Influence of Experimental Parameters in On-line Determination of Floc Size Distribution

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Keywords: activated sludge, floc size distribution, sonication

Abstract

In order to develop an experimental technique to directly monitor the dynamics of activated sludge it is necessary to analyse some parameters that can influence the flocculation process and to find better experimental condition. The effect of sludge concentration, sonication, mixing and of some setup components (i.e. tubes length, T-part) was monitored during on-line floc size distribution measurements. It was observed that the sludge concentration and floc size distribution are interrelated. Moreover, it is demonstrated that sonication inside relatively large sludge volume (2 L) does not create a significant disrupting effect. Related to the setup components it was found that by using long tubes in-line flocculation occurred and T-part does not have an important influence on particle size distribution.

Introduction

The activated sludge process is of great importance for the wastewater treatment. The effectiveness of this process consists in a well separation of the treated wastewater and activated sludge in a clarifier, which is mainly determined by the activated sludge settling.

The bioflocculated microbial aggregates, known as flocs, are the essential components of the system. Of all the physical characteristics of flocs, the most important are probably the floc size and floc structure (Guan et al.,1998).

The measurement of size and size distribution is an efficient way of detecting changes in the floc properties at the various treatment steps, or shifts in growth conditions in the wastewater treatment plant, as well as how well the different separation processes work. The size range can be as wide as from a few microns up to 1000 μm (Parker et al, 1971; Li and Ganczarczyk, 1991).

Various methods have been used to measure the size of activated sludge floc: direct microscopic observation (Barbusinski and Koscielniak, 1995; Li and Ganczarczyk, 1987);

image analysis (Li and Ganczarczyk, 1991; Grijspeerdt and Verstraete, 1997), Coulter Counter (Andreadakis, 1993) and laser light scattering (Biggs, 2000).

Flocculation is a reversible process. When the activated sludge flocs are exposed to different environmental conditions (i.e. shear stress, anaerobic condition) small particles are disrupted from larger flocs, which is known as deflocculation.

Current research aims at evaluating the possibility to measure on-line particle size distributions (PSD) under different experimental conditions, such as sludge concentration, sonication, mixing and at analysing the influence of some setup components. (i.e. tubes length, T-part).

Materials and Methods

Sampling: The activated sludge sample was collected from the Ossemeersen WWTP (Ghent, Belgium). The suspended solids concentration was determined to be X = 4.1÷4.5 g/l. After collection, the samples were stored at 4°C and kept for a maximum period of three days.

Size measurements: Floc sizing was performed using a *Malvern Mastersizer/S* instrument, which is based on laser diffraction (Fraunhofer diffraction theory). A 300RF lens was used for experiments corresponding to a size range 0.05-900 μm. A dilution of the activated sludge sample prior to analysis was required in order to obtain a recommended obscuration level, which has an ideal range between 10 and 30%.

Sonication and Mixing. In order to be able to study the flocculation dynamics of activated sludge it is necessary to break-up the floc. A VC-130 Ultrasonic Processor Vibracell was used to sonicate the sludge in-situ. The impact of sonication on the PSD was checked for different sonication time periods (1-10 minutes) and powers (3-60 W).

For mixing a *RW-20.n IKA stirrer motor* was used and the controlled parameters were the mixing intensity (60-320 rpm) and the mixing time (1-60 minutes).

Experimental Setups: In order to determine the influence of the setup configuration on the PSD and its dynamics two experimental setups were examined. In Setup 1 (Fig. 1,a) the possibility to eliminate the dilution of the sludge in the vessel by pumping the dilution water via a bifurcation (T-part) directly into the tube transporting the sludge to the Malvern was checked. Several dilution ratios (X/2; X/4; X/8) for the activated sludge were used in the 2 L vessel and two peristaltic pumps were used in order to dilute the sludge. The peristaltic pumps (*Masterflex L/S* and *Watson Marlow 505U)* were preferred because it was found to create minimum shear to the flocs (Spicer et al., 1998). According to Biggs, (2000) the pumps were set for a dilution of approximately 5% vol. activated sludge and the flow directed to the Malvern measured approximately 3 ml/s.

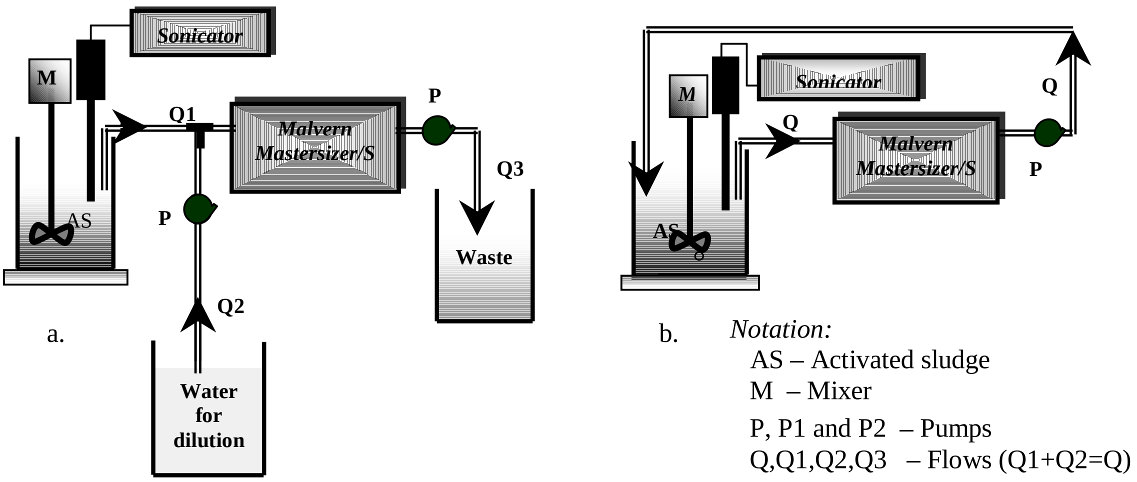

Fig.1: Experimental Setups: a. Setup 1; b. Setup 2.

The purpose of the Setup 2 (Fig. 1,b) was to study the flocculation process at lower sludge concentrations (X/20), which was determined as a function of the obscuration level required to obtain a good diffraction pattern. The on-line dilution was removed and the sludge was continuously recirculated to the vessel. This option led to the possibility of performing a larger number of on-line analyses of the size distribution and thus, monitor the (de)flocculation for a longer time.

Results and Discussion

Influence of mixing

The influence of mixing was investigated for finding the mixing intensities that is able to maintain the flocs in suspension without creating other effects like floc break-up or floc aggregation.

For high concentration sludge (X/2 and X/4) an increase of the mixing intensities creates some but not significant disturbance on the flocs. At low sludge concentration (X/8 and X/20) simultaneous flocs break-up and aggregation were observed by increasing the mixing (Fig. 2). It was found that the 60 rpm mixing intensity constitutes the optimum mixing speed, which could provide representative sample for the Malvern (data not shown here).

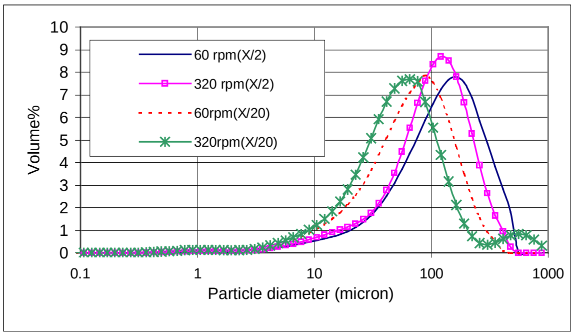

Fig. 2: Influence of mixing on the PSD for X/2 and X/20.

Influence of sonication

By studying the influence of the sonication power it was observed that in general a high sonication power must be applied to create floc disruption. Low sonication power does not affect the size of the flocs. Sonication at low sludge concentration (X/20) creates more significant disruption than at high sludge concentration (X/2) as is shown in Fig. 3.

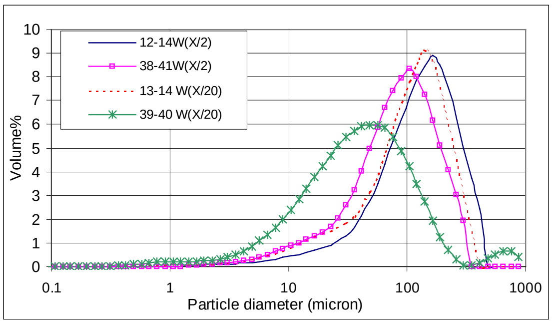

Fig. 3: Sonication power influence on PSD for X/2 and X/20 (sonication time = 4min).

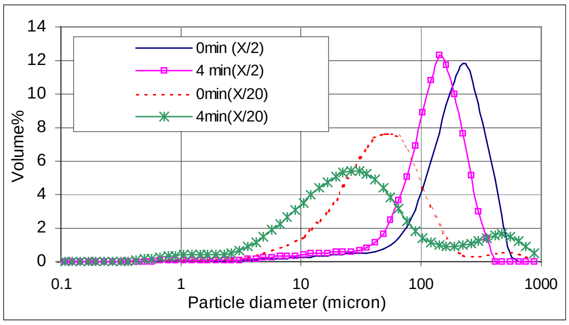

Fig. 4: Sonication time influence on PSD for X/2 and X/20 (sonication power=39-40W).

For a concentration of X/2, sonication at high power leads as expected to floc break-up, but this is not significant. After 4 minutes, the effect of sonication became negligible.

For X/20 concentration it was observed that sonication had a stronger break-up effect compared to the effect at high concentrations (X/2; X/4). Moreover, at the same time the PSD shifts to the left, large particles appear. After 4 minutes of sonication three structural classes could be identified: primary particles of size 3 µm, secondary particles (50 µm) and large particles (600 µm) (Fig. 4).

It must also be remarked that it was difficult to maintain the sonication power constant. It was found that sonication power changed with the place where the sonicator tip is placed and also with the volume decrease (Setup 1).

Influence of the tubes length and T-part

The influence of the tubes length (40 and 60 cm) on the PSD has been studied as it may be expected that flocculation occurs in the tube as well. Fig. 5 shows the PSD obtained under the same experimental conditions by varying only the tube length. It is concluded that flocculation indeed occurs in the tubes. Hence, tubing should be as short as possible to reduce its effect on the flocculation dynamics in the test vessel.

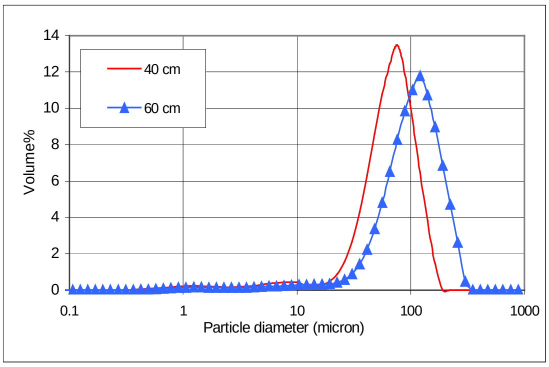

Fig. 5: Tube length influence in PSD.

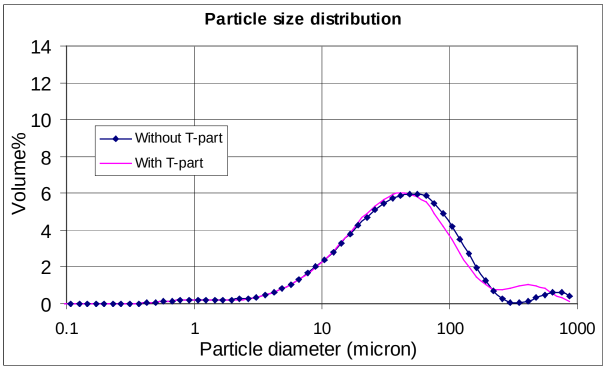

Fig. 6: T-part influence on the PSD.

For the purpose of checking the influence of the T-part connection on the PSD the sludge was pumped to the Malvern by using two tubes joined together by means of a T-part. Since the only difference in the experimental configuration shown in Setup 2 is the T-part, discrepancies in PSD's are due to the latter. Even if some differences were observed, it is concluded that these are not significant (Fig. 6).

Conclusion

The results of this study can be summarised as follows:

- Mixing at 60 rpm was found to maintain the solution in suspension without creating significant changes in PSD, especially for short periods of time. A tendency of floc break-up and aggregation was observed when increasing the mixing intensities.
- Apparently, long tubes show significant in-line flocculation. The effect of sonication was more pronounced when short tubes were used.
- T-part does not have a significant influence on the size distribution.
- As far as the effect of the concentration is concerned, it is concluded that the sonication effect is stronger when the sludge concentration is reduced. For high sludge concentration the disrupting effect of sonication is minimised. To resume, sonicating inside the big volume vessel for high sludge concentration does not constitute a good solution for disrupting the flocs.

- Formation of large particles was observed for experiments performed at low concentrations (<X/8). Possible causes are proposed as follows:
  - One possibility can be due to the local disturbing effect created by sonication. Near the sonication tip the flocs are broken-up into the smaller flocs, but because of the high vessel capacity and slow mixing intensities some particles could remain in a flocculated state and collision between the flocs can take place.
  - Another possibility is that flocculation takes place inside the tubes connecting the Malvern and the vessel and the formation of the flocs of large size is detected by the Malvern. The detection is clearer at lower concentrations because in this concentration range the collision rate in the tube is reduced and the particles can settle in the tubes and form large flocs, which sometimes are dragged to the Malvern.

By resuming, using sonication to disrupt the flocs inside large volume of sludge is not a good practice and another method like, e.g. high shear stress, has to be considered in the next research for floc disrupting. Furthermore, we demonstrated that on-line determination of PSD constitutes a faster and good method to evaluate the structural properties of the flocs. The results show the necessity to find an optimal experimental condition for a correct evaluation of flocs size distribution.

References

1. Andreadakis A. D. (1993) Physical and chemical properties of activated sludge floc, Wat. Res. **27(**12), 1707-1714.
2. Barbusinski K. and Koscielniak H. (1995) Influence of substrate loading intensity on floc size in activated sludge process, Wat.Res., **29**(7), 1703-1710.
3. Biggs C. A. (2000) Activated Sludge Flocculation: Investigating the effect of shear rate and cation concentration on flocculation dynamics, Ph.D. thesis, University of Queensland, Australia.
4. Grijspeerdt K. and Vaerstraete W. (1997) Image analysis to estimate the settleability and concentration of activated sludge, Wat. Res. **31**(5), 1126-1134.
5. Guan J., Waite D. and Amal R. (1998) Rapid Structure Characterization of Bacterial Aggregates, Environ. Sci. Technol. **32**, 3735-3742.
6. Li Da-Hong and Ganczarczyk J. J. (1987) Stroboscopic determination of settling velocity, size and porosity of activated sludge flocs, Wat.Res.,**21**(3), 157-262.
7. Li Da-Hong and Ganczarczyk J. J. (1991) Size distribution of activated sludge flocs, Research Journal WPCF, **63**(5), 806-814.
8. Spicer T.P., Pratsinis E.S., Raper J., Amal R., Bushell G., Meesters G. (1998) Effect on shear schedule on particle size density, and structure during flocculation in stirred tanks, Powder Technology, **97**, 26-37.
9. Parker D.; Kaufman W. and Jenkins D. (1971) Physical conditioning of activated sludge floc, Journal Water Pollution Control Federation, Vol. 43, pp. 1817-1833.