

# Induction of nitrite build-up in water by some common disinfectants

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## Abstract

Nitrite build-up in gold-mine service water could be caused by the biotic oxidation of ammonia in the presence of disinfectants such as chlorine, chlorine dioxide or bromine. It has been demonstrated in bench-scale tests on gold-mine service water that complete nitrification can be inhibited. It was shown in these tests that dosages of chlorine between 3 and 13 mg/l, chlorine dioxide between 2 and 8 mg/l, bromine above 8 mg/l and cyanide above 2 mg/l caused selective inhibition of the second stage of the microbiological nitrification process. The nitrifying bacteria appear to be able to adapt to bromine. Nickel (II) did not significantly affect the nitrification process.

## Introduction

It has been found necessary to disinfect the service water at many South African gold mines because this water is being drunk by many of the mine workers in spite of all the discouragement to do so (Pearson et al., 1990). Faecal contamination causes a risk of the water being contaminated with pathogenic organisms (such as typhoid and cholera). This problem can be amplified because of the need to recycle the service water several times before its discharge. During disinfection studies on the service water of the Kloof Gold Mining Company (Pearson et al., 1989; Van Leeuwen and Van der Westhuizen, 1992), it was found that nitrite exerted a significant demand on the oxidising disinfectants such as chlorine and ozone in the service water. Nitrite in the service water, after filtration, was found to average around 0,98 mg N/l (standard deviation 0,21 mg N/l) with a peak value of 11,9 mg N/l. The recommended criterium for nitrite in potable water is 1 mg/l (Kempster and Smith, 1985). However, the magnitude of the problem in terms of the high disinfectant use warranted a closer investigation into the origin of the nitrite.

This paper is aimed at demonstrating the induction of nitrite build-up in the service water by a microbiological kinetics study in a controlled environment.

## Biotic nitrite production

The production of nitrite as the first step in the microbiological nitrification of ammonia and its subsequent oxidation to nitrate has been extensively described in earlier literature (Knowles et al., 1965; Kholdebarin and Oertli, 1977; Painter, 1977; Strom and Finstein, 1977; Benefield and Randall, 1980).

The biotic oxidation of ammonia is accomplished by, among others, the prokaryotes *Nitrosomonas europaea*, *N. monocella* and *Nitrosococcus*. The species *Nitrobacter winogradskyi*, *N. agilis* and *Nitrocystis*, *inter alia*, are thought to be involved in the subsequent oxidation of nitrite (NO<sub>2</sub> to nitrate (NO<sub>3</sub>)). Both these groups of organisms are gram-negative chemolithotrophs (Watson et al., 1989). The identification of these organisms is

tedious and was not considered essential for the purpose of this investigation.

The build-up of nitrite is not very common and has been ascribed to the breakdown in the microbiological oxidation of nitrite, which is the second step in the biotic mineralisation of ammonia. More recent investigations (Suthersan and Ganczarczyk, 1986; Turk and Mavinic, 1989; Gee et al., 1990a and 1990b) centre around the purposed inhibition of microbiological nitrite oxidation in order to provide a "shortcut" in denitrification during nutrient removal processes. In all the above research it was clearly demonstrated that the nitrite oxidation step is by far the more sensitive step in the nitrification process and is subject to disruption by a number of inhibitive compounds.

## Possible inhibitors

The first step can be inhibited according to the Haldane substrate inhibition model (Haldane, 1965; Painter, 1977) by >2 500 mg/l ammonia as well as by high concentrations (> 2 500 mg/l) nitrite, chelating agents such as thiourea (0,7 mg/l) and 2-chloro-6-trichloromethyl pyridine.

The oxidation of nitrite is inhibited by the simultaneous presence of ammonia (>9 000 mg/l) and nitrite (>170 mg/l) described by a modified Haldane model (Gee et al., 1990 b) as well as by cyanate, chlorate (ClO<sub>2</sub>) and chlorite (ClO<sub>2</sub>) among others. The inhibition level reported for chlorate varies between 0,001 mM (0,08 mg/l; Lees, 1963) and 10 mM (835 mg/l; Belsler and Mayes, 1980). Hynes and Knowles (1983) found that chlorate was reduced to chlorite by *Nitrobacter* under both aerobic and anaerobic conditions and that chlorite was the more potent nitrite oxidation inhibitor. It is noteworthy that chlorite is a reduced form of chlorine dioxide, which is often used as a disinfectant for drinking water and has been used as such on the service water at the Kloof Gold Mine.

Optimum growth temperatures of 35°C and 35 to 42°C have been reported for *Nitrosomonas* and *Nitrobacter* species respectively at an optimum pH of 7,8 (Painter, 1977). It has been noticed though, that there is a marked temperature dependence of the observed growth rate (0) between 10 and 17°C. This differing temperature dependence of  $\mu$  of the nitrite-producing and  $\mu$  of the nitrite-utilising species can contribute to a nett build-up of nitrite (Randall and Buth, 1984).

Assuming these observations to hold true for mine service water, bench-scale investigations into the mechanics of nitrite

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