The Variability of Textural Properties and Drying Characteristics of Dehydrated Sewage Sludge

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Introduction

Wastewater treatment plants (WWTPs) generate sewage sludge (SS) composed of microorganisms, inorganic matter, and pollutants, with its composition varying based on treatment methods, wastewater origin, and plant location. The rising production of SS poses significant management challenges, especially under stricter environmental regulations. Throughout treatment, SS transitions from a Newtonian liquid to a dry solid, eventually forming dehydrated sewage sludge (DSS) after mechanical dewatering. Drying is a critical yet energy-intensive step, with factors such as moisture, volatile content, and viscoelastic properties significantly influencing its efficiency. This study examines the variability of DSS's textural properties and their impact on drying behavior to optimize wastewater management and sustainability.

Variability

Sludge Origin

- Source: Industrial, domestic
- Composition: inorganic, organic

Sludge treatment

- Thickening
- Type and dosage of coagulant and flocculant
- Dehydration technology: filtration, centrifugation
- Storage time

Dehydrated sewage sludge viscoelastic, textural and drying behaviour

↓

Real samples characterization

TSC, LOI, Penetrometry, TPA, Amplitude sweep, Drying

Problems

- Literature focused on liquid sludge
- Non standardized measurements
- Lack of data
- Pasty phase
- Loss of structure

Importance

- Predictable Behaviour: Consistency and Stability
- Improve pumping, mixing
- Enhance dewatering and drying
- Product Quality and Safety
- Reduce Operational Costs

Keywords: Sewage Sludge; Drying Behavior; Textural Properties; Viscoelasticity; Adhesiveness; Cohesiveness.

Materials and Methods

1. Sludge samples origin

	Embourg	Lantin	Gross Battes	Sclessin	Oupeye
Code	S_1	S_2	S_3/S_{L3}	S_4	S_5
Capacity [PE]	24300	31500	53100	135000	402000
Comissioning	1996	2003	2002	2001	2007
Sludge thickening	✔	X	X	X	X
Dewatering technology	Belt Filter	Belt filter	Belt filter	Press filter	Centrifugation
Liming	X	X	✔/X	✔	X
Carbon treatment	✔	✔	✔	✔	✔
Nitrogen treatment	✔	✔	✔	✔	✔
Bacteriological treatment	X	X	X	X	X

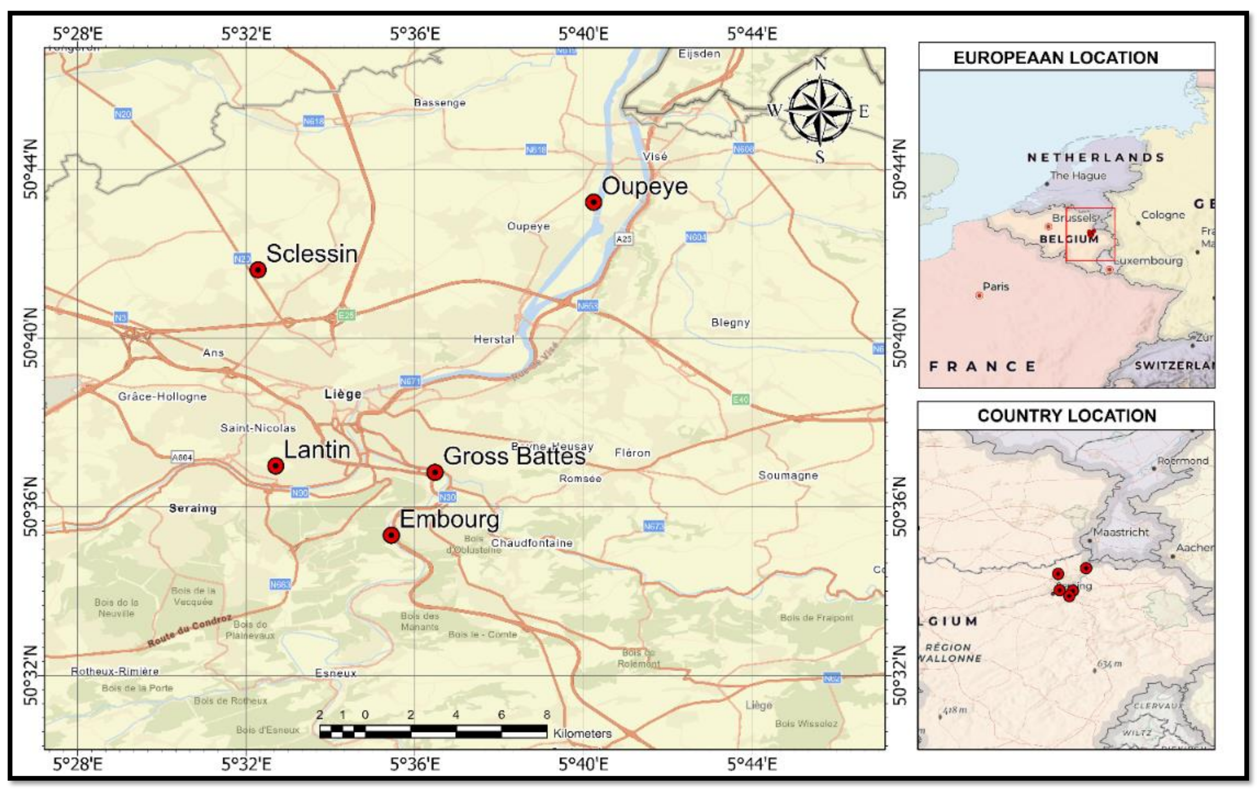


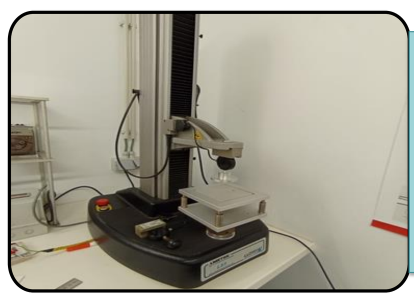
Fig. 1: Map of localization of Liege WWTPs considered in the study.

2. Methodoly

Standard Method

105°C for 24h
550°C for 4h

Total solid content and Volatile Matter



Penetration:
60g; h=15 mm; V=1 mm/s
TPA:
Extruded cylinders
d=18 mm; h=30 mm;
30% double compression

TPA and Penetration test

Amplitude sweep
γ=[0.01-100]%;
ω=1 Hz
1 min of pre-shearing 10 mins of recovery

Rheology test

VESAC Dryer
1 kg of extruded DSS
T = 90 °C , V = 2 m/s
Y = 0.005 kgwater/ kgDS

Drying test

Results

- Penetration results indicate notable differences in the mechanical properties of the DSS samples. Limed samples showed improved cohesiveness, and lower adhesiveness, indicating a significant change in texture.
- The results showed notable differences in the DSS samples. Limed samples had lower cohesiveness, and adhesiveness values were minimal across all samples, suggesting the method was not ideal for this measurement. Hardness was highest in non-limed samples, indicating that liming reduces material firmness.
- The rheological tests revealed key differences in the sludge samples. The limed sample (S_{L3}) showed a larger LVE, suggesting enhanced stability under low strain. he flow point was also highest in the limed sample, implying improved resistance to deformation, supporting the positive impact of liming on sludge stability.
- The drying behavior of the DSS samples varied significantly. Sample S_2 dried the fastest, indicating a more efficient drying process, while Sample S_3 took the longest. The limed sample (S_{L3}) showed an improved drying rate compared to its non-limed counterpart.

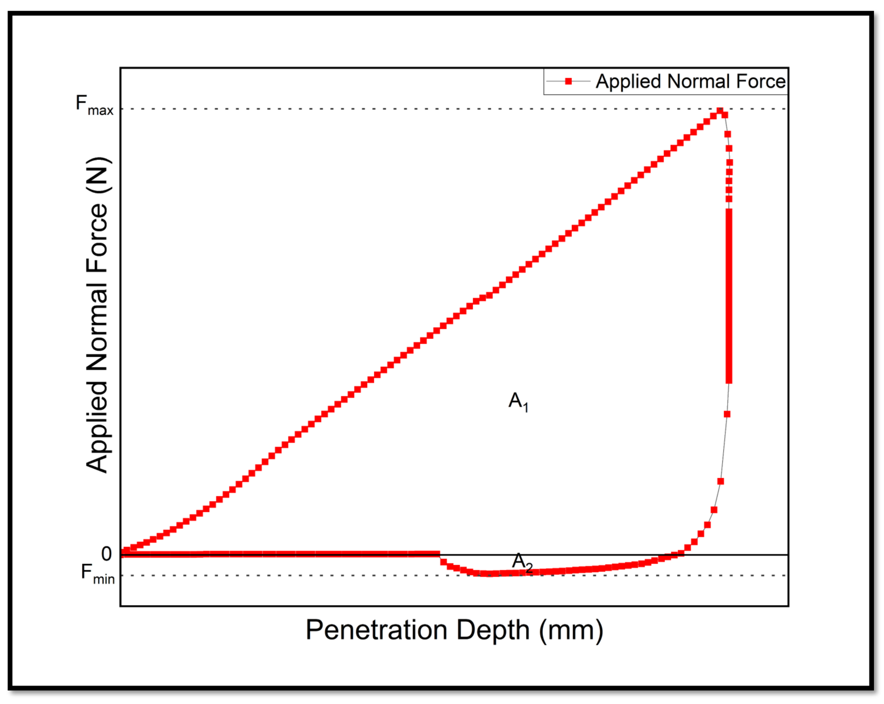


Fig. 2: TPA test Penetration.

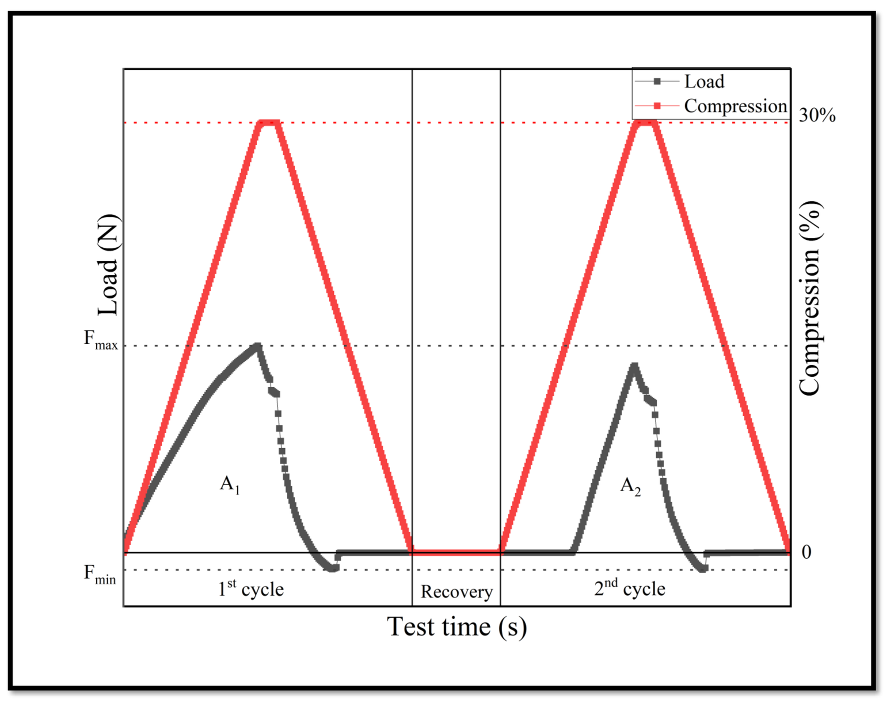


Fig. 3: TPA test results.

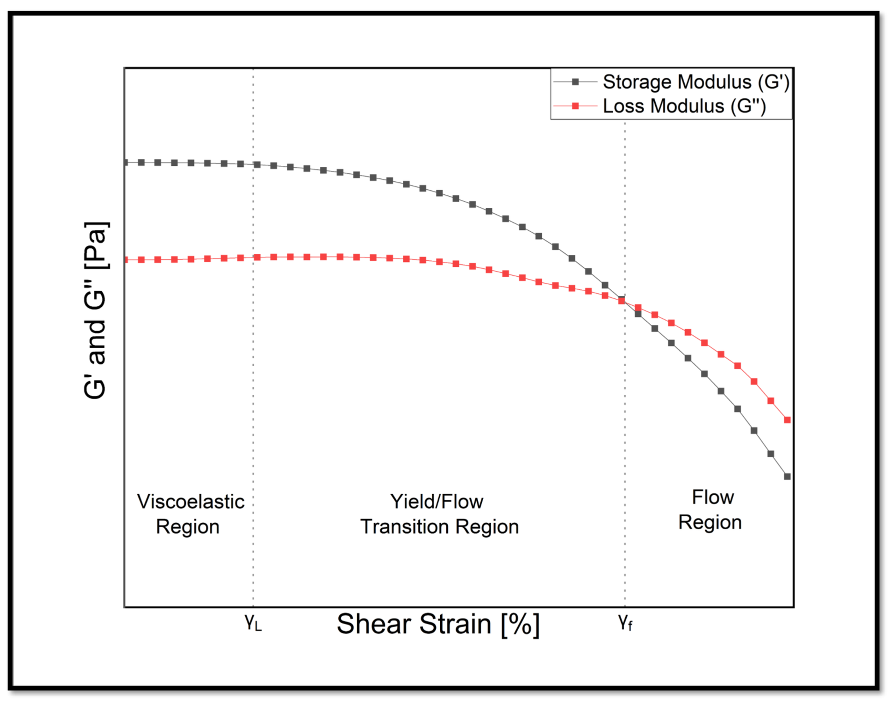


Fig. 4: Rheology test results.

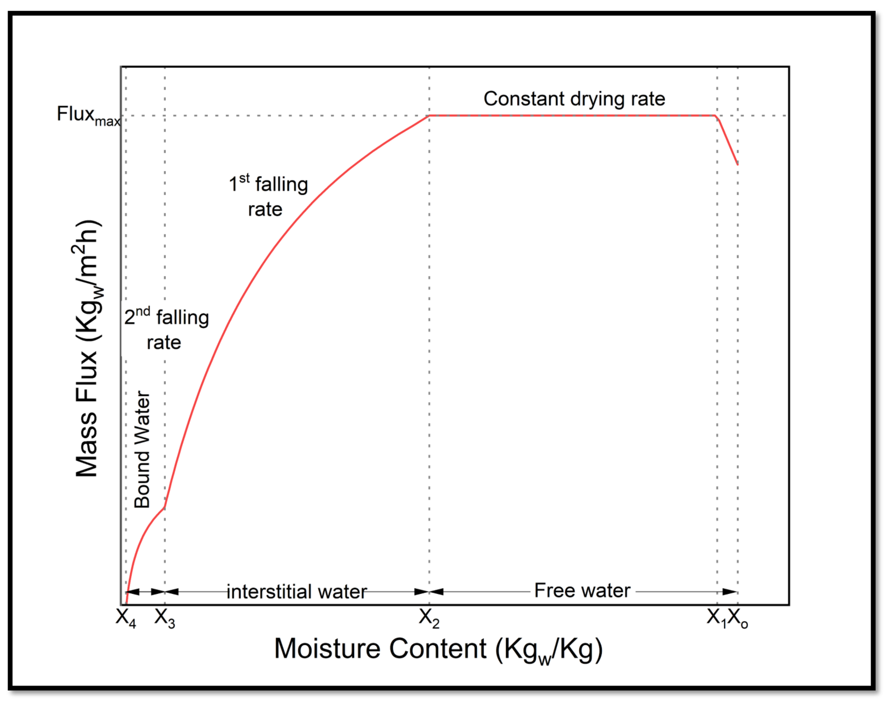


Fig. 5: Drying test results.

No significant correlations were found between specific evaporation capacity and the measured variables. However, a trend suggests that higher G' values are linked to better drying rates, aligning with existing literature. The lack of statistical significance may be due to the limited sample size, highlighting the need for further research with more samples. Testing sludge from the same origin with varying G' values in a controlled laboratory setting would help clarify G's influence on drying performance.

Conclusions

- This study analyzed the drying behavior and rheological properties of dehydrated sewage sludge from treatment plants in Liege.
- Variables like storage modulus (G'), cohesiveness, TSC, and LOI-VSC were evaluated for their impact on evaporation capacity. No significant correlations were found, but a trend suggests higher G' values improve drying rates.
- A strong link between G' and cohesiveness was observed, recommending G' as a key predictor of drying performance.
- The limited sample size may explain the lack of statistical significance, indicating a need for further research.
- Future studies should focus on larger sample sizes and controlled conditions to better understand G's role in drying efficiency.

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