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The impact of temperature on the rheological behaviour of anaerobic digested sludge

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HIGHLIGHTS

- ▶ In this paper, we explored the influence of the temperature on the rheological behaviour of digested sludge.
- ▶ We showed the higher the temperature, the fluider the sludge but a master curve can be obtained.
- ▶ We demonstrated that the yield stress and the Bingham viscosity are the two main parameters.
- ▶ We highlighted the temperature has an irreversible impact on the rheological behaviour.
- ▶ Finally, we demonstrated the usual temperature laws cannot be used because of the irreversible composition change.

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ABSTRACT

The rheological properties of municipal anaerobic digested sludge rheology are temperature dependent. In this paper, we show that both solid and liquid characteristics decrease with temperature. We also show that the yield stress and the high shear (Bingham) viscosity are the two key parameters determining the rheological behaviour. By normalising the shear stress with the yield stress and the shear rate with the yield stress divided by the Bingham viscosity, a master curve was obtained, independent of both temperature and concentration. We also show that the rheological behaviour is irreversibly altered by the thermal history. Dissolution of some of the solids may cause a decrease of the yield stress and an increase of the Bingham viscosity. This result suggests that the usual laws used to describe the thermal evolution of the rheological behaviour of fluids are no longer valid with anaerobic digested sludge. Finally, the impact of temperature and thermal history have to be taken into account for the design of engineering hydrodynamic processes such as mixing and pumping.

1. Introduction

Anaerobic digestion is one of the most important processes for reducing sludge volume by reducing of about 30% of the organic load (part of the solid organic matter is converted into gas) and for producing biogas. To be efficient, anaerobic digestion needs to satisfy at least three conditions: (i) controlled temperature, between 35 and 37 °C for mesophilic processes or between 55 and 58 °C for thermophilic processes, (ii) homogeneous mixing conditions and (iii) no dramatic variation in organic load. To control temperature, biogas is partly used for heating large digesters through heat exchangers installed in recirculation loops [10]. If possible sludge also has to be initially pre-heated to the appropriate temperature and raw sludge is sometimes mixed with digested sludge before entering the digester [11]. In other cases, the digester mixing system ensures that the cold, newly introduced sludge, is mixed with the warm older solids and the bacteria. Finally, the entire digester volume needs to be turned over once every 3–4 h using pumps and recirculation loops. It is imperative that digester design take into account the energy requirements needed to maintain these essential operating conditions, such as the power consumption of pumps and mixing systems, which are directly related to the sludge rheology [19].

Because flow velocities within the digester and the recirculation loops are not of the same order of magnitude, a better understanding of the rheological properties of digested sludge over a wide shear rate range would provide a sound basis for the efficient design of digesters. Monteiro [14] showed that anaerobic digested sludge rheology can be described using the Herschel-Bulkley model, for which the rheological characteristics decreased with

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