Convective Drying of Mixtures of Sewage Sludge and Sawdust in a Fixed Bed

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Introduction

- Increasing amount of wastewater sludge
- Sludge valorization

  Land application, composting, incineration

  Problem: moisture content is a critical parameter
- Drying
  - Mass and volume reduction
  - Stabilisation – Hygienisation
  - Texture improvement
  - Increase of calorific value
- Needs for other valorization options
- Idea = new renewable fuel by mixing sludge with sawdust
  - Could be used for gasification/pyrolysis
  - Interest for pasty sludge, difficult to dry

Goals

- Study of the drying behaviour of sludge/sawdust mixtures
  - Convective drying of fixed bed
  - Raw sludge (before and after mixing)
  - Raw sludge + increasing sawdust addition
  - Use of tomography to characterize the 3D bed structure

Sludge and sawdust

➢ Sludge

- From WWTP (Grosses Battes, Belgium)
- Moisture content (wet basis) = 85.5%

➢ Sawdust

- Pine (90% èpicèa and 10% douglas), from a wood pellet's factory (Industrie du Bois Vielsalm, IBV, Belgium)
- Moisture content (wet basis) = 30%
- Diameter=0~0.5 mm

Samples

Kitchen machine (KM1000, PROline)

- **Original sludge**
- **Sawdust/sludge mixtures**

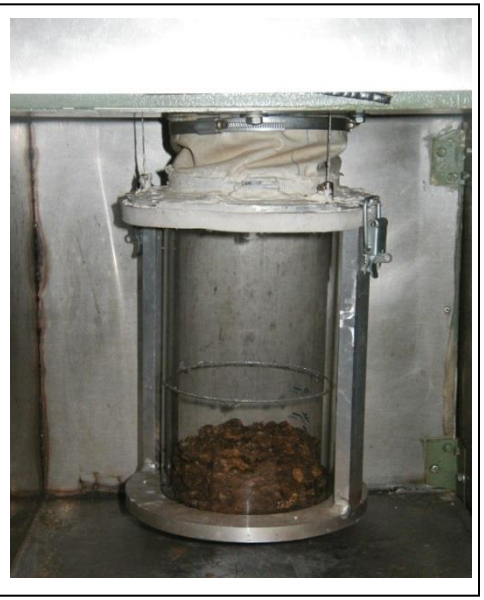
- Mass ratio (dry matter) of sawdust/sludge=1/9, 2/8, 3/7 and 4/6
- Mixing time: 30 s
- Mixing velocity: 40 rpm

Beater

- **Mixed sludge**

- The same protocol was used to mix the original sludge without any sawdust addition.

Convective pilot scale dryer



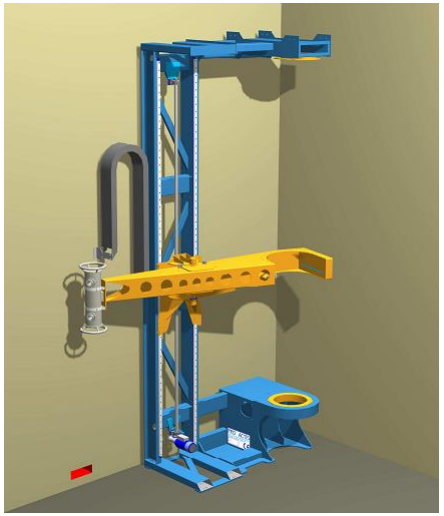
- Extrusion (∅ = 12 mm)
- Fixed bed (cross flow)

- Diameter: 160 mm
- Sample: 500 g

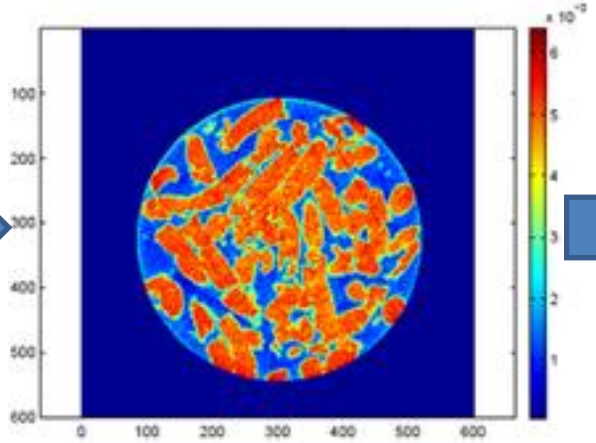
- Temperature: 50, 80 and 110 °C
- Air velocity: 2 m/s
- Humidity(ambient):~0.007 kg/kg

X-ray tomography

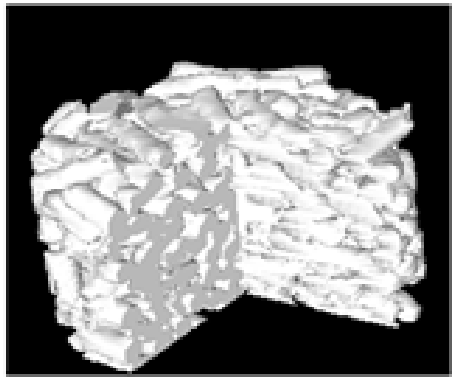
X-ray tomograph



2D image



3D image

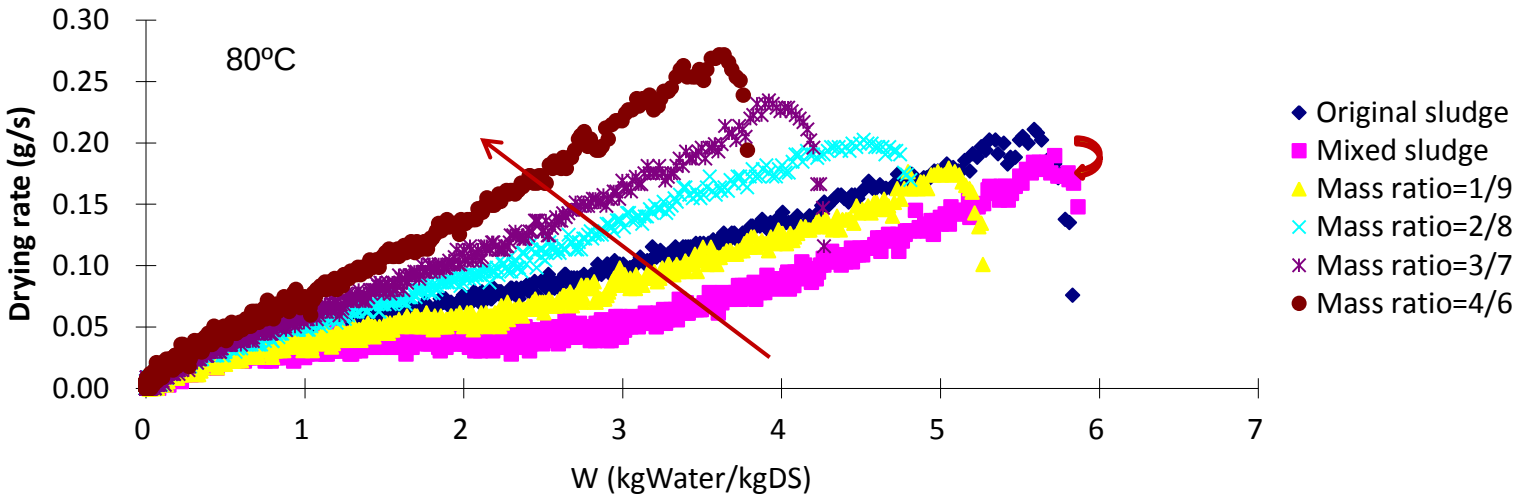


- Non invasive imaging
- High energy (420 kV)
- Large-scale (0.45 m in diameter, 4 m in height)

- Image pixel size: 0.359 mm
- Distance between two slices: 2.2 mm

- Volume
- Bed porosity
- Total exchange surface

Drying behaviour



- **Drying behaviour:** A short preheating period + a short constant rate period + a long falling rate period
- **Original sludge → Mixed sludge:** Drying rate ↓
- **Sawdust addition**

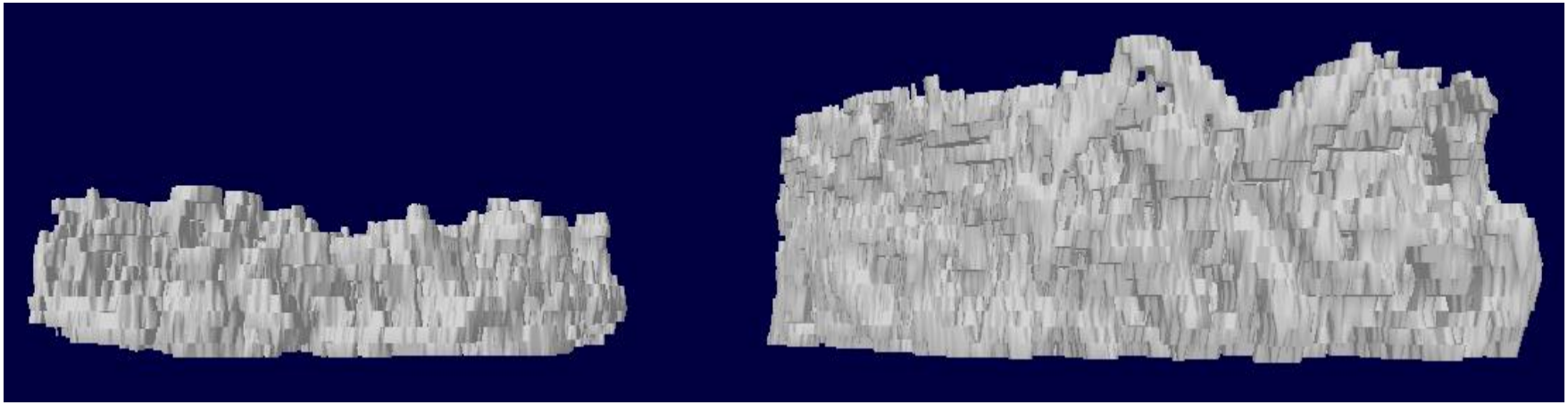
(1) Drying rate ↑

(2) From mass ratio of 2/8, the drying rate exceed the drying rate of original sludge. Sawdust addition has a positive impact on the drying process.

3D images

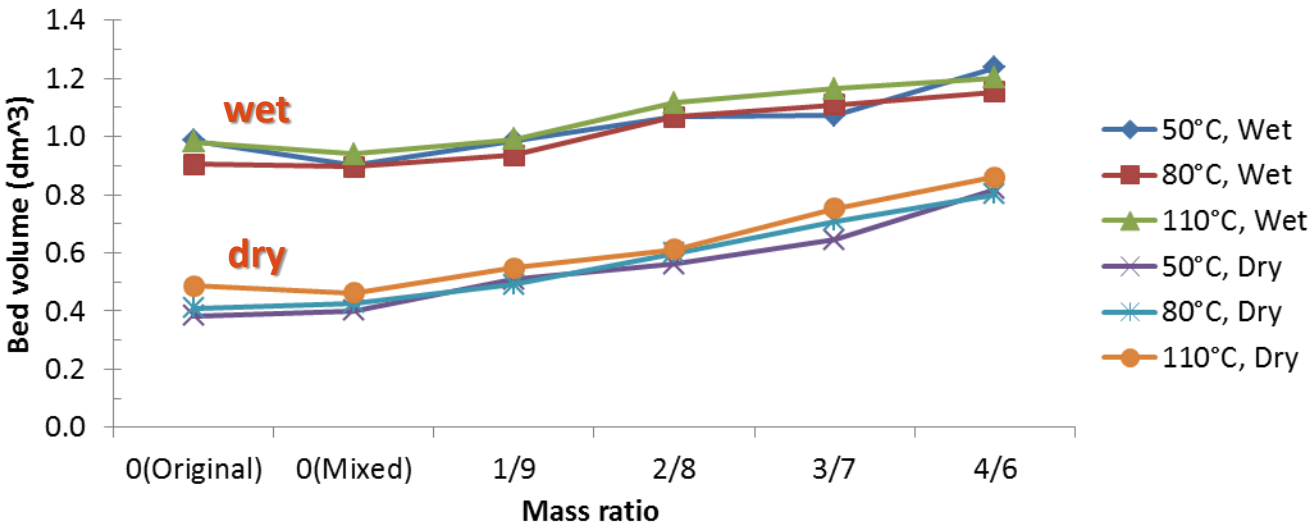
(a) Original sludge

(b) Mass ratio=4/6



The volume after drying increases obviously with sawdust addition.

Bed volume



- Original sludge → Mixed sludge

(1) Before drying: little decrease

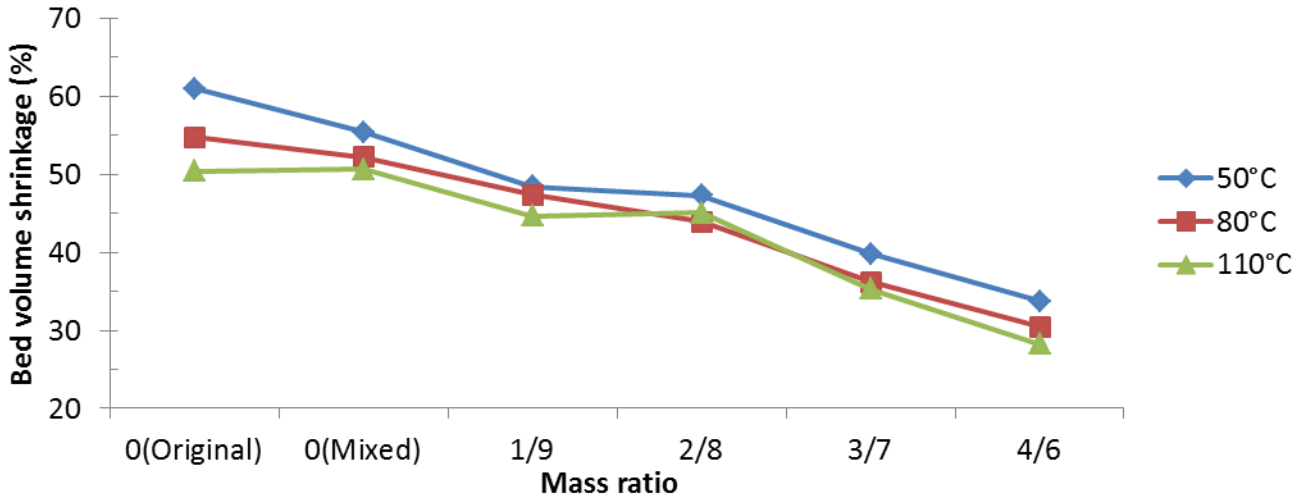
(2) After drying: little change

- Sawdust addition

(1) Before drying: volume ↑

(2) After drying: volume ↑

Shrinkage



- **Original sludge → Mixed sludge**

Volume shrinkage ↓

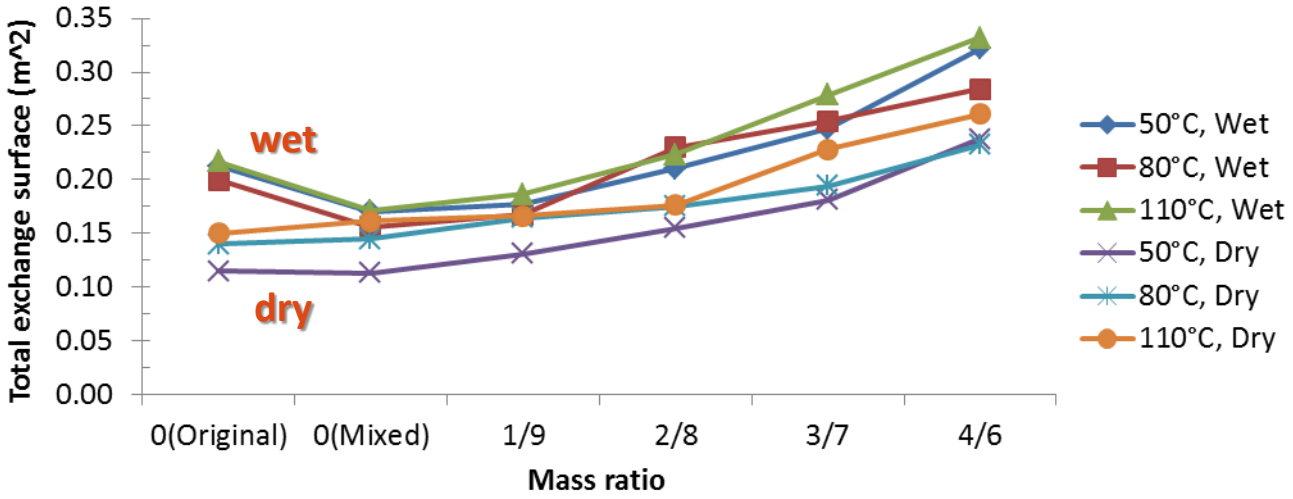
- **Sawdust addition**

Volume shrinkage ↓

- **Temperature**

Temperature ↑ → volume shrinkage ↓

Total exchange surface



- **Original sludge → Mixed sludge**

(1) Before drying: surface ↓

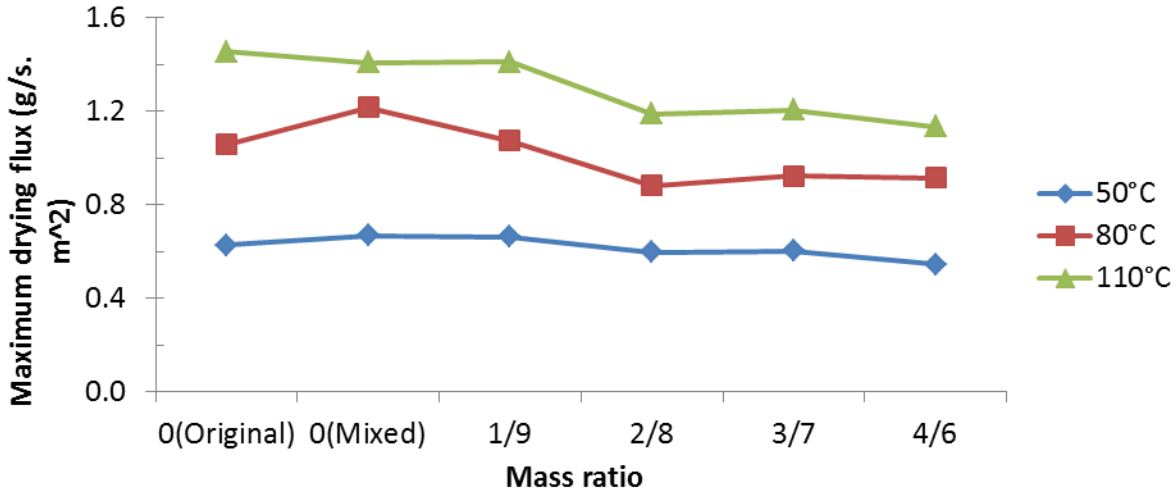
(2) After drying: little change

- **Sawdust addition**

(1) Before drying: surface ↑

(2) After drying: surface ↑

Constant drying rate period



In constant drying rate period, the drying rate depends on the surface.

$$Maximum\ drying\ flux = \frac{Maxiumum\ drying\ rate}{Wet\ surface}$$

The drying flux is independent of the sludge nature but only depends on air temperature, velocity and humidity.

Falling drying rate period

(1) First decreasing zone:

- The evaporation happens at the solid surface
- External diffusion of liquid is controlling
- Drying rate is due to the surface

✓ Mixing → surface ↓ → drying rate ↓

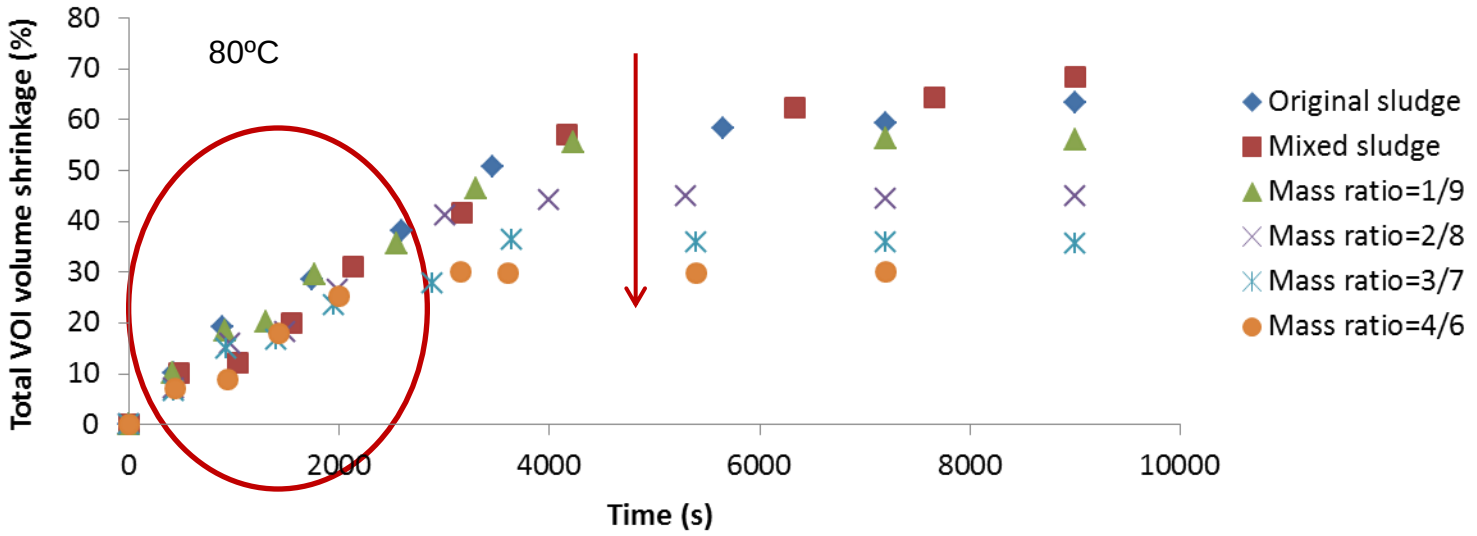
✓ Sawdust addition → surface ↑ → drying rate ↑

(2) Second decreasing zone:

- The evaporation happens within the solid structure
- Internal diffusion of liquid is controlling
- Drying rate isn't due to the surface

- Original sludge and mixed sludge: only the first decreasing zone
- Mixtures: first decreasing zone + second decreasing zone

Shrinkage process



- **Linear increase region:** almost the same
- **Constant region:** sawdust addition ↑ → reaches earlier

The sawdust reinforces the texture of sludge and enhances the heat and mass transfer.

Conclusions

- ✓ The mixing step has a negative impact on the drying process. Nevertheless the sawdust addition is shown to have a positive impact on the drying process from mass ratio of 2/8.

- ✓ Further work will be done in order to characterize the pore texture and the pyrolysis behaviour of the sludges and mixtures.

Thank you for your attention !

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