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Department of Applied Mathematics, Biometrics and Process Control

Activated sludge floc size and size distribution measurements: from reality to sizing techniques

Ruxandra Govoreanu and Peter A. Vanrolleghem

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UGent-BIOMATH, Coupure 653, 9000 Gent, Belgium (e-mail Ruxandra.Govoreanu@ugent.be)

Outline

- Activated sludge flocculation
- Sizing techniques
- Floc size measurements under steady state conditions
- Monitoring of the flocculation dynamics
- Conclusions



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Activated sludge process





Floc structure





- Biological nature
- Irregular shape (fractal)
- Heterogeneous composition

Complex and fragile structure



Factors affecting the flocculation process



Problem statement

Lack of experimental methodology

Influence of different process parameters on flocculation dynamics

Flocculation mechanisms

Lack of a comprehensive flocculation model

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Less

Known

lacksquare

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Equivalent Spheres

Sphere having the same volume







Sphere having the same surface area

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Sphere of the same maximum length



Sphere having the same sedimentation rate



FSD measurements

- Microscopy and image analysis
- Electrical sensing zone (Coulter Counter)
- Laser diffraction
- Light obscuration
- Focused Beam Reflectance



Microscopy and image analysis





Directly examine the individual flocs

- Elaborate sample preparation
- Time consuming only few particles can be examined at once
- Small depth of focus in any field of view (samples having wide size range)

Image analysis

- Faster allow size and shape measurements
- Sample visualization

Dispersed particles (touching particles)

 $\$ Size detection range is limited to the lens magnification - restricted to approx. $3\mu m$

Electrical sensing zone (Coulter principle)

The voltage pulse generated when a particle passes through an aperture, is proportional to particle volume.



Easy and reliable technique

- Sample suspension in electrolyte
- Limited size range due to the aperture opening
- Aperture clogging broad size range
- Not suitable for on-line measurements



Time of Transition

A rotating laser beam scans single particles within its focus. The diameter of the particle is directly correlated to the Time-Of-Transition.



- Suitable for on-line analysis
- Sefractive indices are not required
- Stroad size range measurement

Sample dilution

Longer measurement time (counting technique)



Focused Beam Reflectance (FBRM)

A laser beam is highly focused and illuminates individual particles in its path. The size of each particle is determined by measuring the time that the particle is in the laser beam.



Allow in-situ measurementsHigh concentrated sample

Focal point settings

Particles velocity should be high enough



Laser diffraction

Low angle laser light scattering (LALLS) - ensemble technique

Particles in a laser beam scatter the light at angles that are inversely proportional to the particles size



Suitable for on-line analysis

Fast

Stroad size range measurement

Sample dilution

Require knowledge of the particles optical properties (refractive indices)



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Floc size measurement

How to measure the floc size and quantify the flocculation dynamics?

What is measured? The effect of:

- the measurement principle
- *the shape* Ruxandra Govoreanu - 17

Which measurement techniques suit for measurement purposes?

- 1. Allow broad size range measurement
- 2. Sample preparation and measurement procedure do not significantly alter the floc structure
- 3. Allow on-line or in-situ measurements

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Sizing devices







MastersizerS (volume based)

CIS-100 (TOT/SHAPE) (number based) IMAN (number based)

- Complementary measurement principles
- Flow through cell measurement capabilities (on-line measurements)
- Similar sample preparation (dilution)

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Methodology



FSD - results comparison



Conversion of the results may be misleading and the results should be interpreted function of the device measurement principle



Shape effect



MastersizerS is the most sensitive to the particles shape giving a broader distribution



Conclusions

- The measurement principle is of major importance for correctly interpreting the data.
- Conversion of the results may be misleading and should be used with precaution



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Experimental set-up

Flocculation Unit (FlocUNIT) set-up



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Experimental set-up

Flocculation Unit (FlocUNIT) set-up





The role of mixing intensity



Results comparison from different devices



A good correspondence between the floc size dynamics and the total number of flocs was found BIOMATH

The role of mixing intensity (G=200s⁻¹)

Floc size distribution



Three modal floc-size distribution



The role of calcium on different sludge sample





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Conclusions

The used techniques:

- fast and reliable methods to quantify the flocculation dynamics
- the methods complement each other in terms of given information



- Size range correct evaluation of the flocs larger then $10 \mu m$
- Sample dilution
- Spherical shape assumption
- Results dependent of the measurement principle

Conclusions

Perspectives

- in-situ techniques
- fractal dimension analysis
- image analysis

An "universal" solution for floc size and size distribution measurements still needs to be found!!!!!

