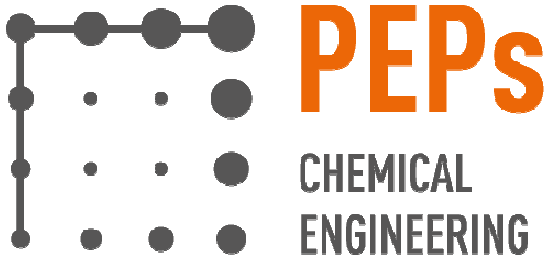
From sludge drying to LCA

Angélique Léonard
a.leonard@uliege.be
Products, Environment, and Processes (PEPs)
Chemical Engineering
Université de Liège
www.chemeng.uliege.be



LIÈGE université

Career …

1998 Chemical Engineer - University of Liège

FRS-FNRS Research Fellow: convective drying – sludge – X-ray µCT

2003 PhD Thesis: Study of wastewater sludge convective drying: texture follow-up using X-ray µCT

2004 FRS-FNRS Postdoctoral Researcher: convective drying – carbon xerogels - modeling

Extension of X-ray µCT applications

Postdoc research stay in Bordeaux (Laboratoire 'TREFLE')

2008 FRS-FNRS Research Associate: Drying – relations between process/product

2009 Associate professor at ULg: Processes and Sustainable development

Development of existing LCA activities

2011 Head of the Dpt (until end 2015)

2013 Professor

2016 Director of the Research Unit
Chair Woman of Drying Working Party of the European Federation of Chemical Engineering
Member of the 'Femmes et Sciences' committee

2017 Full Professor

…

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Drying/Sludge

Drying/sludge

Development of existing LCA activities

LCA

Drying/sludge **&** **LCA**

3 main research topics

- Drying of deformable materials
  - Both experimental and modeling approaches
  - Long expertise in **sludge** drying
    - **Sludge management → whole treatment chain**
  - Relation between drying process and product quality
- Characterization of porous materials by **X-ray microtomography**
  - Initially developed to follow sludge texture during drying
    - Cracks, shrinkage, moisture profiles
  - Extension to different types of cellular materials
  - Used for product-oriented-engineering approach
- Environmental management: **Life Cycle Assessment studies**, eco-design, environmental reporting

Publications:
https://orbi.ulg.ac.be/browse?type=authorulg&rpp=20&value=L%C3%A9onard%2C+Ang%C3%A9lique+p003296

About drying …

Convective drying of deformable materials

- Thermal drying = widely used separation process
  - High energy consumption : 10 to 15% of Europe industrial energy use
  - Need for process optimisation
    - Material behaviour
    - Relevant drying models
- Impact of drying on quality of dried product
  - Shrinkage, cracks, moisture profiles, …
  - Need of characterization tools

    → (micro)-tomography + image analysis

Convective drying of deformable materials

- Which materials ?
  - **Initial focus on wastewater sludges**
  - Extension to resorcinol-formaldehyde xerogels as model material
  - Recent collaborations
    - Geotechnical materials: limestone, clay, cement and concrete (Coll. Geo³ - R. Charlier/F. Collin)
    - Soils (Coll. A. Degré – Mini-ARC) + PhD thesis Sarah Smets (August 2018)
  - + food products
    - Through visiting researchers
- Both experimental data and modeling approach

About sludge management …

Sludge ?

- Origin of urban residual sludges
  - Activated sludge wastewater treatment plant (WWTP)
  - Production of excess sludge during biological process

Oupeye - 446 500 PE

www.aide.be

About sludge drying

- Sludge processing within a WWTP
  - Applied to excess biomass produced by the biological treatment
    - Thickening
    - Stabilisation
      - Liming
      - Digestion (biomethanation)
      - Mechanical dewatering
        - Centrifugation
        - Belt filter
        - Press filter
    - Valorisation: in agriculture or for energy recovery + **P recovery**

Europe :
About 50 to 60 million tons wet sludge/year

Drying

About sludge drying

- Sludge drying → several advantages
  - Mass and volume reduction
  - Stabilisation – Hygienisation
  - Texture improvement
  - Increase of calorific value
- Sludge drying = complex unit operation
  - Depends on **sludge properties and history**
    - Composition, rheology, **treatment**, storage conditions, …
  - Depends on operating conditions
  - Produces gaseous emissions (pollutants, odors, …)
  - Highly energy consuming
    - Needs global energy optimization on the process site

Sludge = nutrient source

Relevant bio-based waste streams - in Europe

[kton P/year]	Total	Recycled	Potential
Sewage sludge	**297**	115	182
Biodegradable solid waste	130	38	92
Meat & bone meal	128	6	122
Total	**427-555**	**153-160**	**274-396**
Manure recycling =	**1 736**		
Mineral fertiliser use =	***1 448***		

Van Dijk & Oenema: Overview of phosphorus flows in wastes in Europe", 2013, Fertilisers Europe seminar, 6 Feb. 2013.
Updated Van Dijk et al. 2015 "

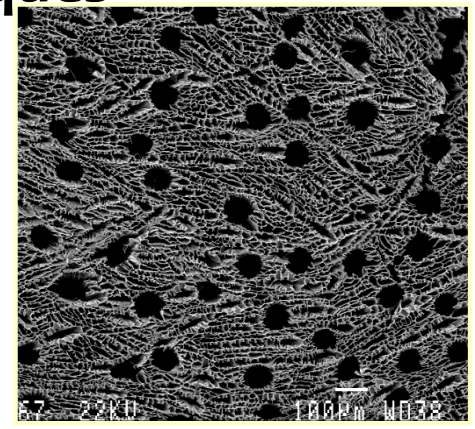
Sewage (sludge) is the second most **relevant** renewable waste stream for P recovery & recycling in Europe!

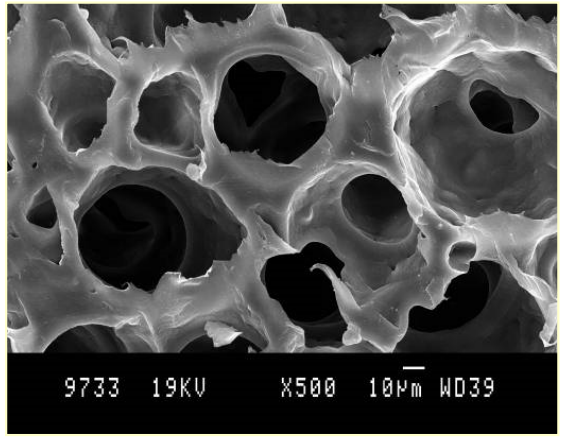
The Netherlands in September 2018

About tomography …

Why tomography ?

- Extension of existing know how (coll. D. Toye)
  - **Limitations of classical characterisation techniques**
    - Mercury porosimetry: 3.5 nm< d_p<150 µm
    - N_2 adsorption-desorption: 2 nm< d_p<50 nm
    - Pycnometry
    - SEM, TEM: destructive, mostly 2D
  - **Non destructive 3D imaging technique**
  - **Follow-up of sample texture during drying**
    - External exchange area → **d**rying kinetics
    - Cracks → drying quality
    - Internal moisture profiles → model validation
    - Sludge bed permeability → sludge rheology

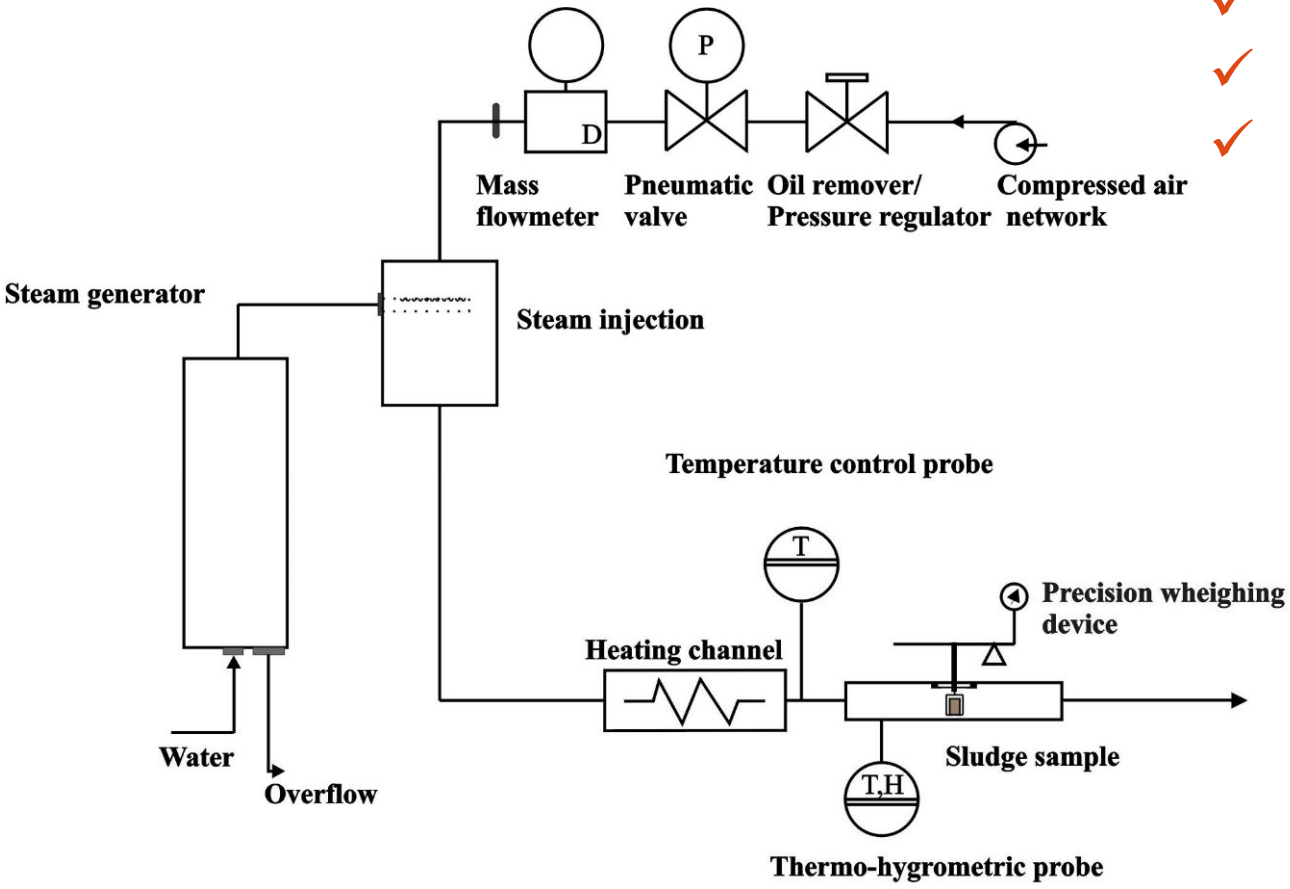




Equipments …

Equipment available

- Micro-dryer

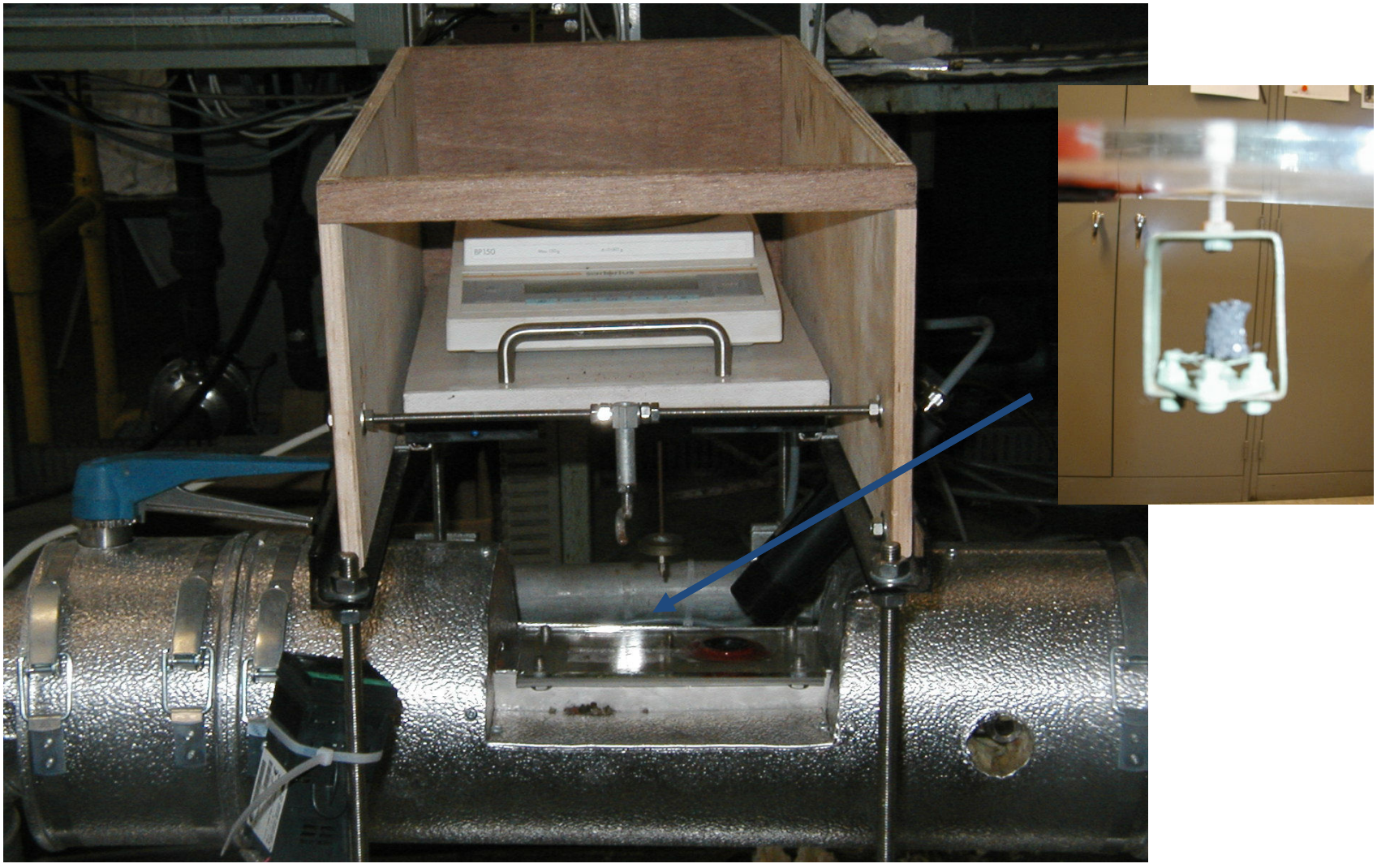


- ✓ Convective drying
- ✓ Individual sample: 1 – 5 g
- ✓ Control of 3 operating conditions
  - ✓ Temperature
  - ✓ Velocity
  - ✓ Humidity

Equipment available

- Micro-dryer

✓ Continuous follow-up of sample mass



Equipment available

- Pilot-scale dryer

- Extrusion

Sevar pilot scale dryer

- Fixed bed (cross flow)

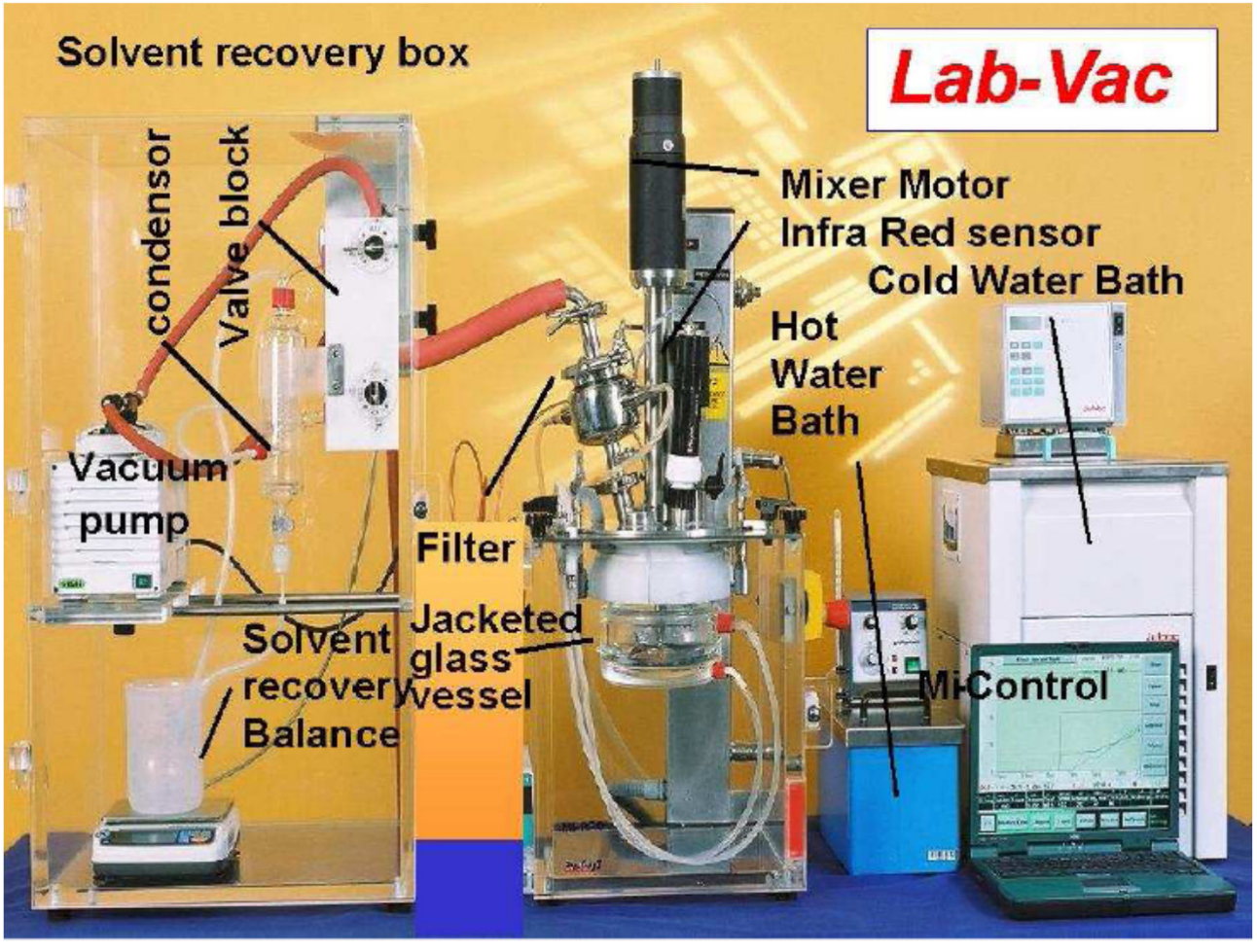
- Capacity
  - 1 to 3 kg
  - Up to 200 kg water/m²h

Equipment available

- Superheated steam dryer

Equipment available

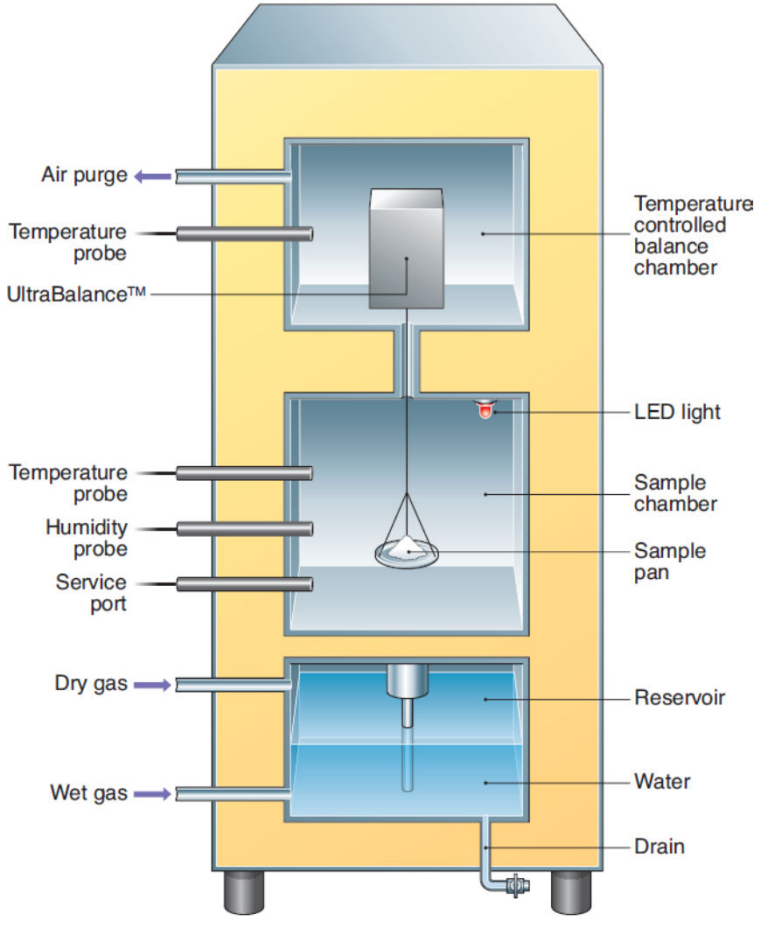
- Vacuum agitated contact dryer

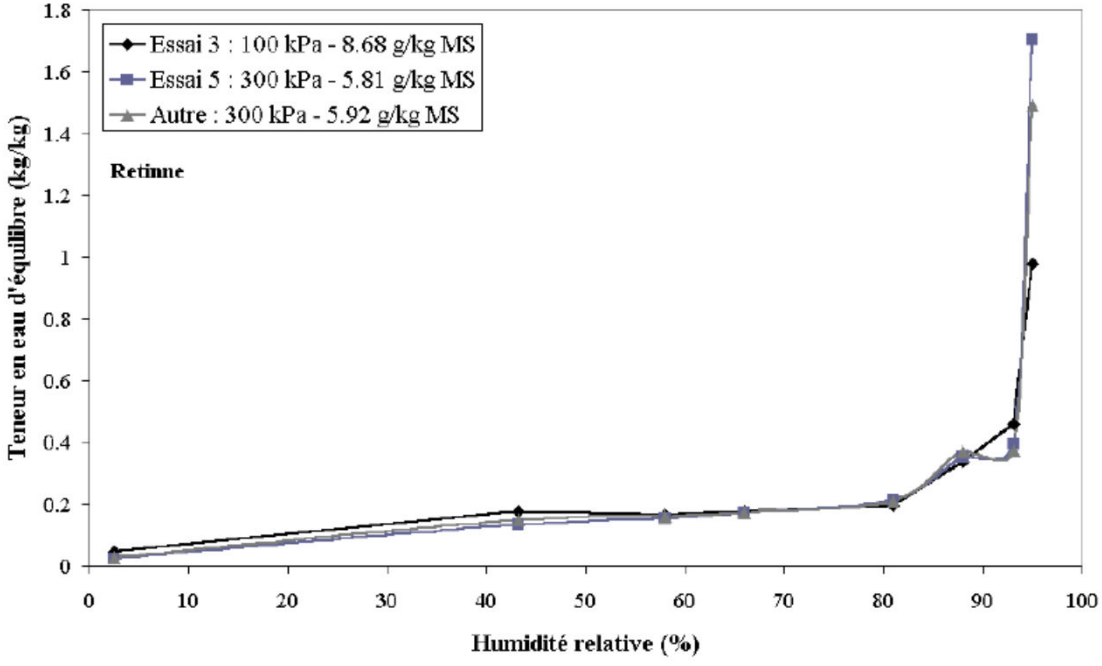


- Thermosensitive products

Equipment available

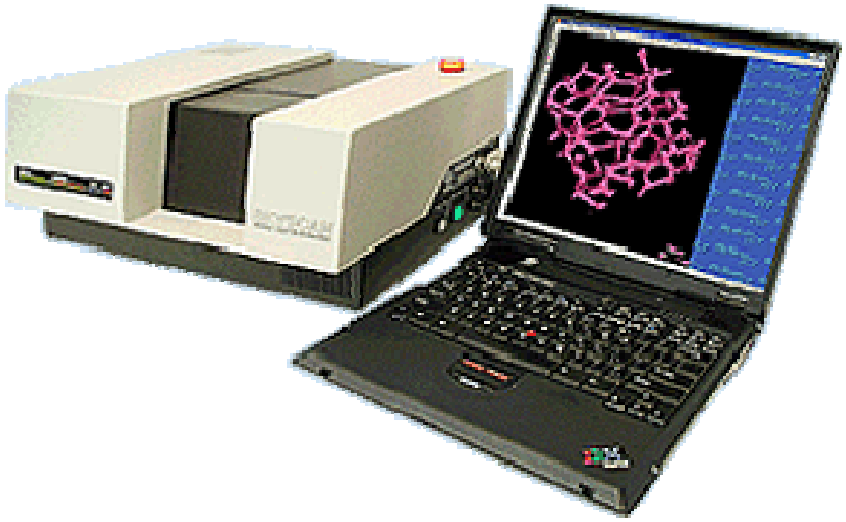
- Dynamic vapour sorption





Equipment available

- Microtomograph



Purchase year: 2000

- **Source: 40 kV - 1 mA - Cone beam**
- **Detector: 768 x 576 pixels**

  8-bit CCD Camera
- **Pixel size: 41 µm**
- **Max sample size: ∅: 30 mm – h: 25 mm**

[1]

Equipment available

- Microtomograph

Purchase year: 2006

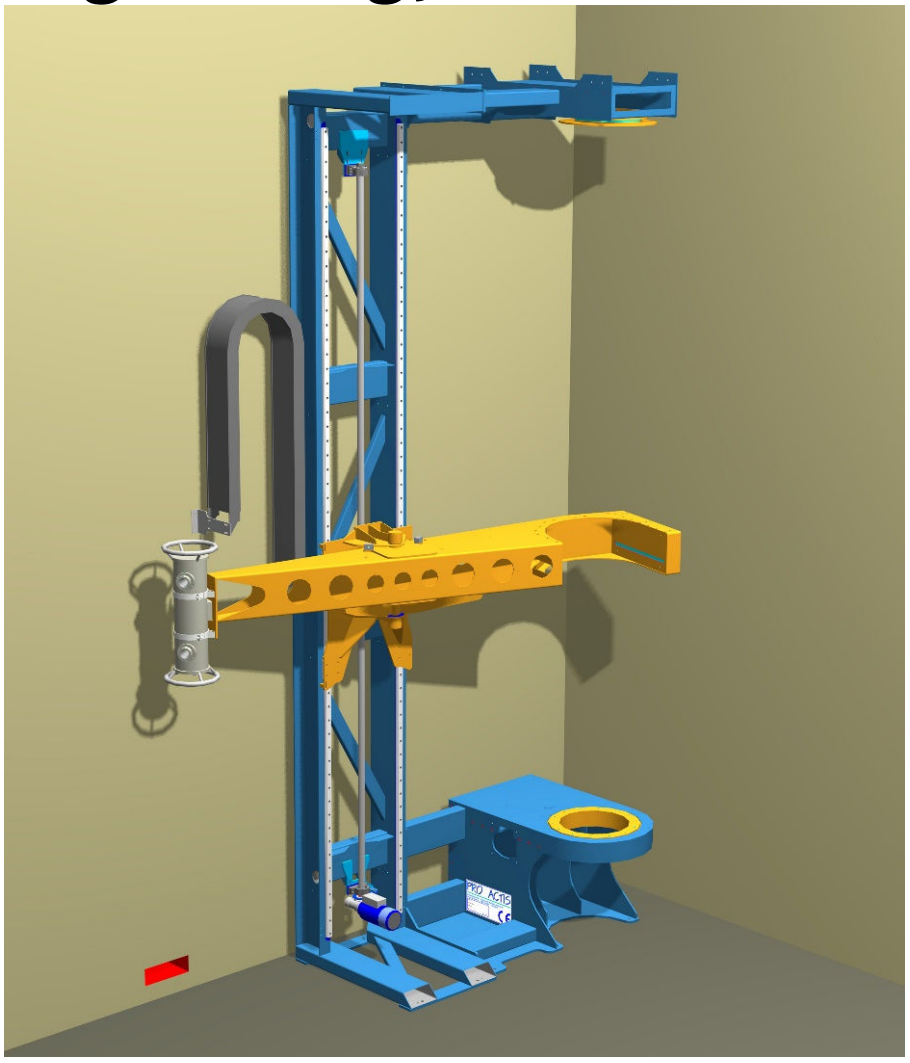
- **Source: 100 kV - 250 mA - Cone beam**
- **Detector: 4000 x 2300 pixels**

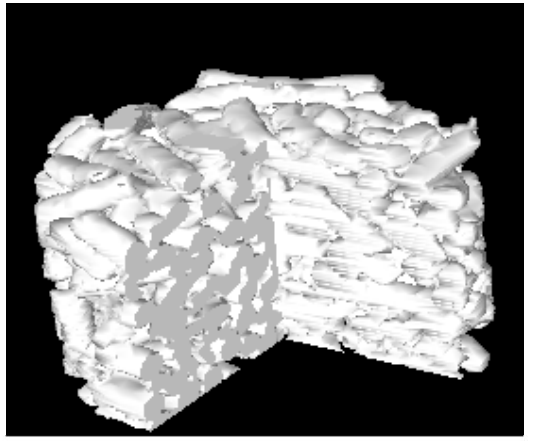
  12-bit CCD Camera
- **Pixel size: from 34 to ≈ 2-3 µm**
- **Max sample size: ∅: 35 mm (68 mm with camera offset)**

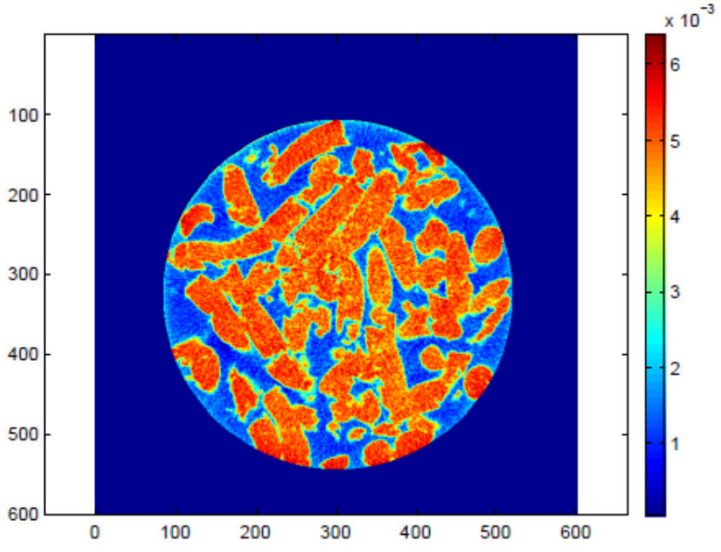
  h: 35 mm (70 mm with camera offset)

Equipment available

- High energy ‘macro’ tomograph (D. Toye)

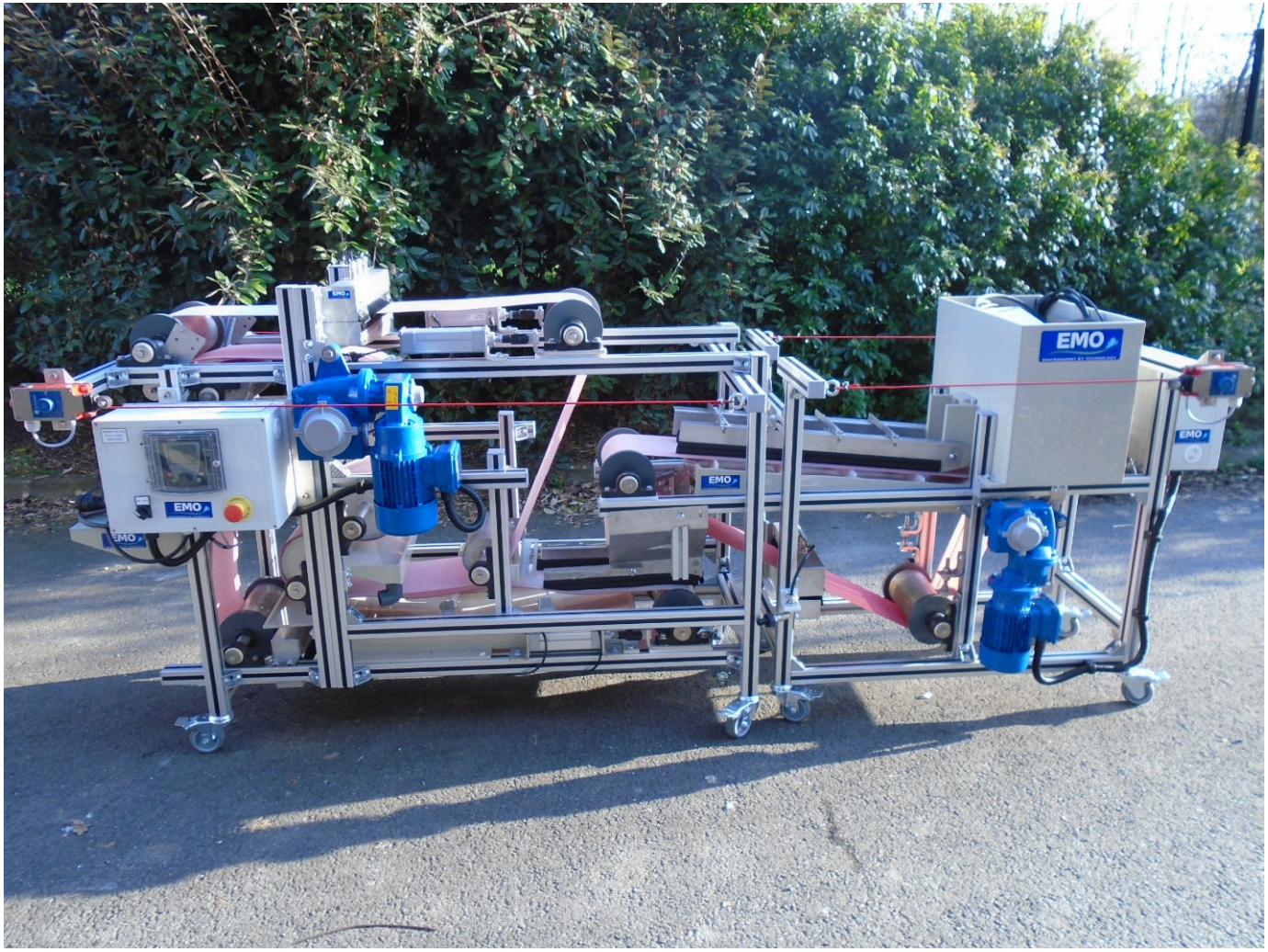






Equipment available

- Belt filter



Purchase year: 2018
EQUIP FRS-FNRS

Equipment available

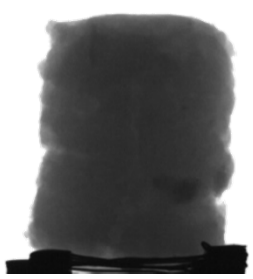
- Decanter-centrifuge (soon)

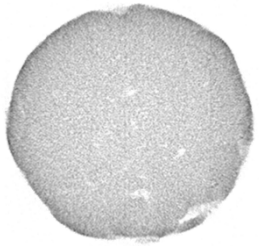
Purchase year: 2018
EQUIP FRS-FNRS +
faculty project

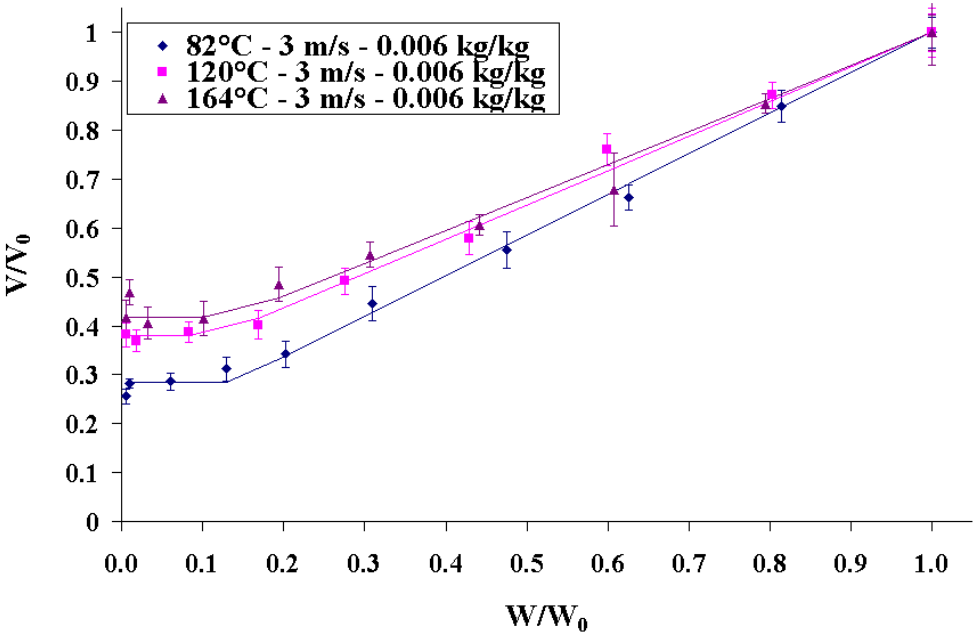
Some results …

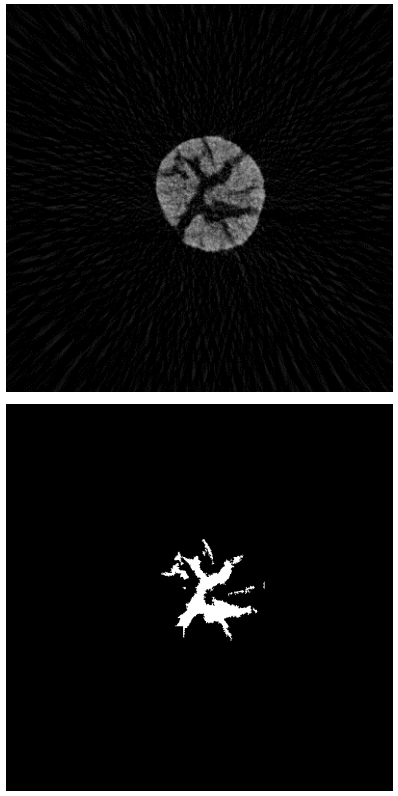
Follow-up of structural changes

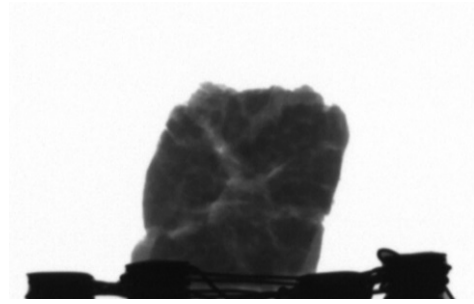
- Shrinkage = necessary to study drying mass flux
- Cracks in relation with quality











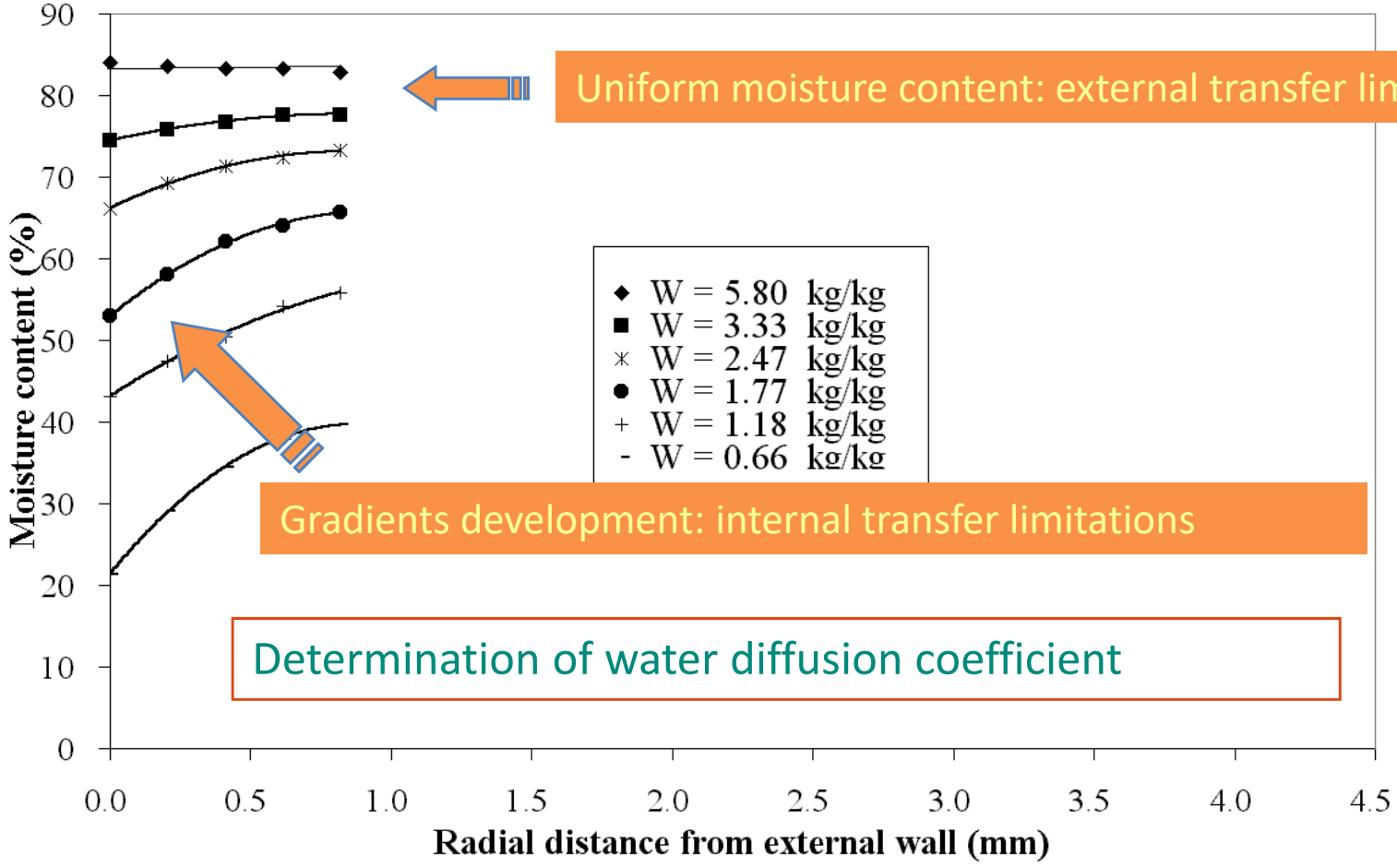
Cracks

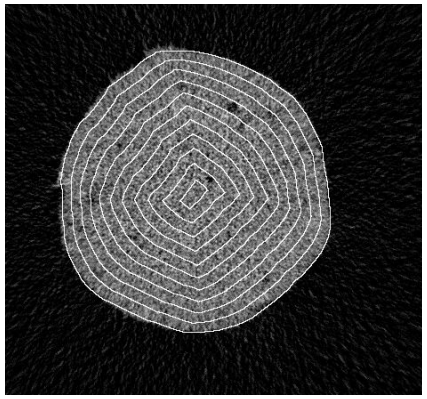
Height

X-ray microtomograph
Micro dryer scale

Follow-up of internal moisture profiles

- Understanding of mass transfer + model validation



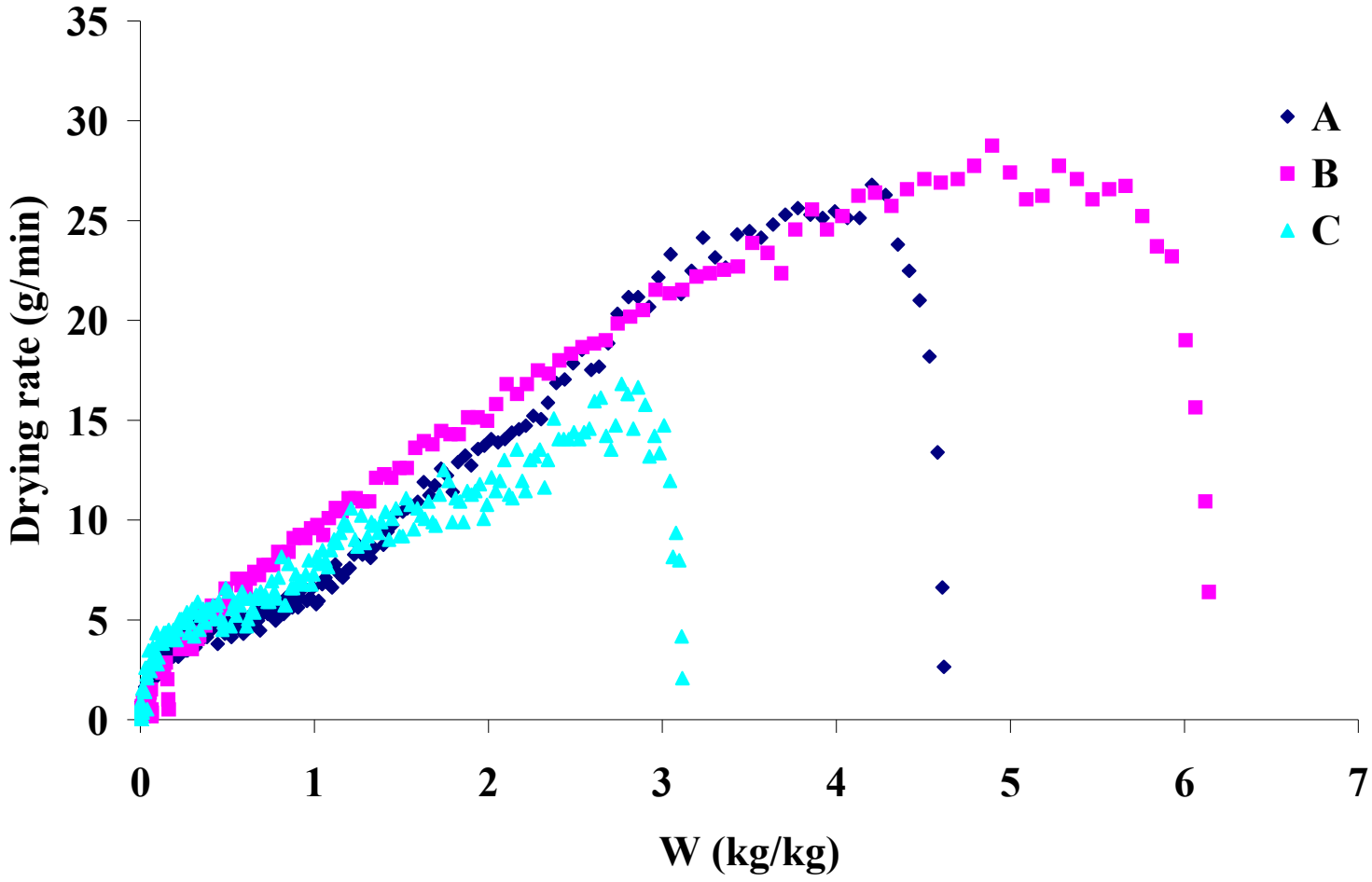


X-ray microtomograph
Micro dryer scale

Use of a calibration curve : moisture content = f(grey level)

Impact of sludge origin

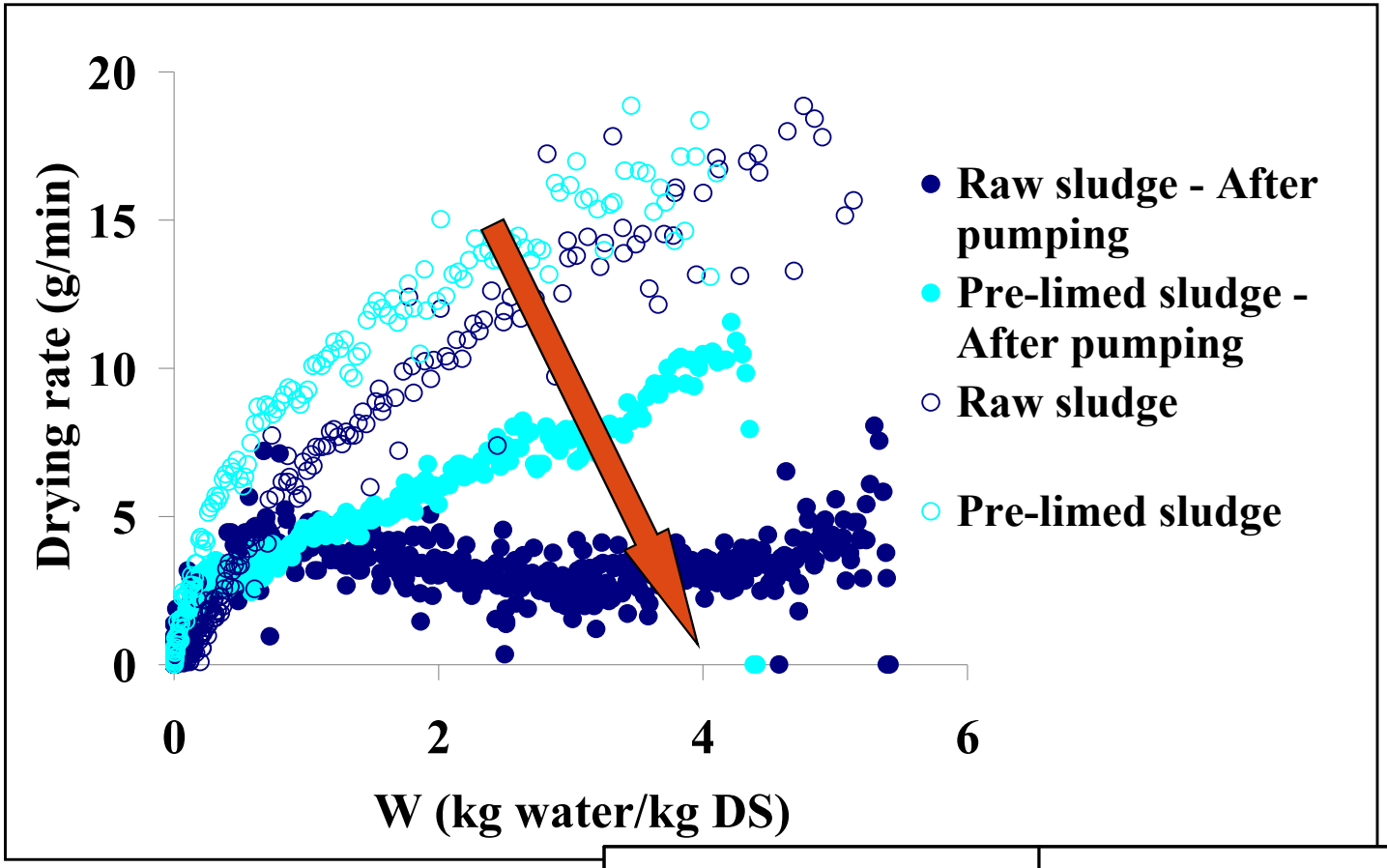
- Max drying rate: ratio up to 3:1



Pilot scale dryer

Impact of sludge pumping

- Influence of pumping on drying kinetics



Pilot scale dryer

	Specific evaporation capacity (kg/m²h)
Raw sludge	21.4
Pumped sludge	9.9

Impact of sludge pumping

- Importance of textural properties

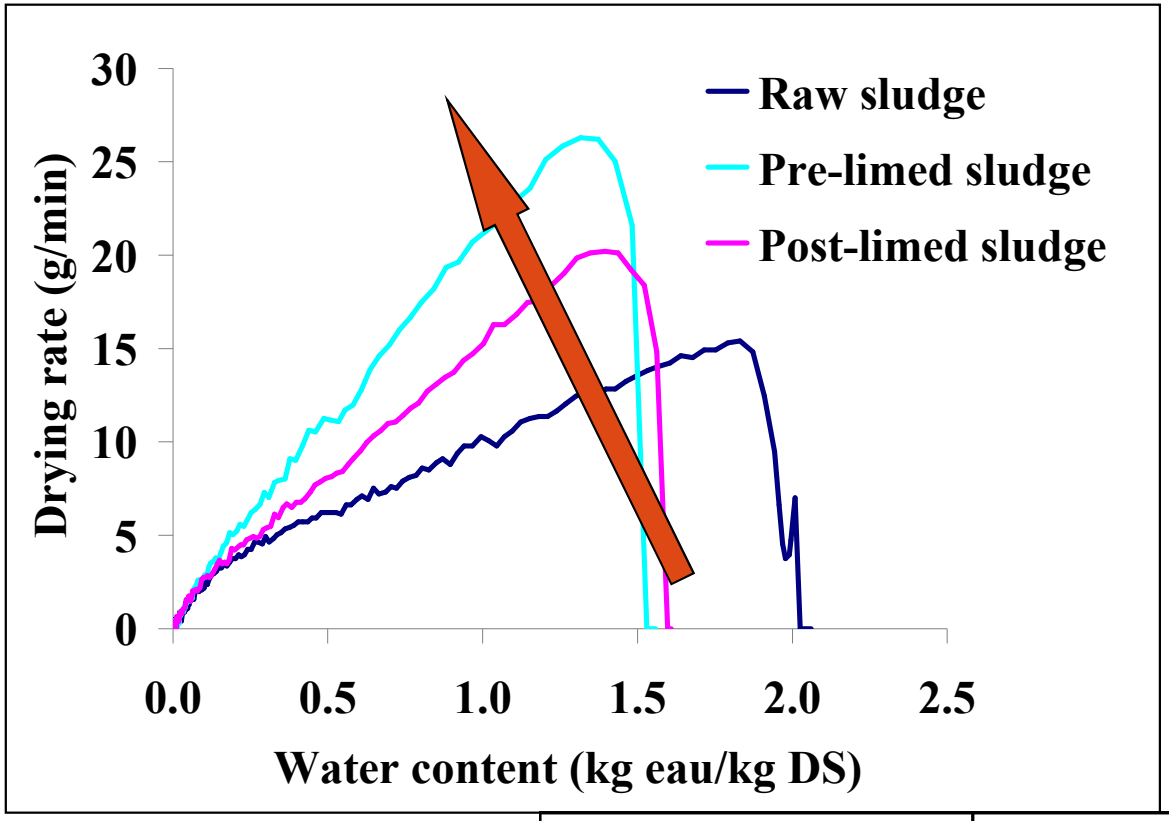
Pumping

Pre liming

Pumping

Impact of sludge liming

- Influence of liming on drying kinetics

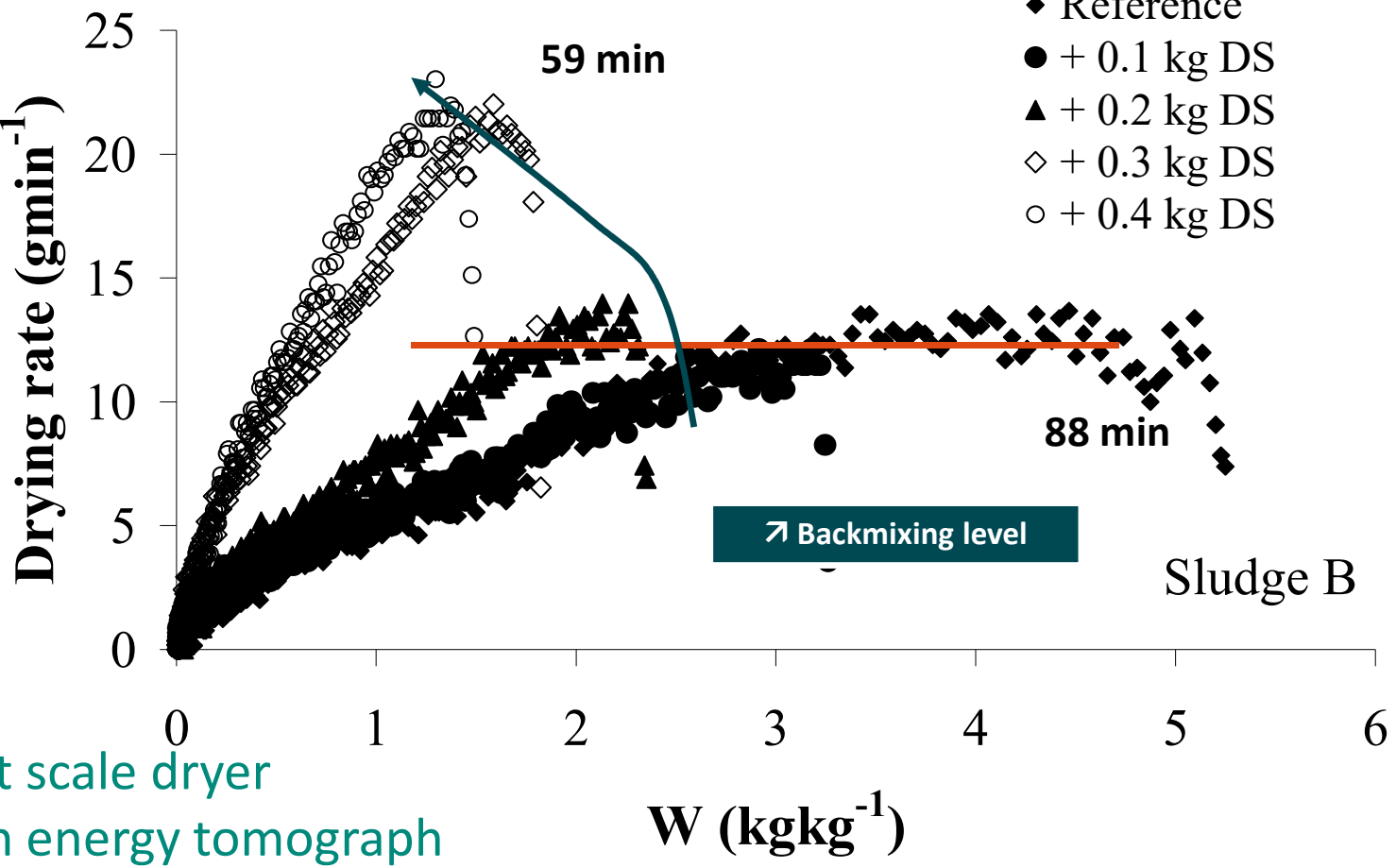


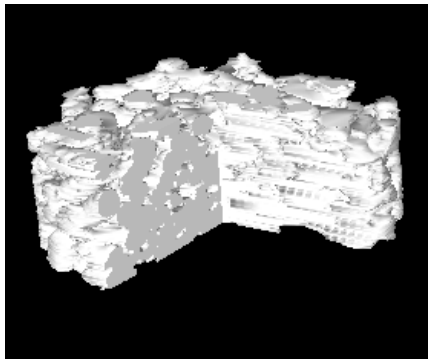
Pilot scale dryer

	Specific evaporation capacity (kg/m²h)
Raw sludge	24.3
Post-liming	28.9
Pre-liming	37.0

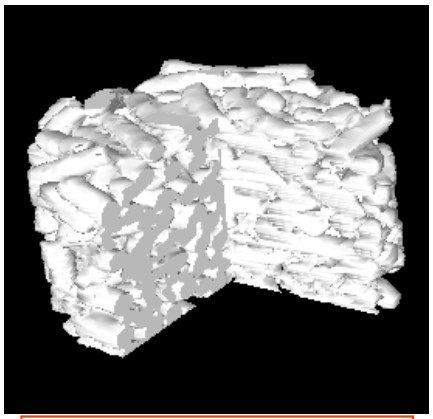
Impact of back-mixing

- Recirculation of dried product → way to correct 'bad texture'





1000 g – 16% DS
Raw sludge

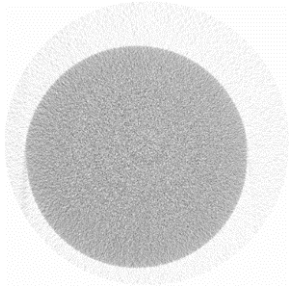


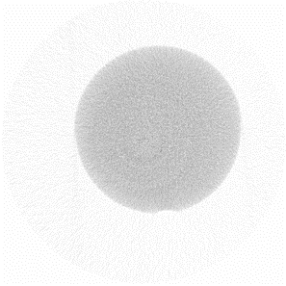
1400 g – 40% DS
+ 400 g DS

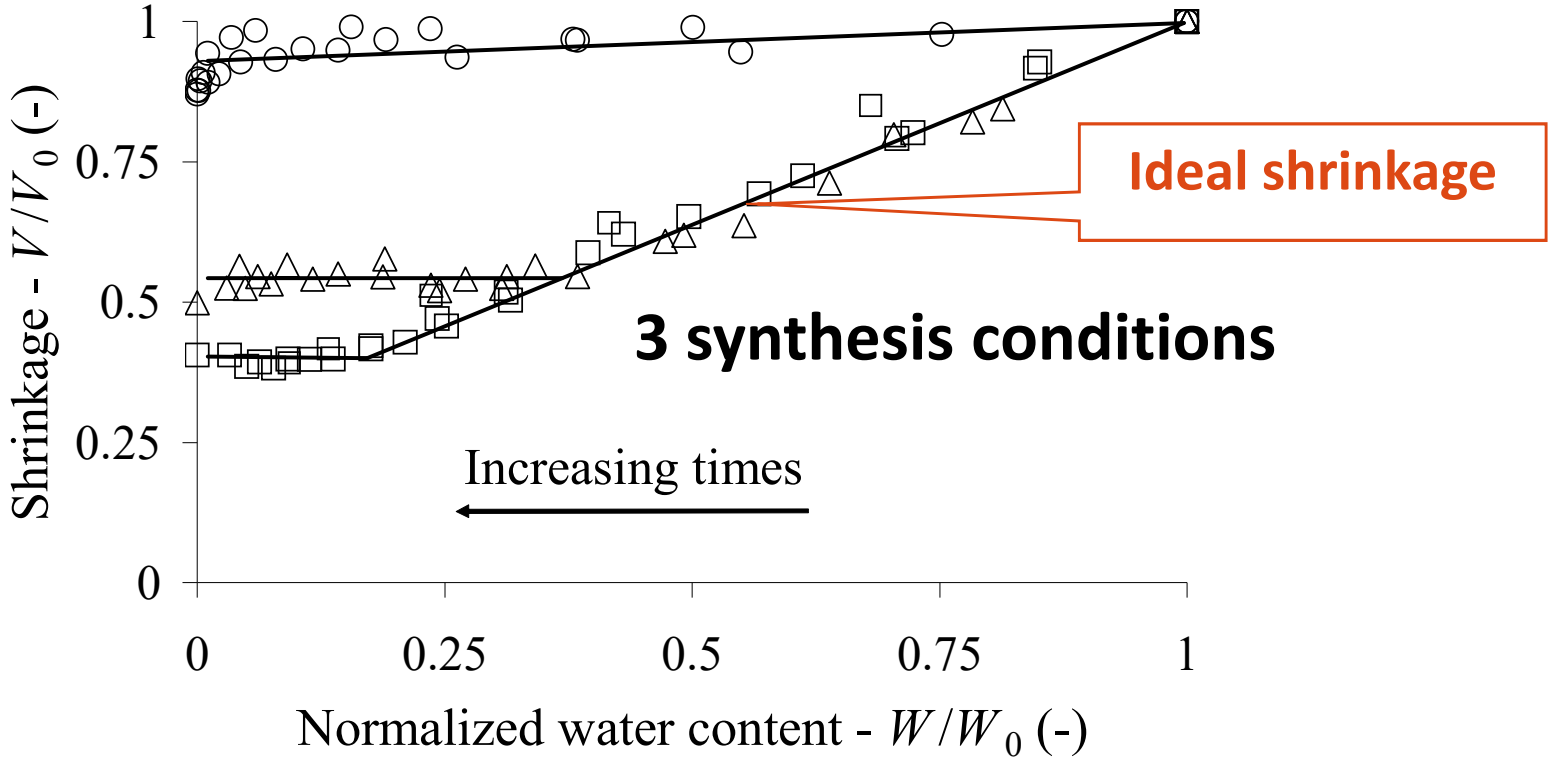
Pilot scale dryer
High energy tomograph

About RF xerogels drying

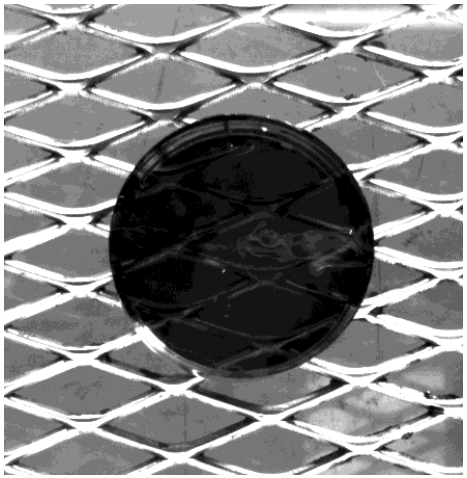
- RF resins = model material -> use in Erwan's project
  - degree of shrinkage can be easily controlled
  - tunable pore texture

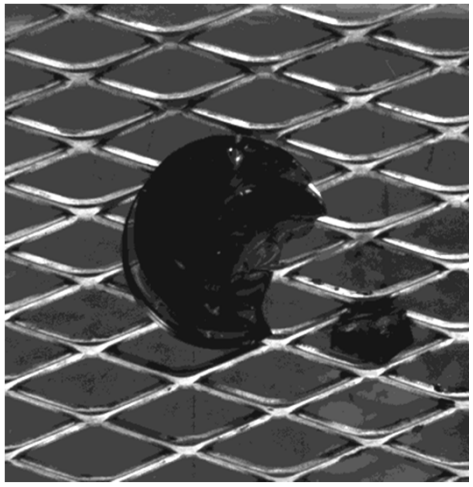




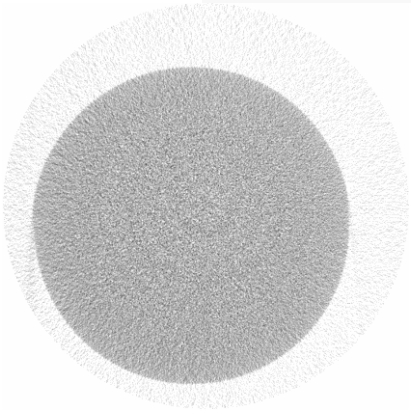


About RF xerogels drying





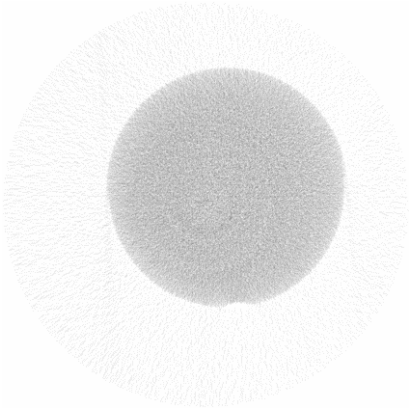
N. Job et al., Carbon, 2006, 44, 2534-42

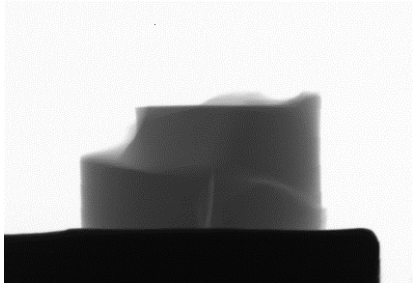


T = 30 °C

T = 70 °C

R/C = 300
pH = 6.6

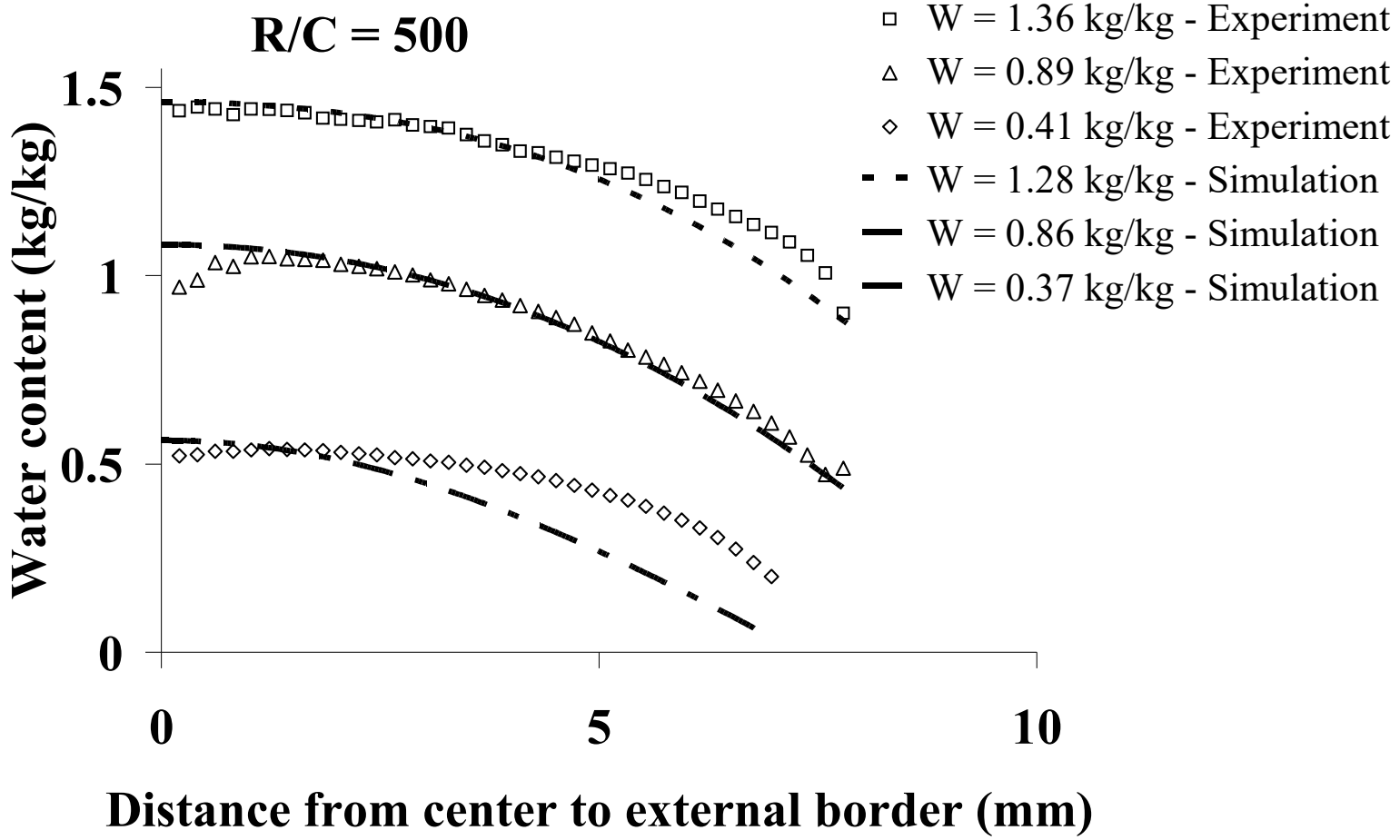




Monolith needs drying control
Thermo-hygro-mechanical coupling

Thermo-hygro-mechanical simulation

- Experimental vs simulated moisture profiles



- New = use of Lagamine FE code (F. Collin)

About LCA

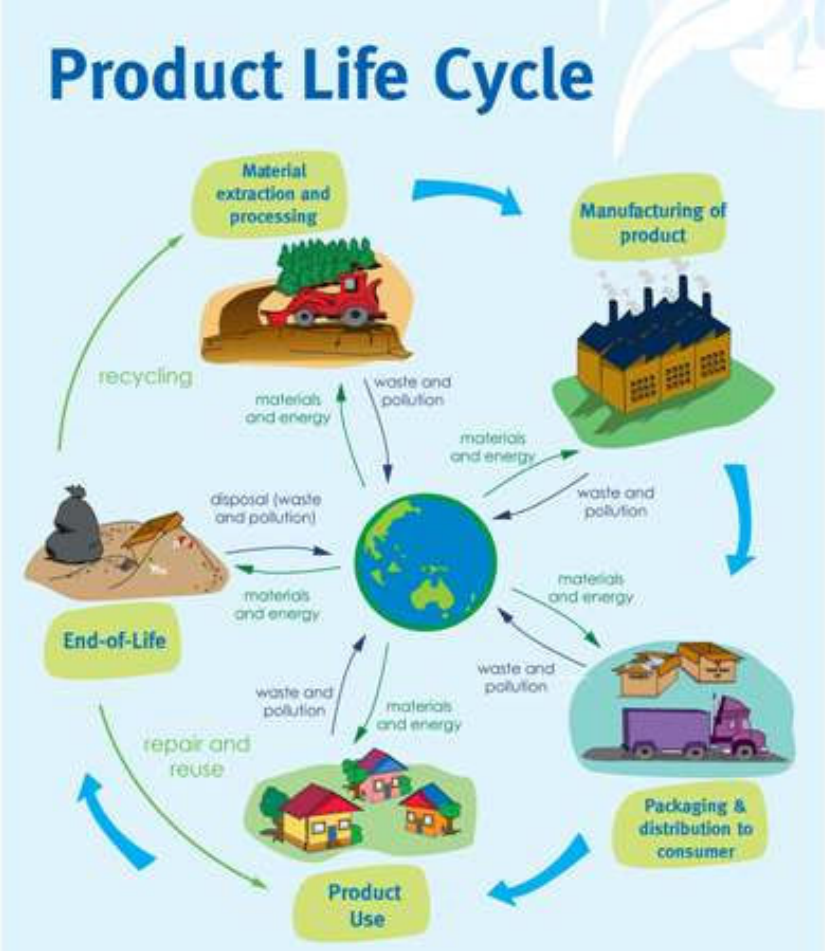
LCA: a standardized methodology

- General framework defined by international standards ISO 14040 - 14044

- « studies all the environmental aspects and potential impacts associated with all the stages of a product's life from cradle to grave, i.e. from raw material extraction to end of life»
- Product = product, activity, system or process

LCA: a standardized methodology

- Life cycle includes
  - Raw material extraction
  - Production
  - Transport
  - Packaging
  - Distribution
  - Use
  - Maintenance - Repair
  - Reuse or recycling
  - Disposal
- « Cradle to grave » approach
- « Cradle to cradle » → circular economy



http://sydney.edu.au/facilities/sustainable_campus/procurement/index.shtml

LCA: typical results

- Life cycle steps 'ranking' following their environnemental impacts
- Identification of susbtances responsible for major environmental impacts

CO_2 footprint = 1 inventory among many others

- Determination of categories with highest environmental impacts
  - Human health, climate change, ecotoxicity …

LCA: why ?

Internal

Strategy

- Potential impacts of products on environment
- Investments decision support

R & D products/process

- Early identification of problems/opportunities
- Assistance in projects selection
- Assistance in defining objectives

External

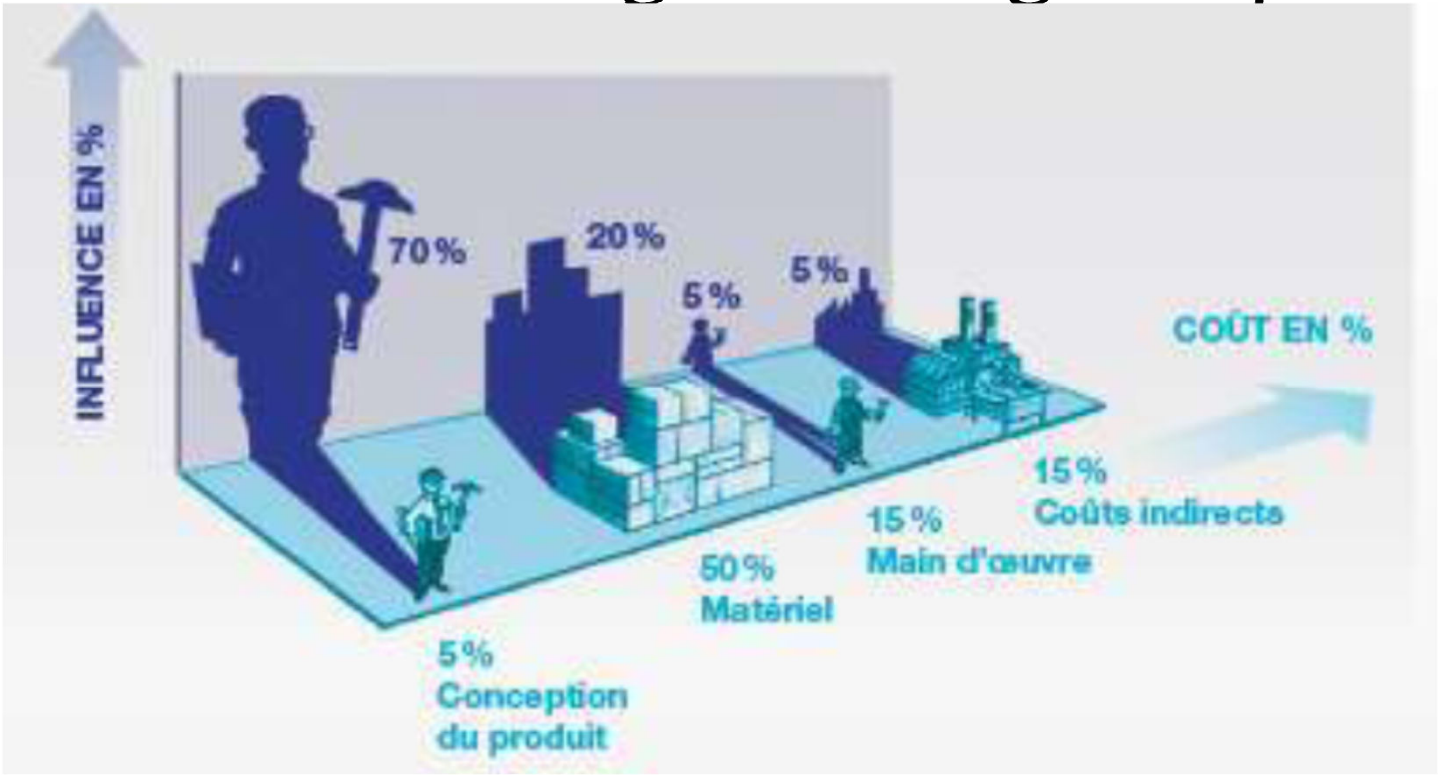
Marketing

Policy

- Best information of authorities, consumers, etc. (legislation/regulation, eco-labels …)
- Comparative analyses

LCA = way to « ecodesign » new processes

- 70% of « the environmental impact » already fixed during the design step



L'écoconception, source d'innovation dans l'approche cycle de vie; l'expérience du Québec, Guy Belletête, Congrès ACV, Lilles, 4/11/2011

Ecodesign = integration of environmental aspects into product or process design with the aim of improving the environmental performance throughout the whole life-cycle

Different types of activities

- Academic research + consultancy
  - Evaluation of the environmental impact of processes
  - Support to process ecodesign
  - Redaction of environmental declarations
  - Development of databases
  - Development of new indicators
- Teaching and coaching
- Participation to several regional, federal and European projects
- LCA FNRS contact group creation
- …

A large number of topics

- Comparison of waste management scenarios
- Comparison of packaging options
- Study of biofuels production
- Study of agro-food by-products valorization ways
- Impact of water management (whole anthropic water cycle)
- CO_2 mapping (sector agreements)
- Study of several fuel cells configurations
- Ecodesign of anti-fingerprint coatings
- Ecodesign of wastewater treatment
- Ecodesign of demolition waste recycling ways
- Impact of intermodal transport
- EPDs of phosphoric acid and derived fertilizers
- …

Team and projects

Laurent Fraikin

- Chemical engineer background
- PhD thesis obtained in June 2012
  - "Contribution to the study of wastewater sludge convective drying and associated gaseous emissions"
- Research engineer
  - Phos4You (Interreg NWE with A. Pfennig)
    - Recovery of phosphorus in wastewater and in sludges
    - **Pilot design + LCA**
- Management of drying facilities
- + supervision of MSc thesis, labs

Erwan Plougonven

- PDR FNRS (coll. F. Collin)
  - Experimental and numerical study of cracking during the drying of porous materials: applications in the fields of chemical engineering and geomechanics
    - 4 years project (ended last July)
    - Drying experiments + tomography + image analysis processing development + modelling (kinetics + cracking criteria)
- + management of microtomograph facilitites
- contribution to many collaborative projects or services for industry or labs

Loubna Kahlerras

- PhD (Co-supervision with Constantine University)
  - Convective drying of cementitious materials
  - Experiments and modelling
  - Redaction under progress

Saïcha Gerbinet

- Chemical engineering background
- PhD thesis (teaching assistant in the Dpt)
  - "LCA of building materials that include a biobased binder: lessons and challenges"
  - Jury meeting → 3rd December
- Services – Consultancy
  - EPDs for Knauf Insulation
- + exercise and lab of several courses

with ECOSE TECHNOLOGY

Saïcha Gerbinet

- After the PhD thesis
- Consultancy
  - Medix
  - Hylife
  - Knauf Insulation
  - …
- Research project
  - ECOLISER – Feder: ÉCOliants pour traitement de Sols, Etanchéité et Routes
  - BestBioSurf ERA CoBioTech

Sylvie Groslambert

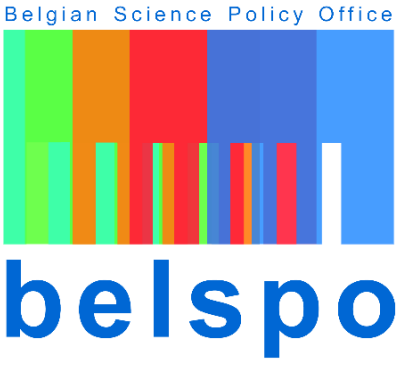
- Chemical engineering backgroung (1989)
- PhD Applied Sciences: ULg October 2001
  - Influence of hydrodynamics of a stirred tank fermenter on the morphology of filamentous bacteria
- Teaching
  - Continued education
  - MS Thesis supervision
- Non-LCA fields of expertise
  - Multiphase (bio)reactors (hydrodynamics, design and optimization, mixing, scale-up, compartmented model, aerobic fermentation,...)
  - Image analysis, Particle Image Velocimetry, rheology
  - Sustainable hydrogen in Belgium (feasibility), PEM FC
  - Algae: downstream processing and harvesting, anaerobic digestion

Sylvie Groslambert

- Past projects as research engineer
  - WAL-AID – Walloon Region (Wagralim): Valorization of the agrofood industry by-products
  - Energy balance of a wastewater treatment plant
  - LCA of the anthropic water cycle + rain water in Wallonia (DGARNE)
  - ReNEW – Interreg IVb NWE: Resource innovation Network for European Waste
  - Coaching of SMEs - Life Cycle In Practice, EU Life+, Greenwin
- Current projects
  - ATISOLC2C – PIT GreenWin: Système Membrane pare-vapeur et d'étanchéité à l'air – Isolant suivant Cradle to Cradle pour bâtiments neufs et la rénovation par l'intérieur des bâtiments existants
  - Valdem – Interreg V FWVL: Solutions intégrées de valorisation des flux « matériaux » issus de la démolition : Approche transfrontalière vers une économie circulaire

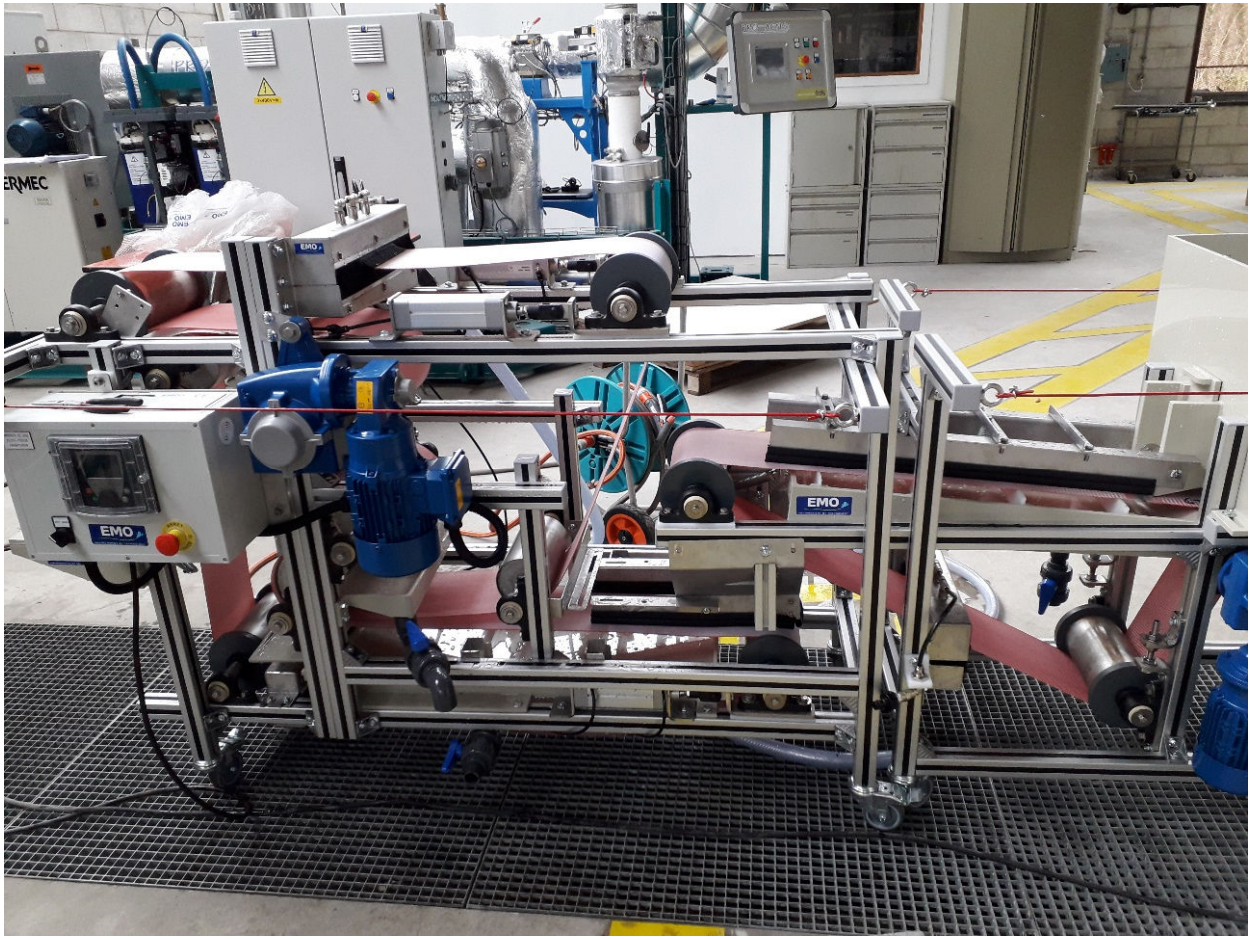
Angel Merchan

- Background: master in environment (Lille)
  - Ms thesis in the field of LCA
- PhD student
  - Brain-Trains – Belspo (federal level)
    - TRansversal Assessment of Intermodal New Strategies
    - LCA work package
      - Focus on train operation + infrastructure
      - Freight focus (not passengers)
      - Data specific to Belgium



Pierre Wuidar

- Background: master in agronomy (Huy)
- Ms Thesis: dewatering of sludge using the belt filter



+ close collaborations

- Zaheer Shariff → P recovery (PhD thesis – A. Pfennig)
- Antoine Merlo: LCA of plasma processes (PhD thesis - G. Léonard)
- Mattéo: LCA of CO_2 capture from natural gas
  (Ms Thesis – G. Léonard)
- Njaka Ralaizafisoloarivony and Kien Tran Duc→ soil dessication
  (PhD thesis and postdoc – A. Degré)

Future projects

- Accepted
  - Aeroperf - Win2Wal
    - “Effet de la microstructure des particules sur les performances d'une poudre pour inhalation“
    - With Brigitte Evrard and Nicolas Vandewalle
- Under evaluation
  - Greenwin - Propur
  - BBI – NOVABLU
    - New processes for the production and formulation of phycocyanin ingredients
  - BBI – FUNZITAIL
    - Tailor-made enzyme cocktails design for lignocellulosic biomass valorization
  - BBI – LOTUSS
    - Logistical, Operational and Technological Upgrade of Seafood Sidestream valorisation

Future projects

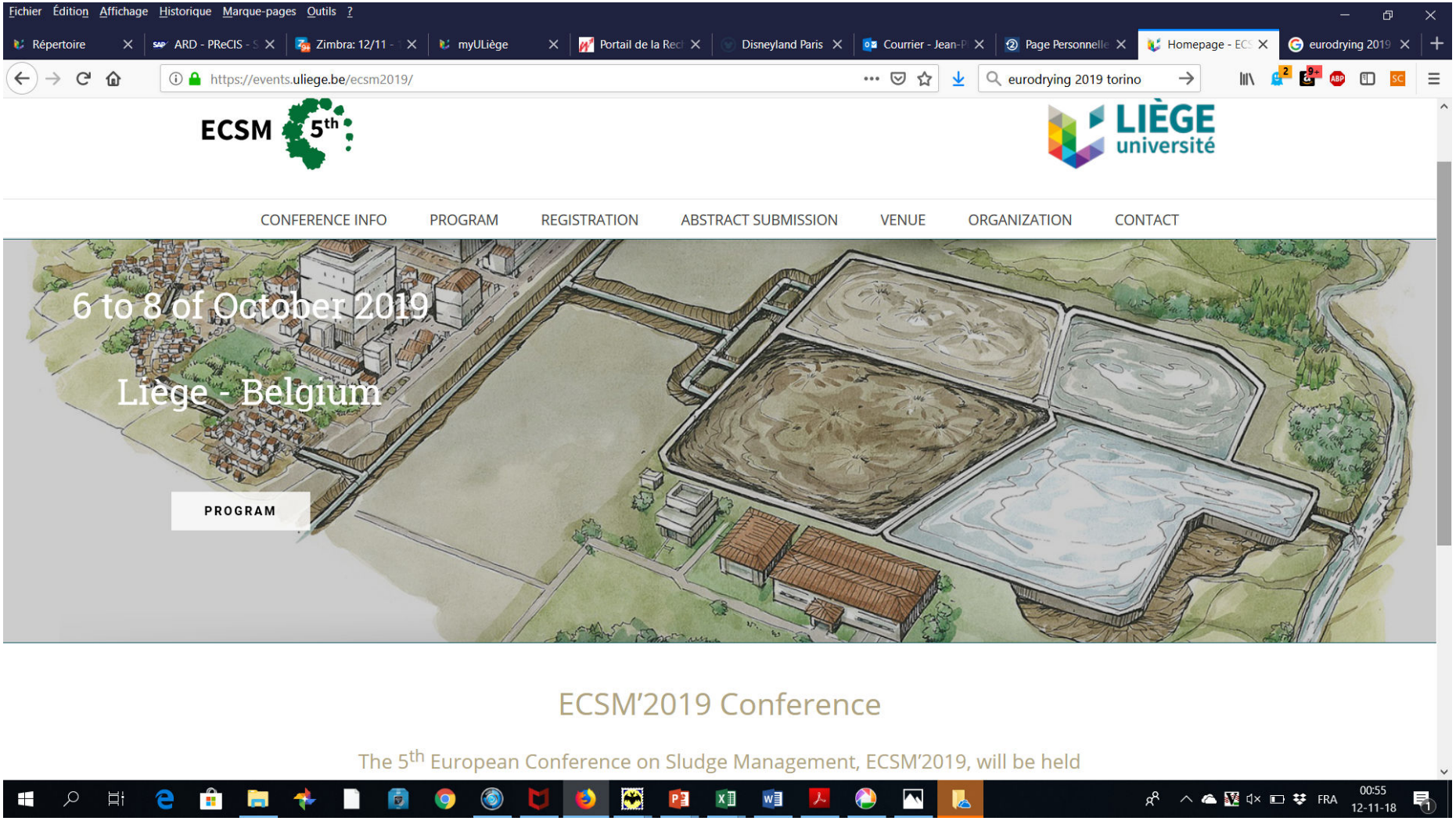
- Under evaluation
  - Fonds spéciaux
    - RheoPEPs
    - With Dominique Toye
  - FNRS - NSFC (China) 2018 – Bilateral projects
    - MicroCT scanning of sludge drying
    - With Jie Li (former postdoc)
- Under redaction
  - Greenwin - COSMOCEM

The program for next weeks

Future agenda

- 19/11 – Sylvie Groslambert
  - Valdem project: from LCA of demolition waste to circular economy of buildings
- 26/11 – Erwan Plougonven
  - Characterising fibrous materials with X-ray tomography
- 3/12 – Laurent Fraikin
  - P-recovery technologies from wasterwater and sludge developed in the Phos4You project
- PhD thesis of Saicha and Angel

ECSM'2019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Liège - Belgium
PROGRAM
ECSM'2019 Conference
The 5th European Conference on Sludge Management, ECSM'2019, will be held

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PEPs
CHEMICAL ENGINEERING

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