Novel Organic Carrier for Aerobic Granulation in Continuous Flow Systems

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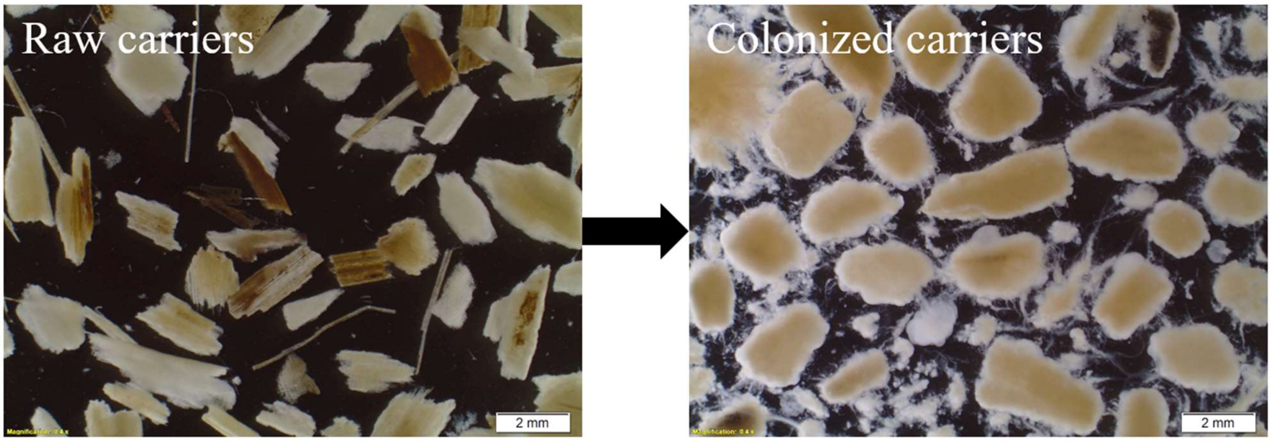

Preliminary reactor operation showing colonization of biomass on the organic kenaf carriers after 49 days.

Background

Rapid urbanization has created a worldwide challenge for municipalities and engineers to increase treatment capacity of existing wastewater treatment plants (WWTP) while facing space limitations and addressing energy efficiency. A promising solution is granulation, a technology where biomass self-aggregates and forms semi-spherical biofilm particles known as aerobic granular sludge (AGS). AGS occupies one-third of the volume needed for activated sludge while eliminating the need for secondary clarifiers (Pronk et al., 2015; Winkler et al., 2018), leading to tremendous increase in biomass concentration without expanding the WWTP footprint. However, AGS technology is established in sequencing batch reactors (SBR) while most existing WWTP are operated in continuous flow (CF) mode that cannot be easily modified into SBRs. SBRs offer both the microbial and physical selections favorable for granulation while the same selection factors are difficult to achieve in CF systems. Therefore, widespread application of the AGS technology is currently limited by the knowledge gap for its integration into CF systems.

Nonetheless, granules have been observed in CF systems, and the authors of these studies speculated that slow-growing heterotrophic bacteria with intracellular polymer-storing capacity play an important role (Wei et al., 2021; Wei et al., 2020). These groups of bacteria are typically the key microbial functional groups performing biological carbon and phosphorus removal and are enriched at WWTP with anaerobic selectors. Recently, a new technology—utilizing an all-organic media carrier made of porous kenaf plant stalks—has been demonstrated effective at achieving granulation at a continuous flow plant that removes phosphorus biologically (Wei et al., 2021). However, most of the WWTPs in Switzerland do not have anaerobic selectors and are instead operated in anoxic/aerobic modes that enrich for microbial functional groups performing nitrogen removal. A key question is whether granulation can be achieved in a system operated without biological P removal (i.e., in anoxic/aerobic modes)? In addition, will the same system establish biological P removal capacity once biomass has accumulated due to granulation? Another key research aspect is related to how microbial functional groups are distributed on the flocs versus biofilm, with practical implications such as: (i) can EBPR performance be sustained if polyphosphate accumulating organisms are mainly on the biofilm? (ii) will nitrification capacity decrease as biofilm thickness increases?

Objectives

The main objective of the proposed master thesis is to investigate: (1) the feasibility of the organic media carrier technology and (2) the role of metabolic processes for achieving biomass colonization and granulation in continuous flow systems.
The specific objectives are:

- To characterize the physical properties of granules formed.
- To investigate the partitioning of microbial functional groups in flocs versus granules.
- To make practical recommendations for integrating AGS technology in CF systems.

Approach

A pilot-scale continuous flow reactor will be operated in anoxic/aerobic mode. The Mobile Organic Biofilm^{TM} process will be used to facilitate granulation, which consists of seeding the reactor with organic carriers made of cellulosic material and selective wasting of flocs. This Master's thesis will consist of operating the reactor, monitoring the granulation process, and measuring the nutrient removal activities of granules and flocs over time. If interested and time allows, molecular techniques such as DNA extraction, amplicon sequencing, and bioinformatics can also be part of the Master's thesis.

Requirements

This master thesis project is suited for students with interests in (1) biological wastewater treatment, (2) microbial processes for nutrient removal in wastewater, and (3) process engineering.

Advisors

Main supervisor: Stephany Wei and Nico Derlon
Advisor (ETHZ responsible professor): Prof. Morgenroth (ETHZ)

Contact information
Name: Stephany Wei
Email: stephany.wei@eawag.ch
Phone : +41 58 765 6846

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