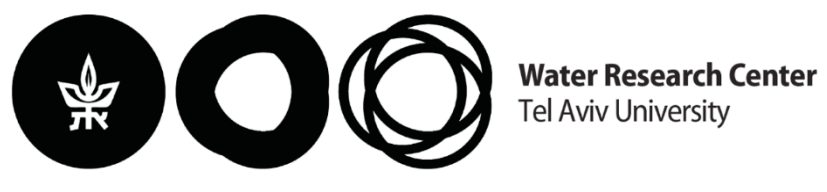


# Analyzing the secondary wastewater-treatment process using Faster R-CNN and YOLOv5 object detection algorithms



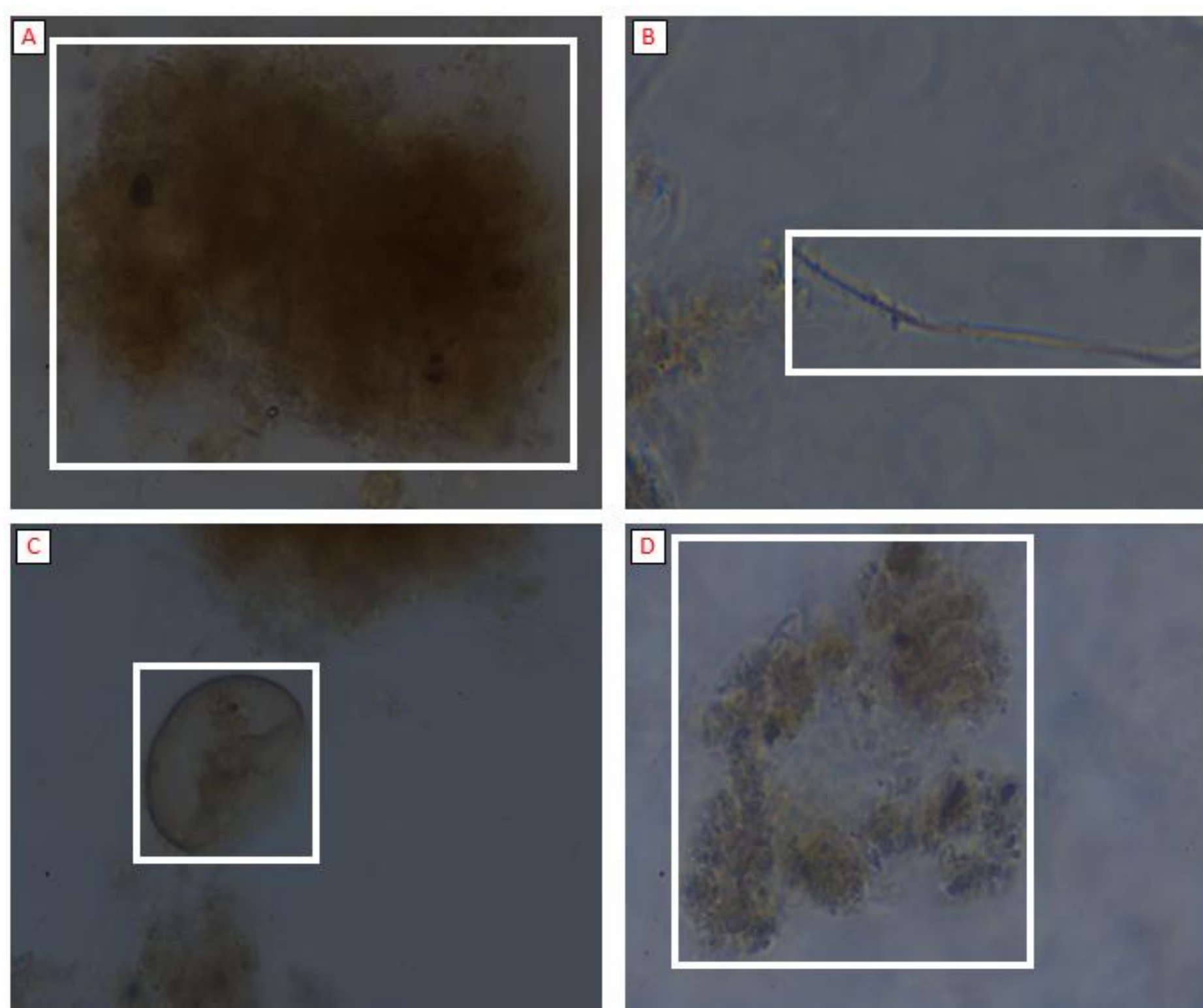
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## 1. Abstract

The activated sludge (AS) process is the **most common type of secondary wastewater treatment**, applied worldwide. Due to the complexity of microbial communities, imbalances between the different types of bacteria may occur and disturb the process, with pronounced economical and environmental consequences. Microscopic inspection of the morphology of flocs and microorganisms provides key information on AS properties and function. This is a time-consuming, highly skilled, and expensive process that is not readily available in all locations. Thus, most wastewater-treatment plants **do not carry out this essential analysis**, resulting in frequent operational faults. In this study, we develop a novel deep learning (DL) object detection algorithm to analyze and monitor the AS process based on a unique microscopic image database of flocs and microorganisms. Specifically, we applied YOLOv5 and Faster R-CNN algorithms as tools for segmentation and object detection to analyze the wastewater. **The mean average precision (mAP) of the YOLOv5 was 0.77**, outperforming the Faster R-CNN by 15%. Histogram equalization preprocessing of both bright-field and phase-contrast images significantly improved the results of the algorithm in all classes in 15-20%. These results demonstrate the potential of leveraging DL algorithms to enhance the analysis and monitoring of waste water treatment plants (WWTPs) in an affordable manner, **consequently reducing environmental pollution caused by contaminated effluent**.

## 2. Methods



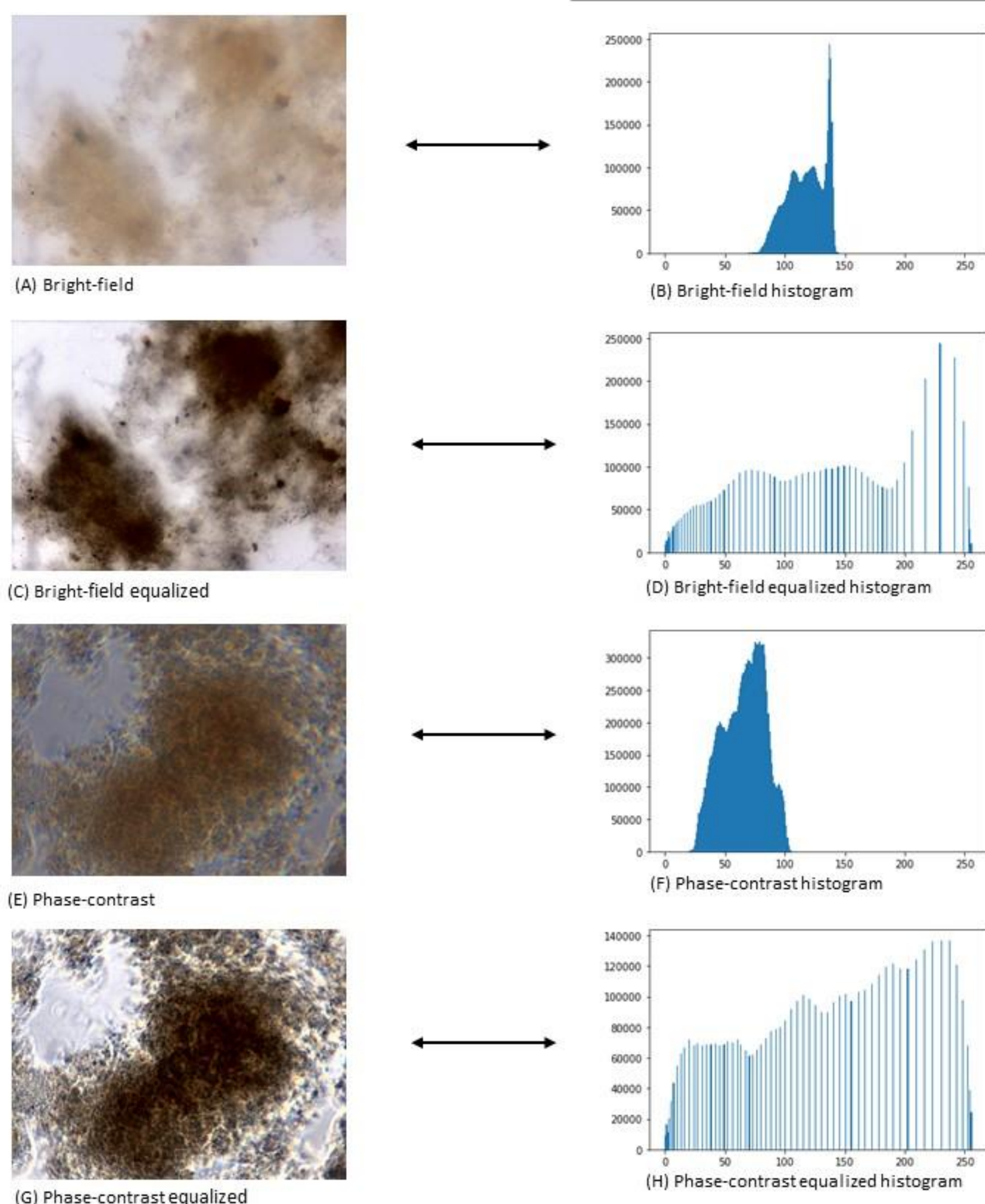
- A. 1448 microscopic AS images were acquired from WWTPs in Israel at X400 magnification.
- B. Spherical flocs, open flocs, protozoa, and filaments were chosen as the indicative classes for AS analysis because they provide key information on the state of the system.
- C. Chosen model: Yolov5 and Faster R-CNN object detection models.

**Figure 1:** An example of microscopic images of activated sludge (at X400 magnification) annotated by bounding boxes that served as the input for the object detection model. (A) Spherical floc, (B) filamentous bacteria, (C) protozoa, and (D) open floc.

## 3. Results

**Table 1:** Comparison of average precision (AP) and mean average precision (mAP) metrics for Faster R-CNN and YOLOv5 with and without histogram equalization.

DL approach	Filaments	Protozoa	Spherical flocs	Open flocs	mAP
YOLOv5I	0.43	0.74	0.82	0.65	0.66
Faster R-CNN	0.49	0.44	0.80	0.57	0.58
YOLOv5I + Histogram equalization	0.52	0.90	0.87	0.80	0.77



**Figure 3:** Images of bright-field and phase-contrast flocs (left) along with their respective intensity histograms before and after equalization (right). Before the equalization, the range of intensity of the bright-field was 75–150, and 25–100 for phase-contrast. Following the equalization process, the histograms are in the equivalent range.

## 4. Conclusions

- Our work offers a potential **alternative to traditional AS analysis** methods that rely on specialized laboratories and expert analysis, which may not be accessible in all areas.
- This study is the first step towards the development of a framework that can be adopted by WWTPs as a **smart tool** that will analyze microscopic images of the AS process, and provide operators with the accurate status of the treatment process.
- The fundamental challenge addressed herein has **important global relevance**, especially in an era in which the demand for high-quality wastewater reuse is expected to increase dramatically.

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## References

O. Inbar, M. Shahar, J. Gidron, I. Cohen, O. Menashe, D. Avisar (2023). Analyzing the secondary wastewater-treatment process using Faster R-CNN and YOLOv5 object detection algorithms. *Journal of Cleaner Production*.



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