Real-time Rheology for Preventing Gearbox Damage in Clarifiers Processing Bluegreen Algal Sludge

The Problem

Blue-green algae (BGA) outbreaks are becoming more frequent in many parts of the world, and global climate change is one of the factors contributing to this trend. Warmer temperatures, changes in precipitation patterns, and altered nutrient cycles associated with climate change can all favour the growth of blue-green algae in bodies of water. The increasing frequency and duration of BGA outbreaks is making it challenging for water authorities to manage available resources and guarantee safe potable water to communities. One such challenge arises in ensuring that the rake torque clarifiers perform in an optimal manner in processing water polluted with BGA. Rake torque clarifiers are often used in water treatment plants because they are efficient and effective at removing solids from liquid. They are also relatively low-maintenance and easy to operate. Typically, untreated water enters the plant from a source body (river, lake etc) and is coagulated with aluminium sulphate, hydrated lime and some polymers. Activated carbon is also added for toxin, contaminant, taste and odour removal. The coagulated water is mixed with flocculants in the hood of the clarifier before settling out as solids (sludge). Sludge is removed by a rake and the clarified water is taken via launders to the filters.

The procedures become more complicated in the presence of BGA, which produces exopolysaccharide (EPS), which are long chain polymeric substance, during the growth phase. The EPS creates a multi-scale volume spanning network within the sludge (D.Q. Yuan, 2014; Moreno J, 2000). The presence of the networked microstructure significantly increases the viscosity of the sludge (BGA-sludge) that settles to the bottom of the clarifier, rendering it almost "gel-like". The high viscosity, "gel-like" nature of the BGA sludge resists the movement of the rake arms in the clarifier so much so that if remedial action is not taken in a timely manner, the resistance over-torques the rake drives and causes gear-box damage rendering the clarifiers unusable. It takes a day and 4 staff to drain the clarifier and manually remove the sludge. Such disruption to operations is not ideal during peak demand periods. The procedures that reduce the resistance offered by the sludge are well-known. However, an early warning of the impending "high viscosity event" is necessary to implement these procedures in a timely manner. Therefore, a suitable rheological sensor is needed for providing this feedback

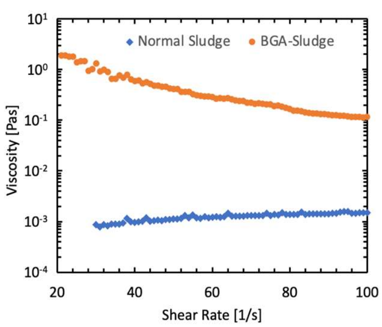
The Opportunity

The OLR M2000 can monitor for the changes in flow properties resulting from the presence of blue green algae (BGA) in source water, in-situ in a continuous and automated manner, and can help in preventing critical infrastructure from failing when the BGA outbreak occurs.

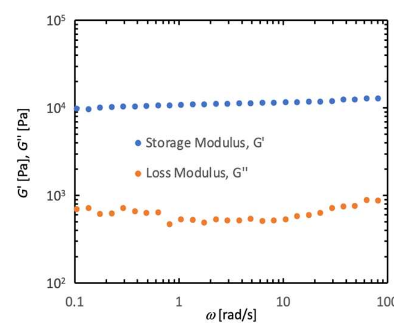
Validation

Figure 1 (a) provides a comparison of the viscosities of the Normal Sludge and BGA Sludge over a range of shear rates. It can be observed from Figure 1 (a) that while the viscosity of the normal sludge remains almost constant at all the shear rates used, the viscosity of the BGA-sludge decreases rapidly with increasing shear rates. Also, it should be noted that the viscosity of the BGA-Sludge is about 2 to 3 orders of magnitude higher than the Normal Sludge, while the latter is only marginally more viscous than water. In Figure 1(b), the linear viscoelastic measurements of the BGA-Sludge are shown over three decades of frequency. It can be observed from Figure 1(b) that the BGA-Sludge shows a significant "solid-like", elastic behaviour (G') which is larger at all measured frequencies than the "liquid-like", viscous behaviour (G''), by almost an order of magnitude. Incidentally the elastic response is not found in the Normal Sludge which is a low viscosity liquid with no elasticity.

These measurements indicate that the presence of the elastic response distinguishes the two types of sludge discussed here. Therefore, a sensor is needed that can distinguish the sludges based on this property.



(a) Steady shear flow characterisation of samples of Normal Sludge and BGA-Sludge showing that the qualitative and quantitative differences between the two materials



(b) Linear viscoelastic response of BGA-Sludge over a three decades of frequency.

Figure 1

We have previously shown that in-situ measurements of the viscoelastic properties of complex liquids are possible using small amplitude oscillatory squeeze flow (OSF) principles (D Konigsberg, 2013). The accuracy of these automated in-line measurements rival laboratory measurements, like the ones shown above in Figure 1(b), under controlled conditions. These measurements have also been used to index the yield stress of flowing material (F Sofrà, 2021). The Online Rheometer Series of instruments that implement these OSF based techniques are well suited for measurements needed for the current application. A version of this instrument OnLine Rheometer M2000 was therefore selected to provide the needed feedback.

In Figure 2 (a) we show the installation location with the clarifier of interest marked. The OLR is placed in a line leading the sludge from the clarifier to the down-stream processes. Figures 2(b) and 2(c) show OLR installation in further detail. Figure 2(d) shows a screenshot where a typical response is shown. The spikes in the data arise from the periodic opening and closing of the isolation valve that route the sludge through the OLR flow cell. In order to include the combined effect of the storage and the loss modulus of the material, the complex viscosity $|\eta^*| = \sqrt{(G'/\omega)^2 + (G''/\omega)^2}$ was monitored at three values of frequency. The OLR was set up such that when Normal Sludge is encountered, the value of $|\eta^*|$remains close to zero. The installation was tested by routing sludge from the filter backwash through the OLR. As expected, the OLR readings increased significantly when concentrated sludge was encountered. These cycles are marked as events in the Figure(2d) while normal conditions manifest with $|\eta^*|$values close to zero. Figure 2(e) shows the relative magnitudes of the storage and the loss modulus. As is observed the *G*' values (red markers) remains below the *G*'' (green markers) indicating that the material is distinct from the BGA-Sludge. The $|\eta^*|$ values (magenta markers), however, decrease with increasing frequencies as is common for complex liquids like flocculated sludge.

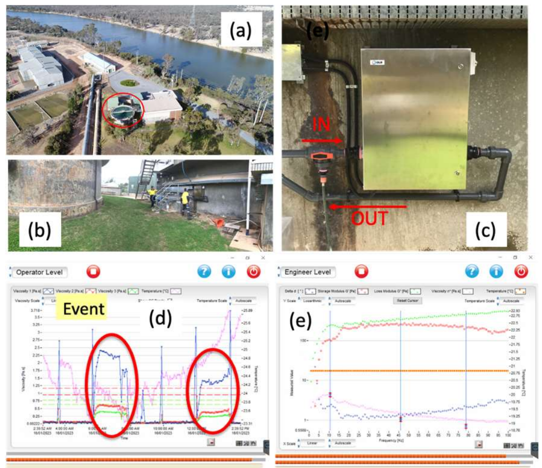


Figure 2. (a) Location of installation showing the river and the clarifier. **(b) – (c)** Location of the OLR M2000 with inflow and outflow indicated. **(d)** Variation of the $|\eta^*|$ values at three different frequencies indicated by the three coloured lines (blue, red, green). Spikes correspond to opening/closing of isolation valves. Backflush sludge events marked by red circles. Magenta line measures the flow cell temperature. **(e)** Measured rheology of back wash sludge routed through the flow-cell. Storage modulus (red markers), Loss modulus (Green markers), G''/G' (blue markers) and complex viscosity (magenta markers) are shown, along with the temperature (gold markers). The loss modulus is higher than the storage modulus indicates the rheological difference between backwash sludge and BGA-Sludge shown in Figure 1(b).

Potential Impact

Real -time monitoring of clarifier sludge rheology has been demonstrated above using the OnLine Rheometer M2000 unit supplied by Rheology Solutions. It was shown that the unit could monitor for and identify changes in sludge rheology in-situ without need for manual sampling and laboratory testing. This information can be used to provide early warning of changes in the sludge rheology during BGA outbreaks and measures can be taken to prevent damage to clarifiers and downstream process units

Bibliography

D Konigsberg et al, 2013 — ***Online process rheometry using oscillatory squeeze flow.*** Applied Rheology, Volume 23, p. 35688..

D.Q. Yuan et al, 2014 — ***Contribution of stratified extracellular polymeric substances to the gel-like and fractal structures of activated sludge***. Water Research, pp. Pages 56-65

F Sofrà et al, 2021 — **Online yield stress measurement for real-time process control. s.l.**, Australian Centre for Geomechanics, pp. 119-130

Moreno J et al, 2000 — ***Chemical and rheological properties of an extracellular polysaccharide produced by the cyanobacterium Anabaena sp***. ATCC 33047.. *Biotechnol Bioeng.,* 67(3), pp. 283-290

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