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Integrating PHA production with municipal wastewater treatment

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Motivation

The increasing world population causes the production of large quantities of urban and industrial waste. Every person can generate up to 30 kg dry sludge solids per year due to wastewater treatment for environment protection. During recent years, a plethora of research has shed much light on the techno-economic feasibility of energy and resource recovery from the wastewater treatment by-products. Production of polyhydroxyalkanoate (PHA) using waste activated sludge (WAS) and fermented organic waste is one valorization route for residual organic material. It is estimated that the PHA accumulation potential of WAS from wastewater treatment plants (WWTPs) can result in more than 60 % (w/w) of the organic matter in the product biomass being PHA[1]. This potential suggests that full-scale WWTPs can serve as process units to supply organic and biomass resources for commercial scale PHA production (Fig 1). Integrating production of PHA with municipal wastewater treatment also opens up an opportunity for reducing the carbon emissions and lowering the combined cost of waste treatment and biopolymer production.

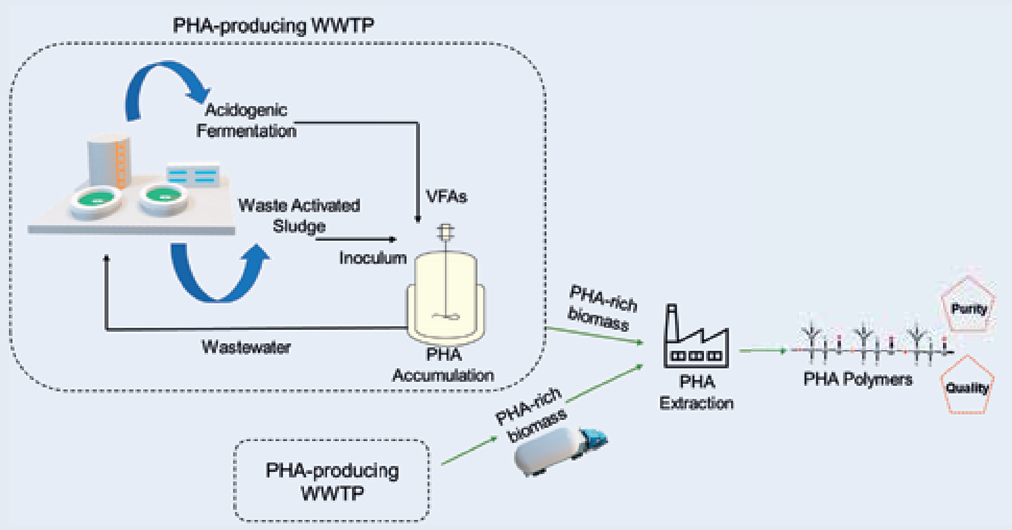

Fig 2. Schematic of PHA production from wastewater treatment by-products.

Technological challenge

Production of PHA as a recovered product coupled to wastewater treatment requires viable process methods that can maximize quantity of product, with quality control (Fig 2).

With the presence of nutrients in the fermentation feedstocks there is a risk for growth of non-PHA storing bacteria and that reduces the PHA process productivity[2]. Methods to promote the selective growth of the PHA-storing biomass while mitigating flanking population growth directly in a PHA accumulation process is a key to the reliable commercial PHA production. Bioprocess methods need to be optimized with help of a deepened understanding of influencing competition strategies for different kinds of bacteria that comprise the WAS biomass.

Moreover, VFA rich feedstocks coming from acidogenic fermentation of primary sludge may often be in the moderate to low VFA concentration (<10 gCOD/L). An industrial facility for PHA production would need to accommodate variability of feedstock VFA composition and concentration, while still guaranteeing predictable quality of the produced polymer.

Lastly, polymer molecular weight is a critical parameter that influences what the polymers can be used for. Quality control of molecular weight has been lacking in the developments to date that have been published in the research literature.

Fig 1. Municipal wastewater treatment plant BATH. This WWTP treats wastewater for 500,000 person equivalents and has the potential to supply biomass to produce 2000-2500 ton PHA/year[1].

Research goals

The project objectives are to:

- Unravel and exploit the underlying mechanisms that favour selective growth of the PHA-producing microorganisms over non-PHA accumulating microorganisms in the PHA accumulation process.
- Establish robust bioprocess methods to accommodate variability of feedstock VFA composition and concentration.
- Maximize the polymer quality with molecular weight in the accumulation process and define boundary conditions of environment(s) to conserve molecular weight in the production of the primary product as a renewable resource from the WWTP – a dried PHA-rich biomass.

[1] Bengtsson et al (2017) PHARIO report, STOWA, 11.
[2] Estévez-Alonso et al (2021) Bioresource Technology, 327: 124790

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