



Sewage Sludge Rheology and Impact on Plant Design

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Melbourne Water
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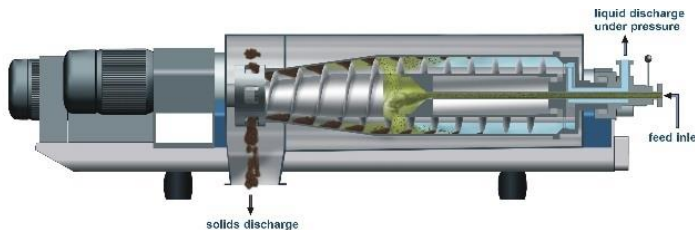
Handling of Sewage Sludge is increasingly a process limit in many WWTP facilities.



Optimising Digestion



Sludge Drying



Mechanical Dewatering



Resource Recovery

- **Understanding of sewage sludge flow properties is critical for:**
 - **Design of new equipment**
 - **Modification/upgrade of process**
 - **Optimisation of existing process**
- **Example: Recuperative thickening at ETP – increase in sludge solids content from ~2.5% to ~3.5%**
 - **What is the impact on pipe flow properties?**

$$\tau = \tau_H + k\dot{\gamma}^n$$

Smart Sludge Pumping Project

Measurement of sludge rheology at Melbourne Water and South-East Water had shown significant variability between measurements.

“Smart Sludge Pumping” project was put together as a collaboration to address this issue.

The logo for South East Water, featuring the text "South East Water" in white on a blue background, with a stylized white wave graphic to the right.

**South East
Water**



**RMIT
UNIVERSITY**



**Melbourne
Water**

Inconsistency in sludge rheology measurement

- **No standard protocol exists for measurement of sludge rheology.**
- **Errors can be introduced by comparing data measured by different methods**
- **Impact of testing protocol was not well understood**
- **Impact of seasonal variation was not well understood**



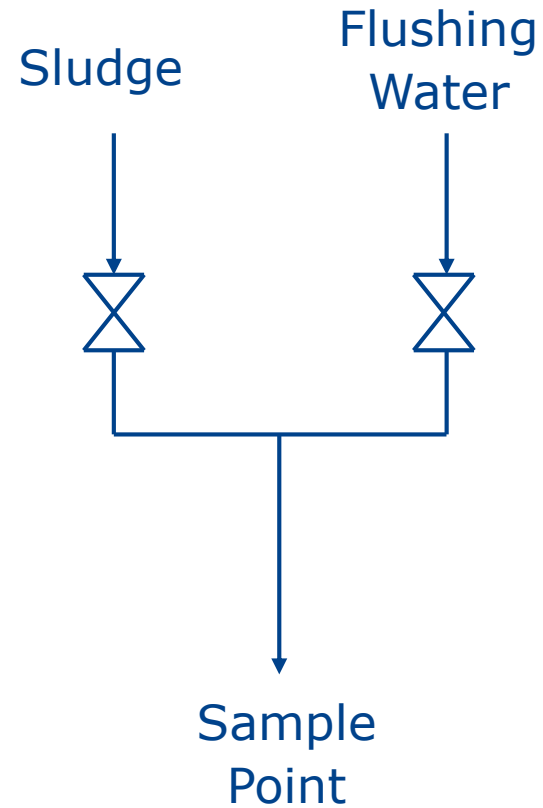
Real variations?

Artefacts of experimental method?

Limit of confidence?

Systematic development of experimental method

- **Sampling**



What mode is the process in?
Feeding or recycle?

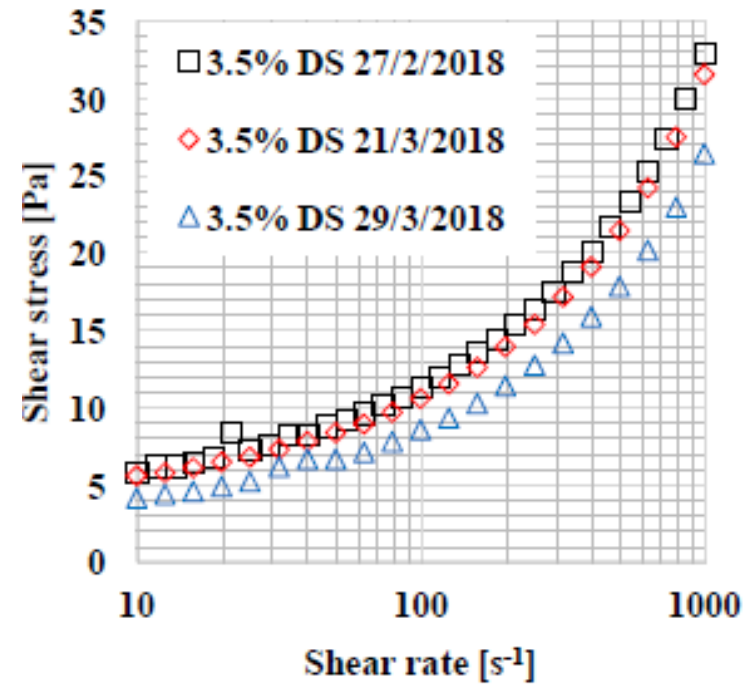
Systematic development of experimental method

- **Sampling**
- **Sludge Storage**



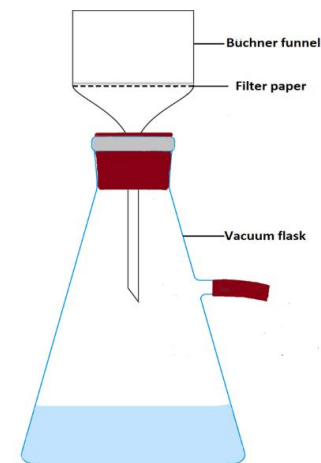
Systematic development of experimental method

- Sampling
- Sludge Storage
- **Age of Sludge**



Systematic development of experimental method

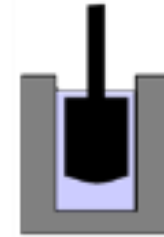
- **Sampling**
- **Sludge Storage**
- **Age of Sludge**
- **Method for thickening sample**



Systematic development of experimental method

- **Sampling**
- **Sludge Storage**
- **Age of Sludge**
- **Method for thickening sample**
- **Rheometer geometry**

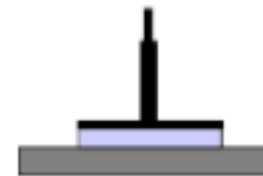
smooth cup-and-bob



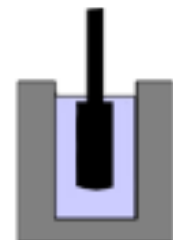
Vane-and-rough cup



Parallel plates

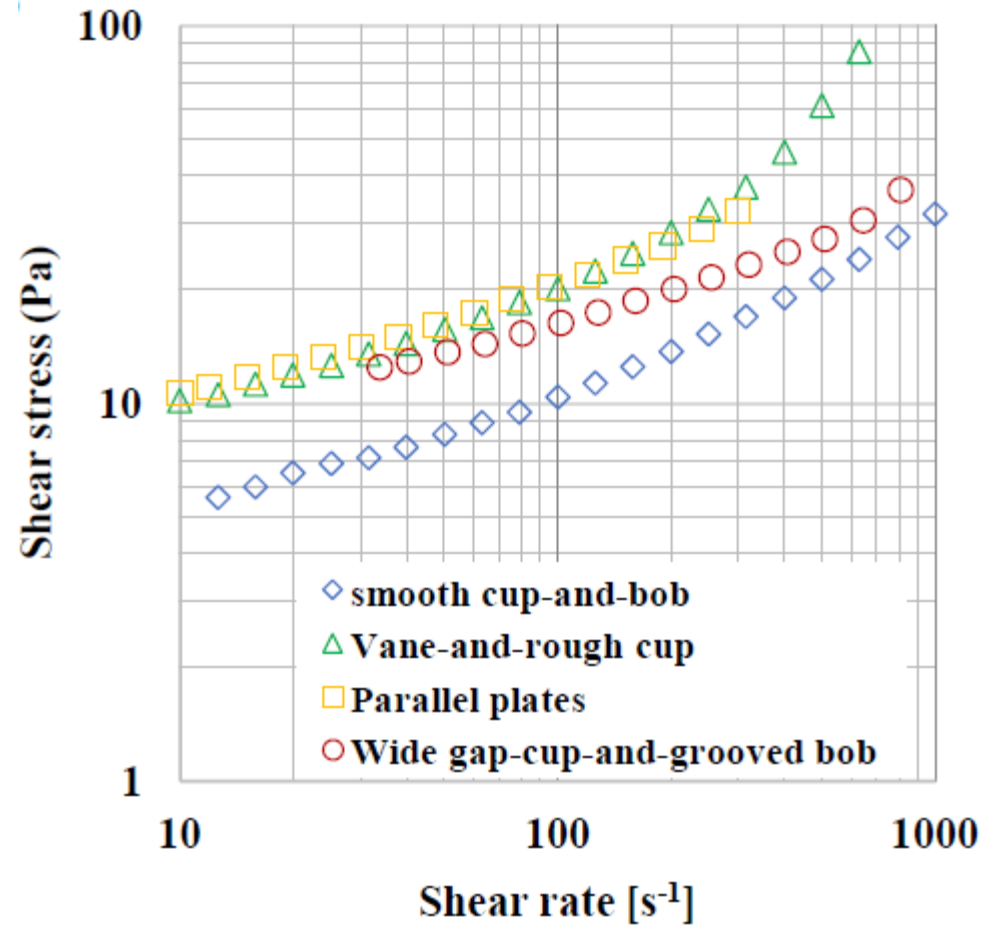


Wide gap-cup-and-grooved bob



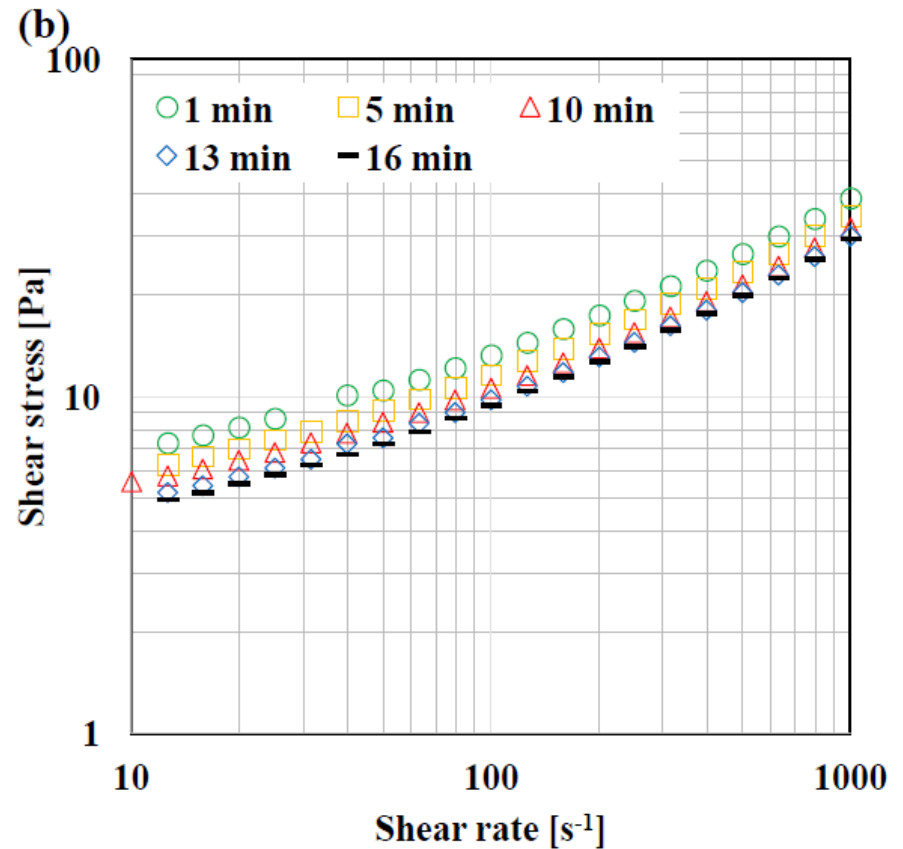
Systematic development of experimental method

- **Sampling**
- **Sludge Storage**
- **Age of Sludge**
- **Method for thickening sample**
- **Rheometer geometry**



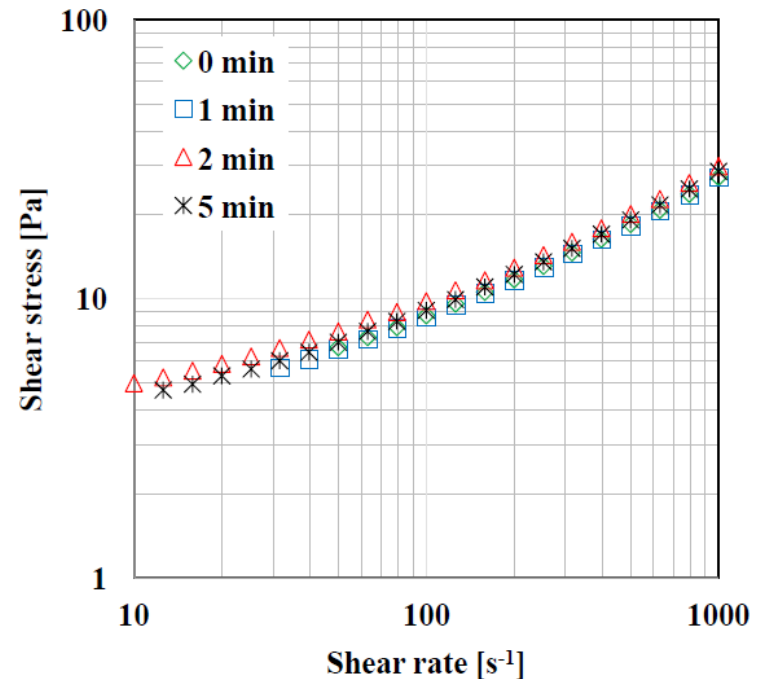
Systematic development of experimental method

- Sampling
- Sludge Storage
- Age of Sludge
- Method for thickening sample
- Rheometer geometry
- **Pre-shear**



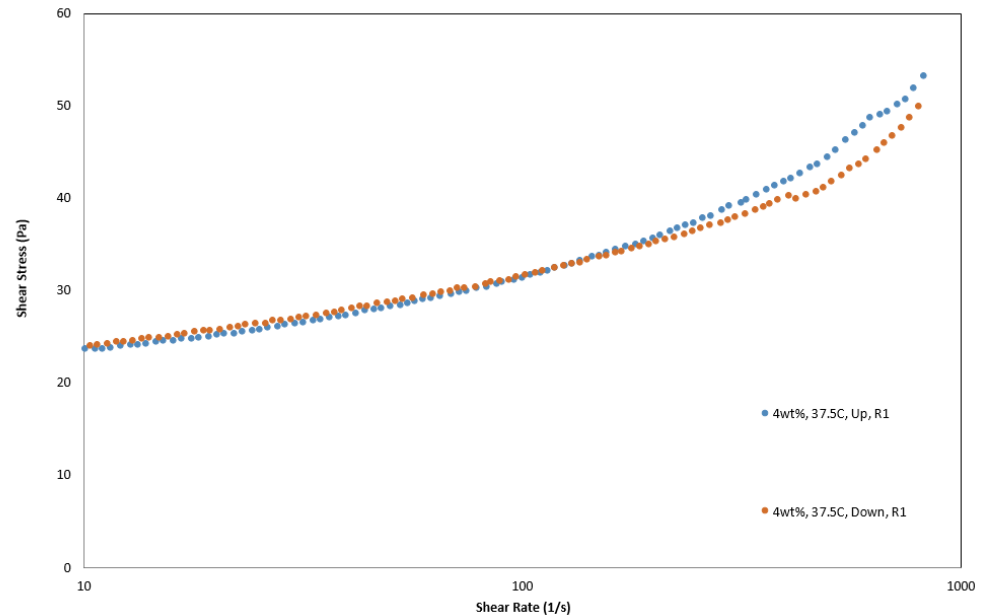
Systematic development of experimental method

- Sampling
- Sludge Storage
- Age of Sludge
- Method for thickening sample
- Rheometer geometry
- Pre-shear
- **Rest-time between pre-shear and measurement**



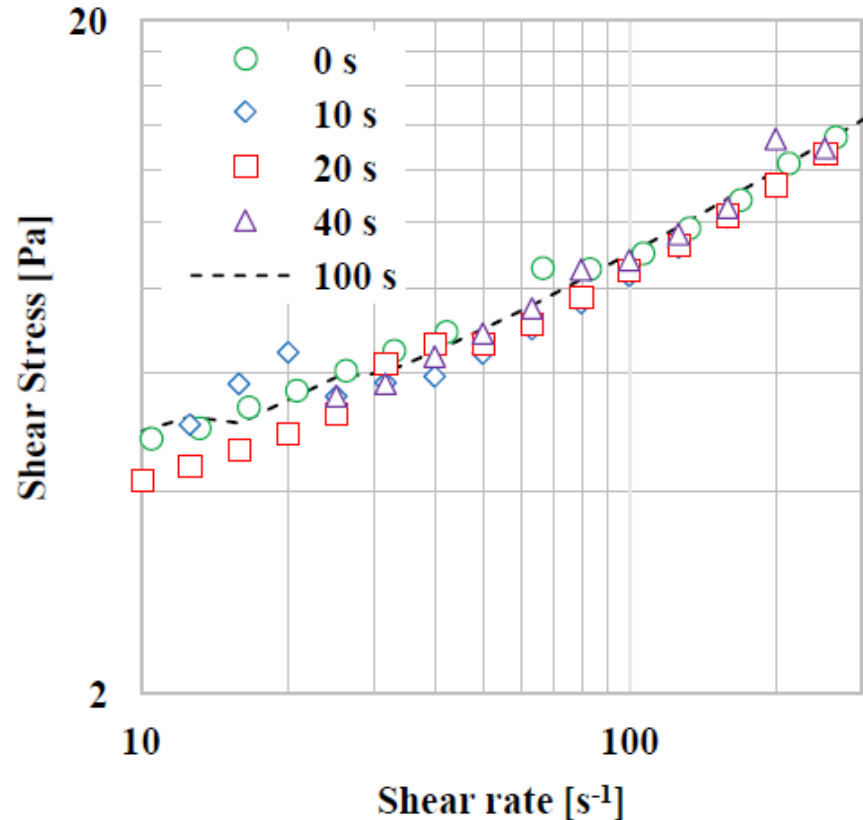
Systematic development of experimental method

- Sampling
- Sludge Storage
- Age of Sludge
- Method for thickening sample
- Rheometer geometry
- Pre-shear
- Rest-time between pre-shear and measurement
- **Direction of rate sweep**



Systematic development of experimental method

- Sampling
- Sludge Storage
- Age of Sludge
- Method for thickening sample
- Rheometer geometry
- Pre-shear
- Rest-time between pre-shear and measurement
- Direction of rate sweep
- **Equilibrium time at each shear rate**



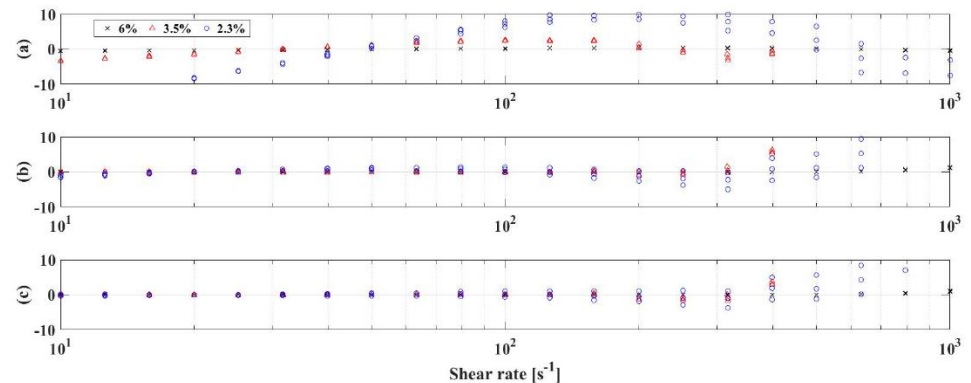
Systematic development of experimental method

- Sampling
- Sludge Storage
- Age of Sludge
- Method for thickening sample
- Rheometer geometry
- Pre-shear
- Rest-time between pre-shear and measurement
- Direction of rate sweep
- Equilibrium time at each shear rate
- **Regression method for determining model parameters**

$$\tau = \tau_B + k\dot{\gamma}$$

$$\tau = \tau_H + k\dot{\gamma}^n$$

$$\tau = \tau_H + k\dot{\gamma}^n + \alpha\dot{\gamma}$$



Role of regression analysis and variation of rheological data in calculation of pressure drop for sludge pipelines

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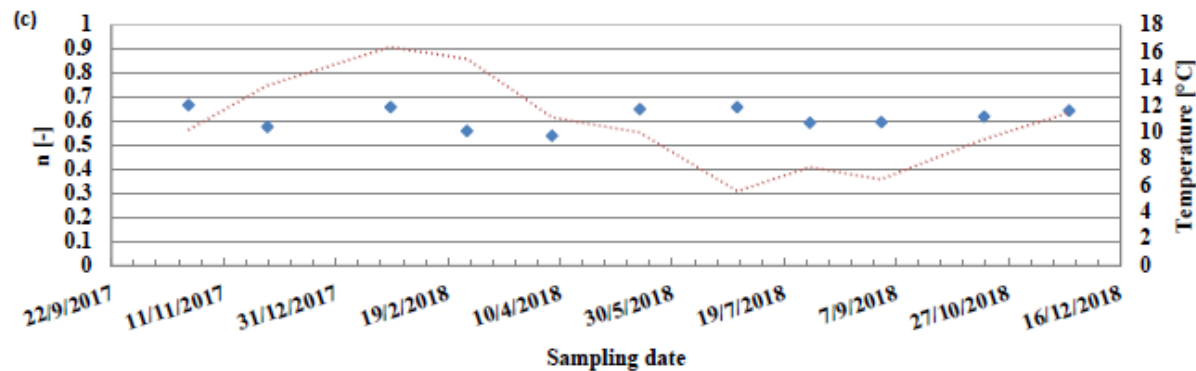
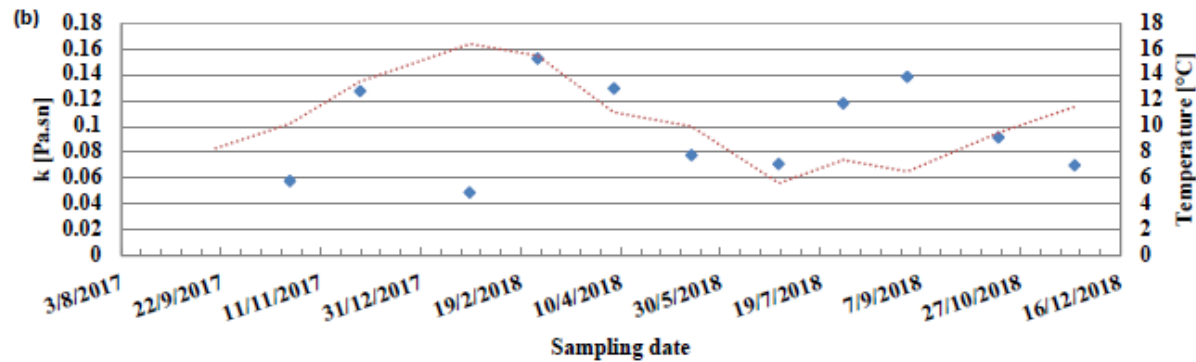
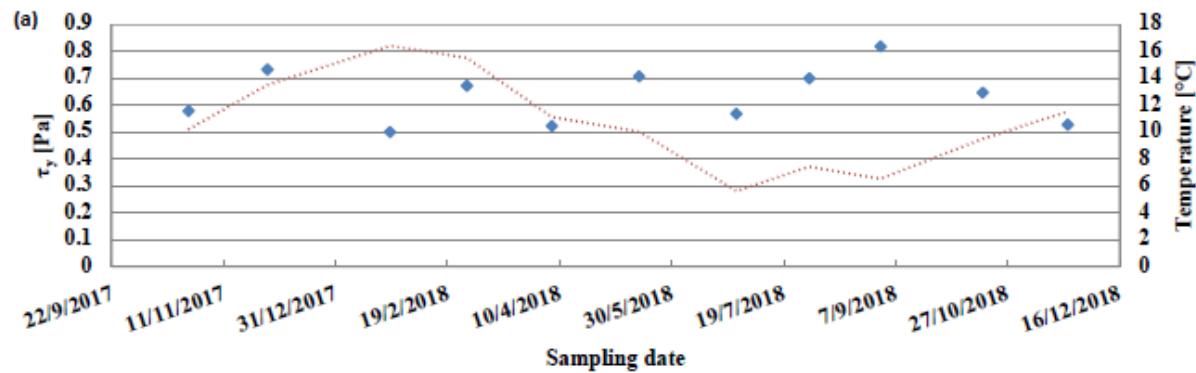
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- No standard protocol exists for measurement of sludge rheology.
- Errors can be introduced by comparing data measured by different methods
- Impact of testing protocol was not well understood
- Impact of seasonal variation was not well understood
- **A standard protocol has been developed for ETP sludge which limits artefacts introduced by experimental method.**
- **Quantified impact of testing protocol.**
- **Impact of seasonal variation on digested sludge is only minor.**

Results – Seasonal Dependence for digested sludge



Next...

We have a reliable protocol for determining Herschel-Bulkley parameters for ETP sewage sludge.

We can use this protocol and data for design of plant upgrades – e.g. ETP recuperative thickening.

Conclusions are applicable for any WWTP facility trying to upgrade its sludge handling.

Can this be validated for pipe flow?

