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Evaluation of sulfur-based autotrophic denitrification and denitritation for biological removal of nitrate and nitrite from contaminated waters

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ABSTRACT

Sulfur-based autotrophic denitrification and denitritation were investigated using an oil reservoir culture. In batch system nitrate up to 20 mM was reduced with concomitant sulfate production. With 20 mM nitrate, reduction of produced nitrite did not occur which was contrary to that under heterotrophic conditions. Reduction of nitrite as the sole substrate occurred even at 50 mM. When both sulfur and acetate were present, only acetate was used as the electron donor. In the continuous biofilm reactor maximum nitrate and nitrite removal rates of 17.3 and 13.2 mM/h, much higher than literature values, were achieved at residence times of 0.4 and 0.6 h, respectively. Bicarbonate functioned effectively as carbon source and alkaline, and eliminated the problems associated with lime addition. Based on these and our earlier findings the highest nitrate and nitrite removal rates are achieved under heterotrophic conditions with acetate, followed by autotrophic rates with sulfide, and then elemental sulfur.

1. Introduction

Contamination of ground and surface waters with nitrogenous compounds such as ammonia, nitrite and nitrate is a major environmental concern, leading to eutrophication and serious ecological damage to the receiving water bodies (Morita et al., 2008; Fernández-Nava et al., 2010). Nitrate is known to impose severe health issues such as methemoglobinemia (blue baby syndrome) and potential formation of carcinogens in the stomach and intestine (Kimura et al., 2002; Liu et al., 2009; Wang et al., 2009; Shao et al., 2010). Exposure to high levels of nitrate through water and feed could also lead to reduced vitality and increased stillbirth, low birth weight, and slow weight gain in livestock. Nitrate contamination of waters, specially ground waters, is a direct result of excessive use of fertilizers which could leach into the ground waters or be carried by the surface waters and run offs into other water bodies (Liu et al., 2009; Shao et al., 2010; Aminzadeh et al., 2010; Read-Daily et al., 2011). Release and disposal of improperly treated wastewaters is the other factor contributing to contamination by nitrate and other nitrogenous compounds (Kimura et al., 2002; Wan et al., 2009).

Treatment of waters contaminated by nitrate or nitrite can be achieved through physicochemical or biological processes. Physicochemical methods such as reverse osmosis and ion exchange, however, are not selective and result in secondary wastes with high levels of nitrate or nitrite (Liu et al., 2009; Wan et al., 2009). Conventional biological processes for the removal of nitrate and nitrite which are referred to as denitrification and denitritation, respectively rely on heterotrophic bacteria which function under anoxic conditions in the presence of organic compounds (BOD). Organic compounds are either constitutes of the wastewater, or supplemented as part of the treatment process when the original level of organics in the wastewater is insufficient for complete nitrate removal (Koenig and Liu, 2001; Oh et al., 2001; Kimura et al., 2002; Kim et al., 2002; Aminzadeh et al., 2010). Autotrophic denitrification with elemental sulfur is an attractive alternative for treatment of waters contaminated by nitrate and nitrite, especially for those organic-deficient wastewaters (Park et al., 2002; Kim et al., 2004; Wan et al., 2009; Zhou et al., 2011). Compared with its heterotrophic counterpart, autotrophic denitrification is advantageous for the treatment of the organic deficient wastewaters as it eliminates the need for addition of organic carbon. Furthermore, the extent of produced sludge under autotrophic condition is substantially lower than that in a heterotrophic process which in turn reduces the cost associated with the treatment of sludge (Koenig and Liu, 2001; Kimura et al., 2002; Kim et al., 2004; Zhou et al., 2011).

Coleville enrichment is a mixed nitrate-reducing, sulfide-oxidizing (NR-SOB) microbial culture which has been enriched from the produce water of a Canadian oil reservoir. The main microbial component of Coleville, *Thiomicrospira* sp. CVO, tolerates sulfide at concentrations as high as 16 mM, a level much higher than that

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