Towards understanding and design of sludge dryers

30th November 2015

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[1]PEPs (Products, Environment, Processes)

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Wastewater sludge: production and quantities

Sludge's origin

- Urban residual sludges
  - Activated sludge wastewater treatment plant (WWTP)

Oupeye - 446 500 PE

www.aide.be

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Structure of a WWTP

Wastewater

Screening

Sand and grease removal

Biological treatment
Activated sludge reactor

Separation between treated water and sludge
Settling tank

Sludge draining and mechanical dewatering

Evacuation of dewatered sludges

« Pasty material»
70 to 85% water !!

Treated water

Structure of a WWTP

- Sludge processing
  - Applied to excess biomass produced by the biological treatment
    - Thickening
    - Stabilisation
      - Liming
      - Digestion (biomethanation)
      - Mechanical dewatering
        - Centrifugation
        - Belt filter
        - Press filter
    - Valorisation

Drying

Quantities

Countries	Sludge Production Volume Tds/a	
	2010 estimate	2020 estimate
USA	**7.000.000**	**10.000.000**
Austria	273.000	280.000
UK	1.640.000	1.640.000
Scotland	200.000	200.000
Spain	1.280.000	1.280.000
Sweden	250.000	250.000
France	1.300.000	1.400.000
Germany	2.000.000	2.000.000
Italy	1.500.000	1.500.000
Romania	165.000	520.000
Portugal	420.000	750.000
Poland	520.000	950.000
Hungary	175.000	200.000
EU27	**11.500.000**	**13.500.000**

Global production > 50 million T DS/year

Europe:
About 50 to 60 million tons of humid sludge

The Netherlands
About 351 000 tons of dry sludge

Sludge valorisation

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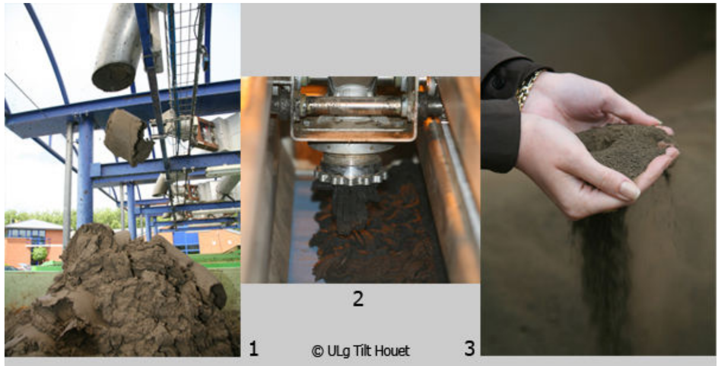
Sludge valorisation

- Valorisation in agriculture
  - Mineral and organic elements
    - Humic value
    - Fertilizer
- Energy valorisation
  - Incineration in a specific furnace
  - Co-incineration with domestic waste
  - Incineration in cement kilns
  - Biomethanation → cogeneration
  - Pyrolysis/gazification → cogeneration
- Land filling
  - Banned

Europe - 2011
Agriculture: 59%
Incineration: 24%
Landfill: 10%
Others: 7%



Au centre de valorisation des déchets d'IDELUX à Tenneville, les boues déshydratées (mais encore humides à 80% environ) sont collectées à la station d'épuration (1) avant d'être alimentées, sous la forme d'extrudats, dans le sécheur industriel (2). Le produit final est une matière parfaitement sèche (3), qui peut servir de combustible pour la production d'électricité. L'usine est capable de produire 300 Kg de matières sèches par heure.

Wallonia - 2013
Incineration: 53%
Agriculture: 47%

The Netherlands - 2011
Incineration: 99%
Others: 1%

Sludge drying

Why ? How ? Difficulties ?

Why drying ?

- Valorisation in agriculture: land spreading
  - Stabilisation, odor reduction (DS > 90%)
  - Mass and volume reduction
  - Concentration of nutrients
  - Hygienisation
  - Pasty texture → solid texture

Transfer

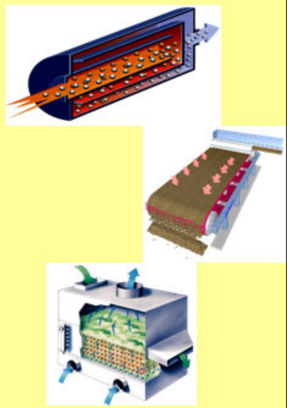
from Waste

Dewatered Sludge

- 20 - 35% DS
- Sticky
- Caloric heating value
  < 4 MJ/kg
- biologically active
  (digestion processes)

by

Sludge Drying



to Product

Dried Granules

- > 90% DS
- free flowing
- Caloric heating value
  - 8 - 11 MJ/kg (digested)
  - > 12 MJ/kg (non-digested)
- pathogen free
- biologically stable

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Why drying ?

- Energy valorisation
  - Drying $\Rightarrow$ Increase of lower heating value

30 < DS < 45%: self combustibility

⇒ Incineration in a specific furnace

60 < DS < 90%: LHV ≅ domestic waste (8400 kJ/kg)

⇒ Co-incineration

DS > 85% **⇒ Pyrolysis or gazification**

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Sludges, a complex material

- Sludge = rheologically complex material

Transition between liquid-pasty-solid states during drying

Increasing siccity					
(% MS)	< 10	10 - 40	40 - 60	60 - 90	> 90
State	Liquid	Viscous liquid – pasty	Glue phase ('sticky')	Granular solid	Dry solid

Sludge rheological behaviour and transition between states is extremely variable:

It depends on: sludge chemical and biological nature
treatment conditions (stabilisation, dewatering, …)
pumping conditions, storage, …

Sludge «history»

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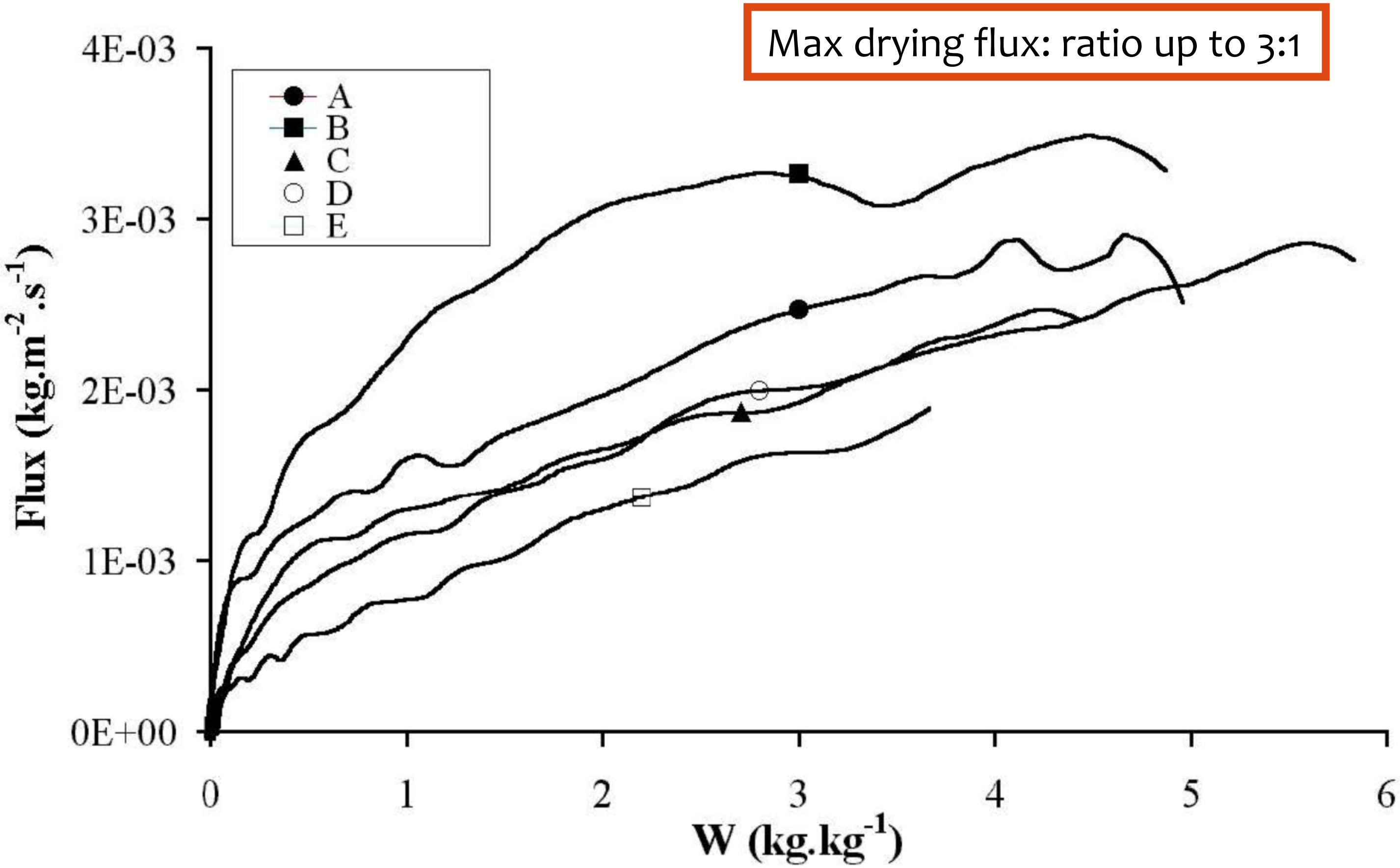
Sludge drying = complex operation

- **Complex process depending on**
  - sludge origin
  - rheological properties
  - composition (organic matter, EPS, fat content, …)
  - treatments underwent within the WWTP
    - flocculation
    - mechanical dewatering
    - liming
    - pumping, conveying …
- **Few specialised manufacturers**
  - Adaptation of existing technologies
  - Bad knowledge of the material → design errors
  - Diffusion of good practices !!

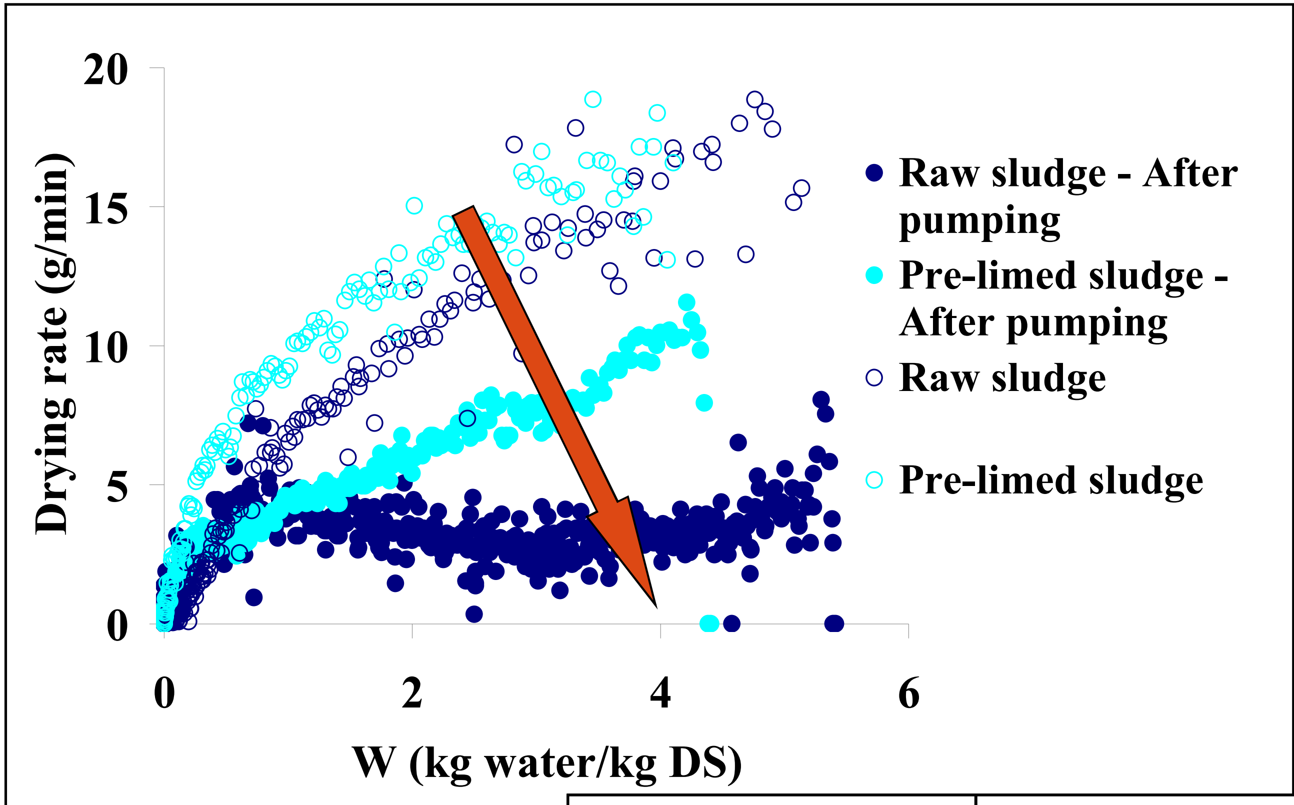
Sludge drying = complex operation

- Influence of sludge origin



Sludge drying = complex operation

- Influence of pumping



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

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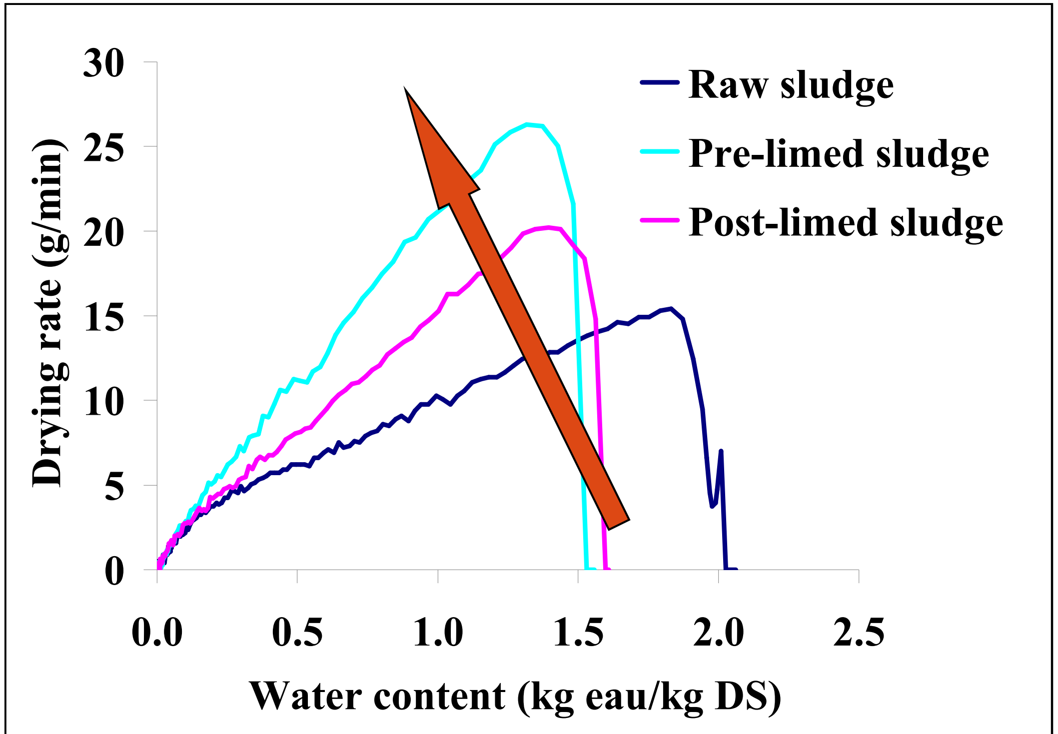
Sludge drying = complex operation

- Influence of liming

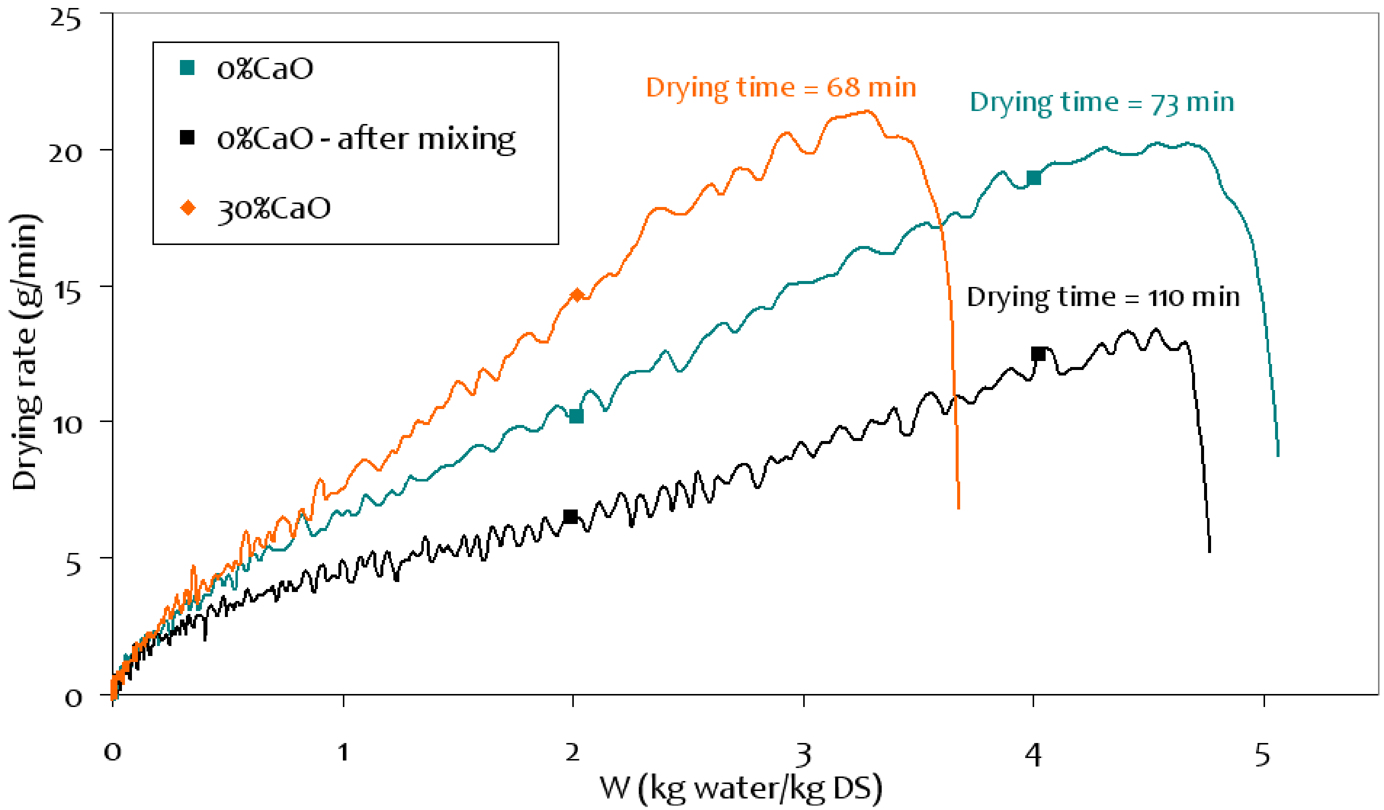


	Specific evaporation capacity (kg/m²h)
Raw sludge	24.3
Post-liming	28.9
Pre-liming	37.0

Sludge drying = complex operation

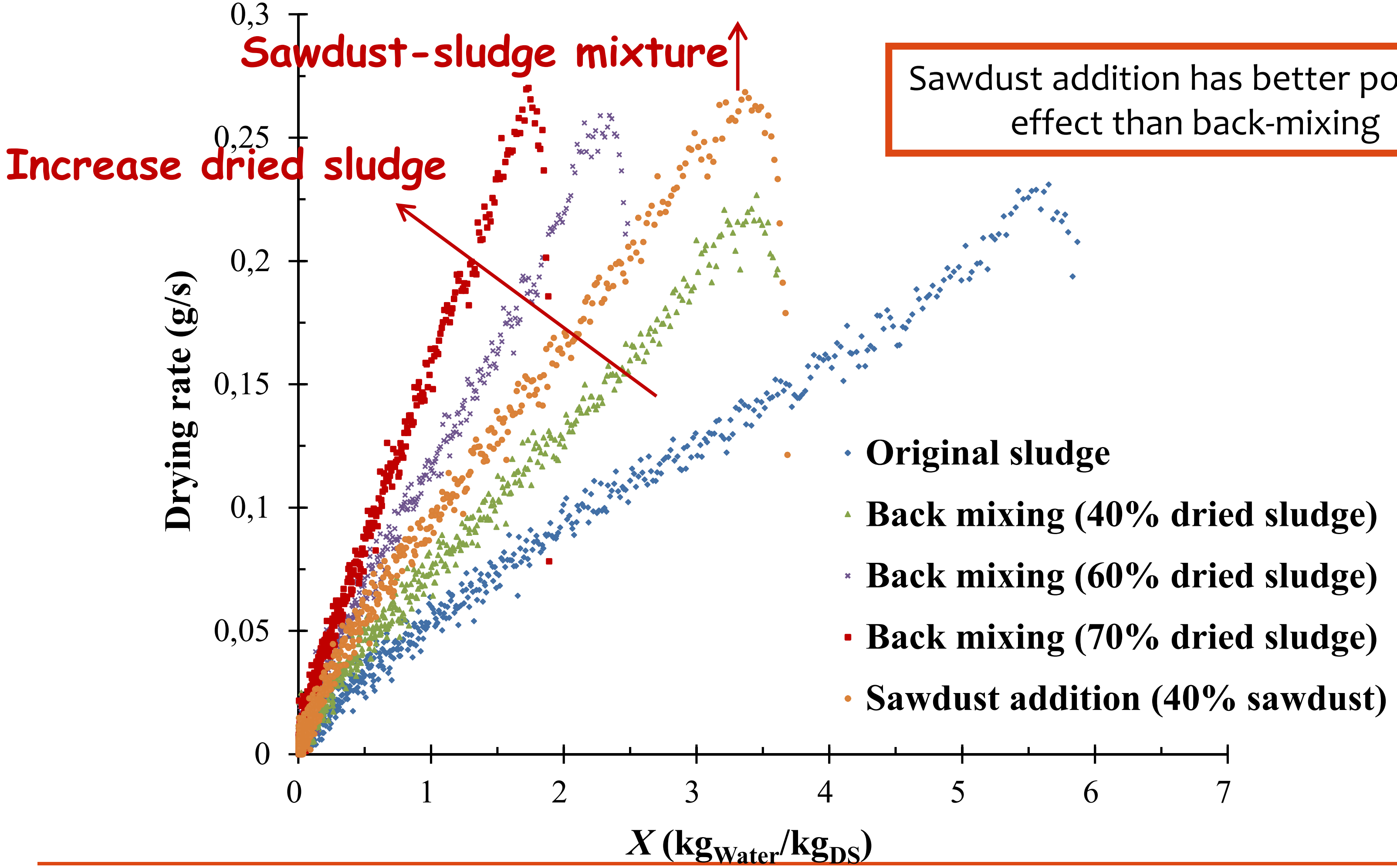
- Influence of mixing

Mixing → increase of drying time
30% CaO post-liming → "recovery" of initial drying behaviour



Sludge drying = complex operation

- Influence of mixing, backmixing and sawdust addition

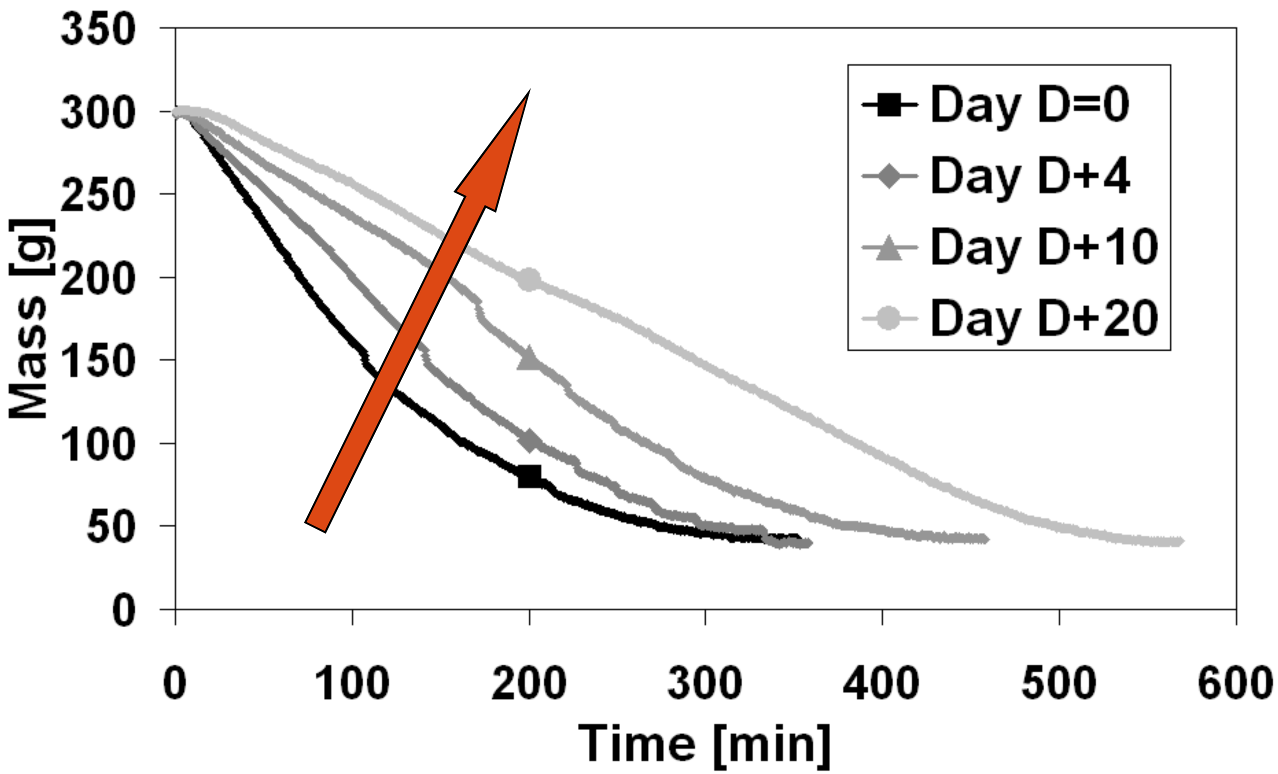


Sawdust addition has better positive effect than back-mixing

Sludge drying = complex operation

- **Influence of storage**

Slowing down of drying kinetics with increasing storage times



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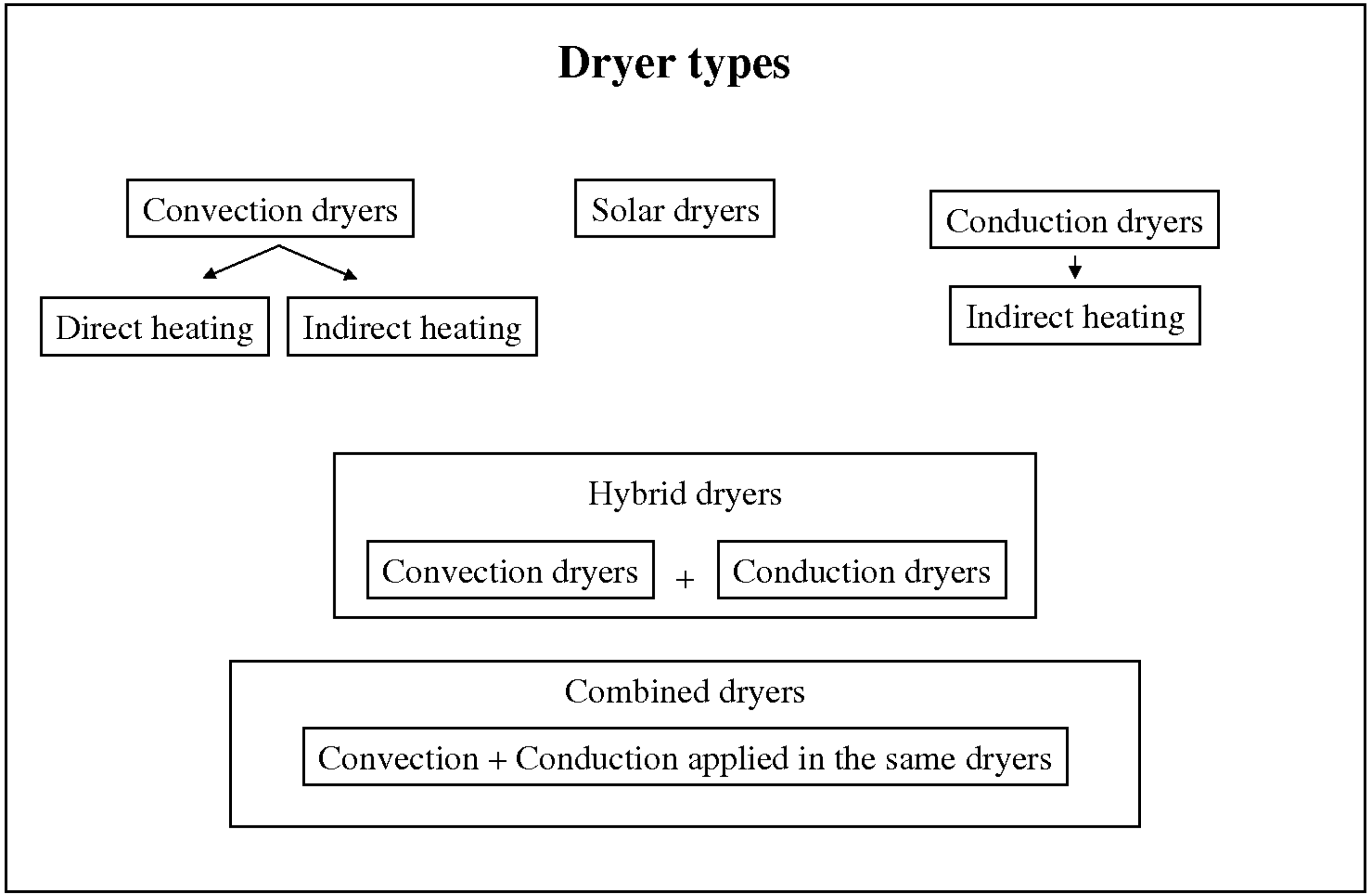
Drying technologies



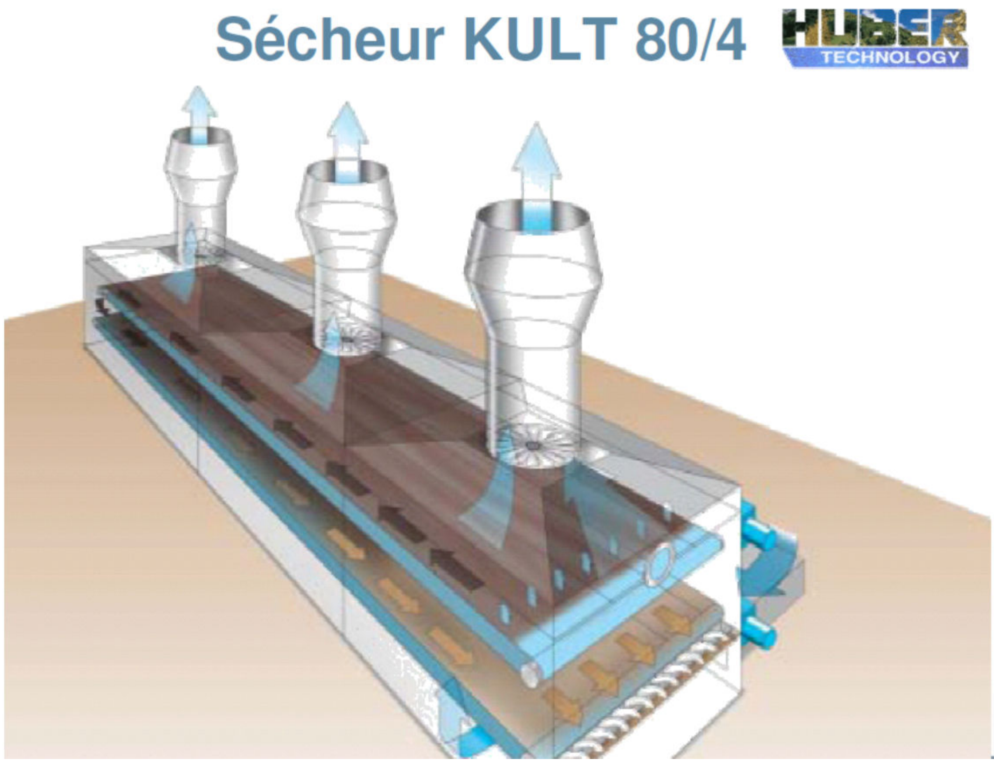
Drying technologies

- Convective dryers

Dryer type	Operating range (in terms of water content X, expressed on a dry basis)	Specific drying rate ($kg\ m^{-2}\ h^{-1}$)	Specific energy consumption ($kWh\ ton^{-1}$)
Belt dryer	Full drying	from 5 to 30	700 to 1140
Direct drum dryer	Full drying, with dry product backmixing: $0.1 \leq X \leq 0.54$	from 3 to 8	900 to 1100
Flash dryer	Full drying	from 0.2 to 1	1200 to 1400

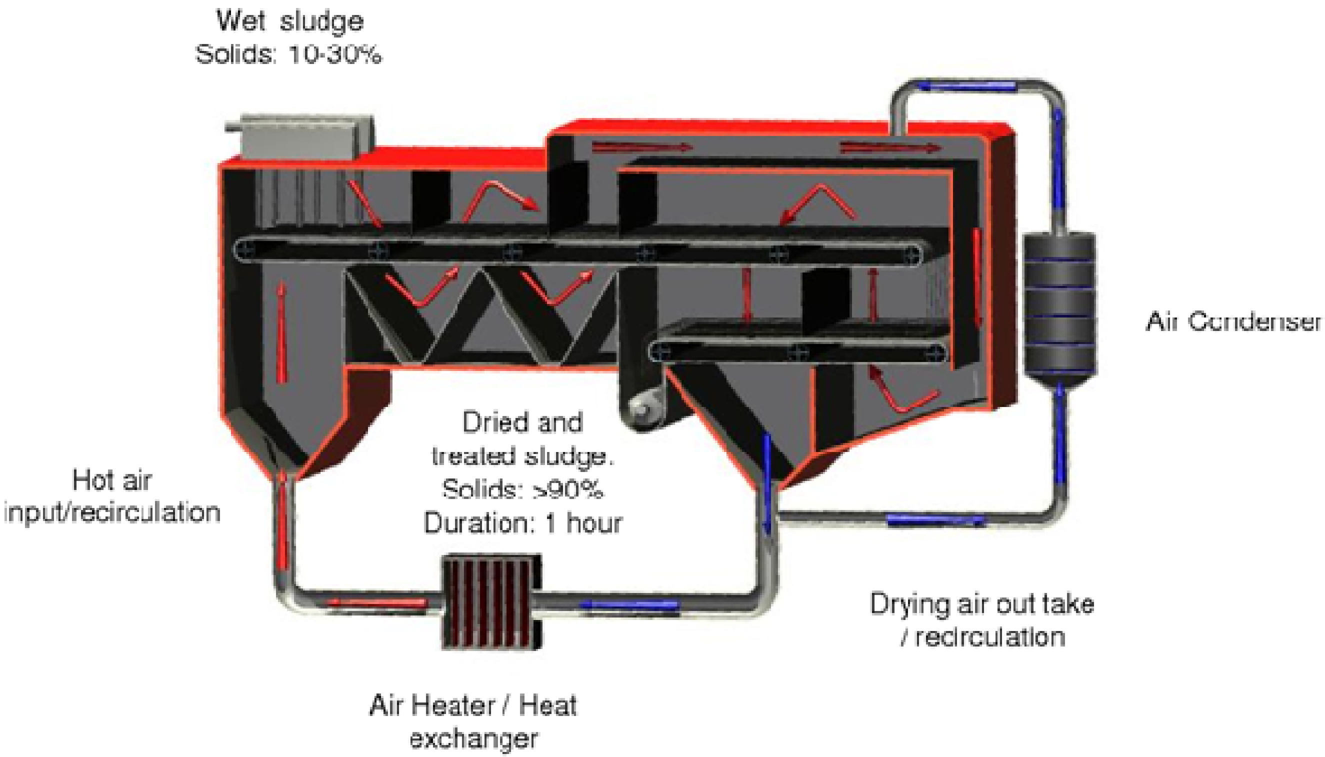
Drying technologies

- Belt dryer: Tenneville - Huber



Drying technologies

- Belt drying: BioCon® - Krüger (USA)



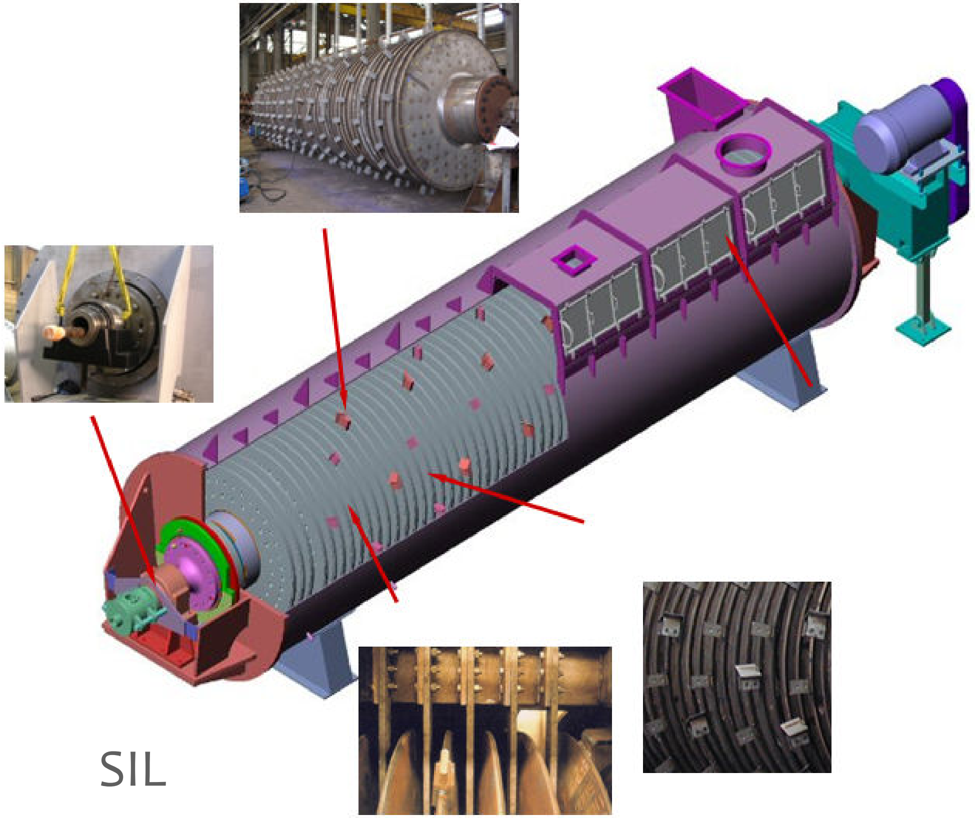
Sludge technologies

- Conductive dryers

Dryer Type	Operating range (in terms of water content X, expressed on a dry basis)	Specific drying rate (kg m^{-2} h^{-1})	Specific energy consumption (kWh ton^{-1})
Disc dryer	Partial drying: $1.25 \leq X \leq 4.5$	from 10 to 12	from 855 to 955
	Full drying, with recycling of dry product upstream : $0.1 \leq X \leq 0.54$	from 7 to 10	
Paddle dryer	Full drying: $0.1 \leq X \leq 4.5$	from 15 to 20	from 800 to 885
Thin film dryer	Partial drying: $0.54 \leq X \leq 4.5$	from 25 to 35	from 800 to 900

Drying technologies

- Disc dryers



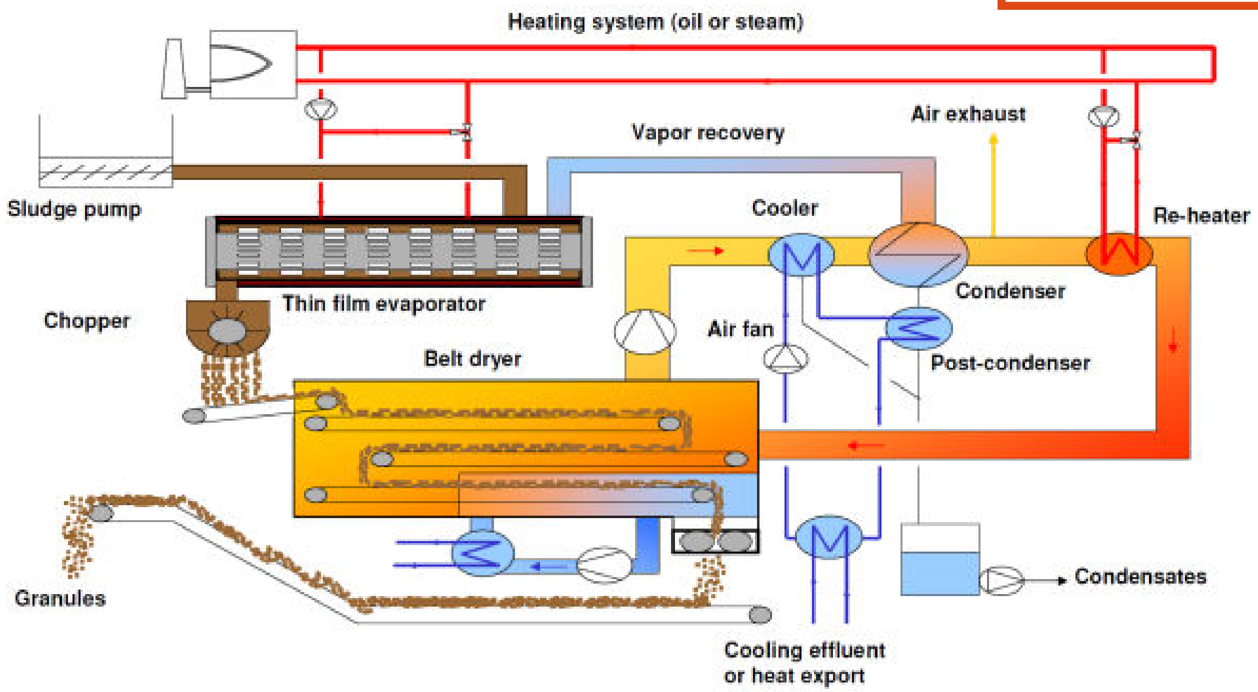
SIL

Gouda GMF

Drying technologies

- Hybrid systems: thin film evaporator + belt dryer

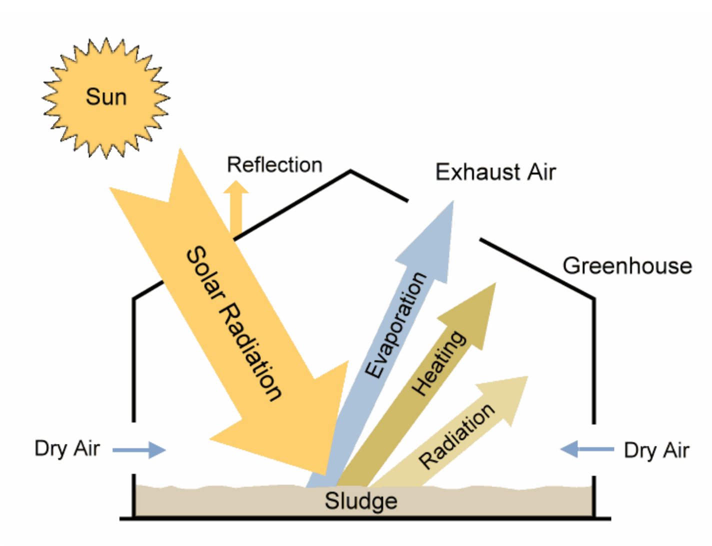
INNODRY 2E® drying process



700 to 900 kWh/t EW – 0.5 to 4 t/h

Drying technologies

- Solar dryers → greenhouses
  - Closed, open, combined with heated floor



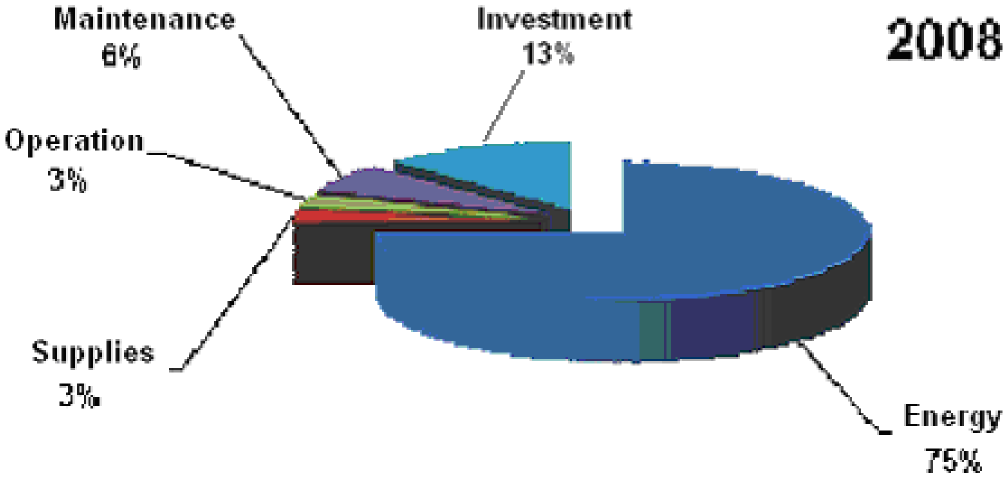
30 to 200 kWh/t EE – up to 1000 in the case of chemical desodorisation

Sludge drying

How to increase performances ?

Reduction of energy invoice

- Essential !!

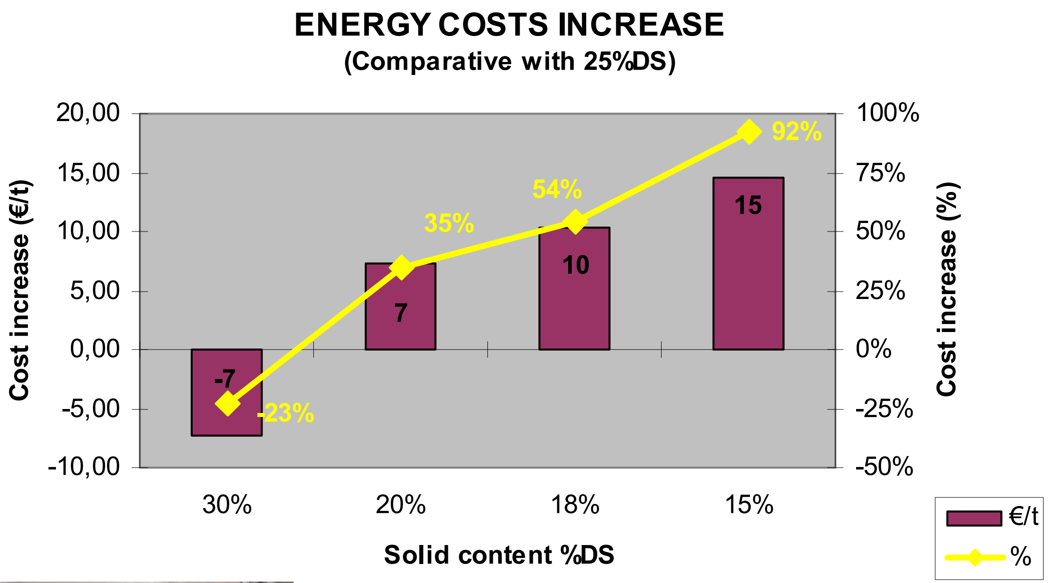


Sludge thermal drying costs distribution

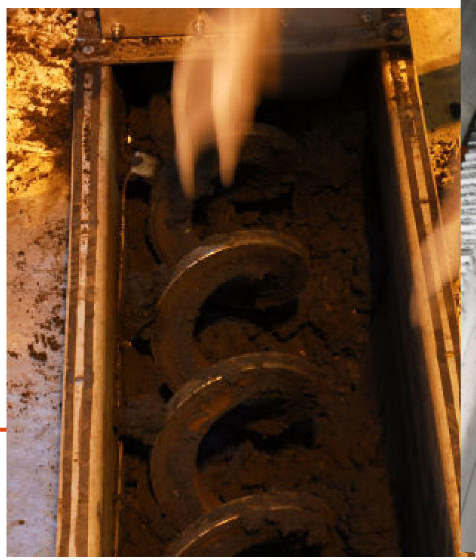
D. Permuy, ECSM 2010, Budapest, Hungary

Reduction of energy invoice

- Inlet siccity increase
- Losses reduction, design and operating conditions optimisation
- Heat valorisation on site
  - Use of biogas
  - Incineration waste heat
  - …

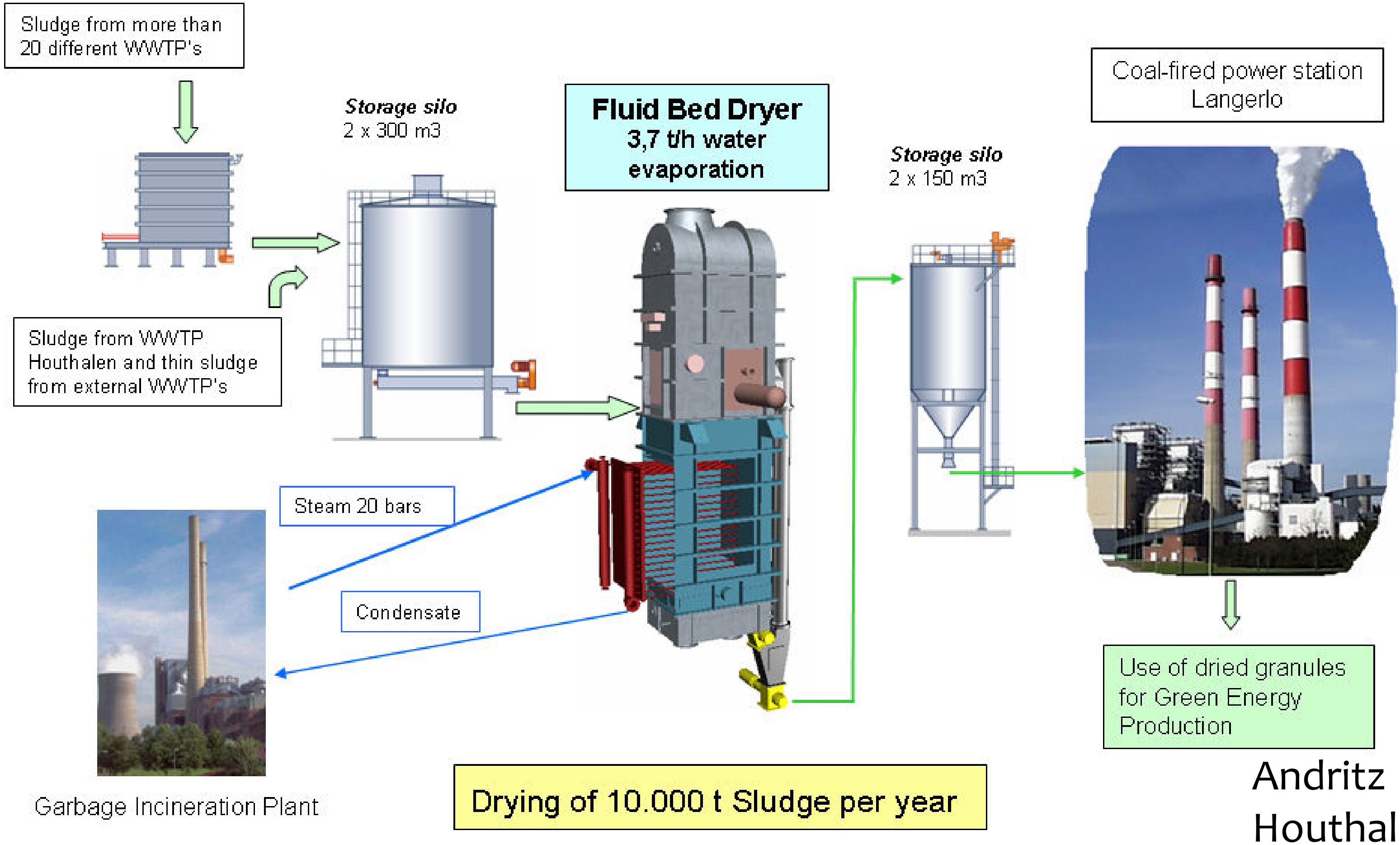


D. Permuy, ECSM 2008, Liège, Belgium



Example of energy integration

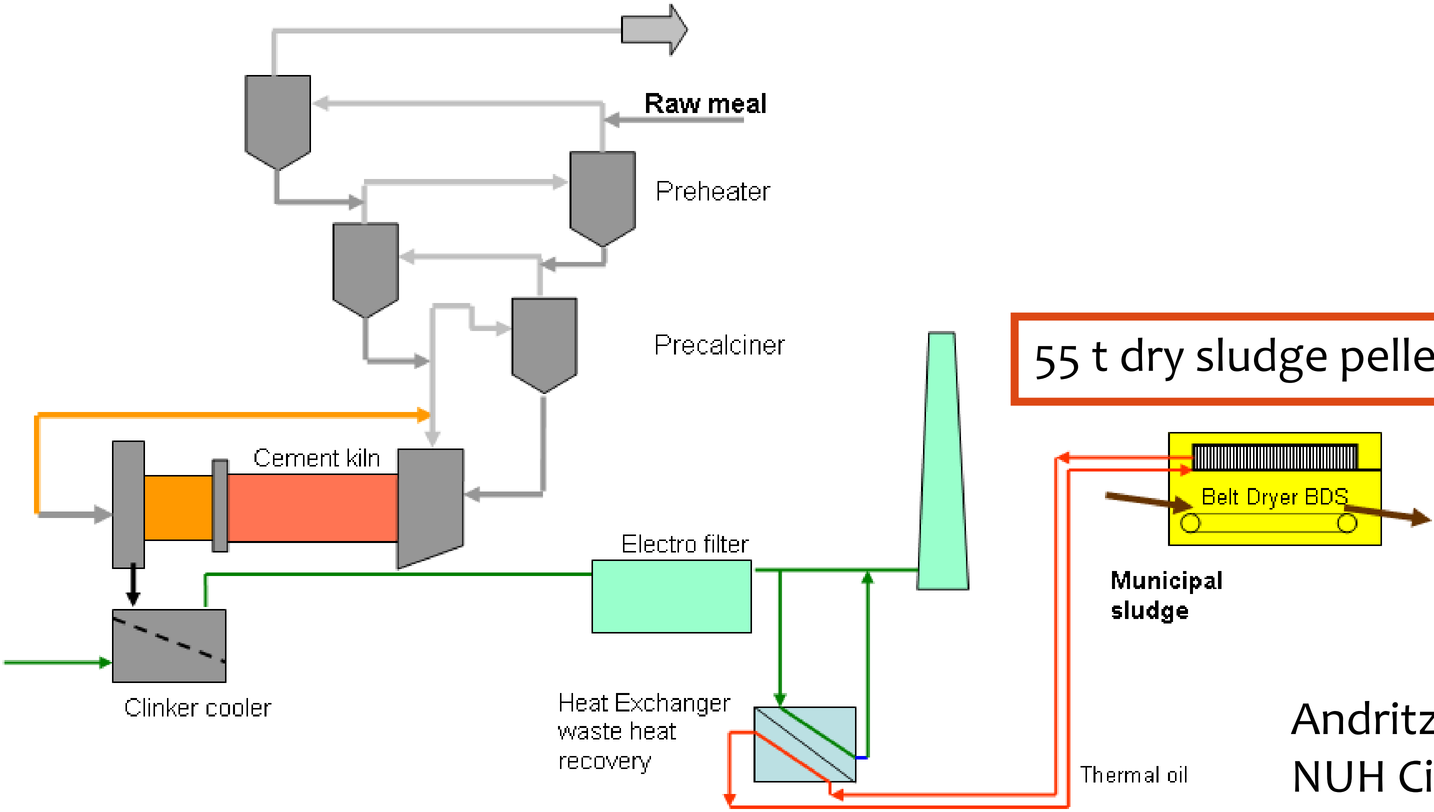
- Incinerator waste heat recovery



Andritz
Houthalen (BE)

Example of energy integration

- Cement kiln waste heat recovery



55 t dry sludge pellets / day

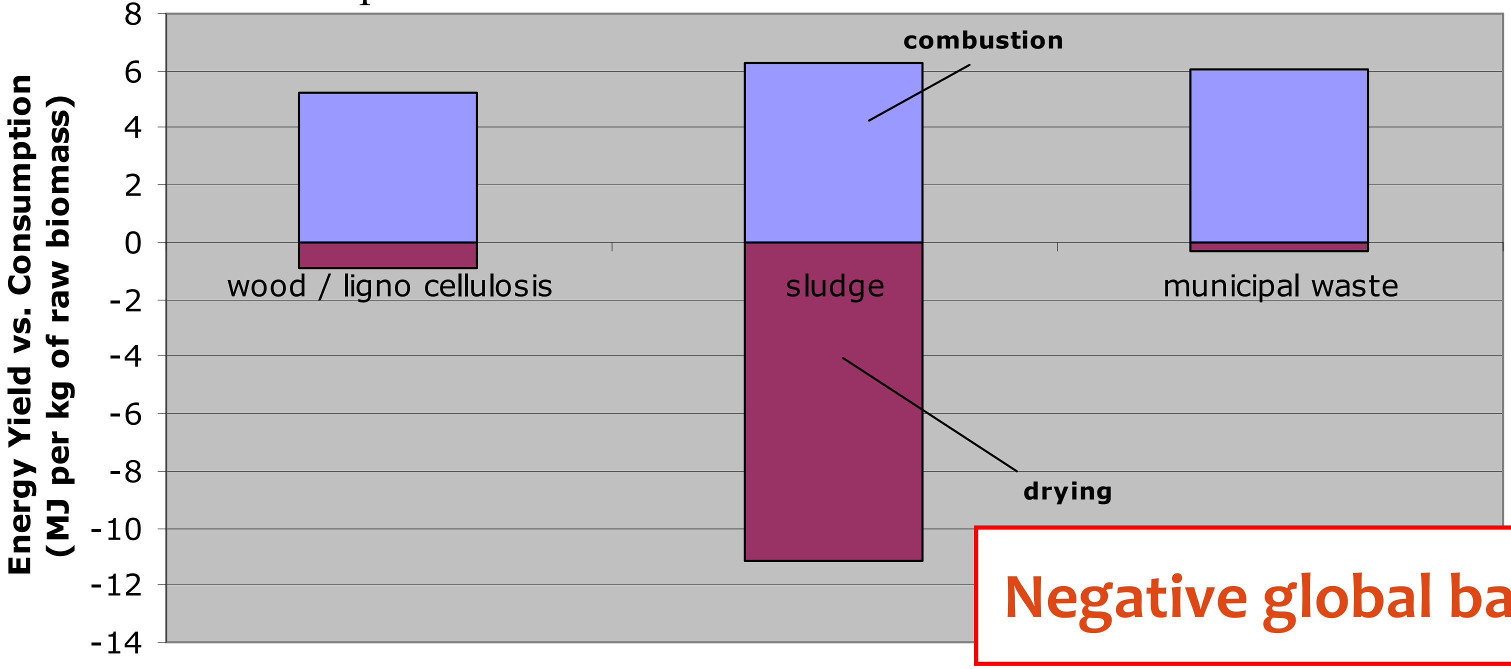
Andritz
NUH Cimento in Hereke, Turkey

Importance of dryer efficiency

- Use of a dryer considered as 'efficient'

$$R_D = \frac{\text{Consumed energy}}{\text{Latent heat of vaporisation}} = 1.25$$

LHV = 8 MJ/kg for each fuel



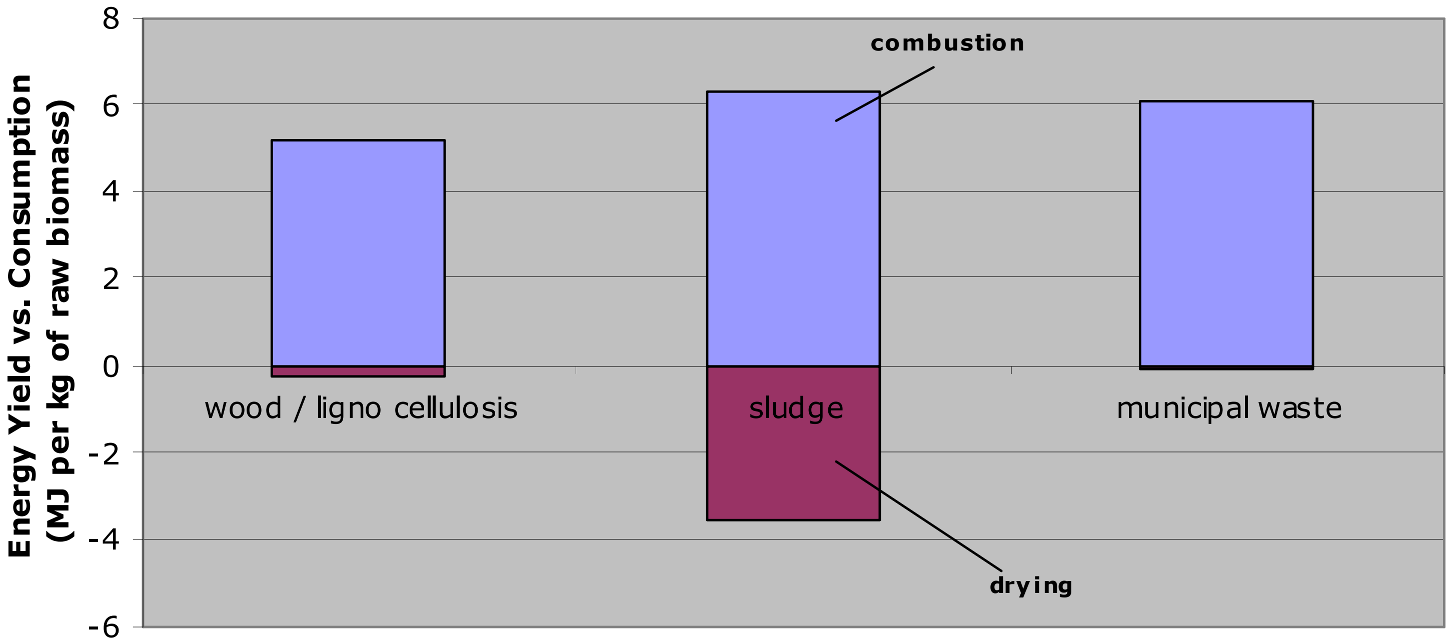
Negative global balance

A. Léonard et al., Efficient sludge thermal processing: from drying to thermal valorization, Modern drying technology, Vol. 4

Importance of dryer efficiency

- Dewatering/drying coupled optimisation → positive balance

$$R_D = \frac{\text{Consumed energy}}{\text{Latent heat of vaporisation}} = 0.4$$



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To conclude …

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Tomorrow ?

- Development of sludge drying within "zero energy" WWTP
- Vision of the whole site and sludge treatments to reach the energy optimum
- Diffusion of other drying technologies
  - SHS, frying, …
- Research efforts
  - Links between sludge nature/history and drying
  - Low temperature + heat pump
  - Links between the texture of dry product and gasification/pyrolysis
  - …

Future events …

- 4th European Conference on Sludge Management – ECSM 2016, November 2016, Aix-en-Provence, France
- 6th European Drying Conference, Liège, 2017
  - Industrial session !!

Thanks for your attention !

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