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Most essential floc properties identified from Mofi images

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Report Title: Most essential floc properties identified from Mofi images

Key words: Activated sludge floc, image analysis, morphology

Abstract

Morphology of activated sludge flocs is critical for the whole activated sludge process. However, the in situ imaging system of floc morphology is still lacking. With the developed novel method, imaging of activated sludge floc is fast and easy. Novel imaging method has been tested with real process samples, and as a result, the most essential floc properties so far are the size of floc and aspect ratio.

Oulu, June 2011

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1 INTRODUCTION

This report presents most essential activated sludge floc parameters and is part of the project of Measurement, Monitoring and Environmental Assessment (MMEA) - programme conducted by The Energy and Environment Strategic Centre (CLEEN).

1.1 Participants

Name	Organization	E-Mail
Elisa Koivuranta	UO	elisa.koivuranta@oulu.fi
Jukka Keskitalo	UO	jukka.keskitalo@oulu.fi
Esko Juuso	UO	esko.juuso@oulu.fi
Tuomas Stoor	UO	tuomas.stoor@oulu.fi
Heli Karaila	Metso Automation Oy	heli.karaila@metso.com
Matti Saren	Metso Automation Oy	matti.saren@metso.com
Marjatta Piironen	Kemira	marjatta.piironen@kemira.com
Ilkka Laakso	Stora Enso	ilkka.laakso@storaenso.com

1.2 Background

The activated sludge treatment is one of the most typical processes in municipal and industrial wastewater treatment plants. It consists of two stages, a biological stage (aeration tank) and physical stage (secondary clarifier). The main role of the process is the development of microorganisms that consume the organic matter of the wastewater. Microorganisms flocculate in aeration tank and are removed in secondary clarifier. Effective settling of flocs in the secondary clarifier is a necessary as the effluent is normally discharged to natural water system.

A common problem in activated sludge process is the excessive growth of filamentous bacteria i.e. bulking sludge, which reduces the settling speed of the flocs. Despite much effort on the fundamental reasons of the formation of bulking sludge, it still seems to be continuous problem in most activated sludge treatment plants. To guarantee the minimum organic load from the activated sludge process to water systems, effective operation of the flocs forming is critical. Nowadays, the main problem in monitoring and controlling the activated sludge treatment process is the lack of on-line measurement of flocs characteristics.

Also dewatering of biosludge produced in secondary clarifier is difficult due to its gelatinous nature. Several studies have shown, that dewatering of biosludge is related to floc structure. Through image-analysis of activated sludge flocs, it could also be possible to control and understand dewatering process.

Image analysis of activated sludge flocs can offer a possibility for fast and reliable way to control activated sludge process, thus better effluent quality and better dewatering can be achieved.

1.3 Objective

Aim of the project is to develop floc measurement equipment to characterize activated sludge flocs. Therefore, the most essential floc parameters have to be identified. The developed method can be used e.g. in control of chemical dosing. Through on-line-measurement better control of activated sludge plant is possible and environmental impacts of wastewater treatment can be diminished.

2 MOST ESSENTIAL FLOC PROPERTIES IDENTIFIED FROM MOFI IMAGES

2.1 Literary survey

2.1.1 Background

Microbial aggregates, flocs, are the major component of activated sludge system and therefore the characteristics of flocs are important in operation of wastewater treatment plants. Almost all the basic phenomena affecting the operation of the activated sludge process are related to the floc properties. Especially, the settleability of flocs is greatly related to the formation of compact flocs. Therefore, it is essential to find a correlation between the morphological parameters and dewatering properties. [1-3]

2.1.2 Structure of activated sludge floc

Activated sludge flocs are highly inhomogeneous, porous bioaggregates. The morphological parameters of flocs can be divided into two groups: size of flocs and shape of flocs. Size of flocs includes parameters such as mean projected area, perimeter and diameter. Respectively, shape of flocs includes parameters such as form factor, fractal dimension and aspect ratio. [2,3]

The structure of activated sludge flocs has been analysed by many researchers [1-9]. In some studies, fractal dimension has been used to describe floc geometric characteristics. Also floc size and shape factors have been related to floc properties, like settling velocity [4-9]. The size and shape of activated sludge samples is highly depended on the measurement method and the origin of sample. Some measured values are presented in Table 1.

	Mean value
Floc size	73,6 μm [4], 35-45 μm [5], 48-124 μm [6], 125 μm [7]
Form factor	0,529 [2], 0,25-0,38 [8]
Fractal dimension	1,29-1,39 [9], 1,958-2,485 [10]

Table 1. Measured morphological values of activated sludge flocs.

2.1.3 Pre-treatment of activated sludge

To improve dewatering properties of activated sludge, several pre-treatment methods such as freezing/thawing, thermal, ultrasonic and acid treatments have been studied [11-14]. As a conclusion, freezing/thawing and acid treatments improved greatly dewatering properties of activated sludge flocs. However, the morphology of treated flocs was not studied [11,12]. Thermal pre-treatment and ultrasonic treatment improved dewaterability of undigested and digested sludge in certain circumstances [13,14].

2.2 Materials and methods

2.2.1 Materials

In all experiments done in this study, samples were collected from activated sludge plant of Stora Enso Oulu mill, which is producer of chemical pulp and coated paper. To avoid deterioration of the samples they were analysed within 6 hours of the sampling moment.

2.2.2 Mofi measurement environment

Filtration, polymer mixing and imaging of flocs was performed with Mofi measurement environment. Mofi and a floc image captured with Mofi are presented in Figure 1.

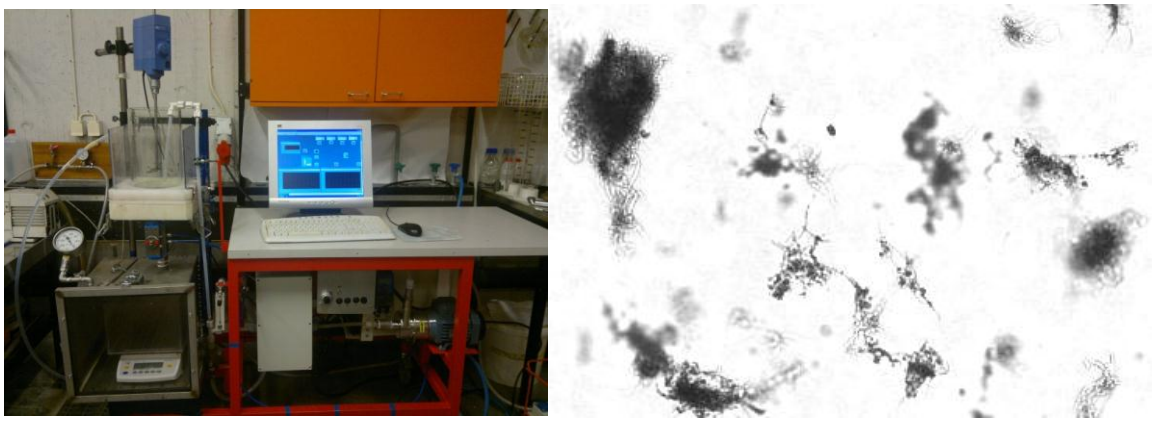

Figure 1. Mofi measurement environment (left) and captured floc image (right).

Mofi has two units: a filtration unit and an imaging unit. With the filtration unit it is possible to filtrate samples through different types of wires. Filtration speed is stored automatically. It is also possible to use pressure to facilitate filtration phenomena. The equipment includes a mixer with controllable rotational speed. In the imaging unit, it is possible to image samples through CCD-camera. The image size is 5.01 x 3.74 mm and resolution 3.6 μm x 3.6 μm.

2.2.3 Image analysis

Floc morphology was analysed with Mofi. Image analysis and floc morphology parameters are described in detail in report 4.2.2.4 “Description of development step of Mofi measurement environment”.

2.2.4 References measurements

In all experiments, two reference measurements were used to analyse sludge dewatering properties: capillary suction time (CST) and gravity filtration.

The CST equipment is a practical method for the determination of sludge dewaterability. Slurry is poured into a small open tube resting of on a piece of filter paper. The filtrate is extracted by capillary suction, and by measuring the time that

the filtrate is required to travel, the dewaterability parameter can be determined. [15] In all experiments, at least 5 concurrent measurements were made.

Filtration experiments were performed with Mofi (Figure 1). In all filtration experiments, cationic polymer was added to the sample. Approximately 0.1 % polymer solution was prepared beforehand. Polymer (75 ml) was added to the sludge (1 l) with mixing speed of 400 rpm and mixing duration of 30 seconds. 500 ml of conditioned sample was filtrated in 2.5 minutes and the initial filtrate speed was measured. Also, totals solids of cake and filtrate were analysed.

2.2.5 Daily variations

Aim of the trial was to survey daily variations of floc morphology. This trial is also a part of a currently running survey, where seasonal variations in the activated sludge are monitored. In March 2011, sample was collected in four sequential days. CST and filtration were measured and floc morphology was analysed by Mofi.

Effect of pre-treatment to floc morphology

Aim of the trial was to study how different pre-treatment methods affect the floc morphology and dewaterability of sludge. The used methods were ultrasound, heating, freezing/thawing, acid and alkali treatments. In the ultrasound method, activated sludge sample was treated with ultrasound for 5, 15 or 30 minutes. In freezing/thawing method, the sample was first frozen for 20 hours and then melted in room temperature. In the heating method, the sample was heated in oven (105 °C) for 2 hours. In the pH-treatment, the effect of sulphuric acid and sodium hydroxide on the sludge properties was studied.

2.3 Results

2.3.1 Daily variations

Dewatering properties

In Figure 2, daily dewatering properties are presented.

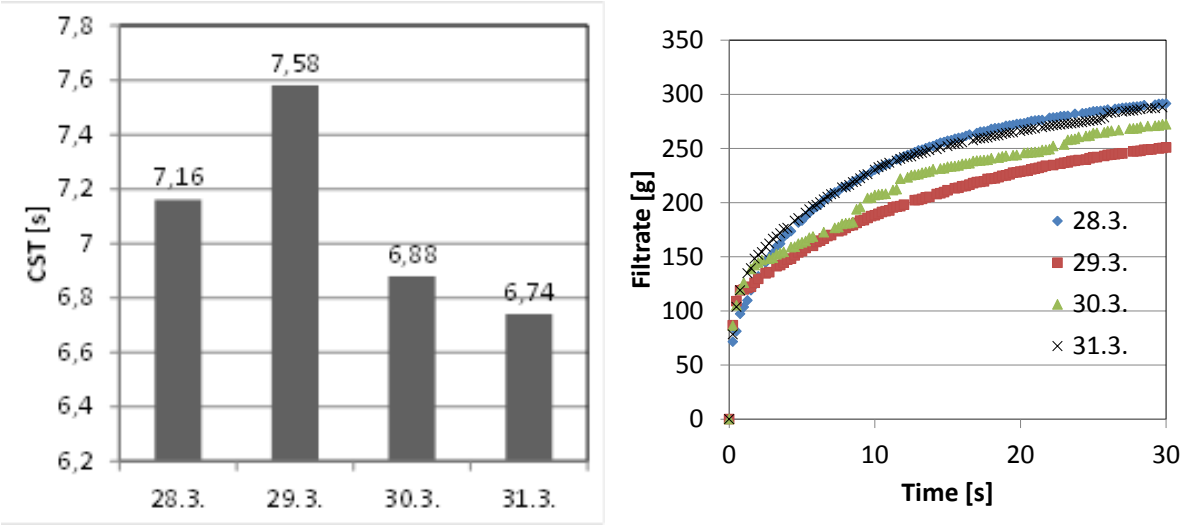

Figure 2. Dewatering properties of activated sludge in March 2011.

Reference measurements indicate that the sludge dewaterability was best on 31.3 and worst on 29.3. However, differences are quite minor.

Floc morphology

Results of floc morphology measurements are presented in Figures 3 and 4.

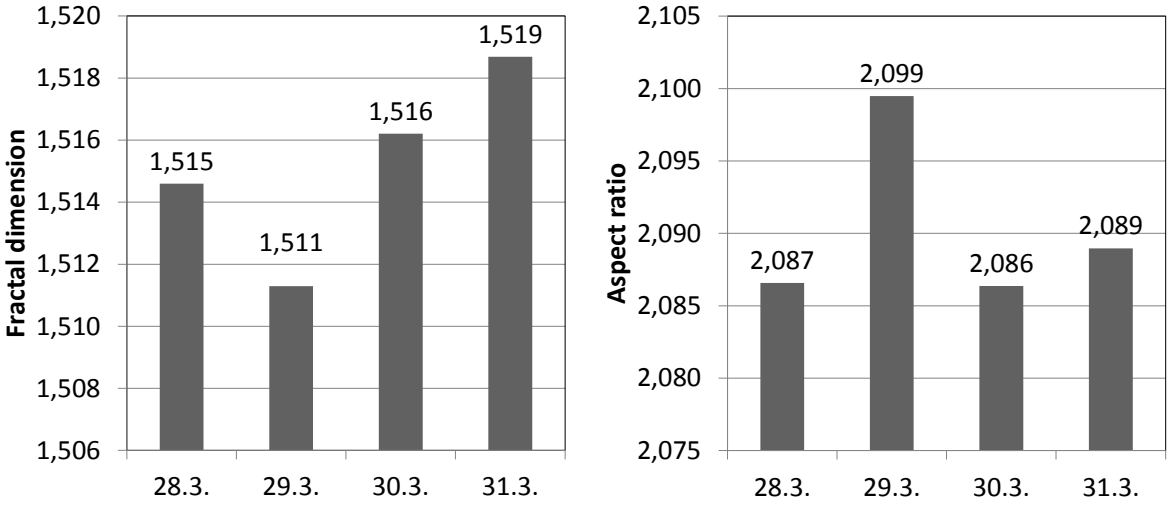

Figure 3. Shape of activated sludge floc in March 2011.

There are no substantial differences in shape factors on different days. However, small value of fractal dimension and large value of aspect ratio may indicate poorer dewatering properties.

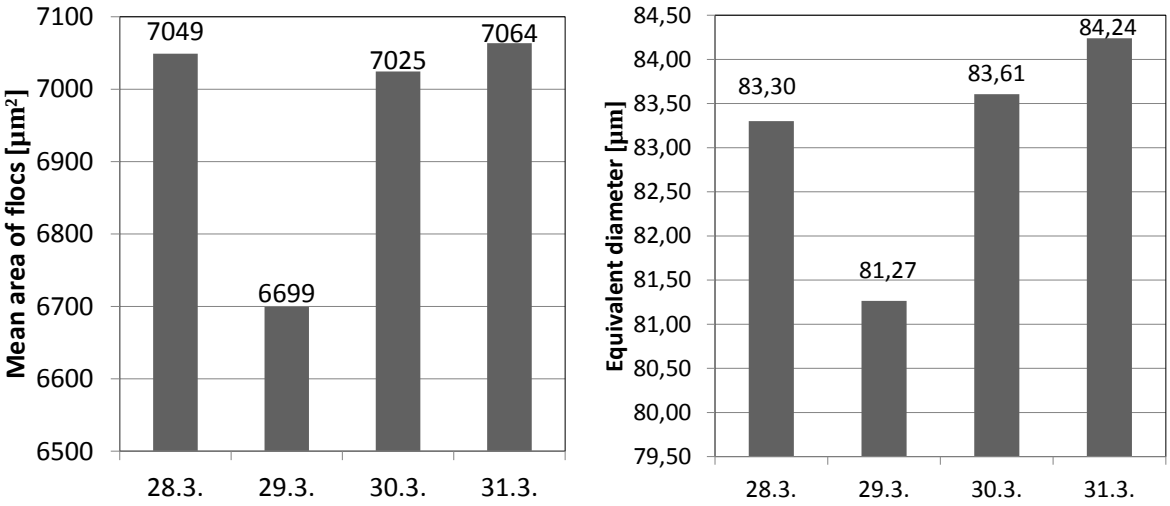

Figure 4. Size of activated sludge floc in March 2011.

Mean area and equivalent diameter of flocs were clearly smaller in 29.3 when also dewatering properties were worst. On other days, there were no substantial differences in size of flocs.

2.3.2 Effect of pre-treatment to floc morphology

Dewatering properties

Effect of different pre-treatment methods is presented in Figure 5. CST-measurements were parallel with filtration measurements.

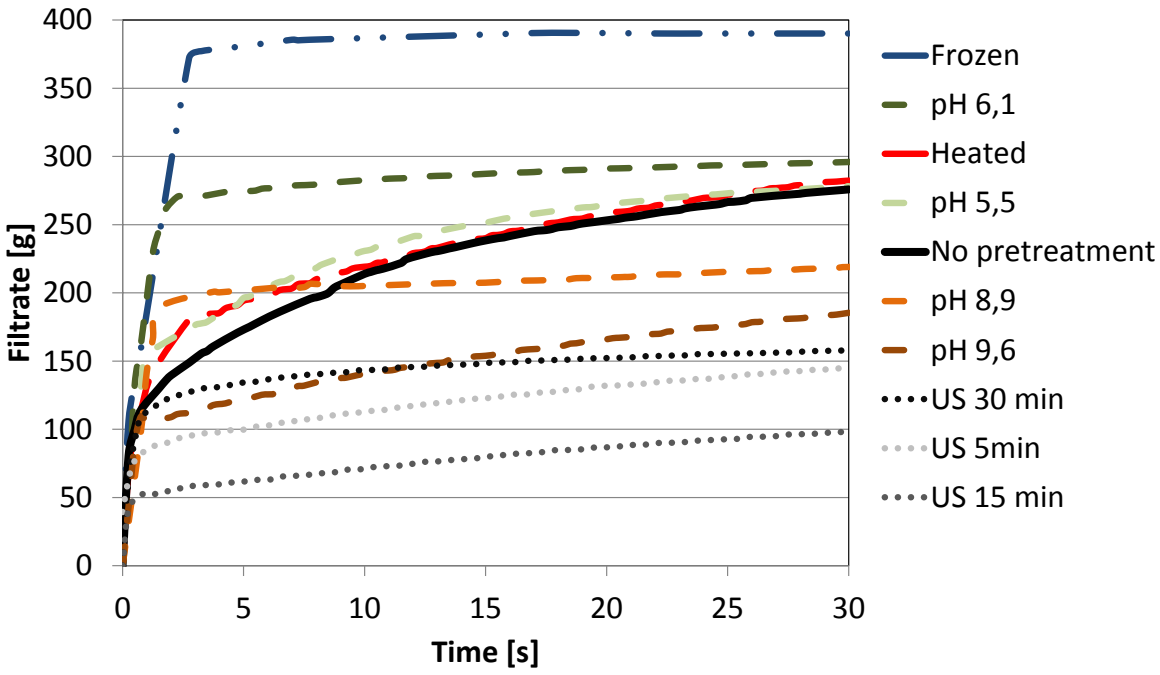

Figure 5. Filtration properties of pre-treated activated sludge flocs.

Both filtration and CST measurements indicate that freezing was clearly the most effective pre-treatment method to improve dewatering properties. Also the sulphuric acid (pH 6.1 and pH 5.5) treatment improved dewatering properties. On the contrary, the sodium hydroxide (pH 8.9 and 9.6) treatment impairs dewatering properties. The most unsatisfactory pre-treatment method was the ultrasonic method (US). The heating method didn't affect the dewatering properties. (Figure 5)

Floc morphology

Unfortunately, frozen flocs were too big to be analysed in Mofi. Other morphology results are presented in figure 6 and 7.

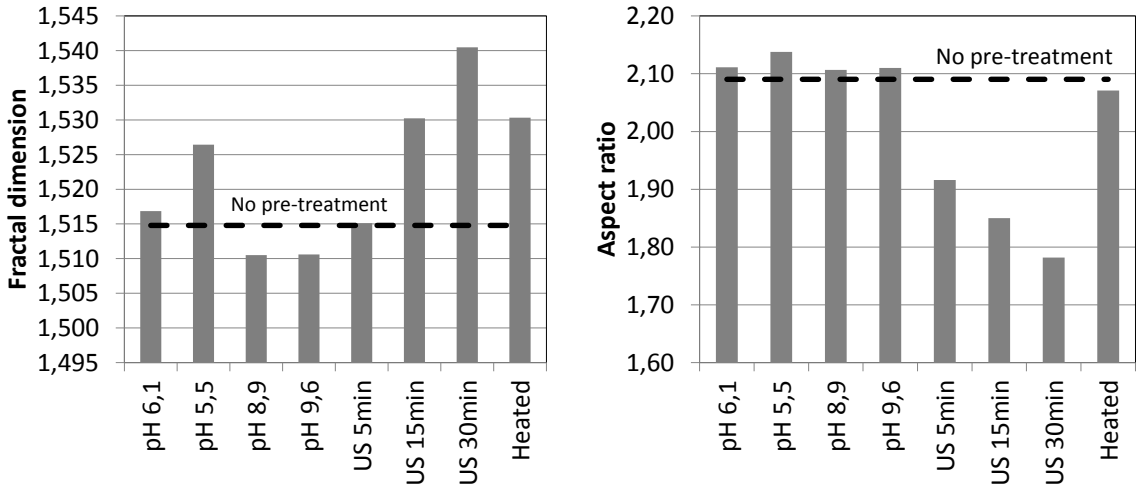

Figure 6. Shape of pre-treated activates sludge flocs.

Fractal dimension was not found to have correlation with dewatering properties of pre-treated activated sludge flocs. On the contrary, aspect ratio of flocs was smaller with ultrasonic treatment which indicates degradation of flocs.

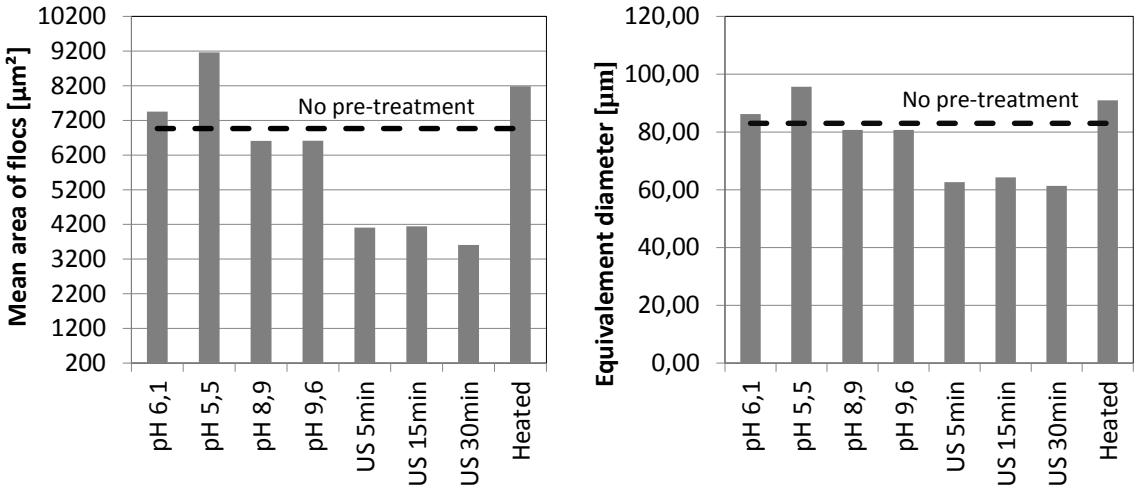

Figure 7. Size of pre-treated activates sludge flocs.

Also the size of pre-treated flocs indicates that the ultrasonic treatment degrades flocs which causes poor dewatering. In the sulphuric acid treatment, floc size was slighter increased, which can be a consequence of floc coagulation. In lower pH-value, activated sludge flocs are usually neutralized and coagulation is possible. Heating of activated sludge also increased floc size.

3 CONCLUSION

Both daily and pre-treatment trials indicate that size of floc is the most critical parameter that affects the dewatering properties of activated sludge. The smaller the floc size, the poorer are the dewatering properties of sludge. Fractal dimension and aspect ratio were also found to be critical properties in daily variations. As a conclusion, with Mofi it is possible to find differences in activated sludge floc morphology but more studies are needed to find correlation between floc morphology and dewatering properties. In addition, the image analysis program will be developed to characterize filamentous properties of flocs.

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