Comprehensive insights into metabolic potentials and engineered applications of two novel simultaneous aerobic denitrification and phosphorus removal bacteria, Achromobacter sp. GAD3 and Agrobacterium sp. LAD9

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Bacteria capable of simultaneous aerobic denitrification and phosphorus removal (SADPR) are promising for the establishment of novel one-stage wastewater treatment systems. Nevertheless, insights into the metabolic potentials and engineered applications of SADPR-related bacteria are limited. Firstly, comprehensive metabolic models of two efficient SADPR bacteria, Achromobacter sp. GAD3 and Agrobacterium sp. LAD9, were obtained by high-throughput genome sequencing. With succinate as the preferred carbon source, both strains employed a complete TCA cycle as the major carbon metabolism for potentials of various organic acids and complex carbon oxidation. Complete and truncated aerobic denitrification routes were confirmed in GAD3 and LAD9, respectively, facilitated by all the major components of the electron transfer chain via oxidative phosphorylation. Comparative genome analysis revealed distinctive ecological niches involved in denitrification among different phylogenetic clades within Achromobacter and Agrobacterium. Excellent phosphorus removal capacities were contributed by inorganic phosphate uptake, polyphosphate synthesis and phosphonate metabolism. Additionally, the physiology of GAD3/LAD9 is different from that displayed by most available polyphosphate accumulating organisms, and reveals both strains to be more versatile, carrying out potentials for diverse organics degradation and outstanding SADPR capacity within a single organism. Secondly, both GAD3 and LAD9 were successfully applied for bioaugmented treatment of municipal wastewater in a pilot-scale sequencing batch reactor. At an appropriate COD/N ratio of 8, the bioaugmentation system exhibited stable and excellent carbon and nutrients removal, the averaged effluent concentrations of COD, NH$_4^+$-N, TN and TP were 20.6, 0.69, 14.1 and 0.40 mg/L, respectively, which could meet the first class requirement of the National Municipal Wastewater Discharge Standards of China (COD < 50 mg/L, TN < 15 mg/L, TP < 0.5 mg/L). Clone library and real-time polymerase chain reaction analysis revealed that the introduced bacteria greatly improved the structure of original microbial community and facilitated their aerobic nutrients removal capacities. This proposed emerging technology was shown to be an alternative technology to establish new wastewater treatment systems and upgrade or retrofit conventional systems from secondary-level to tertiary-level.