Modulation of sewage sludge microbiota for enhancing the transition from wastewater treatment plants into biorefineries in the circular economy era

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Transitioning traditional wastewater treatment plants into biorefineries offers an environmentally and economically sustainable solution. Indeed, valuable compounds can still be extracted from waste. Utilizing sewage sludge (SS) with its microbial component, materials such as volatile fatty acids (VFAs) and polyhydroxyalkanoates (PHAs) within specially designed WWTP reactors can be obtained. VFAs serve as precursors to PHAs, which provide an eco-friendly alternative to petroleum-based plastics. Understanding the impact of various operating conditions on microbial components is crucial for driving microbial metabolism toward the biosynthesis of these molecules. This innovative study, part of the European project “Achieving wider uptake of water-smart solutions”, focused on evaluating the effects of two operating conditions—the headspace volume in the fermenter and the organic loading rate (ORL) in the selective-sequence batch reactor (S-SBR)—on VFA and PHA production. The wastewater from the Palermo University campus was used to inoculate a pilot plant to simulate a real urban WWTP. Our approach is based on comparing the microbial community before and after the incubation process through metagenomic DNA extraction and 16S rDNA sequencing and on quantifying PHA and VFA yields by gas chromatography analysis. This analysis revealed that 40% of headspace volume in a 225L fermenter and an ORL of 1.3 g COD $L^{-1}d^{-1}$ in S-SBR maximized VFA and PHA production. The metataxonomic analysis showed significant changes in the SS microbiota structure, promoting the growth of bacteria like Proteobacteria, Firmicutes, and Actinobacteria while reducing Verrucomicrobia. These findings enhance our understanding of bacterial modulation under various operational conditions and highlight the potential for exploiting the resources in SS within a circular economy framework.