Advancing Bio-based Plastics and Functional Materials for a Circular Economy

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Achieving a sustainable society and addressing global environmental challenges are among the most critical imperatives of our time, as articulated in the United Nations Sustainable Development Goals (SDGs). In particular, goals such as "Responsible Consumption and Production," "Climate Action," and "Life Below Water" highlight the urgent need to transform the ways in which we produce, use, and dispose of materials.

Plastic pollution is a major global concern, primarily due to the persistence of petroleum-based plastics that resist degradation and contribute to environmental contamination and greenhouse gas emissions. In response to this issue, our research focuses on developing a low-energy, sustainable technology for the production of biodegradable plastics, specifically polyhydroxyalkanoates (PHAs), using recalcitrant aromatic organochlorine compounds and industrial carbon dioxide (CO_2) emissions as raw materials.

The proposed process integrates two key innovations. First, an electrochemical dechlorination reaction is conducted under mild conditions, converting hazardous organochlorines into phenolic compounds. These compounds are then utilized as substrates by specially isolated bacteria capable of biosynthesizing PHAs. Second, the system incorporates CO_2 captured directly from industrial flue gases as an additional carbon source, enabling effective carbon recycling and cost-efficient production.

Unlike conventional methods that require high temperatures, high pressures, or rare resources, our approach utilizes recyclable functional electrodes and selective catalysts. This offers significant advantages in terms of both environmental sustainability and economic feasibility. In addition, we are exploring the health-promoting potential of 3-hydroxybutyrate, a key degradation product of PHA, which could further improve the overall value of the process.

This integrated approach provides a promising solution to multiple challenges, including carbon recycling, chemical pollution mitigation, and the promotion of circular economies. By using actual industrial exhaust and aligning with Japan's goal of achieving carbon neutrality by 2050, the technology demonstrates strong potential for broad application in both industrialized and developing regions. Ultimately, by upcycling resources such as sewage, toxic compounds, and carbon dioxide, we aim to establish a platform for producing biodegradable plastics and health-beneficial substances, contributing to the realization of a circular and sustainable society.

Keywords: polyhydroxyalkanoates (PHAs); bioplastic; CO_2 utilization; electrochemical dechlorination reaction; sustainable society