Synergistic Coupling of Plasma with Microbubbles for Enhancing Short-Chain Fatty Acids Production from Waste Activated Sludge

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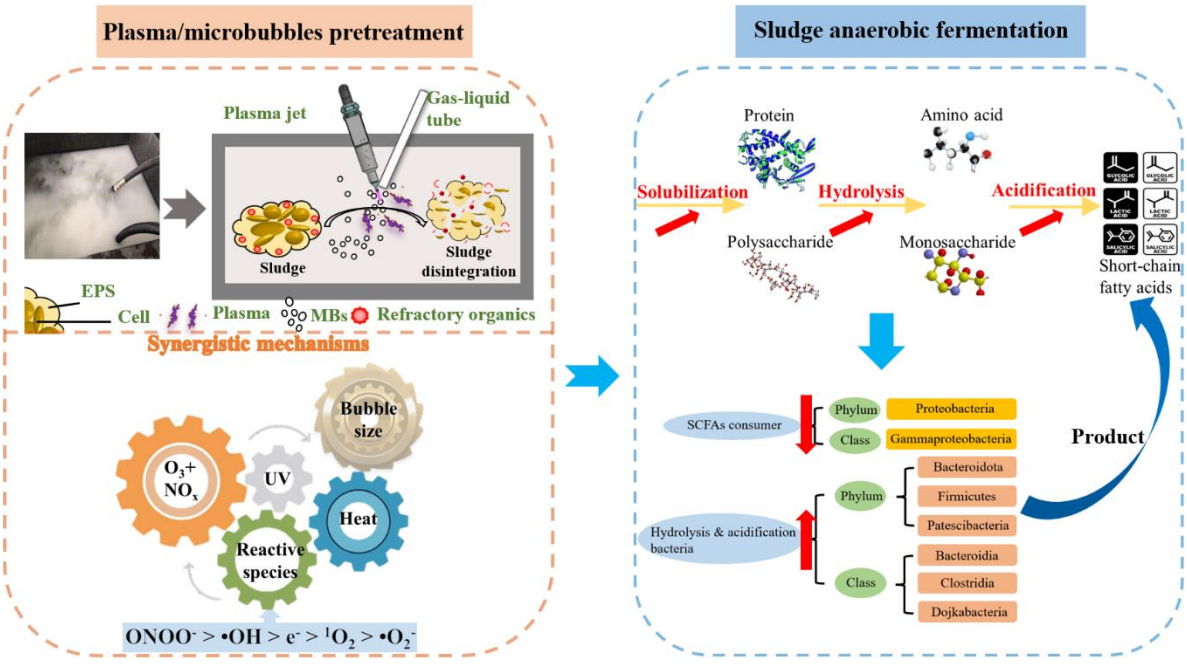
The use of waste activated sludge (WAS) fermentative short-chain fatty acids (SCFAs) as the excellent carbon source of wastewater biological nutrient removal has drawn much attention recently as it can reuse WAS organics and reduce WAS production. This study developed a novel, efficient, and environmental-friendly approach combining atmospheric pressure plasma jet with microbubbles (plasma/MBs) for WAS pretreatment.

Batch experiments were conducted using waste activated sludge (WAS). The novel pretreatment combined an atmospheric pressure plasma jet (500 W, 3 min) with a microbubble generator (7.9 mg/L DO). Following pretreatment, anaerobic fermentation was performed in parallel reactors at 35°C for 25 days. Key parameters including SCOD, proteins, polysaccharides, and SCFAs were quantified. The synergistic mechanisms were investigated using radical scavengers and Electron Paramagnetic Resonance (EPR) to identify reactive species (e.g., •OH, $ONOO^-$). Microbial community dynamics and metabolic pathways were analyzed via 16S rRNA gene sequencing and Tax4Fun.

Compared with the control, plasma/MBs pretreatment enhanced SCFA generation by 92% and acetic acid proportion by 21% with plasma discharge power at 500 W and MBs dosage at 7.9 mg/L dissolved oxygen. The plasma/MBs combination motivated the reaction of various reactive species (such as O_3, NO_x, $ONOO^-$, •OH, e^-, $^1O_2$, and $•O_2^-$) and enhanced the activity of physical energies (such as light and heat). This synergy promoted sludge cell lysis and biodegradable substance release, significantly boosting acetic acid-enriched SCFA generation from fermentation. Moreover, plasma/MBs pretreatment increased the expression of key genes for SCFA production during fermentation, which also contributed to the production of SCFAs. Besides, plasma/MBs pretreatment favored WAS dewatering, heavy metal removal, and organic pollutant degradation, providing a new approach to advancing WAS resource recovery through innocuous management.



Keywords: Non-thermal plasma; Waste activated sludge; Microbubbles; Sludge anaerobic fermentation; Short-chain fatty acids

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