

RHEOLOGICAL PROPERTIES OF WASTEWATER SLUDGE

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ABSTRACT

The paper presents results of rheological tests conducted on activated sludge before and after its anaerobic digestion. The sludge samples were collected at the municipal/industrial wastewater treatment plants (WWTP) in Cracow and Olkusz. Measurements of sludge floc size, chemical oxygen demand COD and total sludge solids were performed. The tested sludge behaved like a plastic-viscous fluid.

KEYWORDS

Rheology, wastewater sludge, non-Newtonian fluid, yield point,

INTRODUCTION

The objective of the wastewater treatment is to protect humans and the natural environment from a negative impact of human metabolism and activity products. Activated sludge technology is the most frequently used treatment process. The microbial biomass, developed throughout the process, forms irregular flocs suspended in the sewage. Microorganisms are kept in a continuously fed reactor and produce a close biological system. The excess biomass, formed as a result of bacterial growth on organic matter present in wastewater, is periodically removed from the system. The volume of sludge, produced throughout the wastewater treatment process, amounts to about 1-2% of the total wastewater flow. Therefore, sludge handling and management at the WWTPs is still a widely discussed issue.

Such unit processes as sludge thickening and dewatering, as well as sludge stabilization and final disposal comprise a substantial element of the WWTP operation and as such they often become a source of some breakdowns and failures. The current research works focus on intensification of both sludge processing and its ultimate disposal in agriculture or utilization in power plants. Right now, the sludge is mainly deposited at the municipal landfills or stored at the WWTP's site.

Wastewater sludge characteristic may be different and it varies with the sludge place of origin. Principal sludge properties involve its physico-chemical characteristic, sanitary and technological parameters as well as its rheological properties [Buraczewski 1994]. Such diversification of sludge characteristic creates some problems during sludge processing, since each type of sludge behaves differently while undergoing the treatment process.

Each method of sludge utilizations requires a proper adjustment of its physical, chemical and biological properties. Anaerobic digestion and dewatering of sludge are the principal processes that are included into sludge treatment. Anaerobic digestion modifies the physical, chemical and biological properties of sludge, decreases pathogenic threat and odour intensity and facilitates sludge dewatering. [Fryźlewicz, Kryłów, Tal-Figiel 2001] The digested sludge is strongly non-Newtonian and its consistence varies according to its water content, which in turn affects its rheological properties. To examine this phenomena sludge flow curves were analysed in this work.

Sludge rheological properties depend on such factors as: shape (size), degree of dispersion, sludge solids content, chemical composition and chemical affinity with particles of the dispersed phase. The main sludge rheological parameter is viscosity, which characterises a real substance subjected to deformation; this parameter is connected with the flow of the substance. Another rheological parameter that describes sludge is the yield point.

The rheological research gradually finds an application in the quality control as well as in determining the best sludge properties with respect to its stability and pumpability [Slatter 1997, Motta, Pons, Roche, Vivier 2001].

EXPERIMENTAL PROCEDURE

The experiments were carried out on activated sludge from the municipal/industrial wastewater treatment plants in Cracow and Olkusz. Two types of sludge were analysed: before and after anaerobic digestion. The sludge was delivered to the laboratory within 30 min after sampling.

The sludge structure and its floc size were determined in microscopic observations. The “Biolar PI” microscope equipped with a high-resolution camera (Sony) was used. The MultiScan program allowed to obtain data concerning surface area, perimeter, length and width of a floc.

The measurements of sludge rheological properties were carried out with the rotational rheometer RS 75, manufactured by Haake; the analysis was conducted in the measurement system of coaxial cylinders in the Searle system. The rheometer worked in a CS (Controlled Stress) mode, which enables a control of shear stress. The viscometer had four different coaxial rotating cylinder systems, which made it possible to measure samples with a different water content. The steady measurement temperature (± 0.1 K) was maintained by an ultrathermostat. The concentrations of sludge dry solids and dry organic matter in individual samples were determined by a gravimetric method (see PN-72/C-04559.02), while a concentration of COD was determined according to the PN-74/C-04578.03 and 5220B (see Standard Methods 17th 1989).

DISCUSSION

Based on the results obtained in the experiments, flow and viscosity curves were drawn and then verified according to the following theoretical models: Bingham, Ostwald-de Waele, Herschel-Bulkley, Casson, Cross, Carreau A, Carreau Yasuda, Meter and Tscheuschner. The best match of the flow and viscosity curves was obtained for the Ostwald-de Waele, Herschel-Bulkley and Casson models [Tal-Figiel, Fryźlewicz-Kozak 2004].

The flow curves are presented in Figures 1 and 2. It can be stated that these types of sludge reveal a distinct yield point and their flow index are different. Therefore, it has a plastic-viscous character, whereas the yield point quantity depends clearly on sludge concentration, determined by sludge solids content. What draws one's attention is the quality difference between the flow curves obtained for the activated sludge before and after anaerobic digestion.

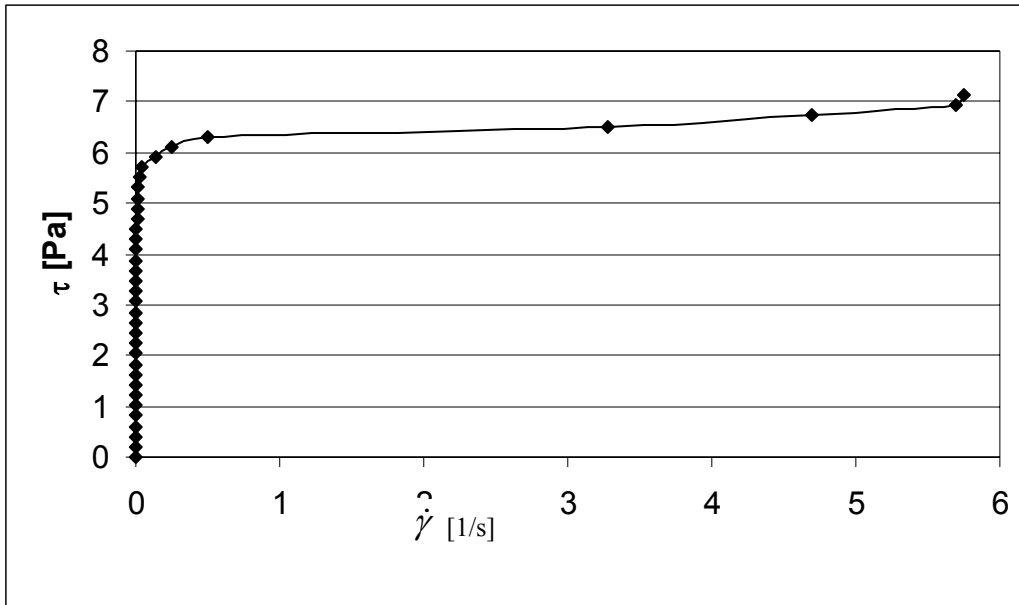


Figure1. Flow curve for activated sludge after anaerobic digestion (Olkusz WWTP).

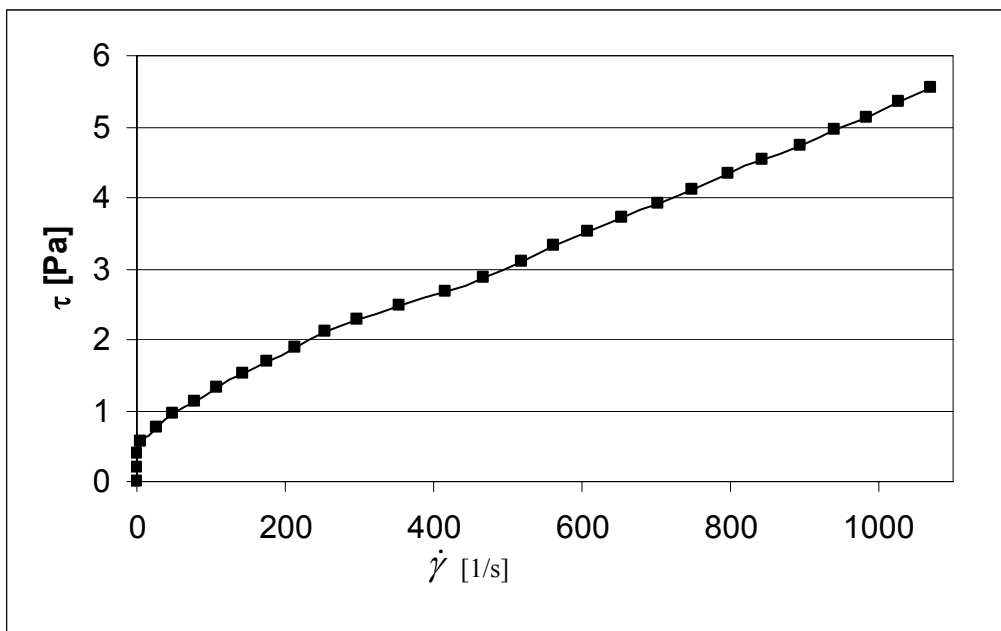


Figure2. Flow curve for activated sludge before anaerobic digestion (Olkusz WWTP).

It was observed that there are differences in activated sludge flow curve shapes. They could be attributed to different dry solids concentrations, type of sludge and sludge structure [Tal-Figiel, Fryźlewicz-Kozak 2003]. Figure 3 presents pictures of activated sludge flocs; the samples were collected at the Olkusz WWTP.

Analyzing the flow and viscosity curves it was observed that all three types of sludge: activated sludge withdrawn directly from the biological reactor, excess sludge and anaerobia digested sludge behave as a non-Newtonian fluid; they have their yield points and are diluted with a shearing stress. Viscosity of these types of sludge strongly decreases along with a shearing rate.

Having analysed the flow curves, a yield point for each sludge was determined. The most important factor influencing the yield point range is the water content in the sludge (sludge moisture).

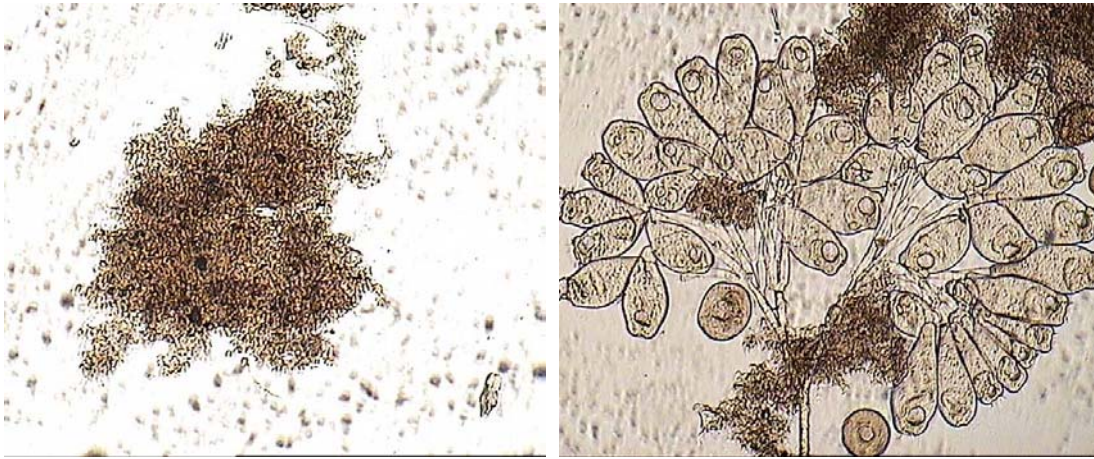


Figure 3. Activated sludge from Olkusz WWTP

It was stated, that within the sludge solids concentration range of 2.28 - 10.62 g/dm³ (activated sludge; Figure 4) and 15.07 - 72.00 g/dm³ (sludge after anaerobic digestion; Figure 5) similar plots were obtained. The curves confirmed that the higher the sludge solids concentration, the higher the yield point values.

In the performed experiments, the yield points for activated sludge varied from 0.0916 [Pa] to 0.4909 [Pa] while for the excess sludge they ranged from 0.1171 [Pa] to 0.5219 [Pa]. The yield points for the anaerobically digested sludge varied from 0.4004 [Pa] to 5.7217 [Pa].

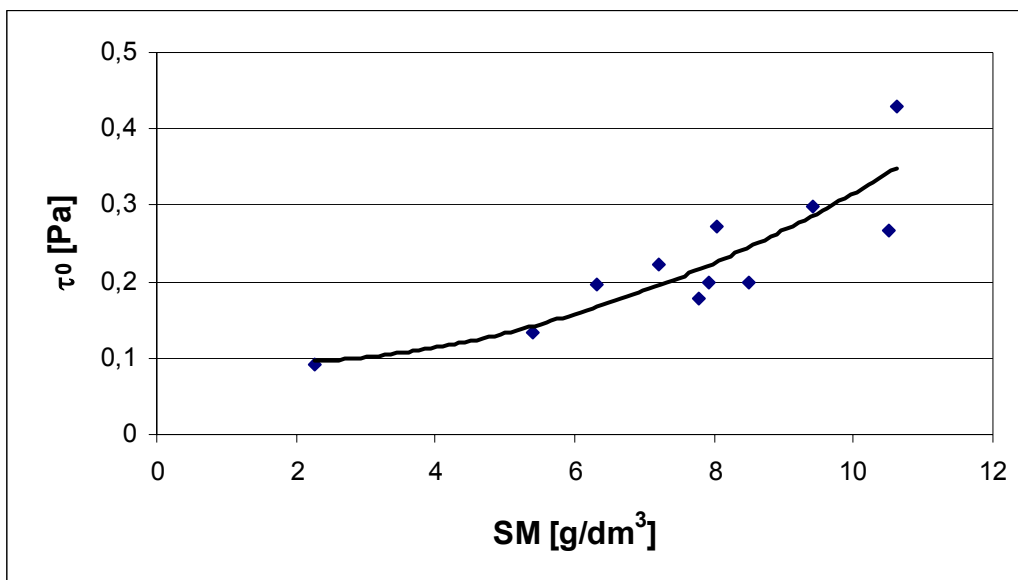


Figure 4 Relationship between yield points and a sludge solids content (activated sludge).

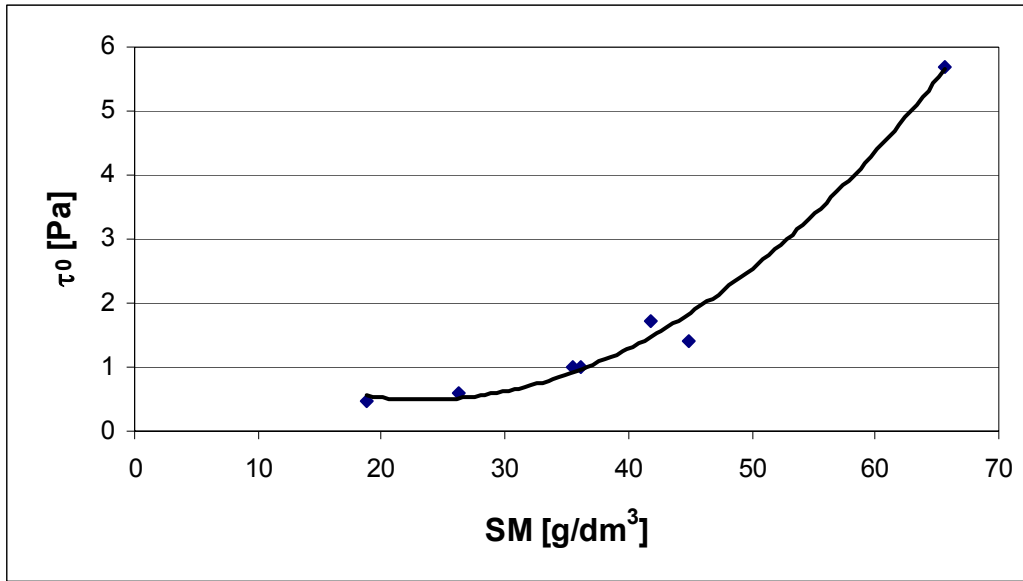


Figure 5 Relationship between yield points and a sludge solids content (sludge after anaerobic digestion).

An impact of both an organic substance concentration (COD) and an organic dry solids concentration on the yield point value was observed. It was found that the value of the yield point increases with the increase of COD; the relationships were presented in Figures 6 and 7.

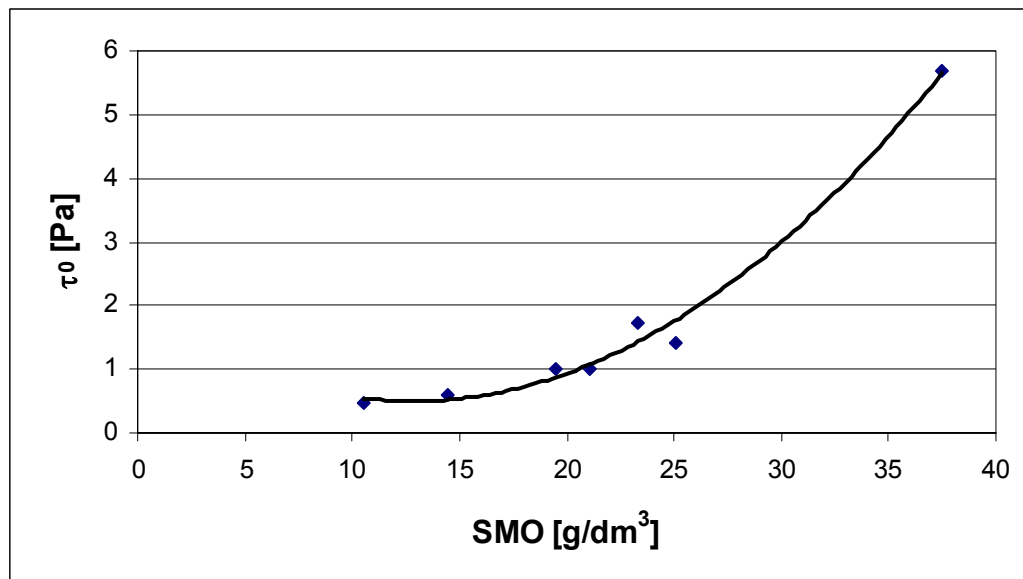


Figure 6 Relationship between yield points and an organic solids content (sludge after anaerobic digestion).

It was observed that regardless of the sewage origin and its quality, the sludge yield point value is affected by sludge moisture, concentration of organics and sludge structure.

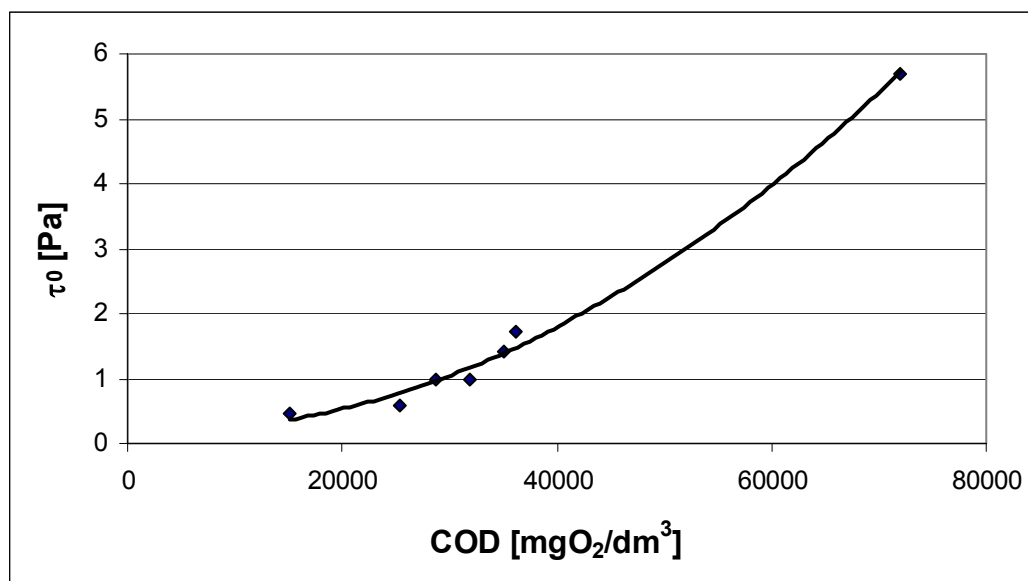


Figure 7 Relationship between yield points and COD (sludge after anaerobic digestion)

SUMMARY

Based on the experimental results the following conclusions may be drawn: wastewater sludge behaves as a non-Newtonian fluid. It is diluted with shearing stress and its yield point can be determined. The yield point value varies with sludge moisture and it increases along with the concentration of organic compounds in the sludge (expressed as COD or organic dry solids). Sludge viscosity depends on its structure and a type of the microorganisms constituting the flocs. Recognition of the rheological properties of the particular type of sludge may be helpful during its further treatment and while transferring it from one treatment units to another. The main objective of activated sludge viscosity determination in a biological reactor is to optimize the mixing conditions inside the reactor and improve the overall reactor performance.

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