Role of Electrically Conductive Nanoparticles in Organic Waste Sludge Biogas Upgrading in Anaerobic Digestion

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Abstract

Anaerobic digestion is commonly used for energy recovery from waste organic sludge generated by wastewater treatment processes, in the form of biogas, consisting mostly of methane and carbon dioxide. Although energetically rich, the significant CO2 content limits the use versatility of this product. Bio-methanation (upgrading to natural gas standards) increases the energy and use value of biogas and is increasingly considered for its upgrading. Supplementation of various electrically conductive nanoparticle materials (nano-ECMs), including magnetite (Fe3O4) nanoparticles has been proposed as a strategy to enhance H2–driven biomethanation in mixed hydrogenotrophic methanogenic anaerobic digestion communities.

Research findings indicate that ECM nanoparticles facilitate direct interspecies electron transfer (DIET) mechanism within anaerobic reactor microbiomes, allowing faster electron shuttling between various bacterial species and methanogens, accelerating biomethanation. These results highlighted the potential of magnetite-mediated DIET to improve waste-to-methane processes, advancing biogas upgrading technologies.

The paper summarizes the state-of-the-art in anaerobic digestion biogas upgrading by ECMs and critically discusses recent laboratory findings and examines possible strategies for full-scale implementation of this innovative technology.