O PAPEL vol. 84, N.o 1, pp. 62- 65 - JAN 2023

# MONITORING BIOSLUDGE CHARACTERISTICS IN A PULP MILL EFFLUENT TREATMENT PLANT WITH COMPUTER VISION

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## ABSTRACT

*Biosludge characteristics from a pulp mill activated sludge process were studied with computer vision for a period of 11 months. Work included computer vision model training, collecting microscope images of biosludge and image analyses. Image analyses demonstrated that changes in biosludge characteristics can be detected and closely monitored with computer vision. For example, the proportion of filamentous bacteria in the biosludge area varied between 1 and 10%. Also, average floc size increase and floc density improvement during the evaluation period were well observed.*

***Keywords:*** *Wastewater treatment optimization, Biosludge, Computer vision*

## INTRODUCTION

The interest towards developing pulp and paper mill wastewater treatment process control has increased in recent years, due to new targets set for final effluent quality. It is well known that poor settling properties of biosludge increase the risk of suspended solids washout to receiving waterways. Therefore, personnel at wastewater treatment plants usually evaluate biosludge structure with a microscope. In this traditional approach, human-based variations in visual interpretation influence the results reported, leaving room for inconsistencies. In addition, the biosludge floc structure is often not reported at all, while maintaining good floc quality is essential for a stable and efficient activated sludge process. To support visual image interpretation, an automated image analysis of biosludge microscopic images was already introduced in previous studies. Results have shown that floc properties, such as size, density and shape, and the occurrence of filamentous bacteria contribute significantly to biosludge settling properties [1, 2, 3]. Even though the benefits of using automated image analysis have already been reported in literature, it is seldom used by mill personnel in their daily work. However, the exponential growth of available computing power [4] has made it possible to use smart technologies to conduct tasks that have previously been out of reach for mill personnel. In this study, a cloud-based computer vision application was utilized to analyze biosludge microscopic images. The microscopic images were collected from an ECF kraft pulp mill for an 11-month period to gain an understanding whether computer vision could be used as a cloud-based soft sensor for monitoring biosludge structural development over time.

## METHODS

### Sample collection and microscopic image settings

Biosludge samples were collected once a week from the end of aeration basin, and taken to the mill laboratory for microscopic evaluation. A drop of mixed fresh biosludge was collected and covered with a cover slip without any sample staining of fixation, which made the sampling procedure rather effortless.

The images were taken with a Leica Microsystems DM2000 microscope that included a digital camera. A single sample series consisted of 4 images with magnification of 100x. Image settings were standardized by brightness and resolution, since it was discovered that both influenced the visual quality of objects in the image.

### Computer vision model training and image uploading

Annotation is defined as a sense-making practice, where the user assigns meaning to visual data using labels and segmentation, which separate objects in the image to different categories [5]. In this study, the objects were categorized to flocs and filaments.

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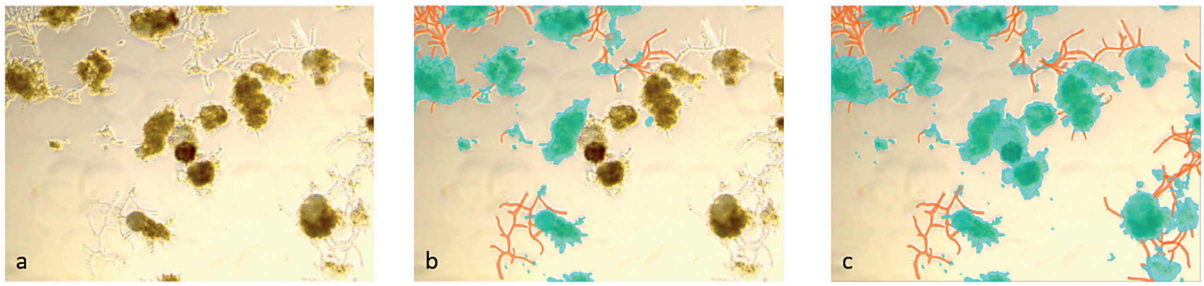


**Figure 1: Manual image annotation process with object categorization to flocs and filaments**

A set of microscopic images was annotated manually to create training data for computer vision to identify objects in the images. In Figure 1, the annotation process is visualized in steps from (a) to (c). Image (a) is the original one taken by mill operators, (b) is partly annotated one object at a time and categorized with label as either "floc" or "filament" category, and (c) is an annotated image where all flocs and filaments are labeled with their own categories.

After the computer vision was calibrated with training data, the microscopic images were uploaded to a computer vision application from the web browser, which was installed on a laboratory computer that was also used for collecting the microscopic images of biosludge.

## Image parameters definition

Based on the literature [1, 2, 3], it was decided that image analysis should cover the amount of filamentous bacteria, floc size, shape, and density. The chosen parameters are presented in Table 1.

To gain informative data of filamentous bacteria relation to flocs, the area of each identified object was defined as number of image pixels in a shape. Floc area was also utilized to evaluate the average floc size and how it developed over time. Brightness levels for each object were defined in grey color scale, where value "0" represents black and value "255" represents white. It can also be considered to represent floc density by estimating floc ability to adsorb light – the denser flocs should be seen as darker flocs in the image. Besides floc brightness, porosity was another parameter that was used to evaluate floc density and uniformity. The porosity scale was set to 0-1. If the floc had more open pores in it, the porosity value was higher. In addition, floc shape was evaluated according to object roundness parameter. In this statistical parameter, value 1 represents a circular object, while lower values represent how far the shape irregulates from circularity.

## RESULTS AND DISCUSSION

Since the extraction of quantitative data from image objects was the primary target for cloud-based computer vision analysis, a total of 50 batches with 4 images per batch was analyzed. As presented in Figure 2, each microscopic image (a) was analyzed, and objects categorized by computer vision as seen in image (b). Each analyzed object contained pixel based numerical information, which was utilized in image data analysis.

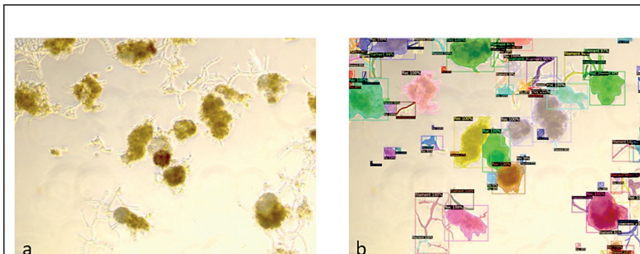


**Figure 2: The original microscopic image (a) and image predicted by computer vision (b)**

**Table 1. Image parameters and features by category chosen for evaluation**

| Parameter | Feature | Floc | Filament |
|---|---|---|---|
| Area | Size/Amount | x | x |
| Brightness | Density | x | |
| Porosity | Density | x | |
| Roundness | Shape | x | |

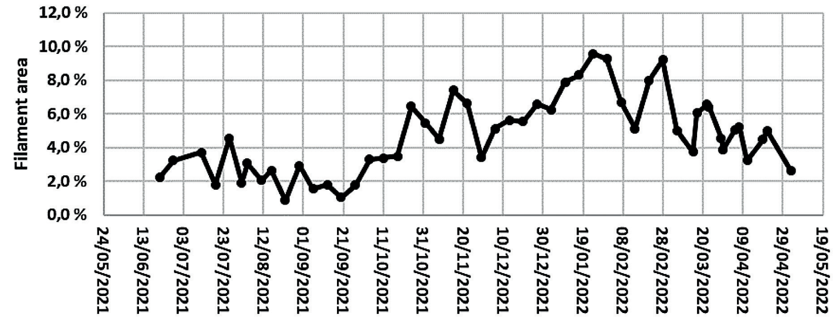


**Figure 3: Filament percentage in biosludge during evaluation period**

Due to the massive amount of data collected, data analysis was done using average values to evaluate the trends in biosludge structural development. In Figure 3, the development of filamentous bacteria is illustrated as their percentage of total biosludge area.

The amount of filamentous bacteria increased between 10/2021 – 03/2022 achieving nearly a 10% share of the total biosludge area. Typically, the increase of filamentous bacteria indicates an appearance of growth limiting factor in biological process, and it is often related with nutrient or oxygen deficiency in secondary treatment. However, in this study, process conditions affecting the filamentous bacteria increase were not evaluated.

In Figures 4-6, biosludge floc characteristics development is illustrated by its average size, brightness, porosity and

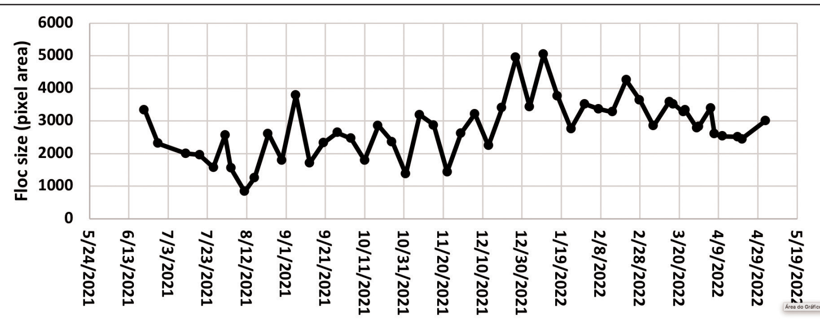


**Figure 4: Average floc size development measured as image pixel area**

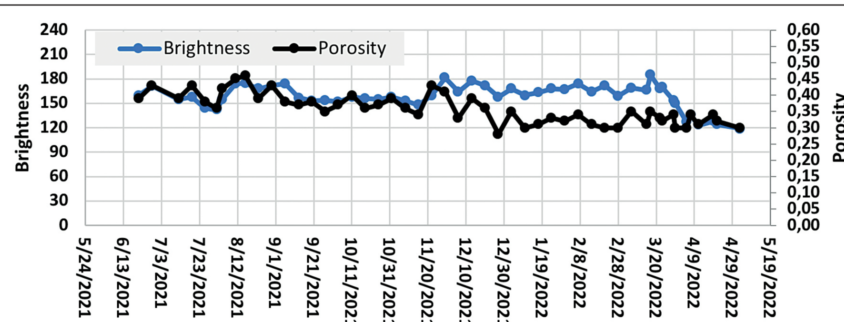


**Figure 5: Floc density evaluation based on average brightness and porosity**

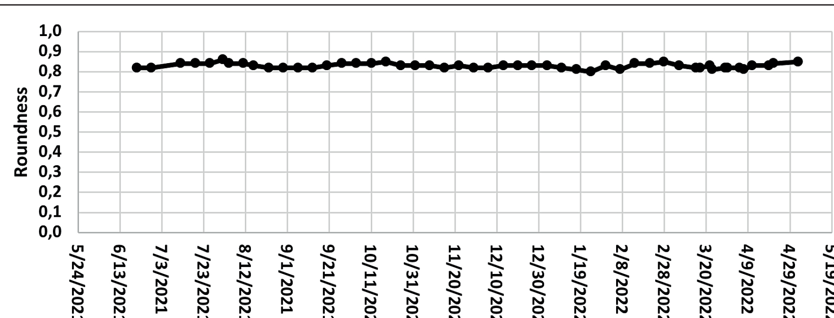


**Figure 6: Floc shape evaluation based on average roundness**

roundness. The conditions in activated sludge process should favor the growth of well-settling biosludge, which consists mainly of large flocs with a strong structure and circular shape.

According to the floc structural development analysis, it can be estimated that average floc size started to increase in 11/2021, which also decreased average floc porosity. However, floc brightness did not change until 03/2022, when average brightness became significantly darker. The reported changes were not seen in the average floc roundness parameter, which remained close to the same level throughout the evaluation period. Interestingly, floc size increase and porosity decrease occurred simultaneously with increased filament amount. This can be at least partly explained by filamentous bacteria's ability to improve floc development until a certain point after which the excessive growth of filaments will deteriorate sludge settling properties.

## CONCLUSIONS

Microscopic image analysis of biosludge with a cloud-based computer vision application seem to provide a consistent, systematic and analytical way to follow biosludge structural development. This could help mill operators identify changes in process conditions that alter biosludge quality. However, the image analysis alone is limited to only categorizing objects that have been labeled in the annotation step. Also, image framing by mill operators influences the information collected, since not all objects in a biosludge sample are captured in a single image. Therefore, it is recommended to take multiple image frames from the sample to improve the representativeness of image data analysis. In addition, the collected image information should be combined with other process variables to gain a deeper understanding on wastewater treatment process performance and factors affecting biosludge quality.

## ACKNOWLEDGEMENTS

*We thank all mill personnel for their rich and fruitful collaboration.* ■

## REFERENCES

1. Schuler, A.J., Jang, H. "Causes of variable biomass density and its effects on settleability in full-scale biological wastewater treatment systems". Environmental Science and Technology 41(5), pp. 1675-1681 (2007)
2. Koivuranta, E., Keskitalo, J., Haapala, A., Stoor, T., Sarén, M., Niinimäki, J. "Optical monitoring of activated sludge flocs in bulking and non-bulking conditions". Environmental Technology 34(5), pp. 679 – 686 (2012)
3. Da Motta, M., Amaral, L-P, Casellas, M., Pons, M-N., Dagot, C., Roche, N., Ferreira, E.C., Vivier, H. "Characterization of activated sludge by automated image analysis: Validation on full-scale plants". IFAC Proceedings Volumes 34(5), pp. 427-431 (2001)
4. Rupp, K. "50 years of Microprocessor Trend Data." github.com/karlrupp/microprocessor-trend-data, (2022)
5. Miceli, M., Schuessler, M., Yang, T. "Between Subjectivity and Imposition: Power Dynamics in Data Annotation for Computer Vision". Proceedings of the ACM on Human-Computer Interaction 4(CSCW2), pp. 1-25