

Influence of temperature on denitrification of an industrial high-strength nitrogen wastewater in a two-sludge system

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Abstract

The temperature effect on denitrification rate of a two-sludge system has been studied. An industrial high-strength wastewater and an industrial by-product containing mainly methanol, as external carbon source, were used in this study. The maximum denitrification rate (MDR) was determined at six different temperatures: 6, 8, 10, 15, 20 and 25°C in batch mode. The temperature coefficient was found to be 1.10 ± 0.01 at temperatures between 10 to 25°C and 1.37 ± 0.01 at temperatures between 6 to 10°C. The MDR obtained in the two-sludge system ($0.28 \text{ mg N} \cdot \text{mg VSS}^{-1} \cdot \text{d}^{-1}$ at 25°C) was higher than the one obtained in a single-sludge system with a similar external carbon source. The COD/N ratio required for complete denitrification in the two-sludge system was approximately stoichiometric, which is $3.7 \pm 0.9 \text{ mg COD} \cdot \text{mg N}^{-1}$.

Introduction

Generally, an excess of nitrates in water is related to public health diseases like methemoglobinemia and carcinogenesis. Therefore, drinking water should not contain more than $10 \text{ mg NO}_3^- \cdot \text{N} \cdot \text{L}^{-1}$ (EPA, 1993). For this reason, the removal of nitrates from wastewater is necessary. There are three main methods to remove nitrates from wastewater: ion exchange, reverse osmosis and biological denitrification. Ion exchange is limited due to the lack of resins with high selectivity for nitrate and the problem of regenerating them. The problem of reverse osmosis is low selectivity of the membranes used for nitrate. Due to these limitations for removal of nitrates from industrial wastewater, the most versatile and widely used technology is biological denitrification (Mateju et al., 1992).

The bacteria responsible for the denitrification are classified as facultative heterotrophs and are able to use nitrate as an acceptor of electrons, transforming it into nitrogen gas. During the process, electrons are transferred from a donor, normally an organic substrate, to an acceptor, nitrate or nitrite. Practically any organic compound that can be biologically degraded under aerobic conditions can be used for denitrification. However, denitrification rates will be different depending on the organic compound used.

Denitrification is determined by the stoichiometric ratio between the organic compound used and the nitrate. Industrial wastewater may not offer the appropriate COD/N ratio for carrying out the denitrification process. In order to treat industrial wastewater with a low COD/N ratio it is necessary to add an external organic carbon source. Different external carbon sources are used for denitrification: glucose (Chevron et al., 1997), saccharose (Sison et al., 1995), acetic acid (Oh and Silverstein, 1999), lactic acid (Akunna et al., 1993), ethanol (Hasselblad and Hallin, 1998; Nyberg et al., 1996) and methanol (Bailey et al., 1998; Bilanovic et al., 1999).

Different criteria have been used to choose a specific external carbon source for the denitrification process. First, it is necessary to consider which carbon compound yields the fastest denitrification rate. Published references give conflicting results. Some authors

suggest that acetic acid achieves greater rate than glucose, methanol or ethanol (Constantin and Fick, 1997). However, other authors showed similar results with denitrification on acetic acid to those achieved with methanol (Nyberg et al., 1992). Several references indicate that ethanol reaches higher rate than methanol (Andersson et al., 1998; Christensson et al., 1994), although another study indicates that the rate with methanol is greater than that with ethanol (Henze, 1991).

It is also necessary to consider the costs and availability of the external carbon source. If the source is a pure chemical compound (ethanol, methanol, acetic acid), it will be available at a market price. An alternative is to use a by-product as the carbon source, for example the sludge produced in the process. However, the organic matter coming from the sludge is not very biodegradable and therefore a previous chemical or thermal hydrolysis is required. This procedure adds extra cost to the process (Barlindhaug and Odegaard, 1996).

To build an industrial scale denitrification plant, the external carbon source should be cheap and available to guarantee the continuous operation of the wastewater treatment plant. These requirements can be achieved using industrial by-products. In the present study, the feasibility to use a by-product as an external carbon source for the denitrification process was evaluated. This by-product is mainly methanol and the rest is acetone and isopropilic alcohol.

The temperature effect on the denitrification rate is another important feature in the design of a denitrification process. This effect is commonly described using an Arrhenius-type equation (Orhon et al., 2000):

$$r_{D,T1} = r_{D,T2} \cdot \theta^{(T1-T2)} \quad (1)$$

where:

$$\begin{aligned} r_{D,Ti} &= \text{denitrification rate at temperature } Ti \\ &\quad \text{mg N} \cdot \text{NO}_3^- \cdot \text{mg VSS}^{-1} \cdot \text{d}^{-1} \\ \theta &= \text{temperature coefficient} \end{aligned}$$

The interest in this topic is reflected in the number of published results on the determination of the effect of temperature on the

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