Understanding Dehydrated Sludge Drying: The Role of Viscoelastic Properties

Sergio Luis PARRA-ANGARITA*, Hajer BEN HAMED, Azeddinee FANTASSE, Angélique LÉONARD
Chemical Engineering Research Unit, PEPs, University of Liège, 4000 Liège, Belgium
Presenting author email: slparraa@uliege.be

1. Abstract

Sewage sludge treatment involves multiple operations and phase changes, with convective drying being the most energy-intensive process. This study explored the impact of the textural and viscoelastic properties of dehydrated sewage sludge (DSS) on its drying behavior. Samples were conditioned with different coagulant and flocculant doses, filtered under varying pressures, and convectively dried at 90°C. Results showed a strong correlation between storage modulus (G') and total solids content (TSC). Additionally, higher G' values led to increased evaporation rates. These findings suggest that viscoelastic properties can serve as predictors of drying performance, contributing to the optimization of wastewater treatment efficiency.

Keywords: Sewage Sludge; Drying Behavior; Texture; Viscoelasticity; Adhesiveness; Cohesiveness.

2. Introduction

The management of sewage sludge (SS) poses significant challenges due to its variable composition and its globally increasing production (Eurostat 2023). SS passes through different phases along its treatment, from a liquid to a granular solid (Collivignarelli et al. 2022; Eshtiaghi et al. 2013; Seyssiecq, Ferrasse, and Roche 2003). Drying is a critical step in sludge treatment (reducing volume, increasing stability and making the SS ready to use in other processes), is energy-intensive consuming and, as indicated by existing literature, its performance is directly influenced by the initial textural and viscoelastic properties of SS, which vary with its origin, treatment conditions, among other variables (Mitchell and Beasley 2011; Santos, Ferreira, and Quina 2022). This study investigated the role of textural and viscoelastic SS properties on its drying, using samples prepared under controlled laboratory conditions.

3. Methodology

Liquid sludge samples were collected from Embourg wastewater treatment plant (Liège, Belgium) and standardized to a TSC of 20 g/L, samples were stored at 4 °C and monitored to ensure consistency. A surface response three factor experimental design was employed (coagulant dose, flocculant dose, and filtration pressure) each with three levels to create different types of dehydrated sewage sludge (DSS). The resulting DSS samples were analyzed for textural and viscoelastic properties, and finally convective dried at 90 °C using a 2 m/s air speed. Experimental methods used are summarized in Figure 1.

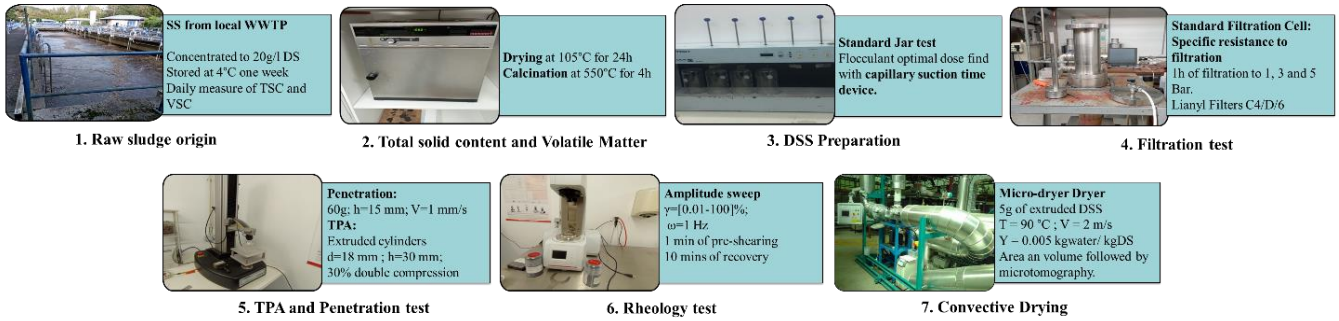

Figure 1. Summarized characterization methods.

4. Results

The behavior of different parameters was evaluated under the studied sludge dehydration conditions, revealing various correlations. Within the applied pressure ranges, no significant impact was observed on the final solid content of the dehydrated sludge. The addition of coagulant did not increase the dry mass of the obtained sludge but resulted in a more structured material. It was also found that exceeding the optimal coagulant dose (determined by capillary suction time) did not lead

to a considerable change in the sludge's dry matter content. The total volatile solids content remained constant across all tests, demonstrating its independence from the processing conditions.

In terms of relationships among the studied parameters, a direct correlation was identified between the G' and TSC. Similarly, G' and cohesiveness—evaluated through penetrometry and TPA tests—exhibited a strong linear correlation. No significant associations were found between specific evaporation capacity and the analyzed variables, except for G', adhesiveness, and cohesiveness. A clear trend emerged, indicating that higher G' values correspond to improved drying rates, as illustrated in Figure 2. Conversely, adhesiveness showed a negative correlation with drying performance. These findings align with existing literature, suggesting that sludge viscoelastic properties could serve as reliable predictors of drying behavior.

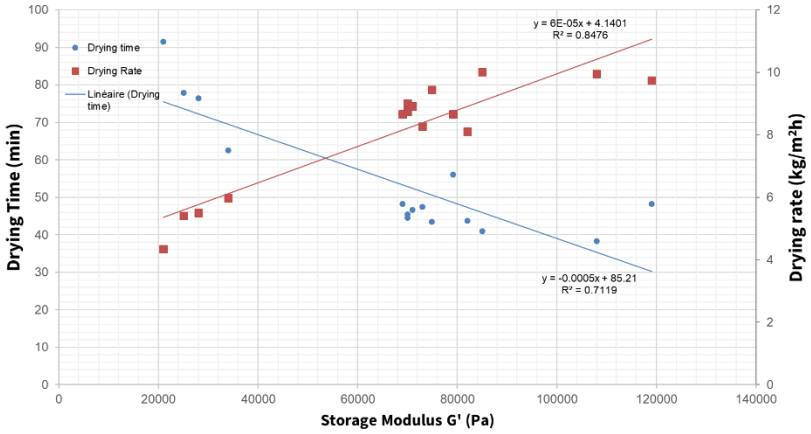

Figure 2. DSS drying performance vs Storage Modulus.

5. Conclusions

This study examined the influence of conditioning and dewatering on the rheological behavior of dehydrated sludge, aiming to assess the relationships between textural, rheological, and viscoelastic properties and drying behavior. This integrated approach provides valuable insights for optimizing DSS processing and contributes to the advancement of sustainable wastewater treatment practices.

6. References

Collivignarelli, M. C., M. Carnevale Miino, S. Bellazzi, F. M. Caccamo, A. Durante, and A. Abbà. 2022. "Review of Rheological Behaviour of Sewage Sludge and Its Importance in the Management of Wastewater Treatment Plants." *Water Practice and Technology* 17(1):483–91. doi: 10.2166/wpt.2021.098.

Eshtiaghi, Nicky, Flora Markis, Shao Dong Yap, Jean Christophe Baudez, and Paul Slatter. 2013. "Rheological Characterisation of Municipal Sludge: A Review." *Water Research* 47(15):5493–5510.

Eurostat. 2023. "Sewage Sludge Production and Disposal from Urban Wastewarer (in Dry Substance (d.S.))." *Data Browser* 1–2. Retrieved April 9, 2024 (https://ec.europa.eu/eurostat/databrowser/view/env_ww_spd/default/table?lang=en&category=env.env_wat.env_nwat).

Mitchell, G., and J. E. Beasley. 2011. *Optimisation of Sludge Treatment and Transport*. Vol. 62.

Santos, Andreia F., Abel G. M. Ferreira, and Margarida J. Quina. 2022. "Efficient Management of Sewage Sludge from Urban Wastewaters with the Addition of Inorganic Waste: Focus on Rheological Properties." *Clean Technologies* 4(3):841–53. doi: 10.3390/cleantechnol4030052.

Seyssiecq, Isabelle, Jean Henry Ferrasse, and Nicolas Roche. 2003. "State-of-the-Art: Rheological Characterisation of Wastewater Treatment Sludge." *Biochemical Engineering Journal* 16(1):41–56. doi: 10.1016/S1369-703X(03)00021-4.

7. Acknowledgements

The authors thank the FNRS (Belgian Fund for Scientific Research) for funding the PDR T015920 'Sludge dewatering and drying vs rheology