Enrichment and characterization of a bacteria consortium capable of heterotrophic nitrification and aerobic denitrification at low temperature

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ABSTRACT

Nitrogen removal in wastewater treatment plants is usually severely inhibited under cold temperature. The present study proposes bioaugmentation using psychrotolerant heterotrophic nitrification–aerobic denitrification consortium to enhance nitrogen removal at low temperature. A functional consortium has been successfully enriched by stepped increase in DO concentration. Using this consortium, the specific removal rates of ammonia and nitrate at 10 °C reached as high as 3.1 mg N/(g SSh) and 9.6 mg N/(g SSh), respectively. PCR-DGGE and clone library analysis both indicated a significant reduction in bacterial diversity during enrichment. Phylogenetic analysis based on nearly full-length 16S rRNA genes showed that Alphaproteobacteria, Deltaproteobacteria and particularly Bacteroidetes declined while Gammaproteobacteria (all clustered into Pseudomonas sp.) and Betaproteobacteria (mainly Rhodoferax ferrireducens) became dominant in the enriched consortium. It is likely that Pseudomonas spp. played a major role in nitrification and denitrification, while R. ferrireducens and its relatives utilized nitrate as both electron acceptor and nitrogen source.

1. Introduction

During the last few decades, the importance of nutrient removal has increased as a result of the necessity to avoid eutrophication of receiving waters. The most common, efficient, and cost-effective way to remove nitrogen from municipal and industrial wastewaters is biological treatment which normally involves autotrophic nitrification and anoxic denitrification. However, the implementation of biological technology is very challenging in the winter months due to high sensitivity of autotrophic nitrifiers to low temperature. Randall and Buth (1984) demonstrated that both nitrite and nitrate formation were strongly inhibited at temperatures of 10 °C or less. Studies of various wastewater treatment systems employing nitrification have reported that failures occurred during the winter (Ilies and Mavinic, 2001; Kim et al., 2006). Additionally, the reliability of denitrification on the temperature was increased when temperature fell below 10 °C (Carrera et al., 2003).

Recent studies have highlighted the existence of bacteria which are both heterotrophic nitrifier and aerobic denitrifier, such as Alcaligenes faecalis (Joo et al., 2005), Acinetobacter calcoaceticus (Zhao et al., 2010), Pseudomonas stutzeri (Zhang et al., 2011), and Bacillus subtilis (Yang et al., 2011). Under aerobic conditions, these heterotrophic microorganisms are able to oxidize ammonia to hydroxylamine, nitrite, or nitrate and immediately denitrify these products to N₂O and/or N₂. As a result, ammonium compounds can be converted to gaseous products in a single aeration phase. Due to their useful characteristics, heterotrophic nitrifying–aerobic denitrifying microorganisms have already been applied in the bioaugmentation treatment of nitrogenous wastewater (Bouchez et al., 2009; Joo et al., 2006; Patureau et al., 2001).

Under cold temperatures conditions, bioaugmentation using heterotrophic nitrifying–aerobic denitrifying microorganisms...