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Reduction of Fe(III)EDTA in a NOx scrubber liquor by a denitrifying bacterium and the effects of inorganic sulfur compounds on this process

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HIGHLIGHTS

- The denitrifying bacterium *Paracoccus denitrificans* could reduce Fe(III)EDTA.
- Fe(III)EDTA reductase was located in membrane and cytoplasmic fractions.
- Fe(III)EDTA reduction rate was linearly related with initial protein concentration.
- Sulfite inhibited Fe(III)EDTA reduction due to direct and indirect toxic effects.

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ABSTRACT

Biological reduction of Fe(III)EDTA is one of the key steps in nitrogen oxides removal in the integrated approach of metal chelate absorption combined with microbial reduction. *Paracoccus denitrificans* ZGL1 was used as a model bacterium to evaluate the process of Fe(III)EDTA reduction by such microorganisms that could carry out the simultaneous reduction of NO chelated by Fe(II)EDTA (Fe(II)EDTA-NO) and Fe(III)EDTA. Enzymes analysis indicated Fe(III)EDTA reductase of ZGL1 was located both in the membrane and cytoplasmic fractions. Glucose was identified as the most efficient electron donor for Fe(III)EDTA reduction. Better reduction performance was obtained with higher initial cell concentration corresponding to a specific reduction rate of 8.7 μmol h^{-1} mg $protein^{-1}$. The presence of sulfate and thiosulfate had no influences on both cell growth and Fe(III)EDTA reduction. Fe(III)EDTA reduction rate and cell growth could be inhibited by addition of sulfite mainly due to its direct and indirect toxic effects.

1. Introduction

Nitrogen oxides (NOx) emitted from fossil fuel combustion processes, mainly comprised of 95% nitric oxide (NO) and 5% nitrogen dioxide (NO_2), are major contributors of air pollution (Jin et al., 2008). They have not only caused serious environmental problems, e.g. photochemical smog, acid rain and depletion of the ozone layer, but also threatened human health seriously (Kampa and Castanas, 2008). Compared to conventional end-of-pipe controls of NOx, such as chemical reduction and adsorption, biological NOx removal is an alternative, cost-effective and environmentally sustainable technology (Cathrine and Raghukumar, 2009; Jin et al., 2008). However, the biological removal efficiencies are restricted by the low solubility of NO in the water, which directly influences retention times. Therefore, the integrated approach of metal chelate absorption combined with microbial reduction is developed (Buisman et al., 1999; Dilmore et al., 2006; Kumaraswamy et al., 2005; van der Maas et al., 2006; Xu and Chang, 2007; Zhang et al., 2007). Fe(II)EDTA is introduced as complexing agent in the scrubber liquid to promote NO absorption. And NO chelated by Fe(II)EDTA (Fe(II)EDTA-NO) is reduced to N_2 by denitrifying bacteria.

Since flue gases typically contain 2–5% (V/V) oxygen, Fe(II)EDTA is easily oxidized to Fe(III)EDTA by dissolved oxygen as described Eq. (1). Furthermore, during the bio-reduction of Fe(II)EDTA-NO, Fe(II)EDTA can also be used as the electron donor which results in oxidation of Fe(II)EDTA to Fe(III)EDTA according to Eq. (2) (Kumaraswamy et al., 2005).

$$4Fe(II)EDTA^{2-} + O_2 + 4H^+ \rightarrow 4Fe(III)EDTA^- + 2H_2O \quad (1)$$

$$2Fe(II)EDTA - NO^{2-} + 2Fe(II)EDTA^{2-} + 4H^+ \rightarrow 4Fe(III)EDTA^- + N_2 + H_2O \quad (2)$$

As Fe(III)EDTA is unable to chelate NO, Fe(III)EDTA should be converted to Fe(II)EDTA to maintain the continuity of NO removal. A method of biological reduction is proposed to regenerate the

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