Plastic, Wastewater treatment, Circular economy

Development of a bioplastic production system using waste activated sludge as biocatalyst

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Abstract

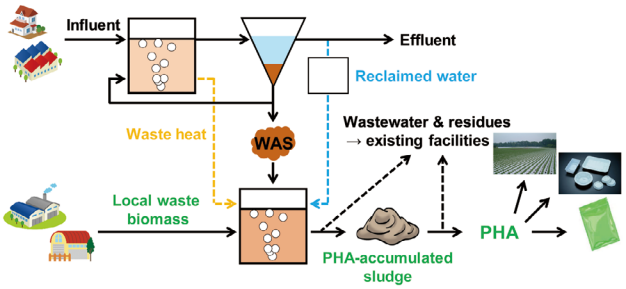
Wastewater treatment by activated sludge processes generate huge amounts of waste activated sludge (WAS) which mainly comprises a variety of microorganisms. The enhanced transformation of WAS to high value-added materials is still a big challenge for sustainable wastewater treatment. Therefore, we plan to use WAS as the biocatalyst to produce polyhydroxyalkanoates (PHA), which are biodegradable and biocompatible thermoplastic substances synthesized by bacteria, from industrial wastewater/wastes as feedstock for establishment of a PHA production system in wastewater treatment plants. To achieve this goal, we have been working to establish the fundamental technologies, such as the methods to rapidly enrich PHA-accumulating bacteria in WAS, and to efficiently recover PHA stored in WAS.

Background & Results

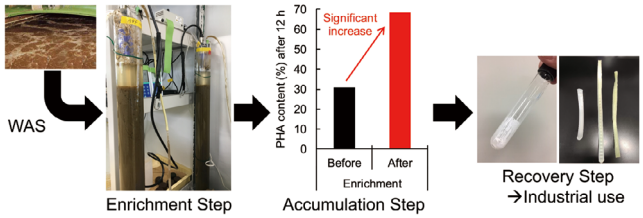
Although WAS can produce PHA from various substrates, its PHA production capability is not necessarily high owing to the co-existence of PHA-accumulating and non-PHA-accumulating bacteria. Consequently, the enrichment of PHA-accumulating bacteria is a key step for efficient PHA production using WAS as the biocatalyst. However, the long enrichment duration in previous methods is a significant obstacle limiting the beneficial use of daily generated WAS in wastewater treatment plants (WWTPs). Therefore, we have studied the methods to achieve high enrichment of PHA-accumulating bacteria within a short period (i.e., several days during which WAS is pooled in WWTPs). With this aim, we employed an aerobic dynamic discharge (ADD) process that selectively enriches PHA-accumulating bacteria by imposing an ecological selective pressure with the feast-famine regime and a physical selective pressure based on the increased cell density by intracellular PHA storage. Till date, we have succeeded in obtaining mixed microbial cultures (MMCs) with a very high PHA accumulation capability within several days, using acetate or glucose as the enrichment substrate. Especially, MMCs capable of storing as much as nearly 70 wt% of PHA could be obtained within only 2 d when acetate was used as the substrate. We have also studied and gained knowledge on the environmentally-friendly method to recover PHA stored in the MMCs with high yield and purity, without losing the physical properties as practically acceptable plastic materials.

Significance of the research and Future perspective

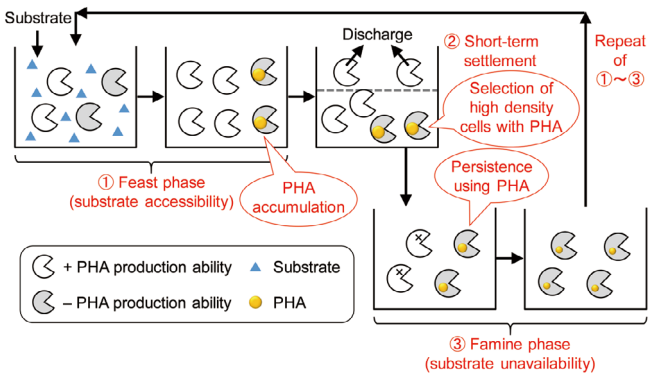
WWTPs are indispensable urban infrastructure for public health, aquatic environmental conservation, and sustainable water use. Our goal is to evolve WWTPs as a core facility to create future circular society by adding the function of bio-refinery to produce PHA and other high value-added materials from wastewater/wastes. Realization of this idea will contribute largely to the carbon neutral society. Additionally, PHA is a promising alternative plastic material applicable in a multitude of fields. PHA production with low cost and energy input, which is aimed in this study, will also be of great importance in the light of environmental protection.



Concept of evolving a wastewater treatment plant as the bio-refinery to produce PHA



Flow of PHA production using WAS as the biocatalyst



Principle of the aerobic dynamic discharge process applied for rapid enrichment of PHA-accumulating bacteria from WAS

Manufacturing technologies

Patent

Treatise
Inoue, Daisuke; Fukuyama, Atsushi; Ike, Michihiko et al. Optimization of aerobic dynamic discharge process for very rapid enrichment of polyhydroxyalkanoates-accumulating bacteria from activated sludge. Bioresource Technology. 2021, 336, 125314, doi: 10.1016/j.biortech.2021.125314
Ike, Michihiko; Okada, Yukihiro; Inoue, Daisuke et al. Potential of waste activated sludge to accumulate polyhydroxyalkanoates and glycogen using industrial wastewater/liquid wastes as substrates. Water Science and Technology. 2019, 80 (12), 2373-2380, doi: 10.2166/wst.2020.059

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http://www.see.eng.osaka-u.ac.jp/wb/ikelab/
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Keyword waste activated sludge, biocatalyst, bioplastic, polyhydroxyalkanoates