Nitrification Inhibition by Heavy Metals in Activated Sludge Process

Feng Mao

ABSTRACT

Nitrification is the most sensitive part in the biologic nutrient removal of wastewaters, since the growth rate of nitrifying microorganisms is very lower and strongly dependent on temperature, substrate concentration, oxygen content, pH, and the presence of inhibiting components. This review addresses the nitrification inhibition by heavy metals. This inhibition can be quantified by different techniques, including screening method, specific oxygen uptake rate (SOUR) assay, pure cultures of *Nitrosomonas* and *Nitrobacter*, and stress protein assay. Metal sorption plays an important role in metal uptake by nitrifying biomass. The sorption process is relatively rapid and controlled by various factors such as pH, type and concentration of complexing agents in wastewater, oxidation state of the metal, and redox potential. Metal internalization is the main mechanism which contributes to nitrification inhibition by heavy metals. The slow kinetics of metal internalization implies that metal inhibition can easily be underestimated from short-term batch assays. The nitrification inhibition of copper is unique among the metals studied and the copper toxicity to nitrifying enrichment cultures may involve disruption of the cytoplasmic membrane. Combining the intraparticle diffusion model with the biological toxicity model, inhibition could be predicted.

KEYWORDS

nitrification, inhibition, heavy metals, activated sludge

INTRODUCTION

Nitrification. Biological nitrogen removal by sequential nitrification and denitrification is a widely applied technology in wastewater treatment facilities. Nitrification is a two-step microbial process by which reduced nitrogen compounds (primarily ammonia) are sequentially oxidized to nitrite and nitrate. In the first step of nitrification, ammonia-oxidizing bacteria oxidize ammonia to nitrite according to equation (1):

$$NH_3 + O_2 \rightarrow NO_2^- + 3H^+ + 2e^- \qquad (1)$$

In the second step of the process, nitrite-oxidizing bacteria oxidize nitrite to nitrate according to equation (2):

$$NO_2^- + H_2O \rightarrow NO_3^- + 2H^+ + 2e^- \qquad (2)$$

The nitrifying bacteria of importance in the activated sludge process consist of *Nitrosomonas* (associated with first step) and *Nitrobacter* (associated with the second step).

Due to the relatively large quantity of ammonium ions and nitrite ions needed assimilate carbon dioxide, the cell yield of nitrifiers is very slow. For the growth of one pound of dry cells, *Nitrosomonas* must oxidize 30 pound of ammonium while *Nitrobacter* must oxidize 100 pounds of nitrite (Gerardi, 2001). In the activated sludge process, a high MCRT is required to increase the number of nitrifying bacteria.

The nitrifying bacteria are also sensitive to a number of environmental conditions such as dissolved oxygen concentration, pH, and temperature. To oxidize 1 mg of ammonium, 4.6 mg of O_2 are needed (Christensen and Harremoes, 1978). An absence of DO for more than 4 hours adversely affects the activity of nitrifying bacteria and an absence of DO for 24 hours or more can destroy the nitrifying bacterial population (Gerardi, 2001). Low pH in wastewater has a primary effect on nitrifying bacteria by inhibiting enzymatic activity and a secondary effect on the availability of alkalinity. Nitrification in an activated sludge process ceases at or below pH 6.0 (Painter and Loveless, 1983), begins to accelerate above pH 6.7, and the optimal pH range for nitrification is 7.5 to 8.5 (U.S.EPA, 1975). The rate of growth of nitrifying bacteria increases considerably with temperature over the range of 8~30ºC. Below 10ºC, the nitrification rate sharply falls. No growth of *Nitrosomonas* and *Nitrobacter* occurs below 4ºC (Gerardi, 2001).

Nitrification inhibition. Low growth rates of nitrifying bacteria and their extremel sensitivity to environmental conditions make the nitrification process very susceptible to inhibition. Although nitrifying