A feasibility study of in-line rheological characterisation of a wastewater sludge using ultrasound technology

R Kotzé[1]*, R Haldenwang[1], V Fester[1] and W Rössle[2]

[1]*Flow Process & Rheology Centre (FPRC), Cape Peninsula University of Technology, PO Box 652, Cape Town 8000, South Africa*

[2] *Wastewater Branch, Water and Sanitation Department, City of Cape Town, 38 Wale Street, Cape Town, South Africa*

ABSTRACT

The rheological characteristics of sludge affect transportation, treatment and the disposal processes involved in sludge system design and management operations such as dewatering, including flocculation and filtration. The concentration of solid matter in the sludge has an effect on rheological parameters such as yield stress and viscosity. These rheological properties of sludge are almost exclusively obtained today using commercially available instruments, such as conventional rotational rheometers or tube (capillary) viscometers. Since these methods are time-consuming and unsuitable for real-time process monitoring, the ultrasonic velocity profiling coupled with pressure drop (UVP+PD) methodology becomes very attractive for in-line flow behaviour monitoring for quality control and process optimisation. The main objective of this research work was to evaluate the UVP+PD technique in a concentrated sludge as found in a wastewater treatment plant. A portable pump test rig with tube viscometer fitted with a UVP+PD system was used to determine the rheological parameters. Conventional UVP installation techniques were tested as well as a new delay line UVP transducer. The results obtained from different installation techniques and transducers are compared. Finally, rheological parameters obtained using UVP+PD compared within 15% of that obtained using the tube viscometer. The results showed that UVP+PD is a feasible and promising technique for in-line real time flow visualisation and rheological characterisation for treated wastewater sludge which, when used as in-line process control, could lead to significant savings in chemicals and will optimise processes producing drier sludges and filter cakes.

Keywords: Ultrasonic velocity profiling, UVP+PD methodology, sludge rheology, non-Newtonian, tube viscometry

NOTATION

A	total area, (m^2)
D	pipe inner diameter, (m)
K	fluid consistency index, ($Pa{\cdot}s^n$)
L	unit length, (m)
n	flow behaviour index, dimensionless
Q	volumetric flow rate, (ℓ/s)
r	radial position, (m)
R	pipe radius, (m)
v	velocity, (m/s)
ΔP	pressure drop, (Pa)
R_{e2}	Reynolds number, dimensionless
R_{plug}	Plug radius, (m)
$\bar{V}$	bulk velocity, (m/s)

Greek letters

τ	shear stress, (Pa)
τ_y	yield stress, (Pa)
$\dot{\gamma}$	shear rate, (ℓ/s)

INTRODUCTION

When sludge suspensions increase in solids concentration they become non-Newtonian in behaviour. Rheology is a tool used for characterising the hydrodynamics of such materials and has been successfully applied in the wastewater treatment industry, from optimising process parameters of plants to excess sludge treatment processes (Seyssiecq et al., 2003). Seyssiecq et al. (2003) give an extensive overview of research conducted on the rheological characterisation of wastewater treatment sludges. Different models used for characterisation of sludges, such as power law, Bingham, Herchel-Bulkley, Casson, etc., are listed and rheological properties are linked by various authors to physico-chemical parameters of suspensions or to operating parameters such as mixing.

In dewatering operations the main objective is to produce the driest sludge at the optimum chemical conditions, which is most often a water-soluble organic polyelectrolyte usually termed a polymer. The flow properties and variability, mixing intensity, and time allowed for mixing all effect the optimal dosing of the flocculation process (Dental et al., 2000).

Örmeci (2007) links the optimal sludge dewatering operation, in terms of polymer dose and mixing intensity, to the rheological properties of wastewater sludge, and a reduction of 50% polymer consumption was achieved with the off-line methods used for both conditioned and unconditioned sludges. Wang and Dentel (2011) investigated the effect of polymer doses and mixing intensity on the rheology of anaerobic digested sludge. The effect of addition of polymers could be distinguished from the rheograms. According to Abu-Orf and Dentel (1999), whose investigation attempted linking the rheological characteristics to the control of sludges conditioned with polymers, this is a complex process where mixing parameters have a substantial effect. The previous authors all used off-line rheometers to establish the rheological properties of the sludges. The early work of Lotito et al. (1997), who tested the

* To whom all correspondence should be addressed.
☎ +27 83 299 2345; reinhardtkotze@yahoo.com
Received 2 September 2013; accepted in revised form 4 September 2014.

http://dx.doi.org/10.4314/wsa.v40i4.1
Available on website http://www.wrc.org.za
ISSN 0378-4738 (Print) = Water SA Vol. 40 No. 4 October 2014
ISSN 1816-7950 (On-line) = Water SA Vol. 40 No. 4 October 2014