

## Biological removal of nitrogen species from metal-processing wastewater<sup>#</sup>

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### Abstract

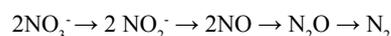
Although several nitrification/denitrification processes are established for the removal of ammonia and nitrate from municipal and industrial wastewaters, there are few reported results on the removal of these ions from metal-processing and finishing wastewaters. Unlike municipal wastewater, there is very little organic content in metal-processing wastewaters. Sources of ammonia and nitrate in the wastewater include the use of ammonium-nitrate-fuel oil as a blasting agent, and the use of other nitrogen-containing reagents during processing. The objective of this work was to investigate a biological process for the removal of nitrogenous compounds from real metal-processing wastewater. The system comprised an aerobic continuously stirred tank reactor (CSTR) followed by an anaerobic packed column and was run using real wastewater from a metal-processing operation. The system was inoculated using humus sludge from a municipal trickling filter and a period of approximately four weeks was required for a denitrifying biofilm to develop. Results showed that ammonia removal occurred readily in the CSTR while nitrite oxidation was slower to develop. The CSTR was found to be suitable for ammonia oxidation; up to 89% ammonia removal was achieved. By employing an integrated process comprising nitrification and denitrification, high ammonia removal efficiencies can be obtained. An effluent that is low in ammonia can be obtained with this system with additional carbon introduced after the CSTR. The gravel-packed column reactor was found to be unsuitable for the removal of nitrate in the configuration used (maximum 15% removal efficiency). The critical parameters for denitrification are nitrate concentration, temperature, influent flow rate and mean cell retention time. Nitrate removal did not meet the expectations projected by previous authors' work using synthetic wastewater.

**Keywords:** metal industry wastewater; ammonia; nitrate; nitrification

### Introduction

Typical metal industry wastewater contains high levels of various toxic compounds which interfere with aquatic and terrestrial life when released into land and water ecosystems. The ratio of ammonia concentration (toxic form) to ammonium ions (relatively non-toxic) increases with rising temperature and pH (Koren et al., 2000). All nitrogenous compounds are of interest, especially nitrate, which is a strong metal ligand. This also makes it difficult to remove trace metal pollutants still contained within the wastewater. Mine and mill effluents usually contain high amounts of ammonia and/or nitrate ions owing to the use of ammonium nitrate based blasting agents and ammonium sulphate as eluent for metal extraction ion exchangers (Koren et al., 2000). In some metal-processing industries, the nitrate concentration in the wastewater can reach up to 1 000 mg/l NO<sub>3</sub>-N (Glass and Silverstein, 1999). Various non-biological methods are available for the removal of these compounds from wastewaters but these are expensive, and disposal of the end product becomes problematic, e.g. with reverse osmosis the end product is a concentrated waste brine which becomes difficult to dispose of. Biological methods are easier to operate and maintain and are consequently cheaper. Often the end products are harmless and disposal is easy.

Biological removal of ammonia and nitrate from municipal wastewaters is a well-established practice with a number of widely used process designs, from the earliest oxidation ditches to the more recent discoveries of the Anammox (Mulder et al., 1995), CANON (Schmidt et al., 2003) and SHARON (Hellinga et al., 1998) processes. Apart from Anammox, biological removal of ammonia, nitrification, is traditionally defined as the aerobic oxidation of NH<sub>3</sub><sup>+</sup> to NO<sub>3</sub><sup>-</sup> via nitrite (NO<sub>2</sub><sup>-</sup>). This is mainly carried out by two groups of autotrophic bacteria; ammonia oxidisers (NH<sub>3</sub> → NO<sub>2</sub><sup>-</sup>), exemplified by *Nitrosococcus* and *Nitrosomonas* spp., and nitrite oxidisers (NO<sub>2</sub><sup>-</sup> → NO<sub>3</sub><sup>-</sup>), such as *Nitrobacter* and *Nitrospira* spp. Denitrification, the biological reduction of nitrogen oxides to dinitrogen gas, is effected by a number of bacteria, among them are *Pseudomonas*, *Flavobacterium*, and *Bacillus* spp. The nitrate ion is reduced to dinitrogen gas by the pathway:



Although the denitrifying bacteria are aerobic microorganisms, they can utilise oxidised nitrogen compounds as terminal electron acceptors in place of oxygen, hence low oxygen concentrations or the absence of oxygen are required for denitrification to occur.

Municipal wastewaters contain sufficient carbon and phosphorus to act as a nutrient supply for biological processing, but mineral processing wastewaters often do not. The recommended pH range for nitrification is 7.5 to 8.6 and for denitrification 7.0 to 8.0 (Metcalf and Eddy, 1991). The ratio at which nutrients should be supplied is contentious, with chemical oxygen

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