Food waste treatment and energy recovery in Megacities

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Effective management and treatment of food waste is an increasingly prominent issue for countries around the world. Approximately 50 million tonnes of food waste were generated in China. The amount of food waste generated is expected to further increase with growing population and economic activity. Besides the resources needed to collect and dispose it, food waste contaminates recyclables, compromises recycling efforts, and causes odour nuisance and vermin proliferation if not managed properly. Due to the high moisture content and high biodegradability of food waste, the disposal of food waste has caused severe environmental pollution in many countries. In view of rising costs for waste disposal as well as depleting energy resources, the anaerobic digestion (AD) of food waste was found to be a more sustainable treatment method due to the high degree of waste stabilization and methane generation.

During AD, anaerobic microorganisms degrade organic waste through metabolic processes while recovering energy in the form of methane, thus serving as a crucial means for pollution reduction and carbon mitigation. However, the lengthy metabolic cycle and low conversion efficiency of methanogens result in suboptimal methane yields, thereby impeding the progress of organic waste valorization. Recent studies have demonstrated that the addition of iron/carbon materials as electron mediators can significantly enhance microbial metabolic processes and improve methane production. Nevertheless, the mechanism of interfacial electron transfer between iron/carbon materials and microorganisms remains unclear. Interfacial electron transfer is closely related to microbial metabolism and energy utilization. The varying characteristics of different iron/carbon materials result in distinct electron mediator-microorganism interfacial transfer efficiencies, limiting their effectiveness in addressing specific environmental issues. Understanding the electron mediator-microorganism interfacial electron transfer mechanisms mediated by iron/carbon materials during anaerobic methanogenesis is crucial for enhancing interfacial reactions. Additionally, leveraging these interfacial electron transfer relationships to address microbial-microbial electron transfer issues is an important approach to improving the efficacy of iron/carbon materials. Therefore, it is essential to investigate the unique electron transfer properties of iron/carbon materials in the context of real environmental problems to enhance methane production efficiency in AD.

To address these issues, our study focuses on three common iron/carbon materials: zero-valent iron (ZVI), iron oxides, and biochar. Based on their shared conductive properties and distinct electron mediator characteristics, the study investigates the limitations of intracellular and extracellular interfacial electron transfer in AD. The research examines the mechanisms and energy flows of microbial intracellular and extracellular interfacial electron transfer mediated by iron/carbon materials in different environmental contexts. The aim is to regulate intracellular and extracellular electron transfer pathways, enhance interfacial electron transfer efficiency, and promote methane production by anaerobic microorganisms. This study seeks to provide a scientific basis for enhancing the efficiency of methane production in AD through iron/carbon materials, thereby accelerating the efficient and stable valorization of organic waste.

Keywords: Anaerobic digestion; Biogas; Extracellular electron transfer; Iron; Biochar