Available online at www.sciencedirect.com

ScienceDirect

Procedia Environmental Sciences 31 (2016) 113 – 121

Procedia Environmental Sciences

The Tenth International Conference on Waste Management and Technology (ICWMT)

Rheological properties of municipal sewage sludge: dependency on solid concentration and temperature

Xiuqin Cao [a,*], Zhuhe Jiang [a], Weisha Cui [a,b], Yuan Wang [a], Ping Yang [a]

[a] *Key Laboratory of Urban Storm Water System and Water Enviroment, Ministry of Education,Beijing University of Civil Engineering and Architecture, Beijing 100044, China*

[b] *New Metallurgy Hig-tech Group Co., LID, Beijing 100044, China*

Abstract

Building centralized sludge treatment plants are a beneficial way to properly treat dewatered sludge from wastewater treatment plants, in which excess sludge haven't been treated properly. Thus, as the directly control parameter in municipal sludge treatment process, sludge rheological data are required for optimized design and operating in pumping and mixing. The main objective of this study was to investigate the rheology of municipal wastewater sludge, especially the different rheological behaviour for sludge from sludge treatment process-stream with or without anaerobic digestion. Besides, the dependency of sludge rheology on solid concentration and temperature and the predictive capability of rheological models were also investigated. The results revealed that the sludge samples showed shear-thinning and thixotropic characteristics. It was found that, irrespective of the existence of anaerobic digestion, sludge samples all performed a qualitatively same rheological behaviour, while they quantitatively behaved differently. It was also proved that both solid concentration and temperature effected sludge rheology critically. The best correlation between limit viscosity or the value of sludge thixotropy and solids concentration were determined by regression analysis. In this study, the Ostwald de Vaele model fits the experimental data best.

Peer-review under responsibility of Tsinghua University/ Basel Convention Regional Centre for Asia and the Pacific

Keywords: Rheology; Municipal sludge; thixotropy; limit viscosity; Solid concentration; Temeprature

Nomenclature

γ	shear rate (s^{-1})

* Corresponding author. Tel.: +0-106-832-2128; fax: +0-106-832-2128.
E-mail address: caoxiuqin@bucea.edu.cn

Peer-review under responsibility of Tsinghua University/ Basel Convention Regional Centre for Asia and the Pacific
doi:10.1016/j.proenv.2016.02.016

τ	shear stress (Pa s^{-1})
τ_0	yield stress (Pa s^{-1})
η	apparent viscosity (mPa s)
η_∞	limit viscosity (mPa s)
rHa	reduced hysteresis area (Pa s^{-1})
k	fluid consistency coefficient (Pa s^{-1})
n	fluid behaviour index (Dimensionless)

1. Introduction

Sludge treatment and disposal is the key part of wastewater treatment plants (WWTPs). With proper sludge treatment and disposal(e.g. anaerobic digestion or incineration), environmental problems (e.g. odours, volumes and putrescence) can be avoided, and energy reuse (e.g. biogas gathering, production for building materials or bioflocculants or biofertilizers) can be realized[1,2,3]. Nevertheless, the situation in China is quite challenged, for the reason that 1/3 of the WWTPs are lack of sewage sludge treatment, 1/3 of the WWTPs doesn't well treat sewage sludge, while the rest conducts a relatively effective sludge treatment process. In order to improve current situation of sludge treatment and disposal, the energy resource recovery centers have been introduced as a way of collectively treating sludge from small or old WWTPs, in which sludge treatment process either don't exist nor be every simple (only consist of thickening and dewatering). Whereas, this project is quite challenging because it deals with a very fundamentally scientifically poorly understood and unpredictable materials[4]. Therefore, an accurate evaluation of sludge characterization is of great necessity.

The complexity of the sludge composition makes it difficult to summarize its characterization [5]. Concerning its bio-chemical and physic-chemical properties, large research and conclusion have been made [6], while sludge rheological characteristics can be studied further. Because the tight correlation between the sludge rheological properties and the hydrodynamic functioning, and its essential role in heat and mass transfer [7], sludge rheology provides a extend point of view for optimizing the design and operating of sludge treatment process and facilities. Not only did it successfully optimized the process of activated sludge [8], but also did it improved the operation of sludge treatment[9,10]. In other words, with a general and comprehensive understanding of sludge rheology, it could be optimized concerning the working conditions and scaling-up calculation of tanks, settlers, pumping stations or installations for sludge transport and storage [9].

According to Slatter's research[11], Measuring the rheological characterization of sludge can be put into 3 parts: (1) viscometry, (2) rheological modeling, and (3) correlation of parameters. Viscosity is defined as the ratio of shear stress to shear rate. As the the viscosity of sludge is not constant and needs to be determined by its fluid-dynamic condition, 'apparent viscosity ' was introduced [12], which could be calculated from the flow curves measured by rheomoters. Among various commercial available rheometers, rotational and capillary are the most common used ones[7]. The obtained data can be evaluated by the rheological models, from which characteristics can be distinguished such as shear thinning or pseudoplastic behavior and shear thickening or dilatant property[13,14]. Solids concentration, temperature, particle size distribution, yield stress (τ_0) and fluid consistency coefficient (k), sludge type, wastewater treatment process and sludge treatment process, etc., are parameters affecting sludge rheology, among which the solid concentration was confirmed to be the most effecting one[11].

This study intends to establish a basic rheological characterization of for the objective sludge of the energy resource recovery centers underbuilding in China, especially for sludge from different origin. Besides the impact of solid content and temperature were examined. This provides fundamental and relatively comprehensive information on the rheological behavior of municipal sewage sludge for optimizing design of the mentioned sludge treating centers.