Water Practice & Technology

IWA PUBLISHING

 Water Practice & Technology Vol 18 No 4, 922 doi: 10.2166/wpt.2023.059

Modelling the effect of salt from road runoff on nitrification of a wastewater treatment plant

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ABSTRACT

Salt (NaCl) that is being dispersed on the roads to prevent the formation of ice and snow can have positive and negative effects on nitrification rates in wastewater treatment plants (WWTPs). Based on experimental data, a numerical model has been derived to describe these effects. The numerical model has been successfully implemented in the SIMBA# simulation software and tested on a real case study, the Freistadt WWTP, located in Upper Austria. A number of parameters impacting nitrification have been investigated: inflow salt concentration, duration of the salt loading, temperature during salt loading, and increasing volumetric inflow to the WWTP during salt loading events. Simulation results revealed that salt concentration lower than 1 g NaCl/l brought improvement in nitrification rates. However, when this threshold was exceeded, inhibition of nitrification occurred. Furthermore, prolonged salt dosing exposure times brought amplification of both positive and negative effects on removal rates. Results show that salt concentration and salt load have the biggest impacts on nitrification.

Key words: dynamic simulation, nitrification, salt, SIMBA#, wastewater treatment

HIGHLIGHTS

- A numerical model for describing the effect on salt on the maximum rate of nitrification in activated sludge plants was developed.
- The numerical model was implemented in the SIMBA# simulation software.
- The model was successfully tested for various scenarios developed for a real wastewater treatment plant.

INTRODUCTION

In many temperate climates, salt (NaCl) is dispersed on the roads and pavements to prevent the formation of ice and snow. Salt runoff flows into the sewer system during snow-melting or rain events in combined sewers and is thus transported to wastewater treatment plants (WWTPs). The increased salt in the runoff increases the chloride concentrations in the influent of WWTPs. Flesch (2020) reported that WWTP operators recorded operational impairments with higher chloride concentrations. These impairments included elevated effluent nitrogen and phosphorus concentrations, the break-up of sludge flocs, sludge settling problems, floating sludge on top of the secondary clarifier, etc.

Pernetti & Palma (2005) examined the impact of continuous and shock salt loadings. It was noted that autotrophic and heterotrophic bacteria respond differently to the type of salt loadings and salt concentrations. Shock salt loading caused respiration inhibition of 4–84%; however, the bacteria adapted quickly to continuous loadings. The biggest impactor on autotrophic and heterotrophic bacteria's oxygen uptake rates are salt concentration and time of exposure of bacteria to salt (Flesch 2020; Tauber *et al.* 2021). Laboratory-scale experiments showed that there were no negative effects on autotrophic and heterotrophic bacteria when the salt concentration was below 1 g NaCl/l whereby for 75% of these tests a positive increase in both autotrophic and heterotrophic oxygen uptake rates was measured (Flesch 2020). Conversely, when the salt concentration was higher than 1 g NaCl/l, the oxygen uptake rate decreased significantly. The hindering salt impacts influenced the WWTP only in the short to medium term. Microorganisms could adjust quickly to the inhibiting and newly created conditions. After the end of the salt event, the activity of the microorganisms normalized after about 4–5 days. Microorganisms showed similar behaviour also in submerged biofilters (Flesch 2020).

Aslan & Simsek (2012) performed tests with submerged biofilters adding various salt loadings (0–40 g NaCl/l). They observed an increase in the activity of autotrophic and heterotrophic bacteria at a concentration of 1 g NaCl/l. Likewise, there was a decrease in activity at higher concentrations. At a salt concentration of 40 g NaCl/l, there was a 60% diminishment in ammonium oxidizing rate and nitrite production rate. Wang *et al.* (2005) examined the impact of different salt concentrations on oxygen uptake rates and removal rates of total organic carbon in activated sludge systems. Both parameters exhibited an increase in performance for the salt concentration of less than 1 g NaCl/l and a decrease in performance when the chloride concentration exceeded the threshold of 1 g NaCl/l. Tauber *et al.* (2021) and Flesch (2020) reported that concentrations of salt higher than 1 g NaCl/l influenced the structure of the sludge floc particles. Higher concentrations led to the break-up of sludge particles and to an increase in the sludge volume index. Furthermore, the settling characteristics of the secondary clarifier were impaired and a floating sludge layer formed on the water surface of the secondary clarifier.

Chloride concentrations from road salt runoff in the inflow of WWTPs are reported in the range of a maximum 2–3 g NaCl/l (Flesch 2020). In wastewater treatment, these concentrations are generally considered as moderate concentrations. Higher concentrations (>10 g NaCl/l) only occur in coastal areas or from specific industrial discharges. The available literature on these lower salt concentrations is very scarce; thus, the exact effects of salt loading on WWTPs are still being researched.

The main objectives of this study were to develop a numerical model for salt impact on nitrification and to test the numerical model on a case study (Freistadt WWTP) to show the effects of increased salt concentrations on treatment performance.