

AN AUTOMATED IMAGE ANALYSIS SYSTEM FOR ON-LINE STRUCTURAL CHARACTERIZATION OF THE ACTIVATED SLUDGE FLOCS

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INTRODUCTION

The effectiveness of the clarification step in the activated sludge process is highly determined by the activated sludge flocs properties. Even if considerable effort has been devoted in order to gain insight in the activated sludge flocculation and to demonstrate the influence of the flocs' structural properties on the sedimentation process, these issues still remain poorly understood.

Microscopy is a widely used approach for structural characterisation of the activated sludge flocs (Andreadakis, 1993; Barbusinski and Koscielniak, 1995). It is an excellent technique as it allows to directly examine the flocs. Consequently, the shape of the flocs can be observed and this is important for understanding the real structure of the flocs. However, for manual microscopy elaborate sample preparation is necessary and only few particles can be examined. Recently, by connecting the microscope to automated image analysis software it became possible to faster evaluate the activated sludge properties (Li and Ganczarczyk, 1991; Grijspeerdt and Verstraete, 1997; Alves et al., 2000).

A dynamic evaluation of the flocs structural properties by using image analysis was developed aiming at improving the understanding of the flocculation process. In this paper the resulting image analysis system is described and the working methodology is demonstrated for structural characterization of activated sludge flocs.

MATERIALS AND METHODS

A schematic drawing of the setup used for on-line quantification of the flocculation process is illustrated in Figure 1. The activated sludge samples are taken from an 80L pilot scale SBR operated under stable environmental conditions.

Set-up description

Images of activated sludge samples are taken using an CX40 optical microscope (Olympus, Japan) connected to a ICD-46E CCD camera (Ikegami Electronics Inc., USA) and digitized with a frame grabber PCI – 1411 (NI, USA). The digitized images are processed on a PC, by means of specific software developed in LabView 6i

(NI, USA). A 4x magnification lens is used in measurements and in order to enlarge the image view on the PC's a 0.35X C – mount adapter was placed between the CCD camera and the microscope.

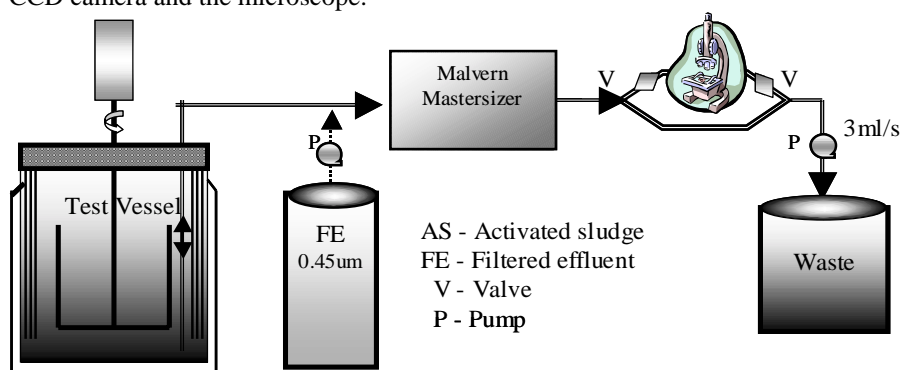


Figure 1. Schematic illustration of the set-up

Software description

For prototyping and testing the image processing algorithms IMAQ Vision Builder (NI, USA) was used. After prototyping, LabVIEW software was used to implement the algorithm and to perform real-time acquisition, analysis and storage of the images. This has the advantage of allowing for the automatic control of the valves.

The image analysis software consists of 3 main steps:

- 1: *Configuration* - file logging, takes the background and the threshold.
- 2: *Image acquisition* – acquires the images (manual or automated).
- 3: *Image analysis* – performs the images analysis and saves the results.

First the background is automatically acquired and then a manual threshold operation enables to select the desired range of greyscale pixel values (Figure 2).

The image analysis can be applied to every acquired picture and consists in the following sequence:

1. **Background subtraction** - The acquired background is subtracted from the pictures.
2. The **lookup table** (LUT) transformations highlight details in areas containing significant information. The *equalize* function alters the grey-level values of pixels so that they become evenly distributed in a defined greyscale range. The *exponential* function expands high grey level ranges while compressing low grey-level ranges.
4. The **threshold** values set before are further applied to every acquired image.
5. A simple **calibration** is used to transform the pixels into microns by using a calibration grid image.
6. The **advanced morphological operations** are used to fill holes in particles and to remove the particles that touch the border of the image.
7. The **particles filter** allows to set the particles size, which are to be analysed.
8. The **particle analysis** gives information about the size and the shape of the particles that have been analysed. The results are automatically generated and saved.

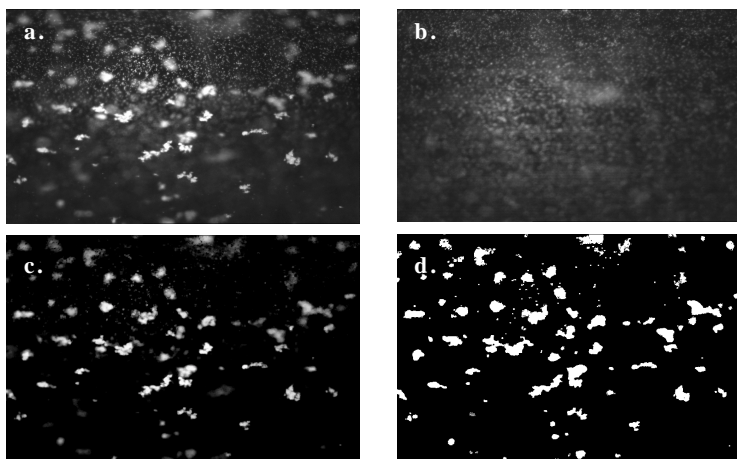


Figure 2. Manual thresholding: a. Original image; b. The background; c. The image after background subtraction, c. Thresholded image

RESULTS

The selected particle analysis parameters are separated in two groups. The first group covers measures of size while the second deals with various aspects of the particles' shape. Within each of these categories, there are a variety of individual parameters that can be measured or calculated from others that are measured directly.

1. Particle size measurements

The size measurement results were first evaluated starting from the assumption of a spherical shape of the flocs and, second from the real size parameters of the flocs (area, perimeter, length, width).

Size measurements based on spherical assumption of the flocs

A linear measure of the size is often more useful than the area and it is common to convert the measured area to the *equivalent sphere diameter*. The data analysis is performed by using a program developed in Matlab, which is running within LabVIEW. Particle size distributions are further obtained as function of number, area and volume. The distributions are generated as histograms on a semi-logarithmic scale.

Size measurements based on size parameters

The most important size parameters are the particles area and number. By using these two parameters the area number frequency distribution is determined. A particularly useful size parameter is also the particle length (maximum Feret's

diameter) defined as the length of the longest segment in the convex hull of a particle in all possible directions of projection (Figure 3a).

2. Shape factors

A major category of measurement parameters is represented by the particles shape factors, which are generally dimensionless numbers and are usually obtained by combining size parameters in various ways.

The Heywood circularity factor (HCF) is used to describe the flocs' circularity.

$$HCF = \frac{Perimeter}{2\sqrt{\pi Area}} \quad (1)$$

Another shape parameter is the *elongation factor (EF)*, which represents the ratio of the longest segment within a particle to the mean length of the perpendicular segment. The more elongated the shape of the flocs, the higher is its EF (Figure 3b).

The ratio of a particle area to the area of the smallest rectangle containing the particle represents the *compactness factor (CF)*.

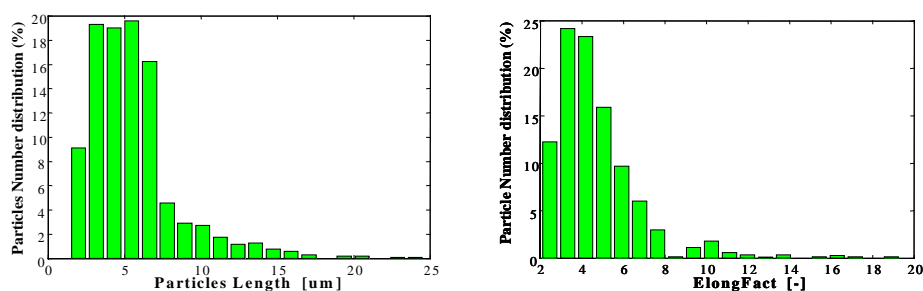


Figure 3. Number distribution function of the particles length (a) and the EF (b)

CONCLUSION

The developed image analysis system represents a useful and automated tool for a faster evaluation of activated sludge flocs' size and structural properties. Moreover, together with other on-line techniques it helps in improving the knowledge in the flocculation process.

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