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TECHNICAL BRIEF

Sanitation infrastructure

Optimising sludge pipeline design

A completed Water Research Commission (WRC) study aimed to optimise pressure drop prediction to enhance sludge pipeline design.

Background

Head loss data for wastewater treatment sludge is not available in standard design tables and is therefore mostly estimated.

The more highly concentrated the sludges becomes, the more non-Newtonian the flow behaviour is and the higher the pressure drop or energy required to transport the sludge. There is still now widely accepted design correlation of sludge viscous properties as a function of solids content, causing frustration to design engineers who, in the absence of obtaining costly rheological data, have to make estimates which could compromise efficient design of pump and pipe systems.

Objectives of WRC study

The measurement of the flow behaviour of non-Newtonian fluids, such as sludge, also called rheology, is not a simple matter. Wastewater treatment sludges due to their non-Newtonian behaviour don't have a simple constant viscosity and therefore require more complex modelling.

This has been researched worldwide, but because the properties of sludges vary so much from plant to plant, there has not been much success in presenting pressure loss predictions.

Thus the objectives of this WRC-funded project were to:

- Expand the existing sludge database obtained from tube viscometer measurements to validate/improve, if neces sary, the pressure drop-flow rate predictions developed and published previously;
- To test the application of the in-house developed Ultrasound Velocity Profiling (UVP) viscometer over a range of sludge concentrations.

Methodology

The selection of suitable wastewater treatment sites in and around Cape Town where high concentration sludges are available was key to the successful completion of the project. Three sites were ultimately identified, namely Potsdam, Melkbosstrand and Wesfleur.

The portable tube viscometer was used for all the flow tests. A 4 x 3-inch centrifugal pump with a variable speed drive was used to control the flow rate.

Flow rates were measured with a magnetic flow meter and pressure drop with differential pressure transducers. Calibration tests were done with water and the measured data in both pipes was compared with the Colebrook-White equation for determining head losses in straight pipes in turbulent flow.

A test consisted of recirculating the sludge I the pipe loop and taking pressure drop and flow rate measurements in the three pipes with different diameters. From this a flow curve for each sludge concentration was constructed.

The flow curves, or rheograms, were obtained using the Rabinowitch-Mooney method. The rheograms were then used to determine the rheological parameters, namely yield stress and Bingham viscosity.

Thickened sludge was obtained from the three identified wastewater treatment plants. Sludge and process water were collected from Melkbosstrand and Wesfleur and all

tests were conducted at Potsdam since there was enough space for the experimental setup.

Additional sludges from Wellington, Paarl and Stellenbosch wastewater treatment plants were tested in a smaller tube viscometer rig for consultants, who required the data for the design of a pipeline. Permission was obtained from Drakenstein Municipality (the client) to use the data in the final report.

For the final objective, an in-house UVP pressure drop system was used to determine the rheology of three sludges from Potsdam in-line and in real time. These results were compared with those obtained from the tube viscometer.

Main results

Rheological characterisation of viscous wastewater sludges

The original scope was to rheologically characterise sludges from three wastewater treatment plants. Sludges were obtained from Potsdam, Wesfleur and Melbosstrand wastewater treatment plants with solids concentration varying between 2% and 7.8%.

The tube viscometer data of wall shear stress versus shear rate was produced for each sludge and the Bingham yield stress and viscosity were derived.

In addition, four sludges from Wellington, Paarl and Stellenbosch wastewater treatment plants were tested. The concentration of these sludges was lower, ranging from 3% to 4.7%.

Testing of the UVP-DP system

During May 2014 the portable tube viscometer was taken to Potsdam and the UVP-PD system with a new non-invasive sensor unit was used to test three secondary sludges from the filter belt press. The rheology obtained from the UVP-PD system was compared with that obtained from the tube viscometer and for all three sludges the results were excellent.

Conclusions

The rheological properties of 21 sludges from 21 wastewater treatment plants in the Western Cape were tested ranging in solids concentration between 2% and 7.8%. Most tests were done in tube viscometers which are really small pipelines. The sludges tested comprised of primary and secondary as well as filter bed sludge.

The rheological properties of these sludges range widely, with Bingham yield stresses varying between 1 Pa and 34 Pa and the Bingham viscosity from 0.005 to 0.079 Pa.s.

The effect on pressure drop predictions is significant. The data was combined with that previously published and new predictions for both Bingham yield stress and Bingham viscosity were compiled. The data can only be predicted in a range of around 60% certainty.

It was envisaged that the results would be closer grouped because of the act that all the tests were done in the same tube viscometer. This was, however, not the case and again shows how complex sewage sludges are.

The rheological parameters, such as Bingham yield stress and viscosity cannot only be linked to concentration. There are many other factors that influence the behaviour of these sludges, such as the process, flocculation pre-shear history etc.

This again confirms the fact that when designing pipelines to transport viscous sludges, great care should be taken when estimating the rheology of such sludges. This will become more and more important as plants are trying to increase concentrations in the processes and the viscous properties increase. It will take further work before more accurate predictions will become available due to the complex nature of sewage sludge.

New UVP-transducer, which can measure non-invasively through a stainless steel pipe, was tested with sludges for the first time. The UVP-PD system was successfully tested with three concentrations secondary sludge, and the results were compared with the tube viscometer. The fact that one can now determine the rheology of sludges in-line and in real-time, has huge potential for process control in the wastewater treatment industry.

Further reading:

To order the report, *Pressure drop prediction for efficient sludge pipeline design* (**Report No. 2216/1/14**) contact Publications at Tel: (012) 330-0340, Email: orders@wrc.org.za or Visit: www.wrc.org.za to download a free copy.