Water Research 134 (2018) 86–91

Contents lists available at ScienceDirect

Water Research

journal homepage: www.elsevier.com/locate/watres

Influence of gas injection on viscous and viscoelastic properties of Xanthan gum

Veena Bobade, Madalyn Cheetham, Jamal Hashim, Nicky Eshtiaghi*

RMIT University, School of Civil, Environmental and Chemical Engineering, 124 La Trobe St, Melbourne, Vic 3000, Australia

ARTICLE INFO

Article history:
Received 11 September 2017
Received in revised form
26 January 2018
Accepted 29 January 2018
Available online 3 February 2018

Keywords:
Gas injection
Xanthan gum
Viscoelastic properties
Flow behaviour
Herschel-Bulkley model

ABSTRACT

Xanthan gum is widely used as a model fluid for sludge to mimic the rheological behaviour under various conditions including impact of gas injection in sludge. However, there is no study to show the influence of gas injection on rheological properties of xanthan gum specifically at the concentrations at which it is used as a model fluid for sludge with solids concentration above 2%.

In this paper, the rheological properties of aqueous xanthan gum solutions at different concentrations were measured over a range of gas injection flow rates. The effect of gas injection on both the flow and viscoelastic behaviour of Xanthan gum (using two different methods - a creep test and a time sweep test) was evaluated. The viscosity curve of different solid concentrations of digested sludge and waste activated sludge were compared with different solid concentrations of Xanthan gum and the results showed that Xanthan gum can mimic the flow behaviour of sludge in flow regime.

The results in linear viscoelastic regime showed that increasing gas flow rate increases storage modulus (G'), indicating an increase in the intermolecular associations within the material structure leading to an increase in material strength and solid behaviour. Similarly, in creep test an increase in the gas flow rate decreased strain%, signifying that the material has become more resistant to flow. Both observed behaviour is opposite to what occurs in sludge under similar conditions.

The results of both the creep test and the time sweep test indicated that choosing Xanthan gum aqueous solution as a transparent model fluid for sludge in viscoelastic regime under similar conditions involving gas injection in a concentration range studied is not feasible. However Xanthan gum can be used as a model material for sludge in flow regime; because it shows a similar behaviour to sludge.

1. Introduction

Xanthan gum is a naturally occurring polysaccharide, produced by fermenting glucose with the bacteria Xanthomonas campestris, with a backbone of β-(1,4)τ-D-glucose (Kennedy et al., 2015). The primary structure of the material is shown in Fig. 1. The structure consists of repetitive pentasaccharide units formed with two glucose units, two mannose units, and one glucuronic acid unit, with the molar ratio being 2.8:2.0:2.0 (Garcı;a-Ochoa et al., 2000).

When mixed in aqueous solution, xanthan gum exists in an ordered helical conformation, either single or double stranded. The molecular structure of the material actively contributes to its rheological properties, with the structuration pattern of the solutions being related to hydrogen-bridging between lateral chains and binding networks formed by molecular entanglement (Laneuville et al., 2013). Additionally, Fig. 2 shows that dehydration can affect the conformation of molecules, in which the intra and intermolecular ester bonds cause crosslinking with an extended polymer structure (Bueno et al., 2013). Xanthan solutions are known to have a non-Newtonian rheology, with a shear-thinning behaviour under increasing shear rate. It has been widely reported that an initial yield stress is exhibited by xanthan solutions must be overcome for the solution to start flowing (Garcı;a-Ochoa et al., 2000; Marcotte et al., 2001; Song et al., 2006). Only when the magnitude of stress reaches above the yield stress, the structure is broken down, orienting the polymer chains to align with flow stream. The yield stress is attributed to the molecular structure of the material and a large number of hydrogen bonds which exist in the solution (Bradshaw et al., 1983).

Xanthan gum is widely used as a model fluid for sludge to mimic sludge shear thinning behaviour (Garcı;a-Ochoa et al., 2000; Kennedy et al., 2015; Saha and Bhattacharya, 2010). Sludge is the

* Corresponding author.
E-mail address: Nicky.eshtiaghi@rmit.edu.au (N. Eshtiaghi).

https://doi.org/10.1016/j.watres.2018.01.071
0043-1354/

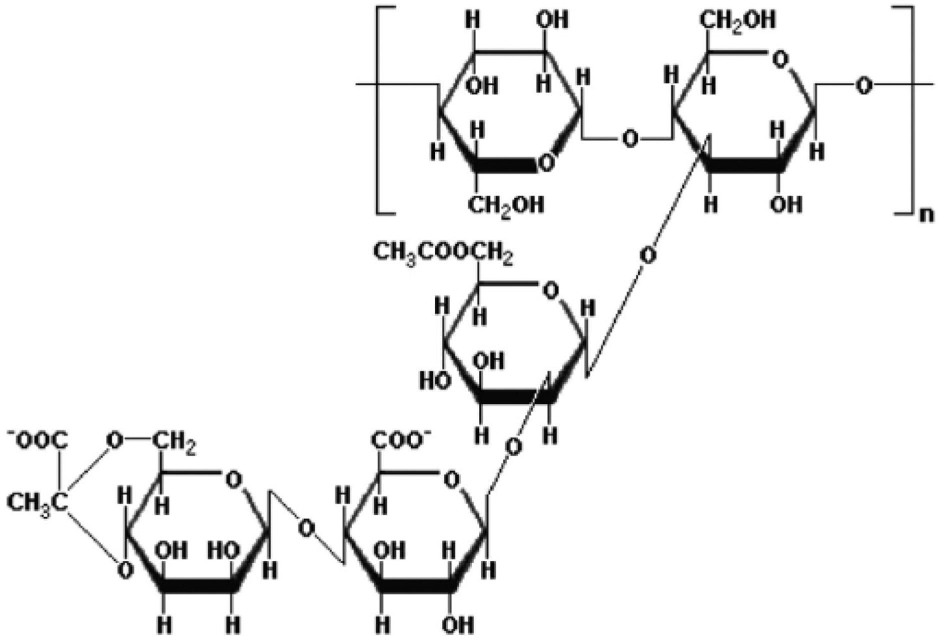

Fig. 1. Molecular structure of Xanthan gum (Garcı;a-Ochoa et al., 2000).

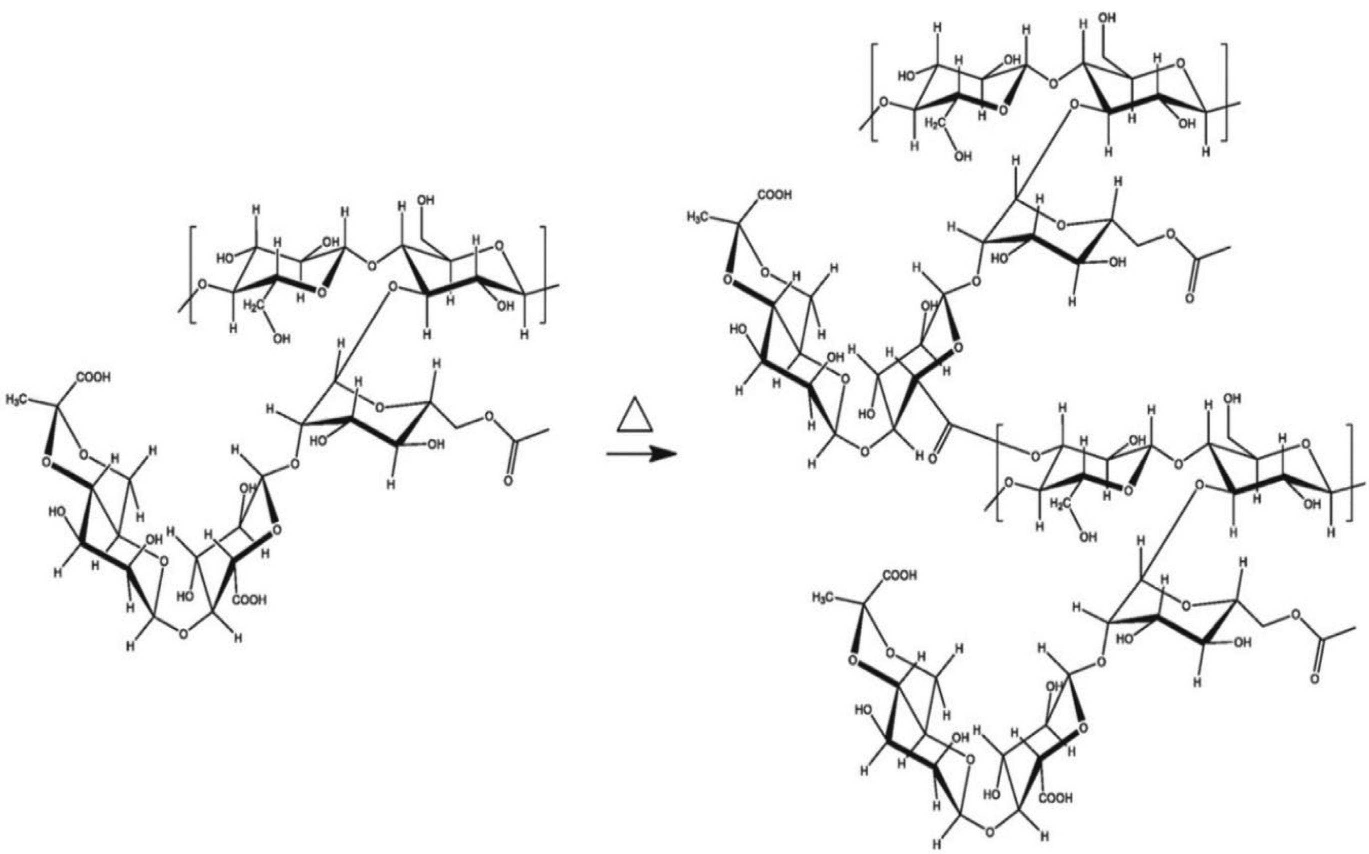

Fig. 2. Intra & Inter molecule ester bonds crosslinking causing extended Xanthan gum structure (Bueno et al., 2013).

residual, semi-solid slurry produced from waste water treatment process. It is also well known that sludge is a mixture of complex biological material and difficult to characterize (Eshtiaghi et al., 2013; Ratkovich et al., 2013; Seyssiecq. et al., 2003). Moreover, the opaque nature of sludge makes it difficult to estimate the accurate bubble behaviour and impacts on hydrodynamics of the process. Changes in complex rheological behaviour of sludge over time because of aging and microbial activity cause variations in