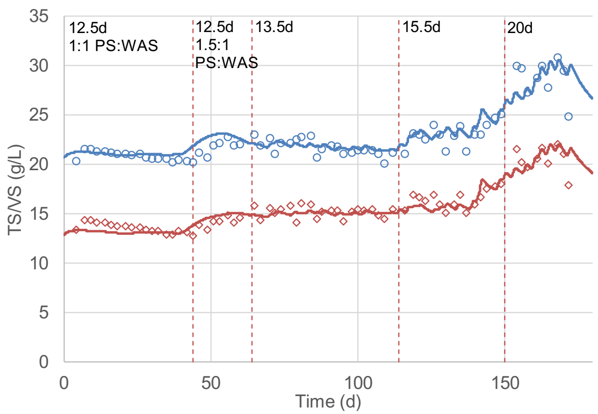
MULTISCALE ANALYSIS



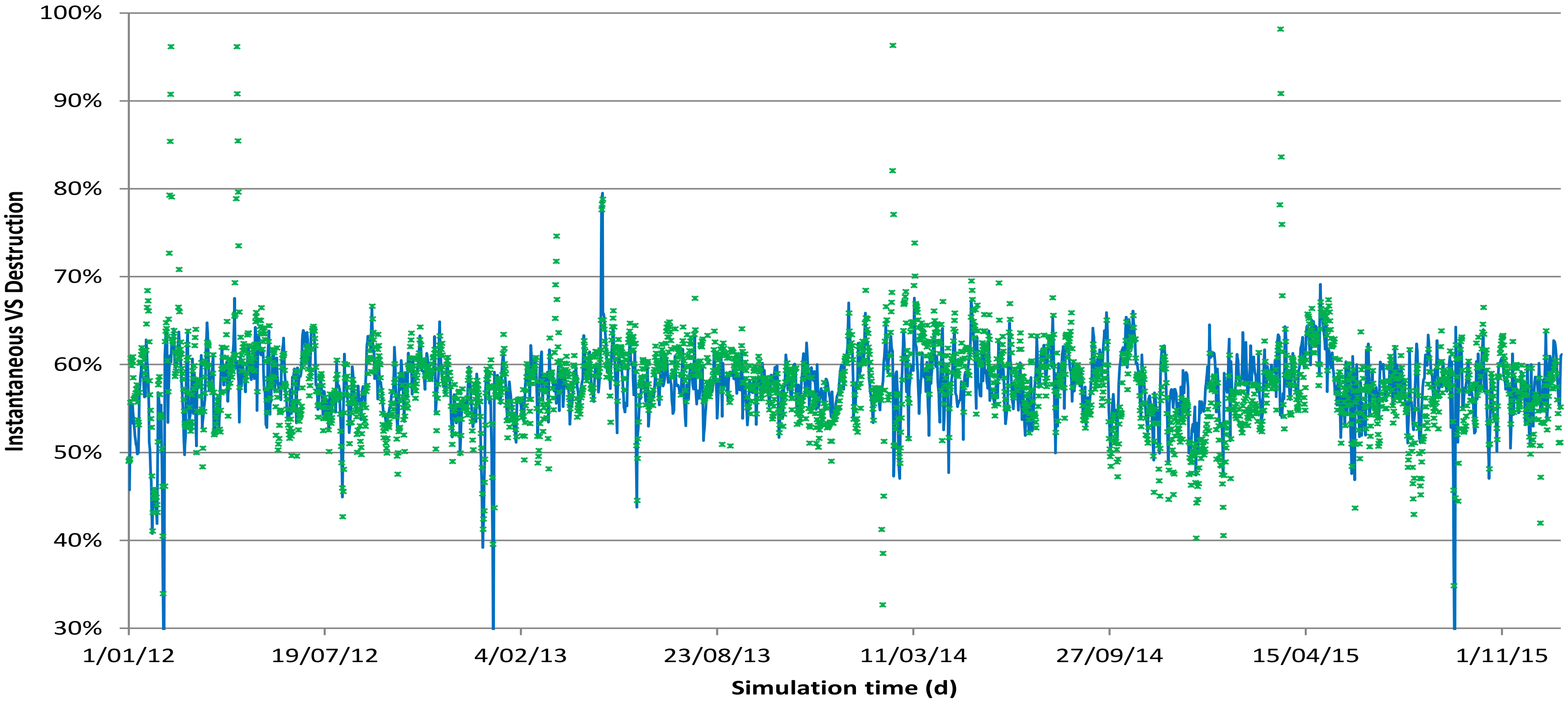
k_{hyd}, f_d

k_{hyd}, f_d

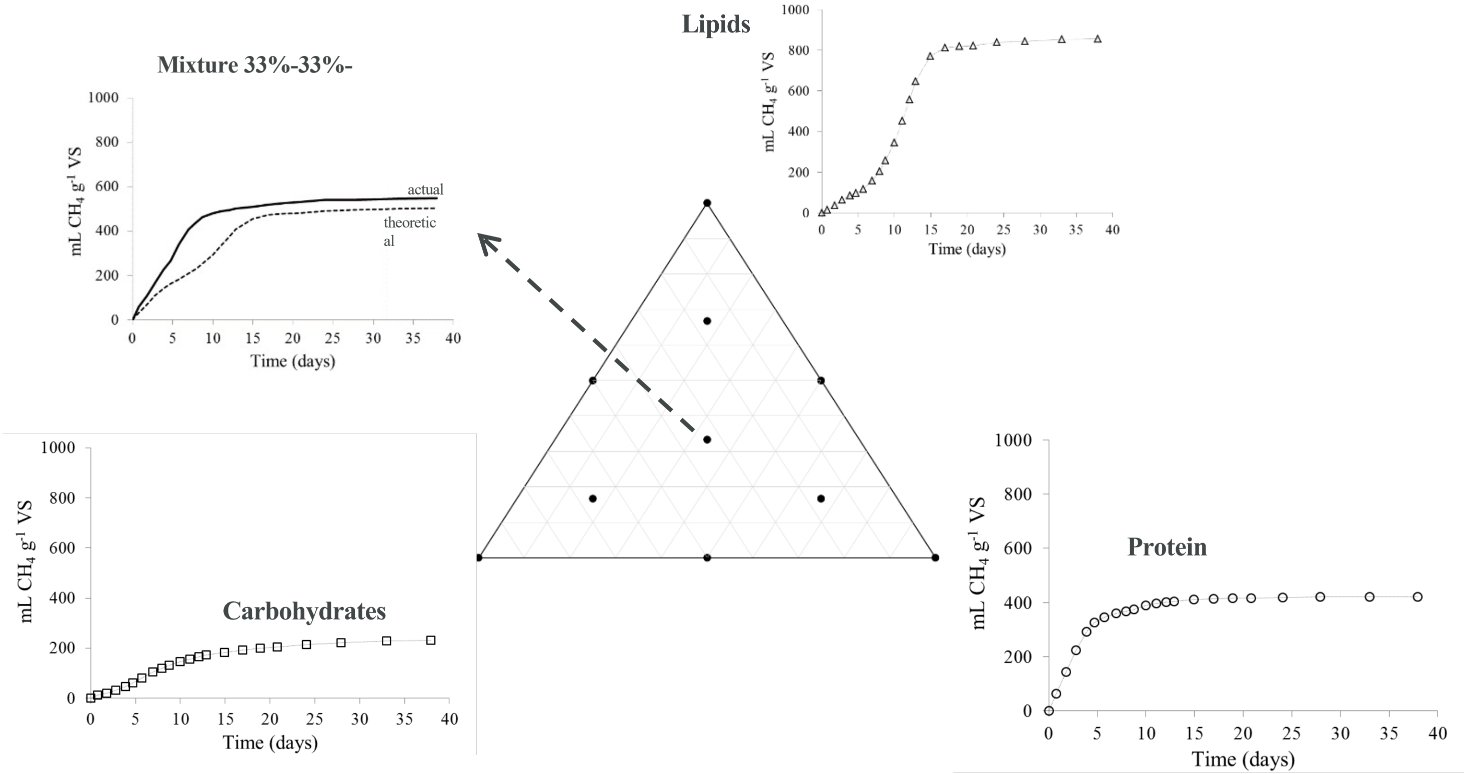




AIM FOR DATA RICH

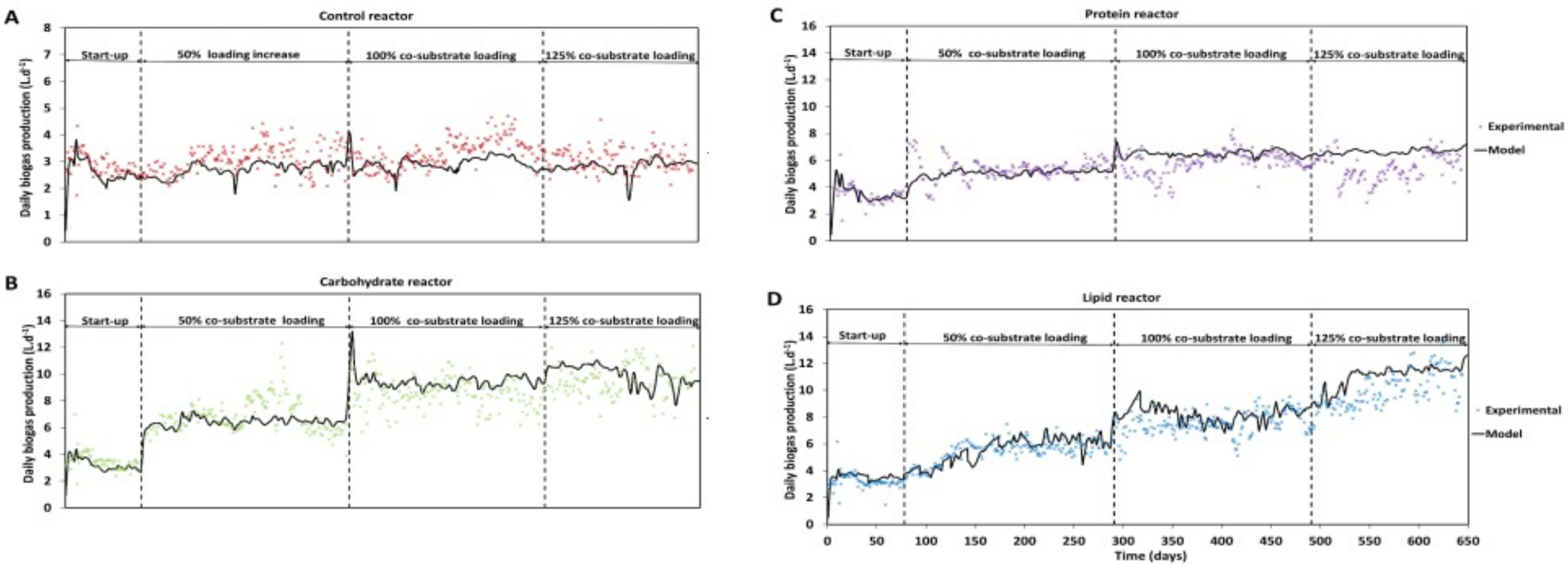


MIXED FEEDS & CODIGESTION

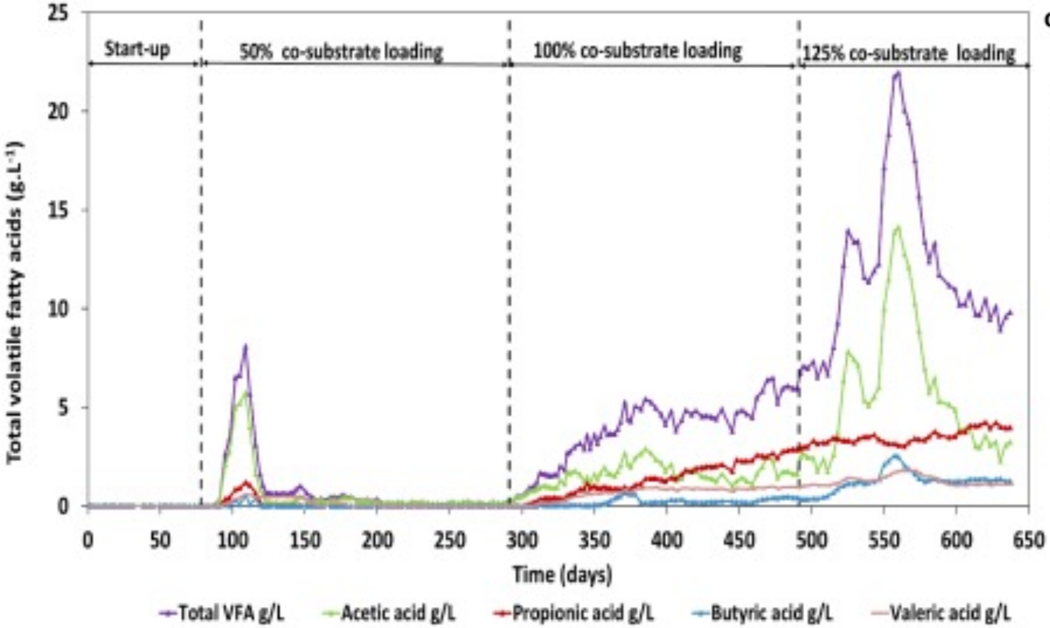


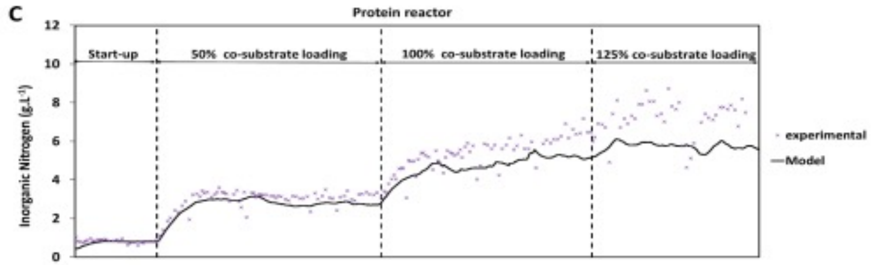
Astals *et al.*, Bioresource Technology

COMPARING IN CONTINUOUS

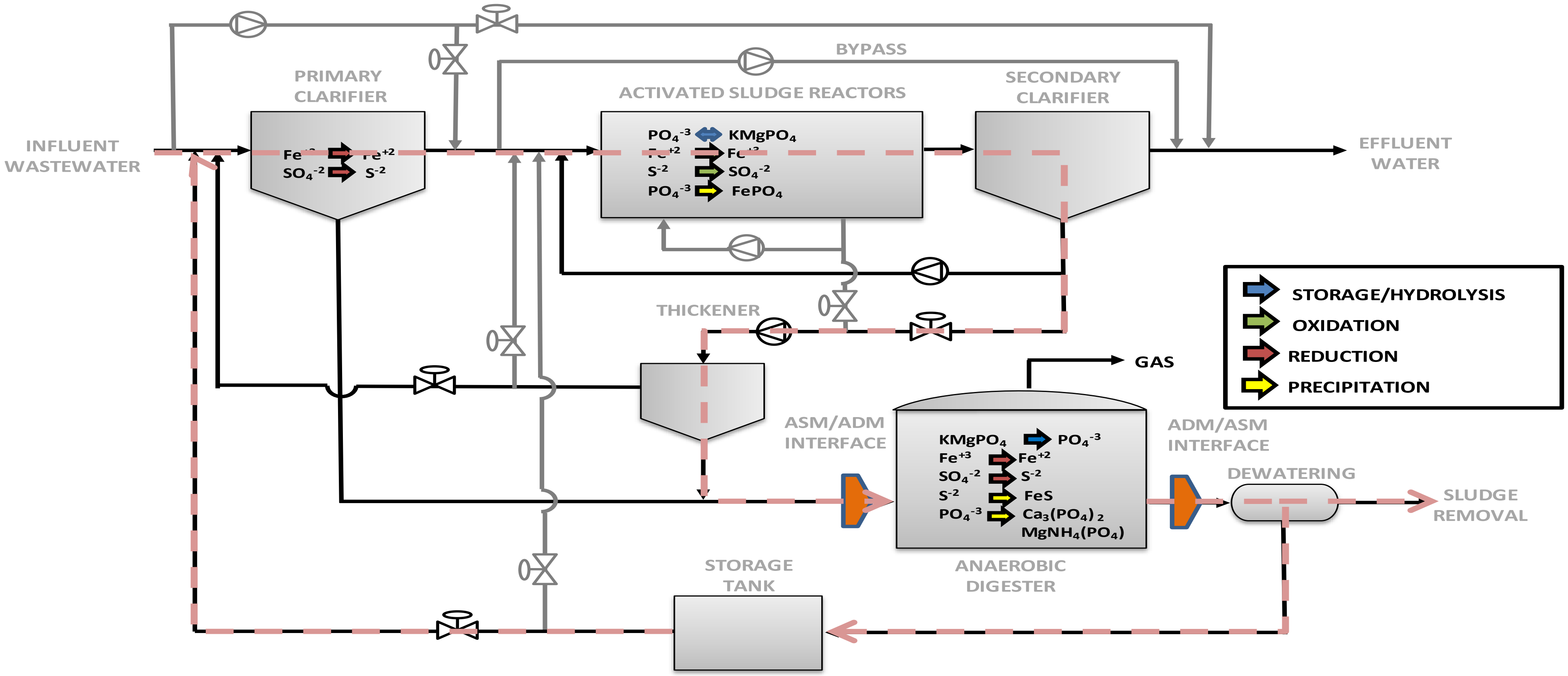


AMMONIA INHIBITION IN PROTEIN REACTORS



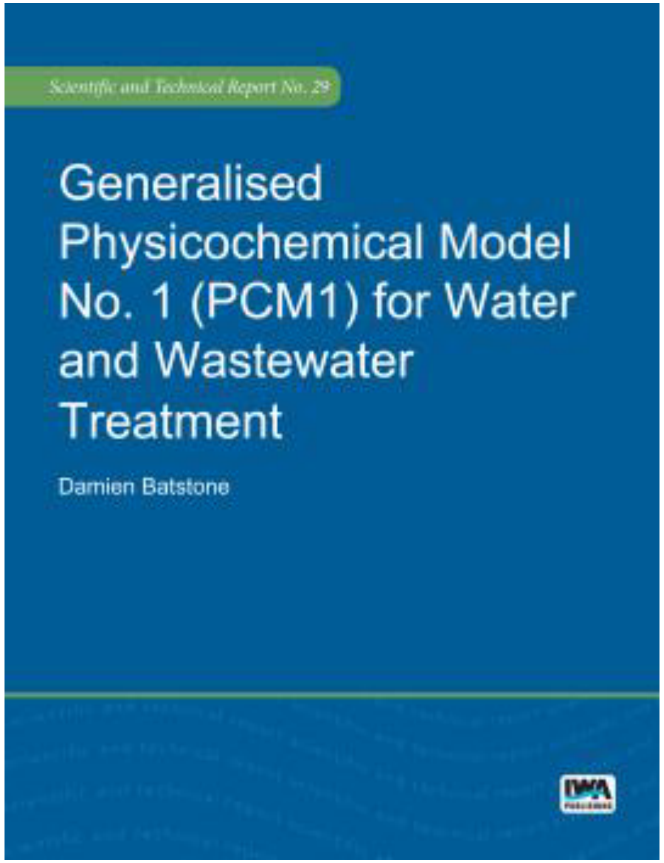


PLANT WIDE MODELLING - XAVI



WHY DON’T I TALK ABOUT THE PH MODEL?

- Emerging technology relies heavily on chemistry
- No unified approach
- Lack of theory
- PCM1 due for publication end 2021



OVERALL

- Consistent themes are:-
  - Increased complexity and demands on modelling
    - Unified model difficult
  - Need for distributed parameter (including CFD)
  - Interactions with new elements and new concepts
- Emerging period of innovation and development
- Currently limited scope to generalise
  - Further underlying research & application needed

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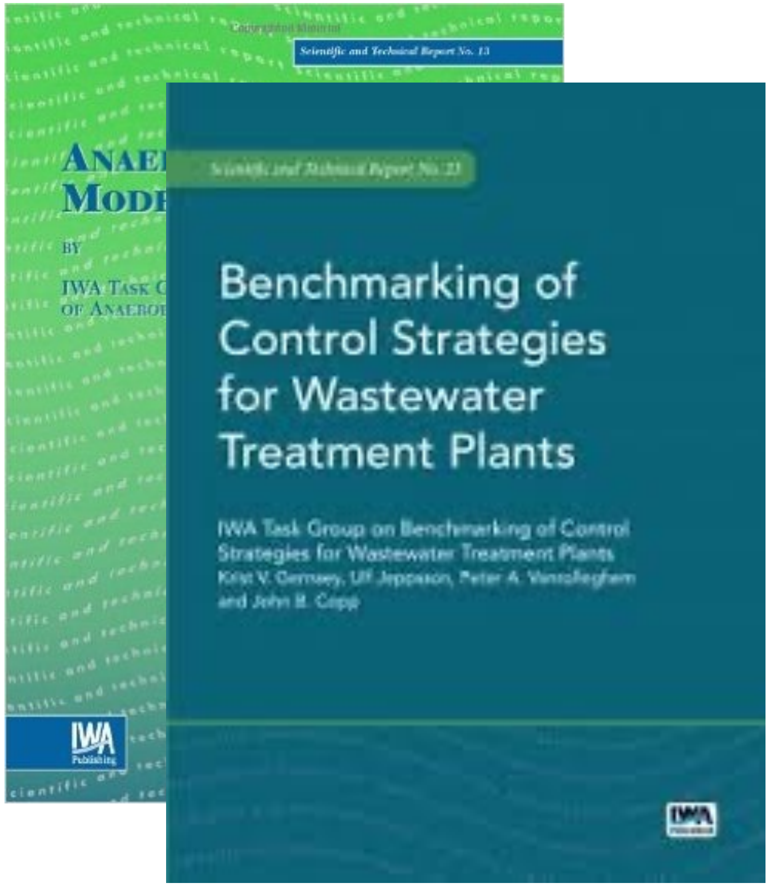
RECENT MODIFICATIONS AND ADAPTATIONS OF THE ADM1

Xavier Flores-Alsina
Technical University of Denmark

EXTENSION OF THE ADM1



- Widely used in both industry and academia (> 500 citations)
- Describes COD, C and N transformations.
- It does not account some of the new challengues that WWTP are facing nowadays

  1) Phosphorus (**P**) transformations and recovery

  2) Sulfur (**S**) transformations and potential sulfide inhibition

  3) Iron (**Fe**) transformations

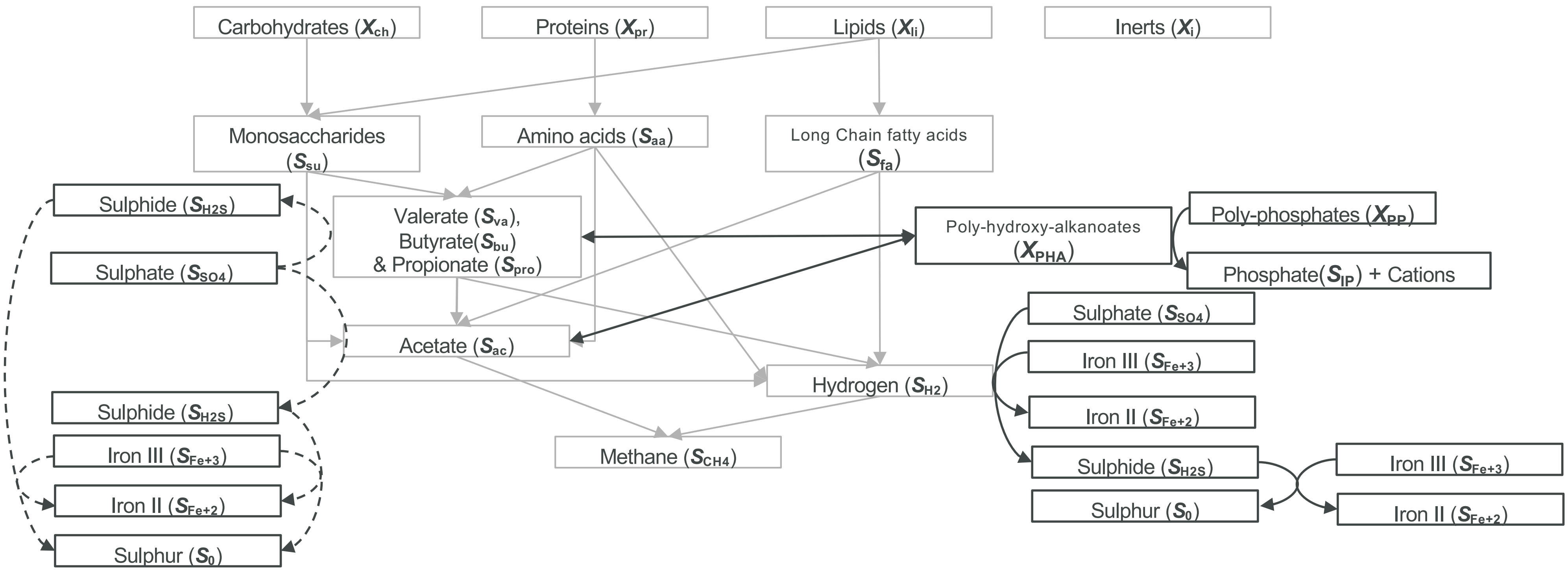
NEW PHYSICO-CHEMICAL DESCRIPTION

NEW BIOCHEMICAL DESCRIPTION

NEW SOLVING ROUTINE

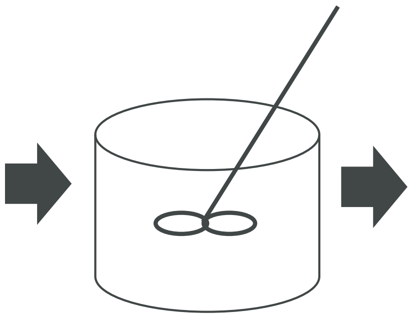
Batstone D.J. et al. (2002). **Anaerobic Digestion Model No 1**. IWA STR No 13, IWA Publishing, London, UK.
Gernaey K.V. et al, (2014). **Benchmarking of control strategies for wastewater treatment plants**. IWA Scientific and Technical Report No. 23. IWA Publishing, London, UK.

NEW BIOCHEMICAL PROCESSES



NEW PHYSICO-CHEMICAL DESCRIPTION (I)

ORIGINAL SPECIATION MODEL



Tot_Na
Tot_K
Tot_NHx
Tot_Cl
Tot_Ac
Tot_Pro
Tot_Ca
Tot_Mg
Tot_iC
Tot_SO
Tot_iP
Tot_SH
Tot_Fe2
Tot_Fe3
Tot_Bu

EQULIBRIUM MODELLING

PO4 | HPO4 | H2PO4 | H3PO4

Al2PO4 | AlHPO4 | CaH2PO4 | CaHPO4 | CaPO4 | FeH2PO4

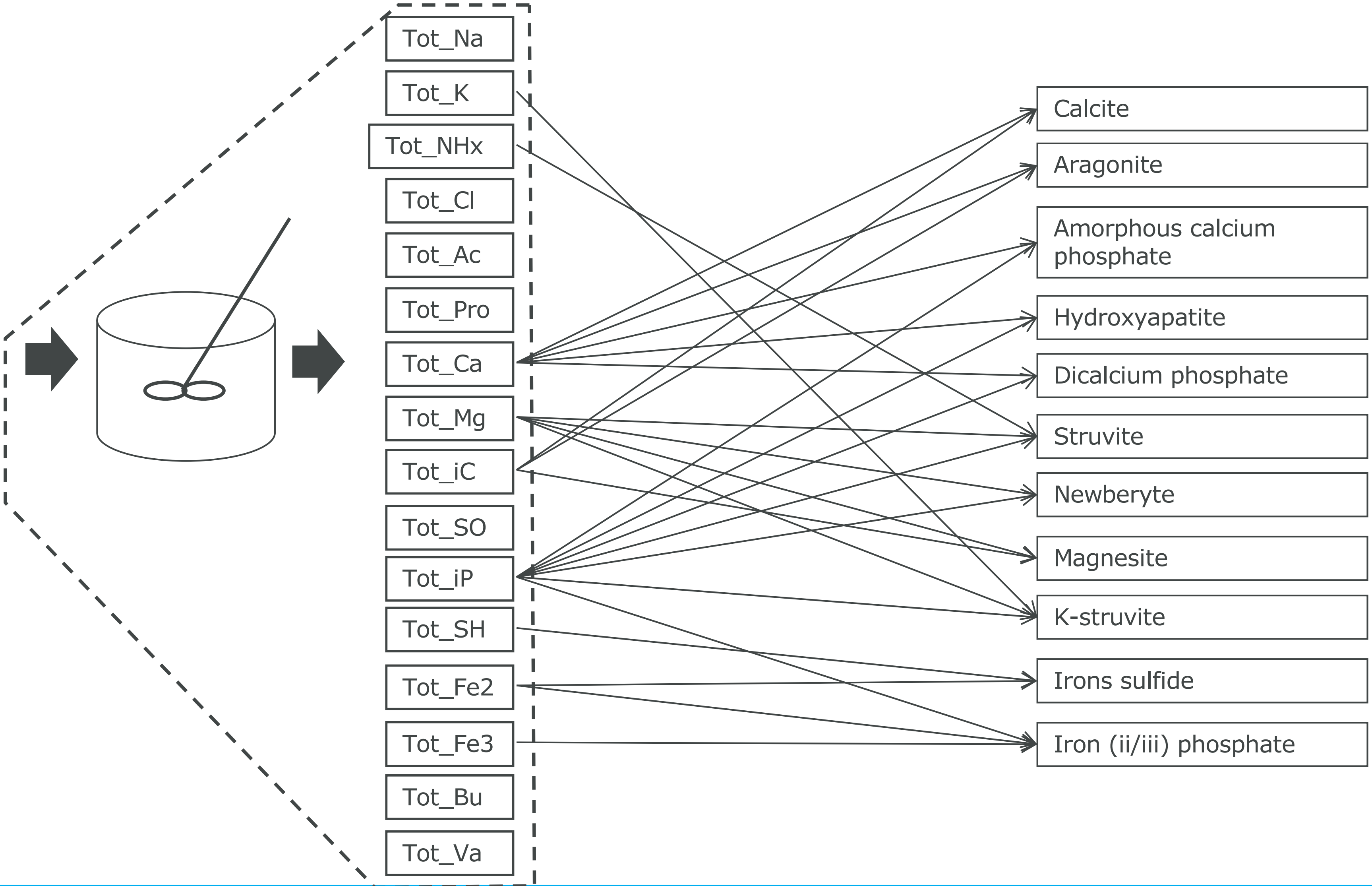
FeH2PO4(2) | FeH2PO4 | FeHPO4 | K2HPO4 | K2PO4 | KH2PO4

KHPO4 | KPO4 | MgHPO4 | MgPO4 | Na2HPO4 | Na2PO4

NaH2PO4 | NaHPO4 | NaPO4

Acid-base chemistry (pH)
Ion speciation / pairing
Ionic strengh / activity corrections

NEW PHYSICO-CHEMICAL DESCRIPTION (II)



NEW SOLVING ROUTINE

Very Stiff system: combination of very slow (ODE) and fast systems (DAE)

1) Stiff solvers (ode15s):

special features to handle ODE/DAE systems (MASS)

They can not be used with buffer-blocks, delay blocks, noise blocks (sensor / actuators) models **CONTROL**

2) Non stiff solvers (ode45):

They can handle buffer blocks, delay bloks, noise blocks

Non suitable for combined ODE/DAE systems **CONTROL**

DAEs are handled with an interative method (Newton Rapshon)

1) NR unidimensional
2) NR multidimensional + simulated annealing

MANY SCIENTIFIC OUTPUTS.....

Water Research

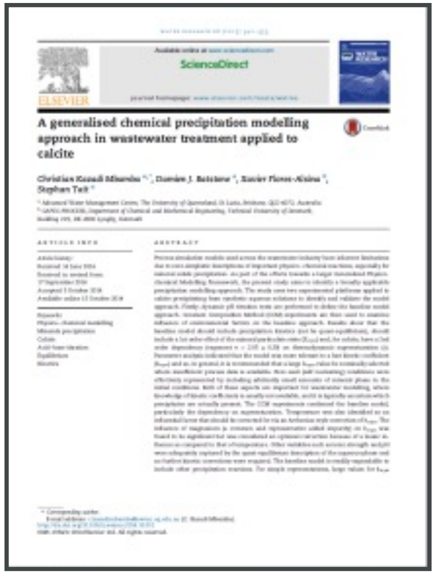
A plant-wide aqueous phase chemistry module describing pH variations and ion speciation/pairing in wastewater treatment process models

ScienceDirect

Effects of ionic strength and ion pairing on (plant-wide) modelling of anaerobic digestion

Water Research

Modelling phosphorus (P), sulfur (S) and iron (Fe) interactions for dynamic simulations of anaerobic digestion processes



ScienceDirect

A generalised chemical precipitation modelling approach in wastewater treatment applied to calcite

Water Research

A systematic study of multiple minerals precipitation modelling in wastewater treatment

Water Research

Plant-wide modelling of phosphorus transformations in wastewater treatment systems: impacts of control and operational strategies

FULL SCALE VALIDATION 1: ANAEROBIC GRANULAR SLUDGE REACTOR (NVZ, DK)

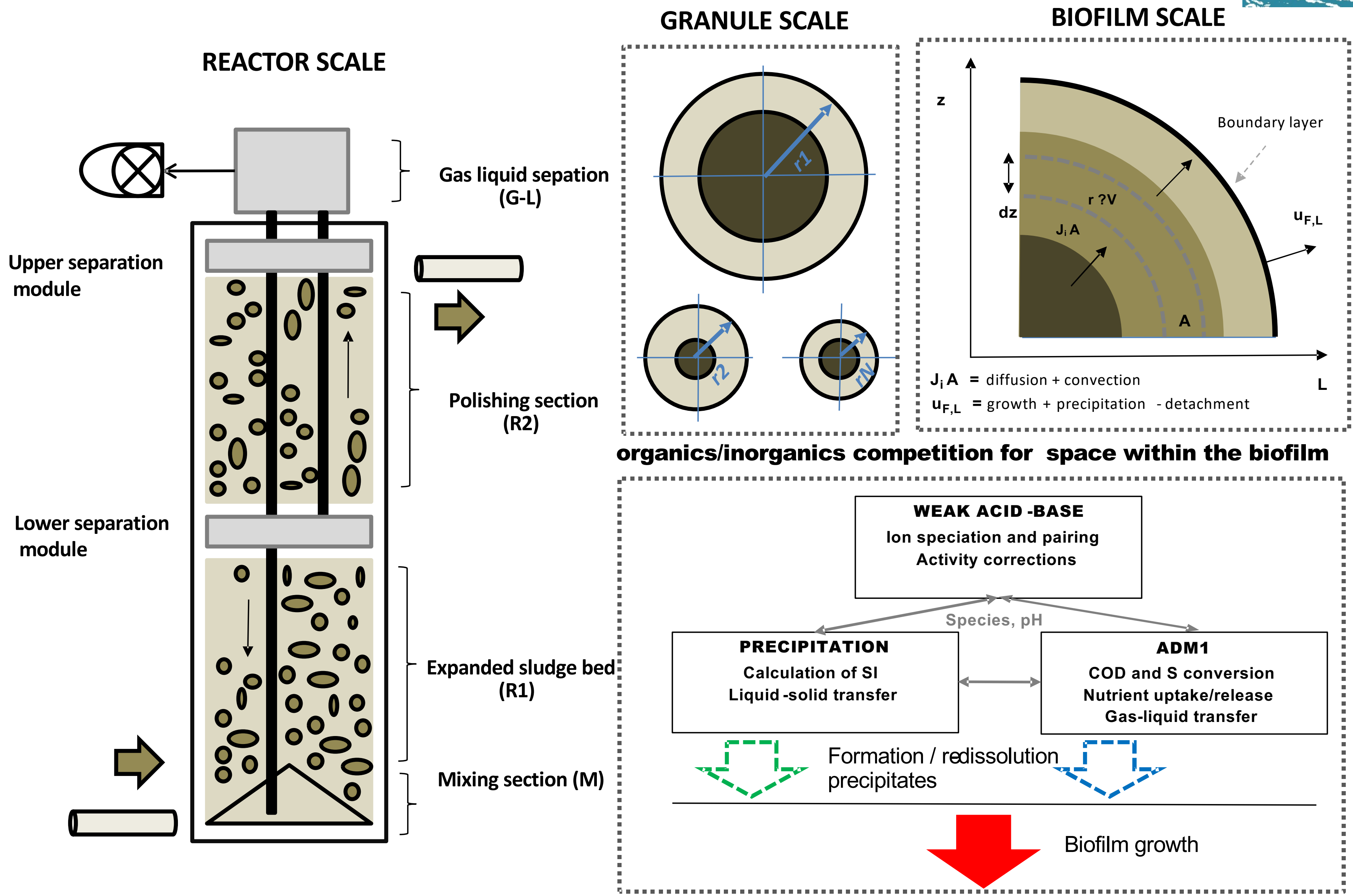
novozymes Rethink Tomorrow

THE UNIVERSITY OF QUEENSLAND AUSTRALIA

DTU

LUND UNIVERSITY

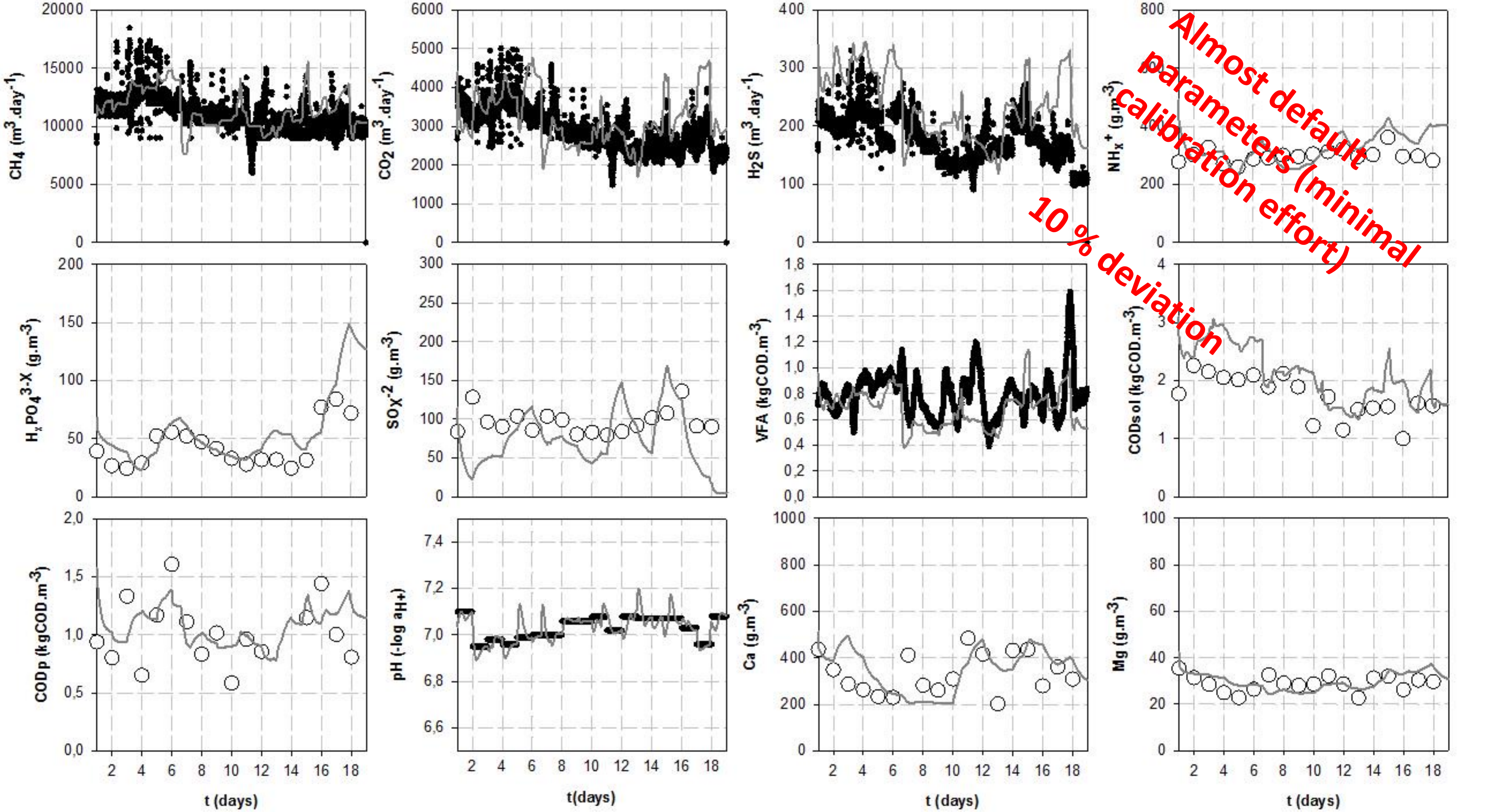
MULTI-SCALE MODELLING APPROACH



Feldman H., Flores-Alsina X., Ramin P., Kjellberg K., Batstone D.J., Jeppsson U., Gernaey K.V. (2017) Modelling an industrial anaerobic granular reactor using a multi-scale approach. **Water Research**, 126; 488-500

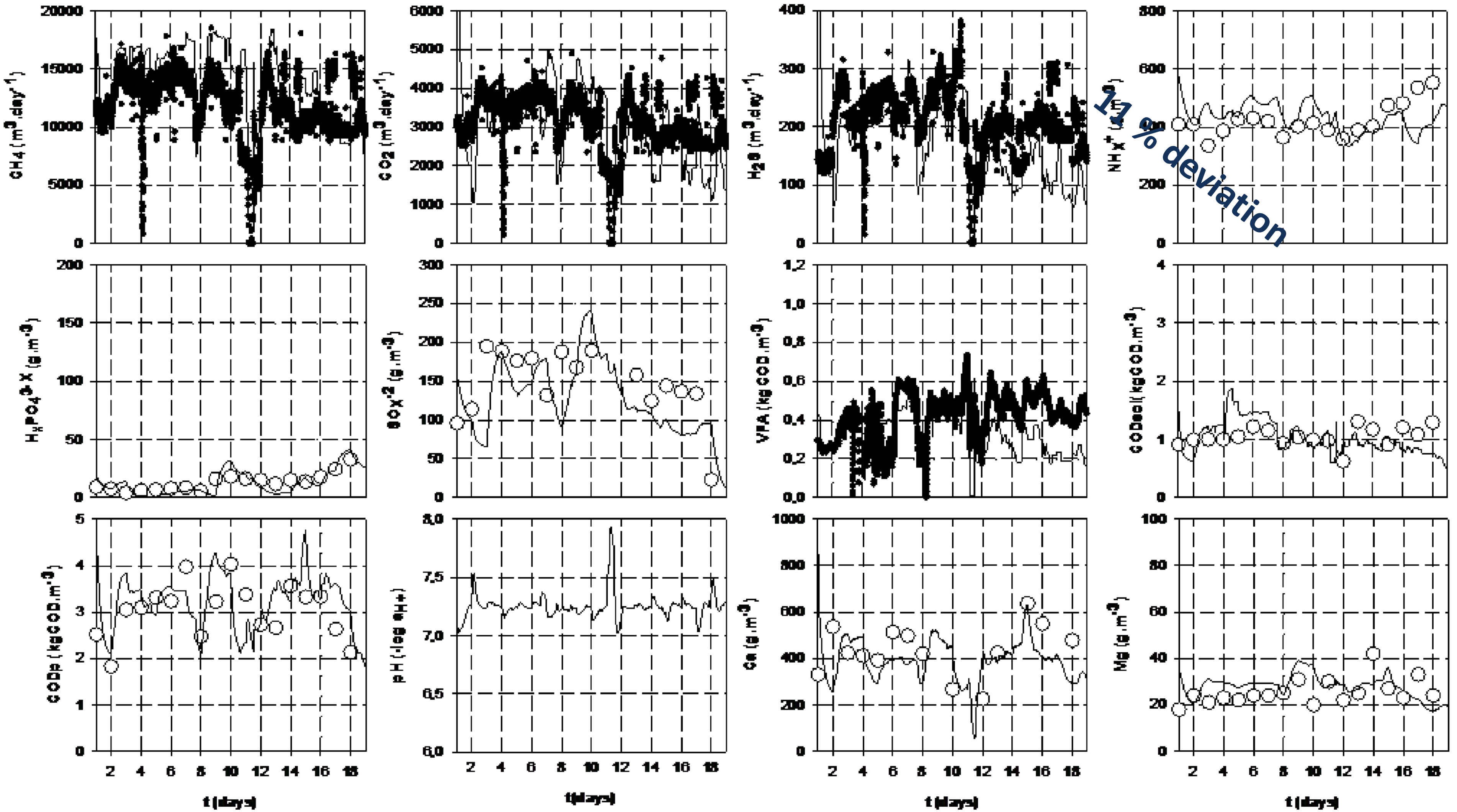
MODEL TESTING: DATA SET #1

HYDROLYSIS	*ACIDOGENSIS*	*ACETOGENEGIS*	*METHANOGENESIS*
SULFIDOGENESIS	*N AND P RELEASE*	*WEAK ACID BASE CHEMISTRY*	*ION BEHAVIOUR*

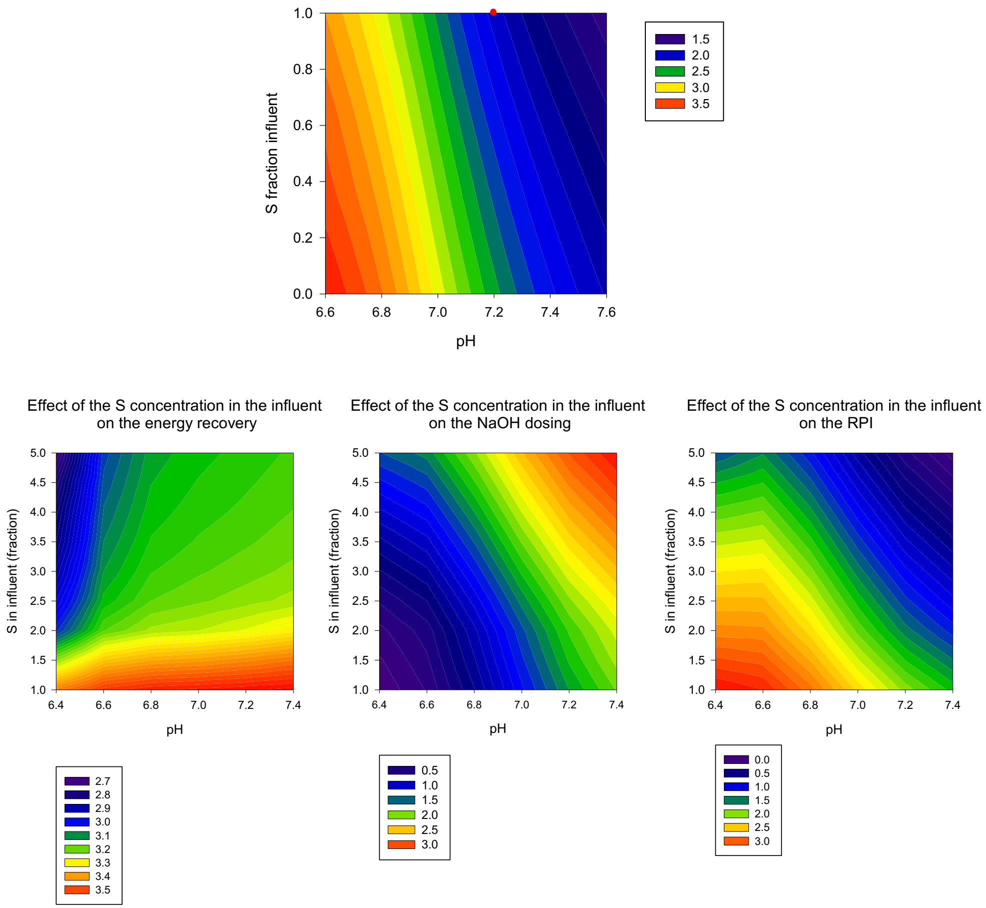


MODEL TESTING: DATA SET #2

HYDROLYSIS	*ACIDOGENSIS*	*ACETOGENEGIS*	*METHANOGENESIS*
SULFIDOGENESIS	*N AND P RELEASE*	*WEAK ACID BASE CHEMISTRY*	*ION BEHAVIOUR*

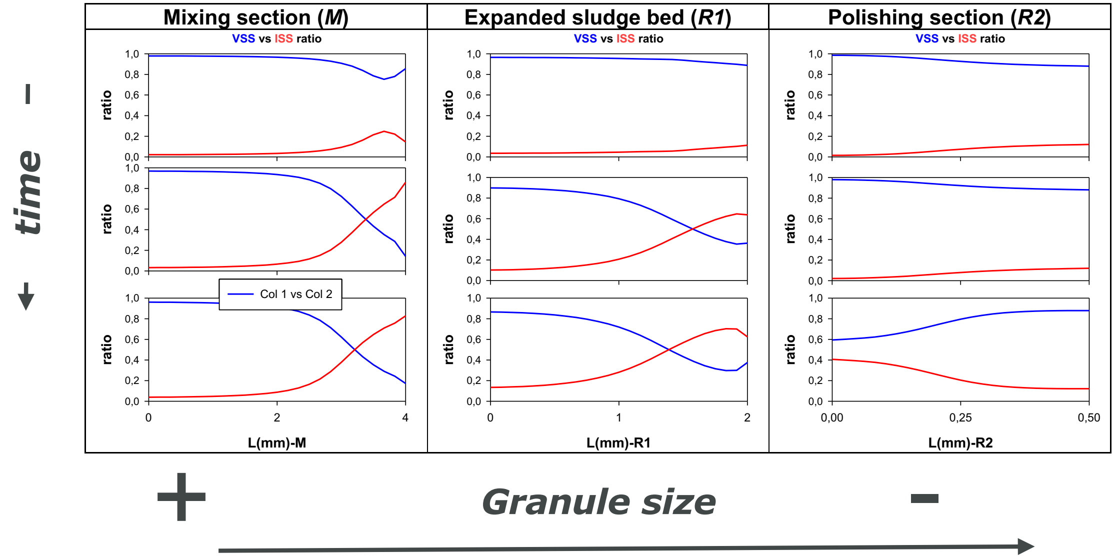


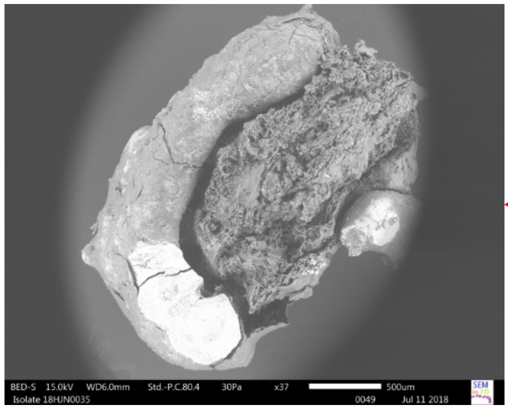
OPTIMIZATION STUDIES: MODEL BASED ASSESSMENT OF DIFFERENT OPERATIONAL CONDITIONS



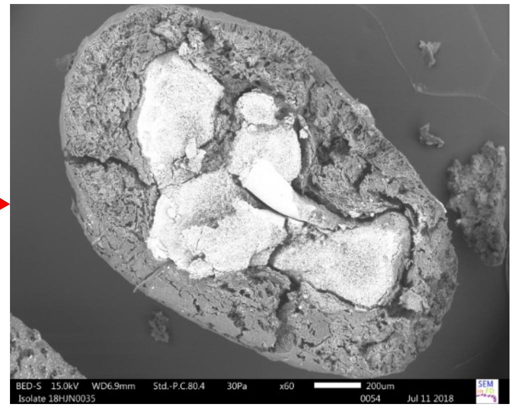
- Chemical cost can be reduced by **40 %** by moving the pH from 7.2 to 6.8 (ensuring the same yield) (**less precipitation too**)
- Increase the CO2 stripping in the PA reduce the cost of chemicals
- Influent **S does not impose sufficient negative impacts on energy recovery** (+0.20 M€/year when influent S is removed) to warrant the cost of its removal (3.58 M€/year)

LOCATION OF PRECIPITATES DEPENDS OF THE GRANULAR SIZE

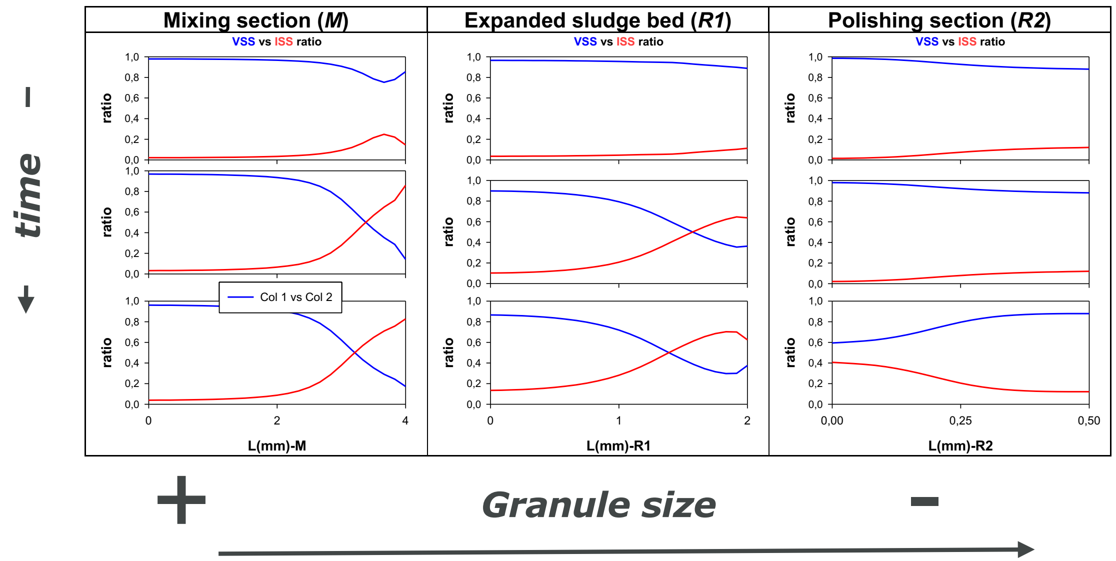


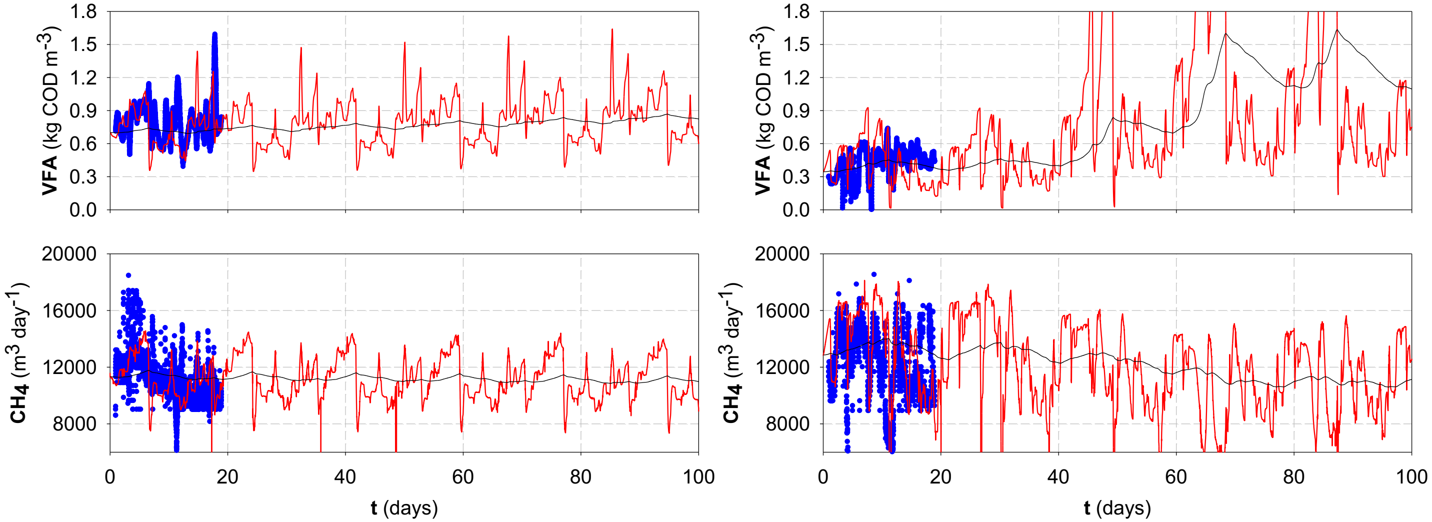


Experimental validation of the location of precipitates in granular size



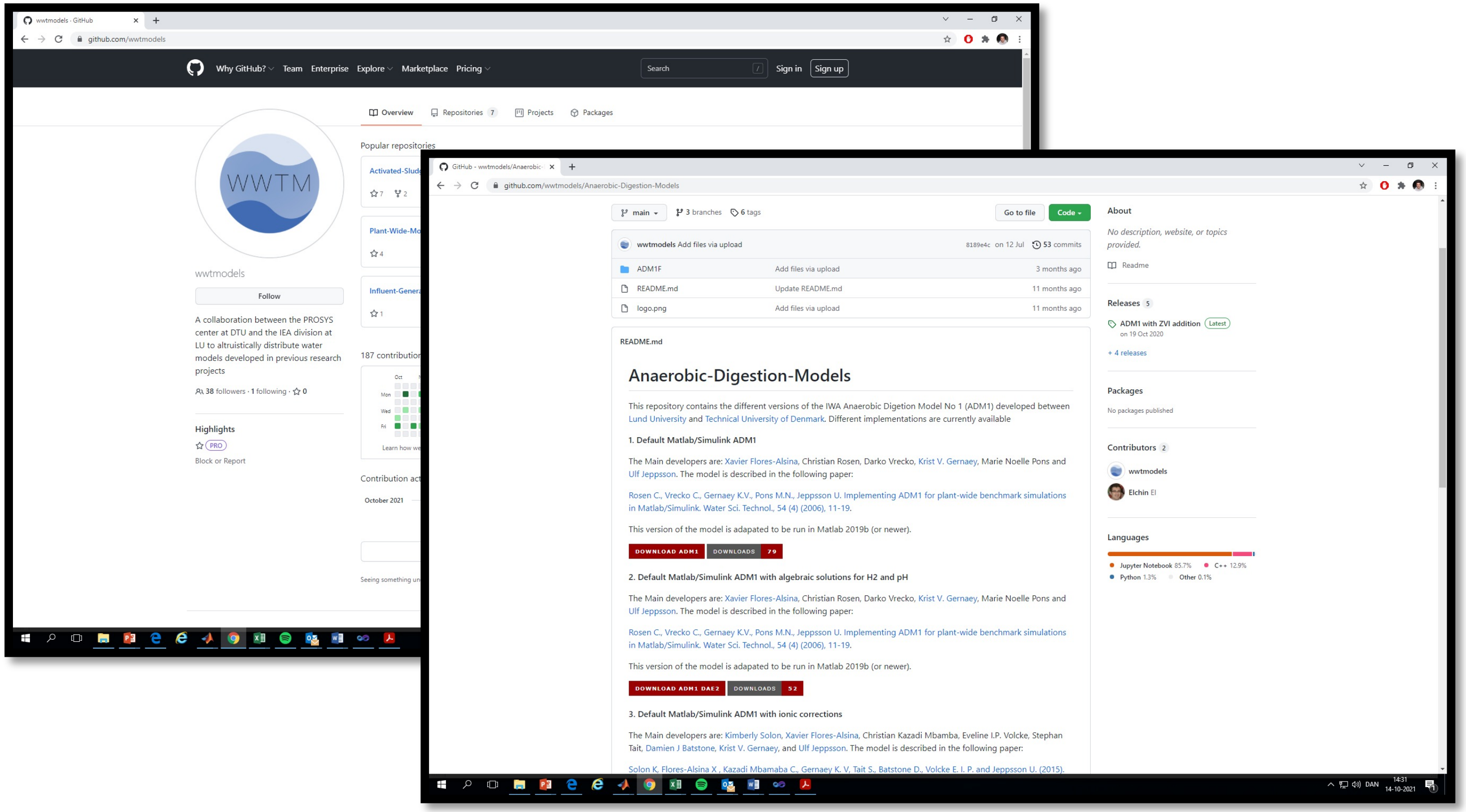
LONG TERM EFFECTS OF INTRA-GRANULE PRECIPITATION





SHARING IS CARING ☺



SUMMARY OF THE KEY FINDINGS

- The case studies have contributed enourmously to gain credibility
- The process of constructing the model has been the main learning experience
- Model simultions (scenario analysis) confirms what process engineers already know
- In some other ocasiones, the model has been very useful to assess the capacity of the plant
- The github webpage has been extremly succesful (1000 downloads)

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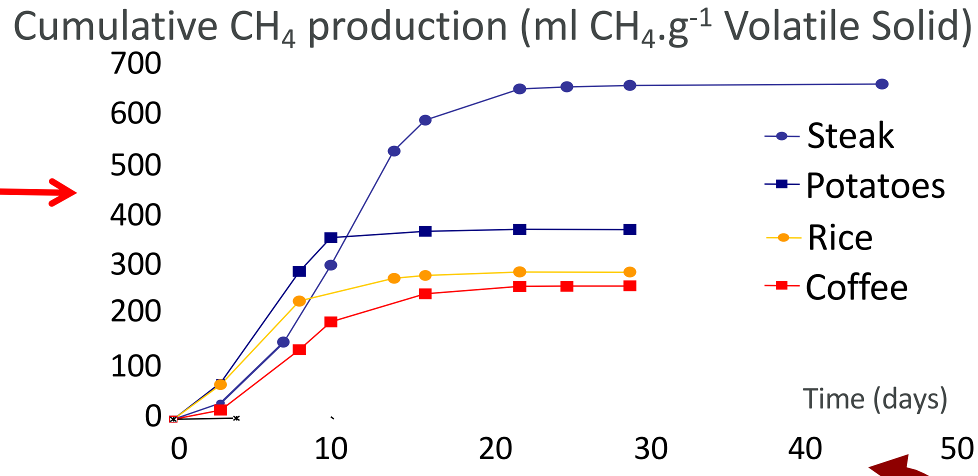
ADVANCED INSTRUMENTATION FOR AUTOMATIC ADM1 PARAMETERS CALIBRATION

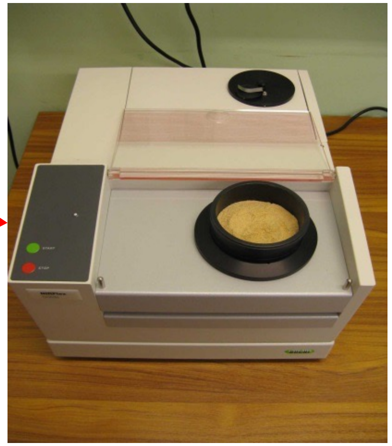
Jean-Philippe Steyer
INRAE-LBE, France

USE OF NEAR INFRARED SPECTROMETRY TO PREDICT OM BIODEGRADABILITY

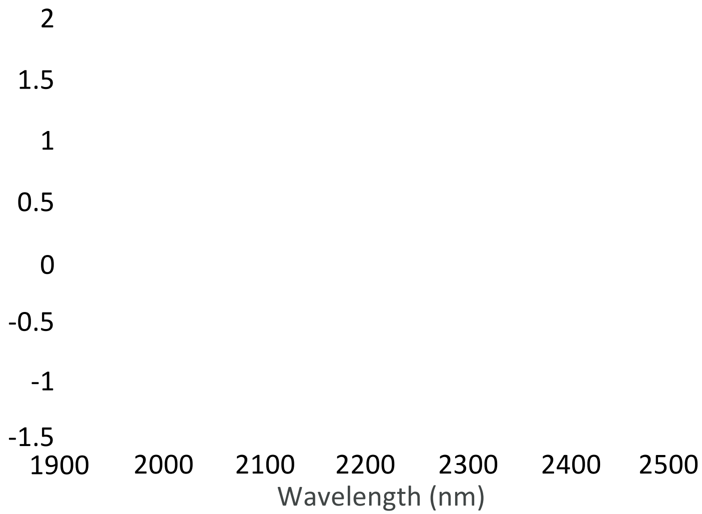
Biochemical Methane Potential



Biodegradability ?

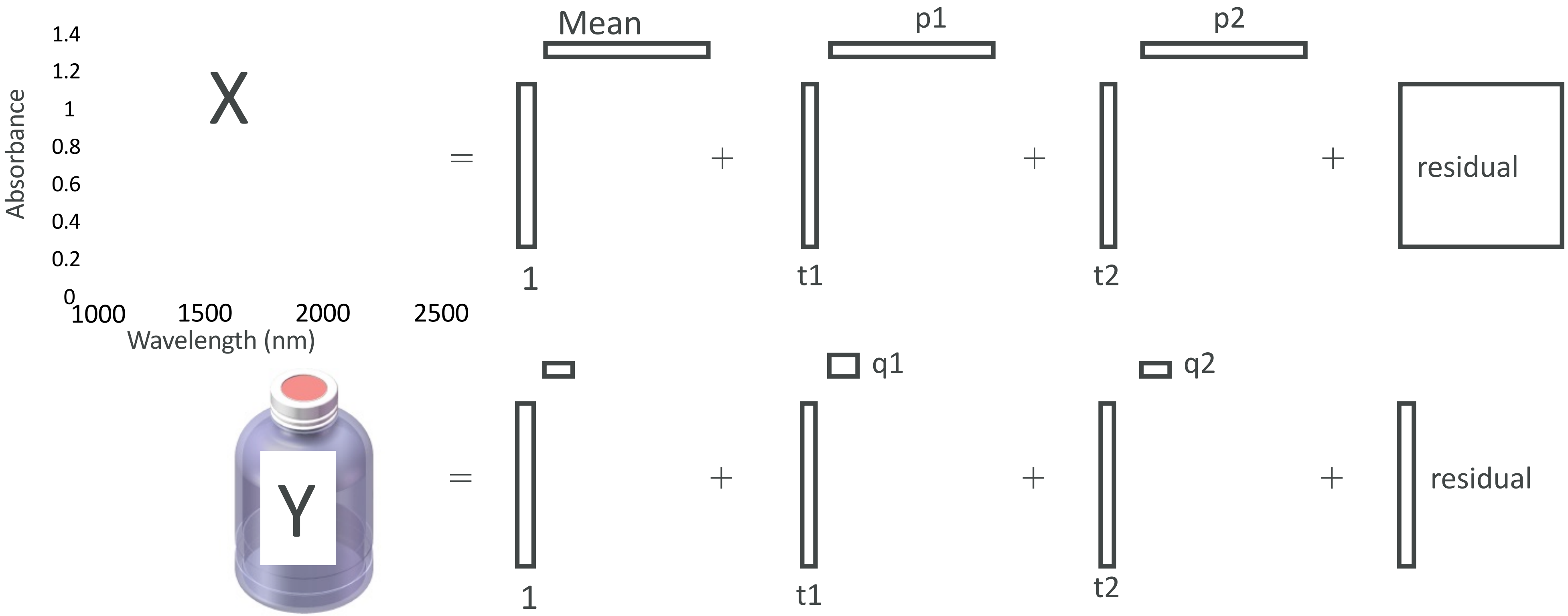


Model ?



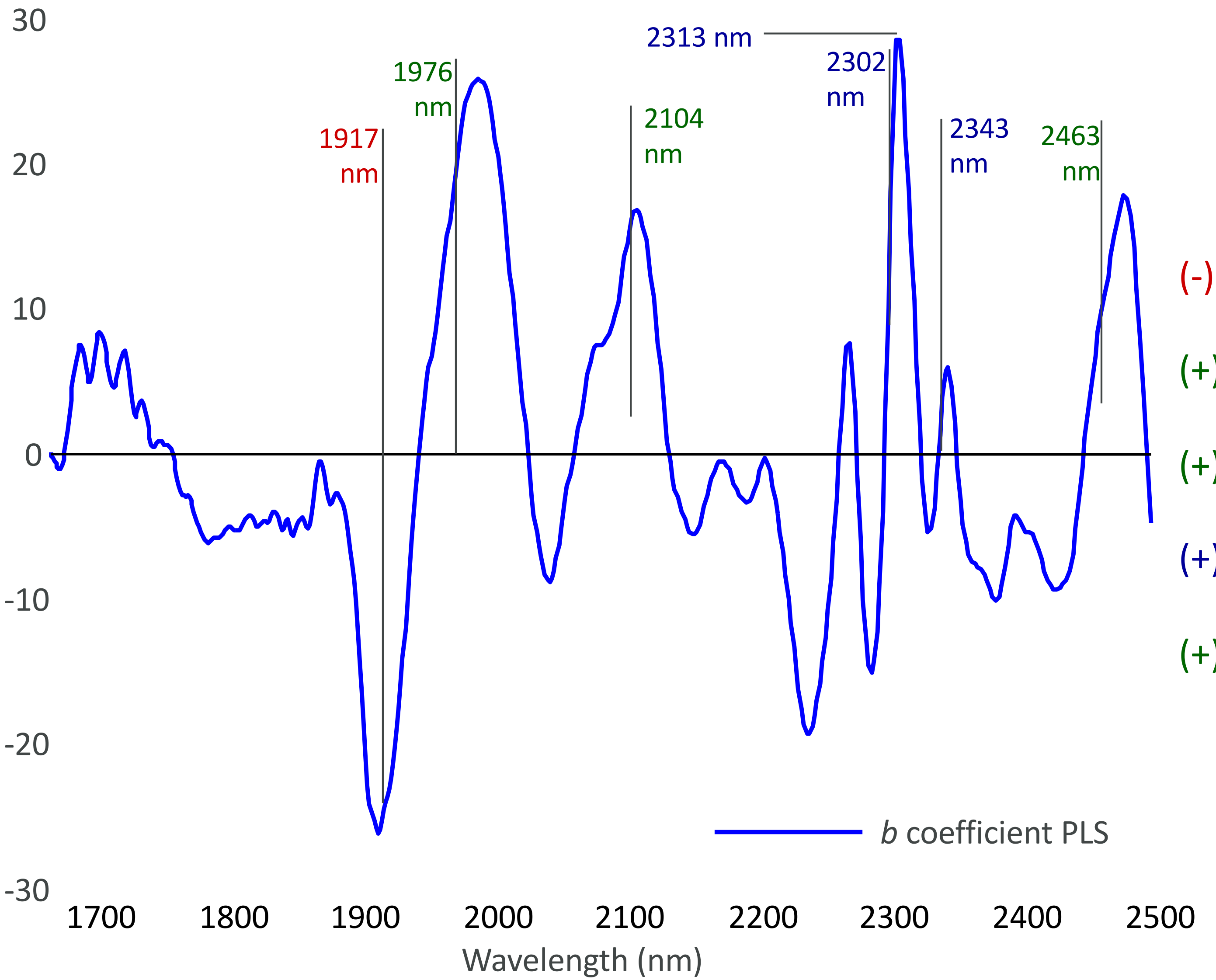
USE OF NEAR INFRARED SPECTROMETRY TO PREDICT OM BIODEGRADABILITY

PLS regression to determine the model



$$\hat{y} = b_1 A_{\lambda_1} + b_2 A_{\lambda_2} + b_3 A_{\lambda_3} + \dots + b_n A_{\lambda_n}$$

b-COEFFICIENTS OF THE MODEL



(-) 1917 nm : Lignin

(+) 1976 nm : starch-cellulose

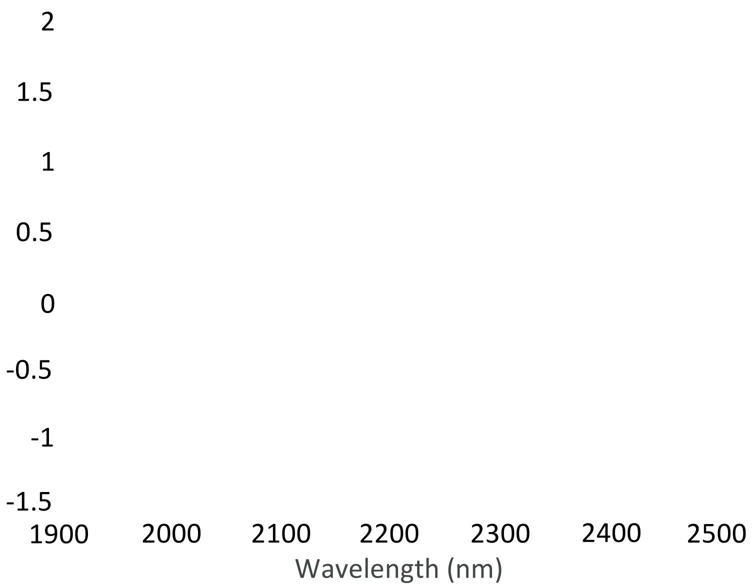
(+) 2104 nm : Starch - cellulose

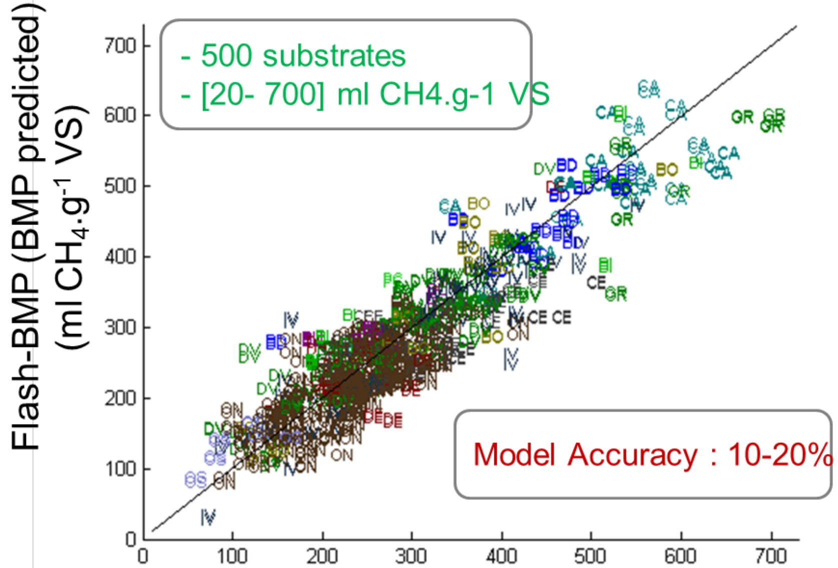
(+) 2302 - 2343 nm : Lipids

(+) 2463 nm : Starch

USE OF NEAR INFRARED SPECTROMETRY TO CHARACTERIZE BIODEGRADABILITY

Near InfraRed Spectroscopy





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Contents lists available at ScienceDirect

Bioresource Technology

journal homepage: www.elsevier.com/locate/biortech

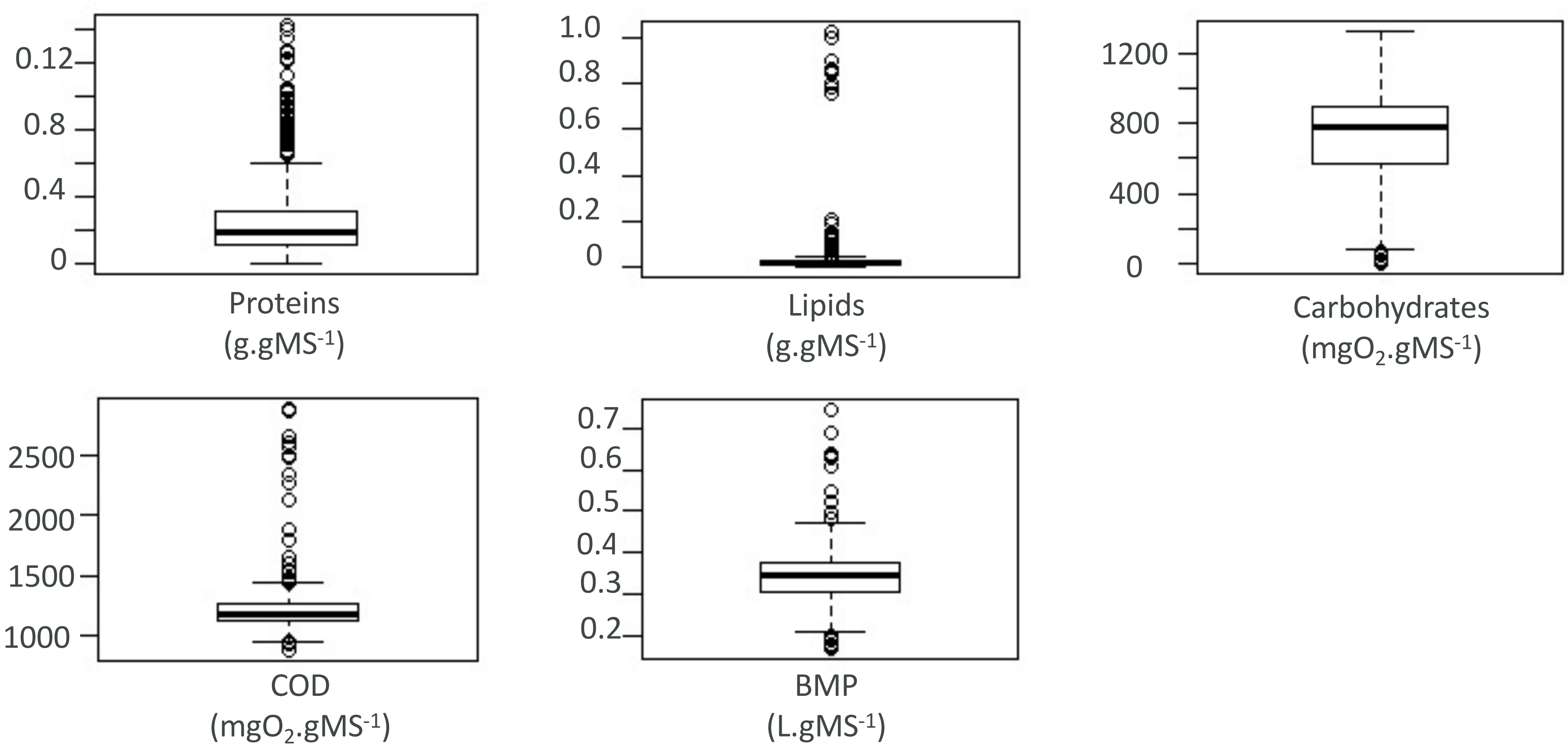
First step towards a fast analytical method for the determination of Biochemical Methane Potential of solid wastes by near infrared spectroscopy

M. Lesteur [a,b,c], E. Latrille [a], V. Bellon Maurel [b], J.M. Roger [b], C. Gonzalez [c], G. Junqua [c], J.P. Steyer [a,*]

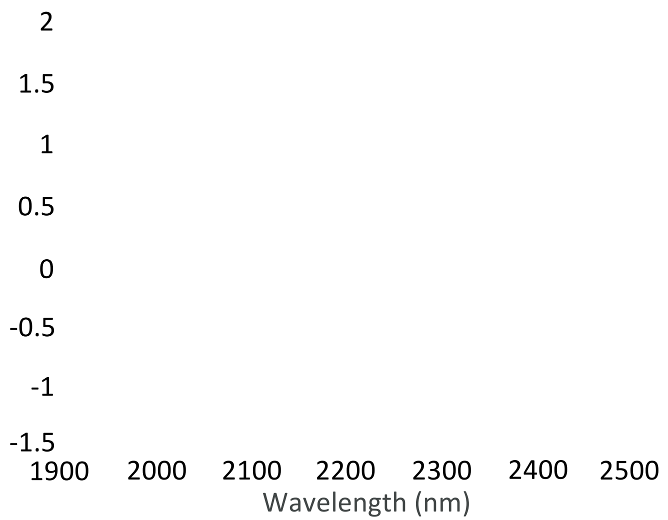
[a] INRA, UR050, Laboratoire de Biotechnologie de l'Environnement, Avenue des Etangs, Narbonne F-11100, France
[b] Cemagref-Montpellier SupAgro, UMR ITAP – Information and Technologies for AgroProcesses, BP 5095, 34033 Montpellier Cedex 1, France
[c] Laboratoire Génie de L'Environnement Industriel, Ecole des Mines d'Alès, 6 avenue de Clavières, 30319 Alès Cedex, France

TO GO FURTHER WITH NIR SPECTROSCOPY

340 samples: grease and oil, fruits, vegetables, meat, fish, microalgae, sludge and slurries…



TO GO FURTHER WITH NIR SPECTROSCOPY

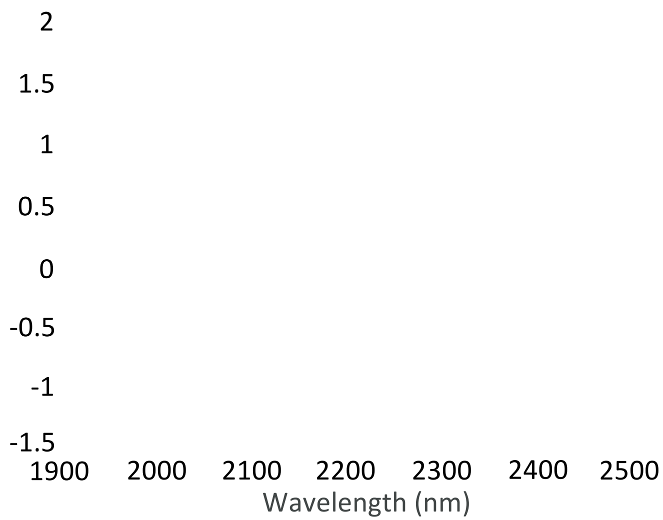


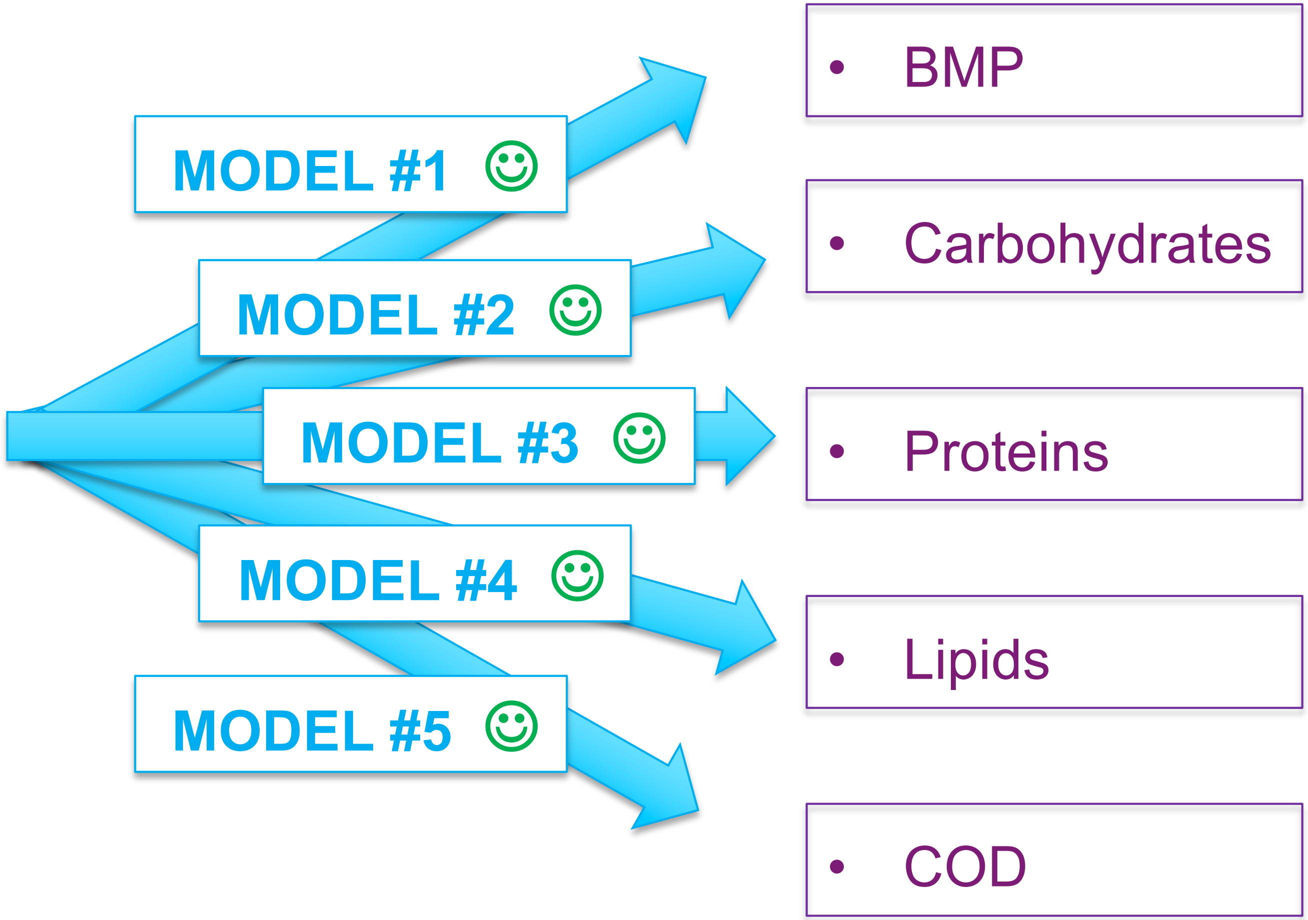
ONE MODEL ?

☹

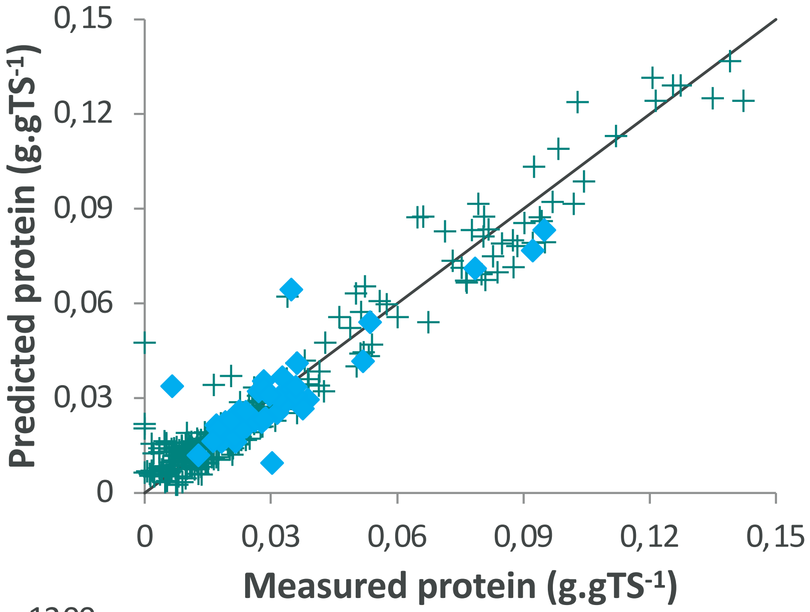
- BMP
- Carbohydrates
- Proteins
- Lipids
- COD

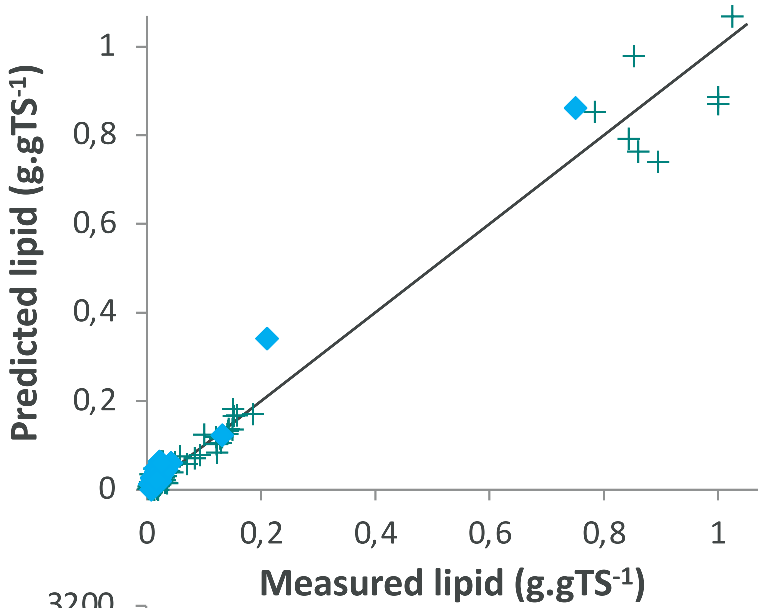
TO GO FURTHER WITH NIR SPECTROSCOPY

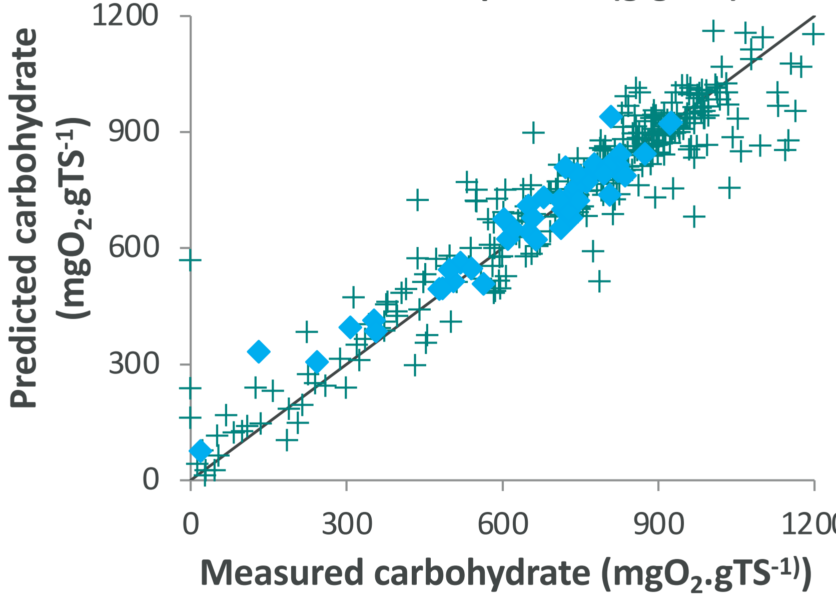


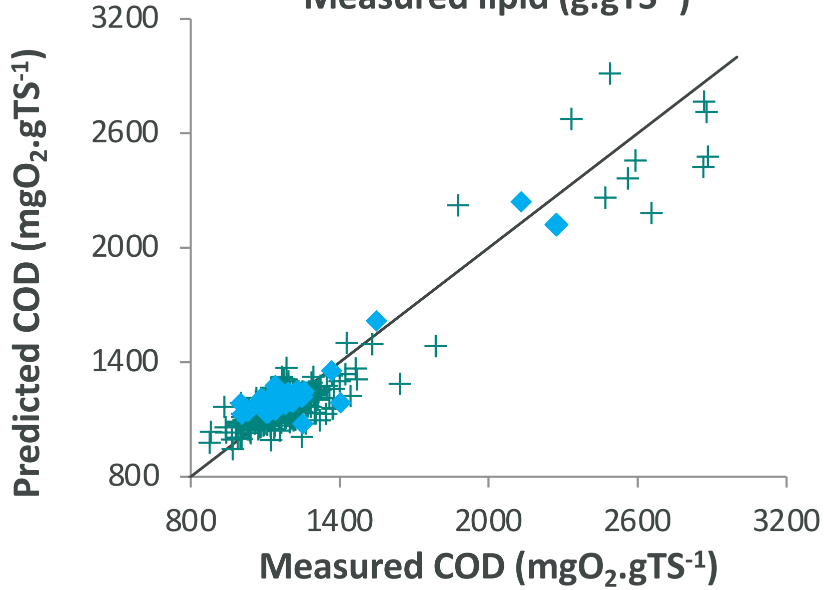


TO GO FURTHER WITH NIR SPECTROSCOPY



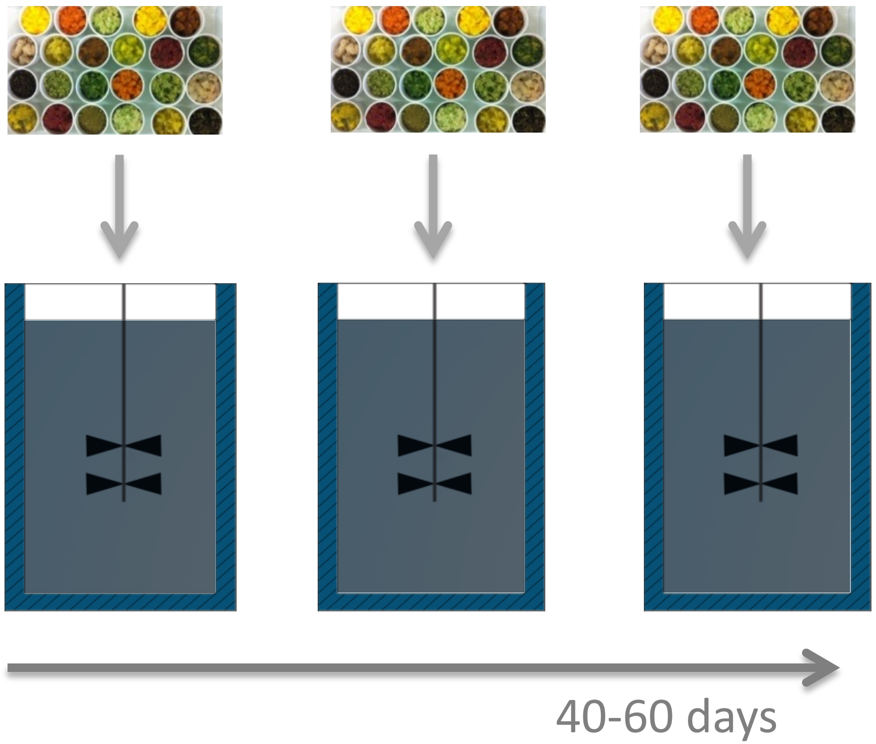




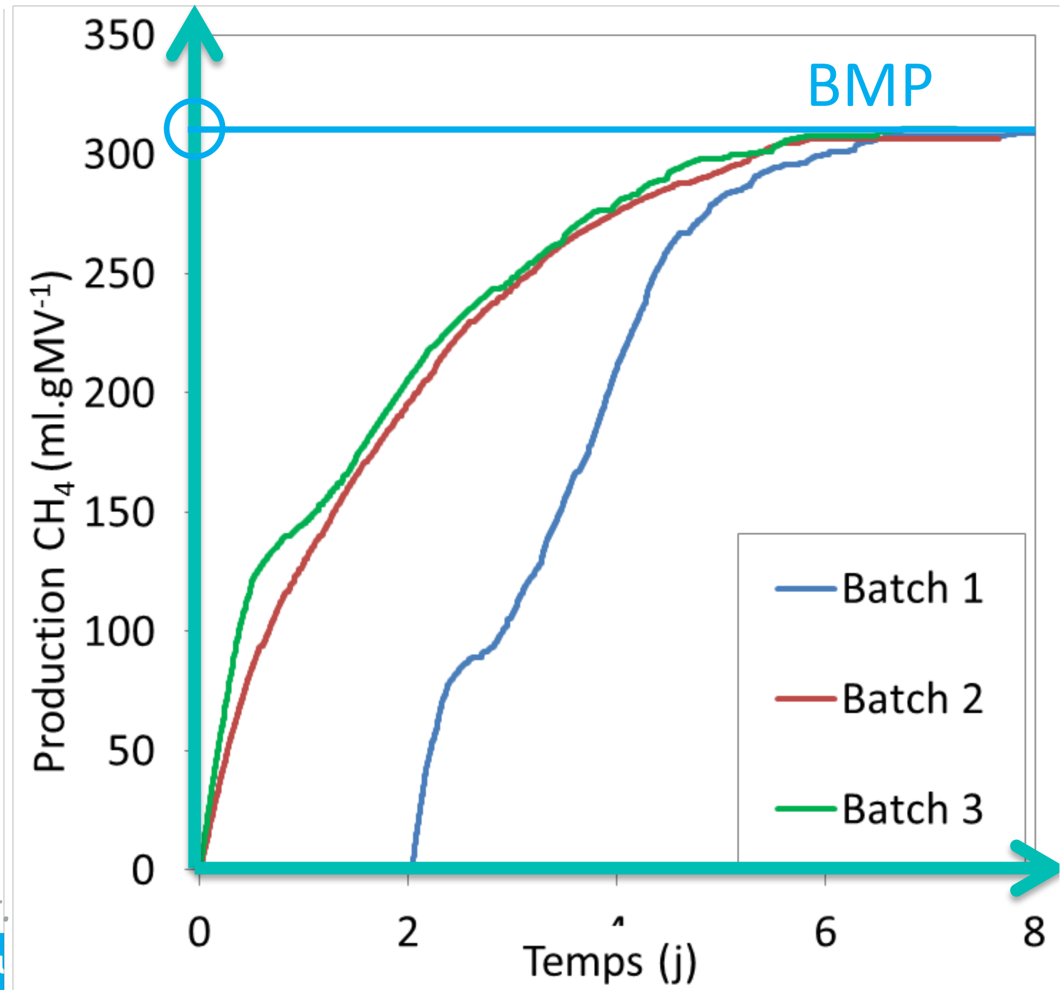


WHAT ABOUT THE KINETICS ?

1^{st} batch (one week) 2^{nd} batch… X^{th} batch



Kinetics after adaptation can be used for modeling

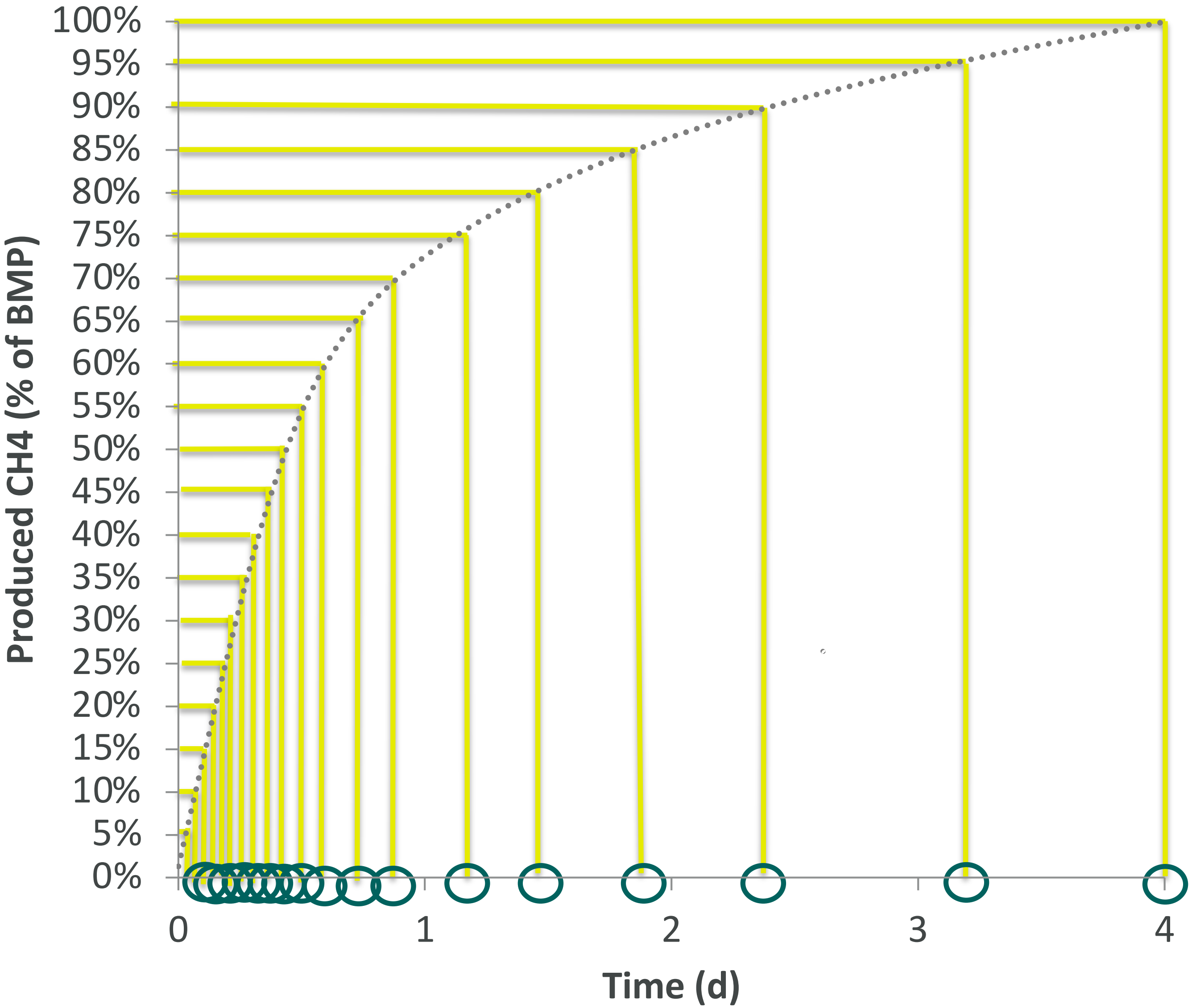


$1gVS.L^{-1}$ no inhibition

Adaptation of the inoculum

Source: Garcia-Gen et al., 2015, Waste Management.

TO GO FURTHER WITH NIR SPECTROSCOPY

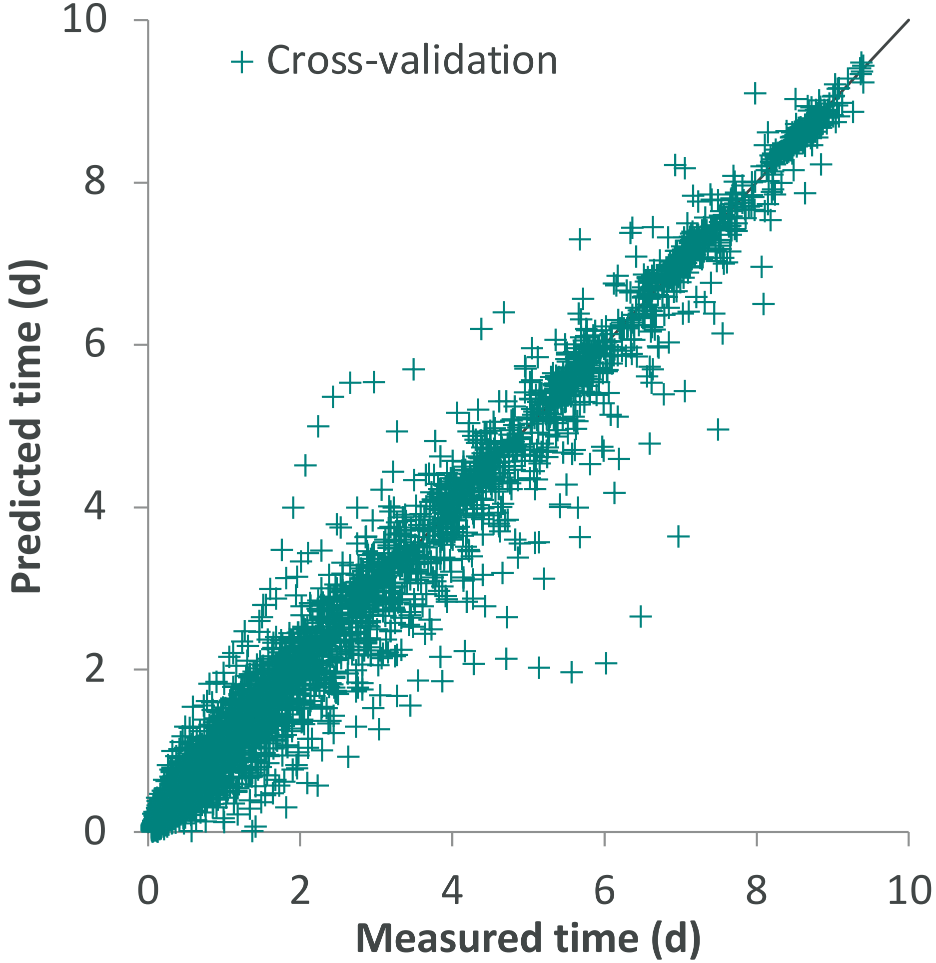


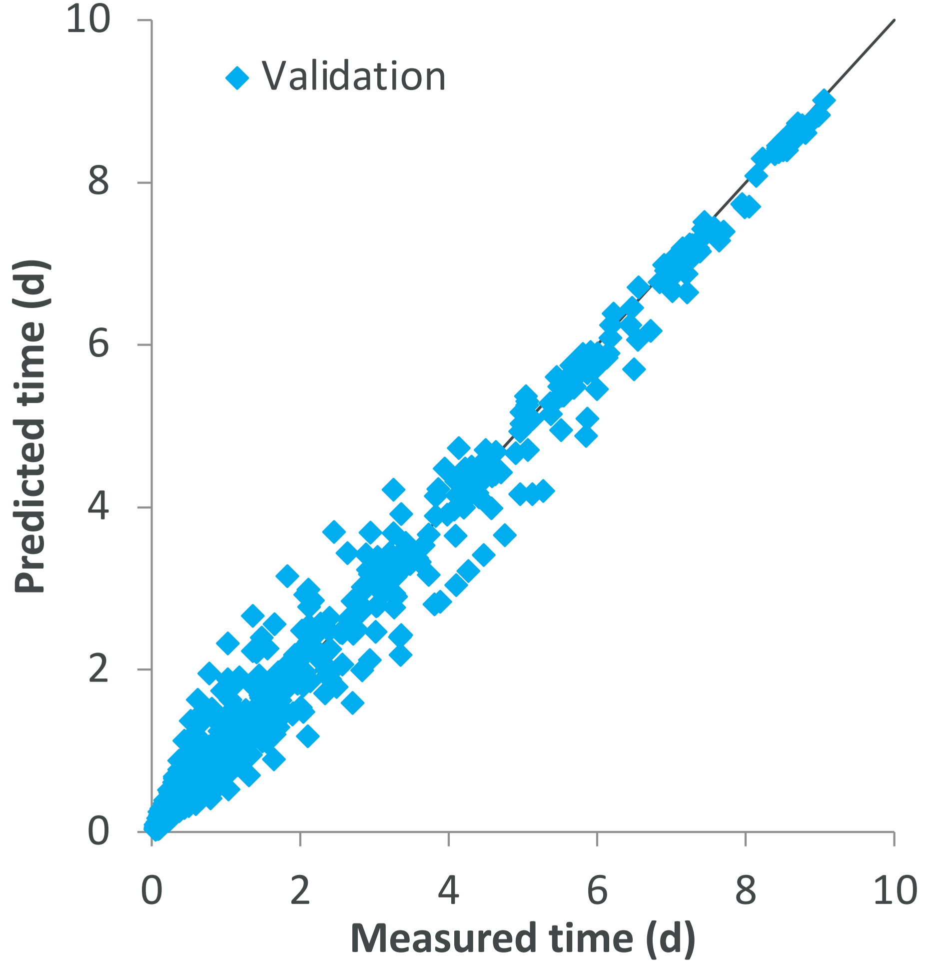
19 points:

- Time for 5%
- Time for 10%
- …
- Time for 90%
- Time for 95%

➡ **19 PLS models**

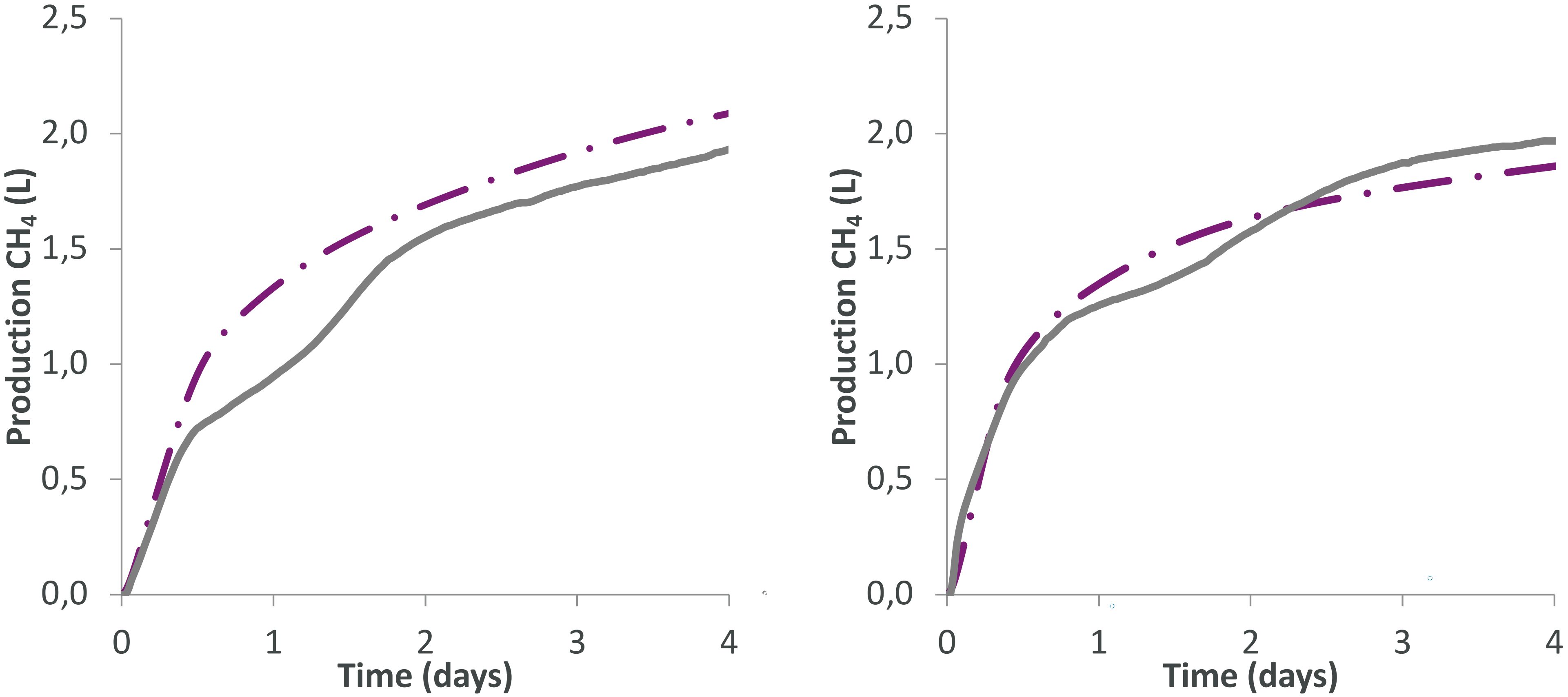
TO GO FURTHER WITH NIR SPECTROSCOPY





NIR PREDICTED CH_4 KINETICS USED TO CALIBRATE ADM1

Test on two agricultural residues

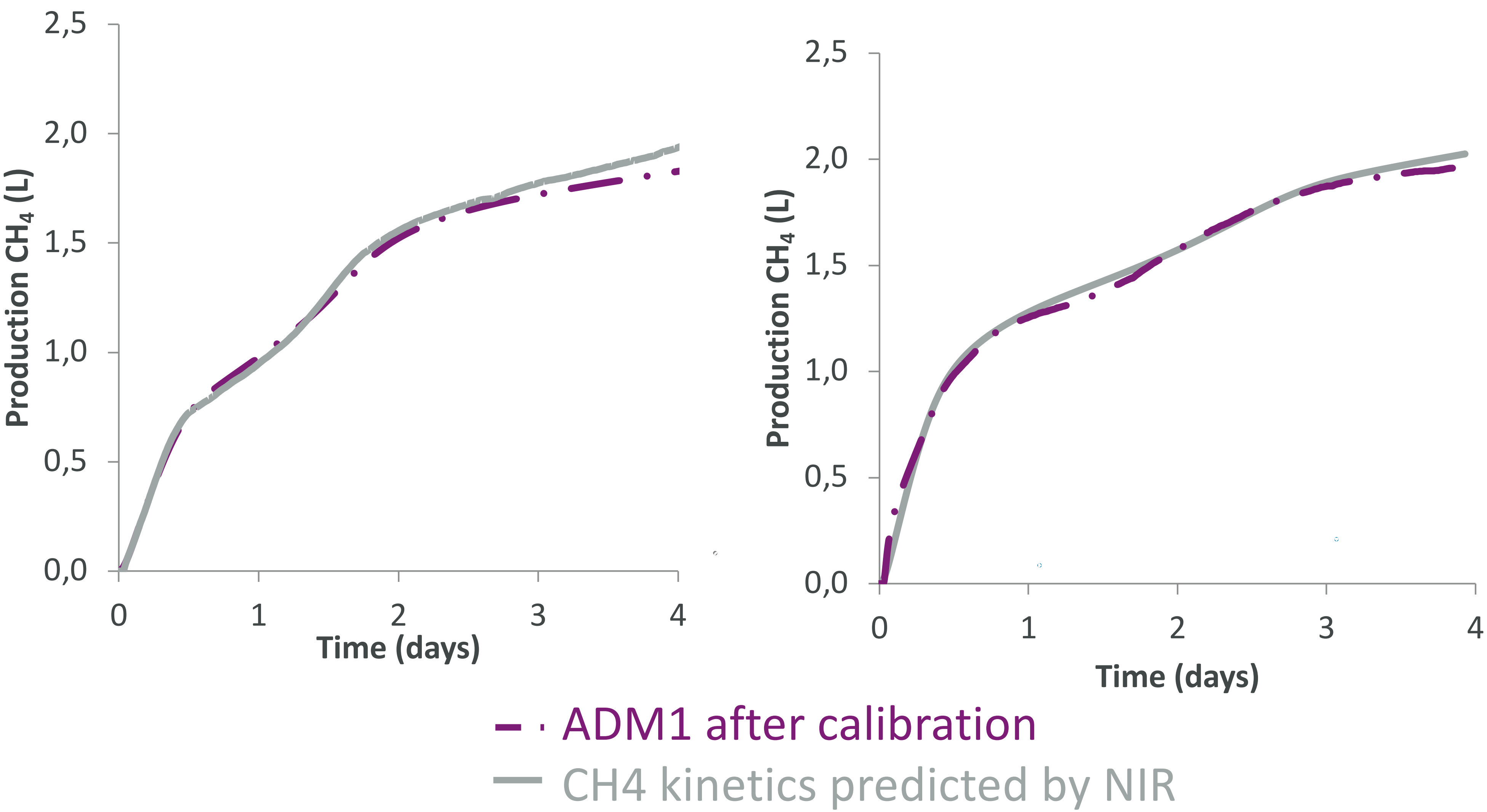


ADM1 before calibration

CH4 kinetics predicted by NIR

NIR PREDICTED CH_4 KINETICS USED TO CALIBRATE ADM1

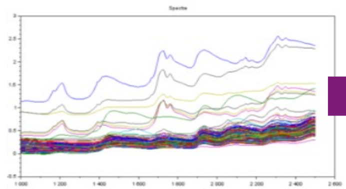
Test on two agricultural residues



TO GO FURTHER WITH NIR SPECTROSCOPY

Waste

Freeze-drying and grinding



NIR spectra

- BMP
- Carbohydrates
- Proteins
- Lipids
- COD
- CH_4 kinetics
- ADM1 parameters

0 → 4 days

Contents lists available at ScienceDirect
Waste Management
journal homepage: www.elsevier.com/locate/wasman

Fast characterization of solid organic waste content with near infrared spectroscopy in anaerobic digestion

Cyrille Charnier [a,b,*], Eric Latrille [a], Julie Jimenez [a], Margaux Lemoine [a], Jean-Claude Boulet [c], Jérémie Miroux [b], Jean-Philippe Steyer [a]

[a] INRA, UR0050, Laboratoire de Biotechnologie de l'Environnement, 102 Av. des Etangs, Narbonne F-11100, France
[b] BioEnTech, 74 Av. Paul Sabatier, 11100 Narbonne, France
[c] INRA, UMR1083 Sciences pour l'œnologie, 2 Place Viala, F-34060 Montpellier, France

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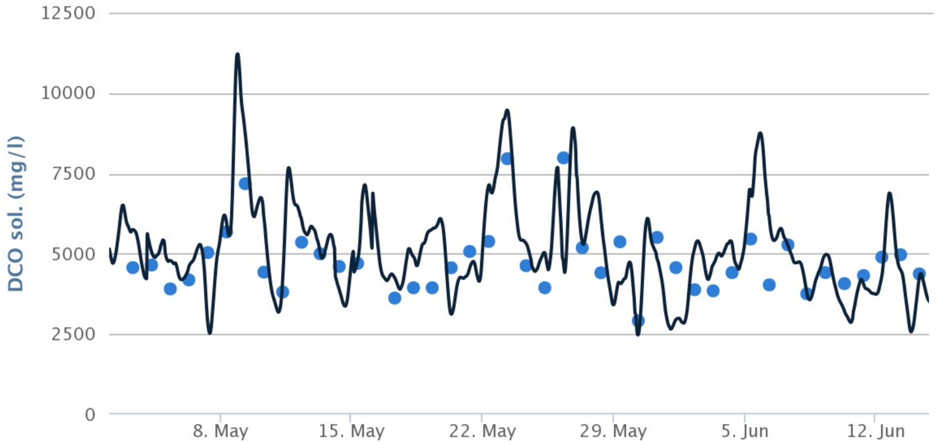
journal homepage: www.elsevier.com/locate/watres

Fast ADM1 implementation for the optimization of feeding strategy using near infrared spectroscopy

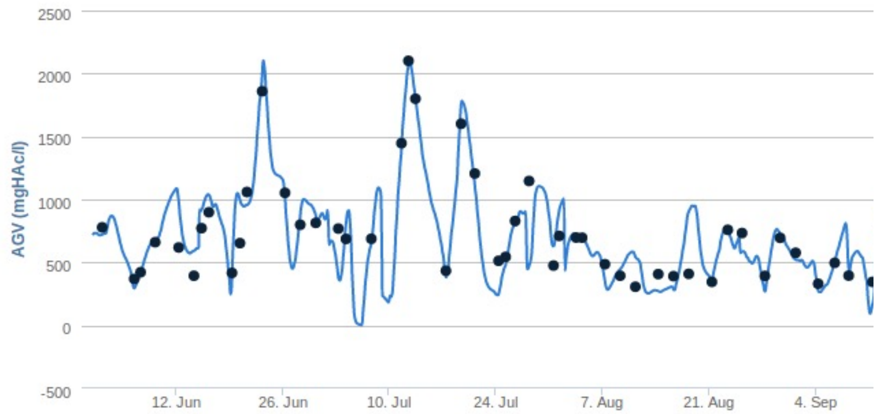
Cyrille Charnier [a, b, *], Eric Latrille [a], Julie Jimenez [a], Michel Torrijos [a], Philippe Sousbie [a], Jérémie Miroux [b], Jean-Philippe Steyer [a]

[a] LBE, INRA, 102 Av. des Etangs, F-11100 Narbonne, France
[b] BioEnTech, 74 Av. Paul Sabatier, F-11100 Narbonne, France

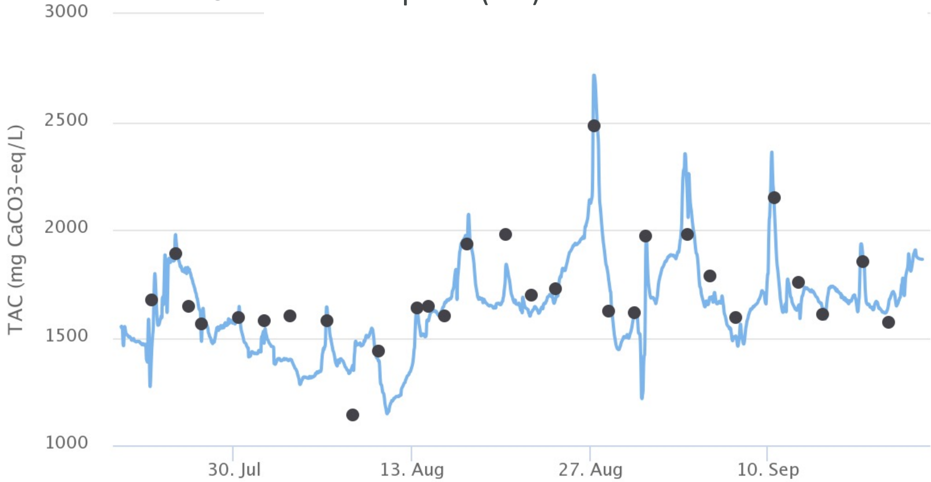
GOOD SUBSTRATE CHARACTERIZATION LEADS TO GOOD PROCESS UNDERSTANDING



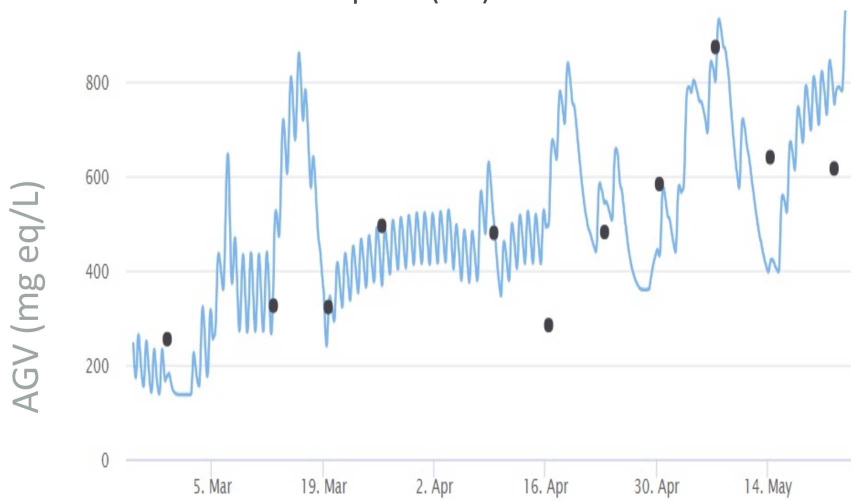
COD AD plant (model)
COD AD plant (lab)



VFA AD plant (model)
VFA AD plant (lab)



Alkalinity AD plant (model)
Alkalinity AD plant (lab)



VFA digester (model)
VFA digester (lab)

THANK YOU VERY MUCH FOR YOUR ATTENTION

http://www.montpellier.inra.fr/narbonne

jean-philippe.steyer@inrae.fr

AGENDA AND HOUSEKEEPING

Speaker 1
Raul Muñoz (University of Valladolid, Spain)

Speaker 2
Damien Batstone (The University of Queensland, Australia)

Speaker 3
Xavier Flores-Alsina (Technical University of Denmark)

Speaker 4
Jean-Philippe Steyer (INRAE-LBE, France)

Q&A Session Moderator: *Ángel Robles (Universitat de València, Spain)*

- This session is being recorded;
- Microphones and cameras have been disabled due to the large number of attendees;
- The normal chat function is disabled;
- Please put any questions and comments you may have in the Q&A and we will do our best to answer them during the session (in writing or orally).

ACKNOWLEDGEMENTS TO:

Gabriel Capson-Tojo

Universidade de Santiago de Compostela

Spain

for arranging large parts of this webinar

CLOSING REMARKS

Great thanks to all presenters for a wonderful show!

Look out for MIA's NEXT webinar in February 2022:

"Topic to be decided"

If you have ideas for your own future webinar then contact MIA MC and we will help you make it happen!

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