Form No
RES FOR 13

Water Research Australia

Form: Project initiation – TITLE

The purpose of this document is to describe a research idea to WaterRA, initiating a possible project. The information will be used to communicate the idea with WaterRA members and the water industry to garner support, allowing the idea to progress to the next stage which is usually a workshop.
Once complete, submit to info@waterra.com.au.

Title
Smart sludge pumping: A design toolkit for the next generation of high-intensity sludge transport

Focus Area

1. *Climate Change*
2. *Sustainable management of Environmental impacts*
3. *Operational (Service) Risk Reduction and productivity*
4. *Resource recovery and re-use*

What is the problem?
Pressure is intensifying to increase the capacity of existing water treatment plants by moving to tertiary processing of higher concentration sewerage sludges. However, the design and optimization of next-generation pipeline systems is currently limited by the lack of accurate pipe flow theory for these materials. This issue hinders both intensification of wastewater treatment processes and minimization of pumping energy.

Background
Population growth and climate change are strong drivers for the intensification of wastewater treatment plants. For tertiary treatment processes, this inevitably means a transition to processing of more concentrated sludges. However, this transition represents a serious challenge, as the rheology of these sludges then changes from slightly non-Newtonian (water-like) to strongly visco-elasto-plastic (gloopy and gooey). Such rheological change demands new approaches to the design and operation of sludge transportation systems that cannot be addressed naively by simply increasing pumping power or pipe diameter.

For example, with increasing concentration, pipe flows can suddenly change from turbulent to laminar flow. The associated transition velocity then informs the ideal operating point (termed best efficiency point, BEP) for a pumping system, and deviation from the BEP can result in excess power consumption, excess shear stress and temperature rise in the sludge. To design pipeline systems for concentrated sludges, tools are required to quantitatively predict the BEP from sludge rheology and pipeline design parameters. Whilst these tools exist for dilute mineral slurries [1], they are not appropriate for concentrated wastewater sludges [2] due to fundamental differences in rheology [3,4].

The complexity of these flows also means it is not possible to accurately predict the BEP in industrial-scale flows from laboratory-scale rheometry. Instead, what is required is experimental data from pipe-loop studies at scales similar to those of industrial processes. In combination with Computational Fluid Dynamics (CFD) and recent theories [6] for wastewater sludge pipe flow, such data provides the means to develop *accurate predictions of BEP and operating data (pressure drop etc) over a broad range of operating conditions.*

What is the desired outcome?

This project will address this challenge by developing a validated, quantitative toolkit for the prediction of the flow behaviour of concentrated sewage sludges in process equipment. This toolkit shall be achieved through a combination of lab-based rheological characterisation, on-site pipe-loop testing and CFD, leading to validated, predictive computational models of the flow behaviour of concentrated sludges.

Results generated by this toolkit shall be packaged in the form of an easy-to-use GUI-based software app for use by industry to design process flow loops, including valves, bends, contractions and expansions and pumping infrastructure. Specifically this app will facilitate prediction of the pressure drop over a given pipe loop for a given sludge at a specific solids concentration, with the opportunity to develop predictive models based upon rheological measurements of project sponsor's particular sludges.

Why would this idea be of benefit to the water industry?

This project will facilitate the next generation of high-intensity wastewater treatment technologies by developing a toolkit for design of sludge transport systems. This will enable wastewater treatment plants to increase the treatment capacity and to reduce excessive energy consumption in sludge transportation systems. Also, the transformation from low-solid to high-solid reduces the environmental footprints of wastewater treatment processes helping them to adapt to new climate change protocols. Biological treatment processes operate more efficiently at high-solid concentration which in turn increases biogas production and reduces the greenhouse gas emission from landfilled sludge.

How would the work/project be delivered?

The aim is to submit as an ARC –Linkage scheme. Project team as follows:

RMIT:

- *A./Prof. Nicky Eshtiaghi, RMIT University, Chemical and Environmental Engineering*
- *Dr Daniel Lester, RMIT University, Chemical and Environmental Engineering*
- *Dr Ehsan Farno (research fellow on the project), RMIT University,*

External consultants:

- *Prof Murray Rudman, Monash University, Dept. of Mechanical and Aerospace Engineering*
- *Prof. Paul Slatter, Sheridan College, Faculty of Mathematics, Physical Sciences and Life Sciences*

Researches wish to maintain confidentiality of idea and should not be made publicly available via Water RA website.

Is there wider support for the project idea?

Currently Melbourne Water and RMIT University are interested parties to support this idea.

List any relevant references

1. Sanks, R.L., D.G. Hanna, and G.M. Jones, *Pumping Station for Sewage, Sludge, and Air*, in *Pumping Station for Sewage, Sludge, and Air in Water Storage, Transportation and Distribution*. 2009, in Encyclopedia of Life Support Systems (EOLSS), Developed under the Auspices of the UNESCO, Eolss Publishers, Paris, France, [http://www.eolss.net]. p. 369-399.

2. Anderson, C.N., et al., *Chapter 19 - System Design for Sludge Pumping*, in *Pumping Station Design (Third Edition)*. 2008, Butterworth-Heinemann: Burlington. p. 19.1-19.29.
3. Farno, E., et al., *The viscoelastic characterisation of thermally-treated waste activated sludge.* Chemical Engineering Journal, 2016. **304**: p. 362-368.
4. Eshtiaghi, N., et al., *Rheological characterisation of municipal sludge: A review.* Water Research, 2013. **47**(15): p. 5493-5510.
5. Slatter, P.T., *Transitional and turbulent flow of non-Newtonian slurries in pipes*. 1995, University of Cape Town.
6. Slatter, P., *Pipe flow of highly concentrated sludge.* Journal of Environmental Science and Health. Part A, Toxic/Hazardous Substances & Environmental Engineering, 2008. **43**(13): p. 1516-20.
7. Slatter, P., *Pipeline transport of thickened sludges.* Water 21, 2003: p. 56-57.
8. Kabwe, A.M., V.G. Fester, and P.T. Slatter, *Prediction of non-Newtonian head losses through diaphragm valves at different opening positions.* Chemical Engineering Research and Design, 2010. **88**(8): p. 959-970.
9. Barnes, H.A., *Thixotropy—a review.* Journal of Non-Newtonian fluid mechanics, 1997. **70**(1-2): p. 1-33.
10. Jay, P., A. Magnin, and J.M. Piau, *Viscoplastic fluid flow through a sudden axisymmetric expansion.* AIChE Journal, 2001. **47**(10): p. 2155-2166.
11. Rudman, M. and H.M. Blackburn. *Turbulent Pipe Flow of Non-Newtonian Fluids*. 2003. Berlin, Heidelberg: Springer Berlin Heidelberg.
12. Metzner, A. and J. Reed, *Flow of non-newtonian fluids—correlation of the laminar, transition, and turbulent-flow regions.* Aiche journal, 1955. **1**(4): p. 434-440.
13. Slatter, P. and E. Wasp, *Laminar/turbulent transition in large pipes.* Zeszyty Naukowe Akademii Rolniczej we Wroclawiu. Konferencje (Poland), 2000: p. 1-6.