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Fate and effect of benzalkonium chlorides in a continuous-flow biological nitrogen removal system treating poultry processing wastewater

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HIGHLIGHTS

- BAC initially inhibited nitrification in a BNR system at 5 mg BAC/L in the feed.
- Acclimation and degradation resulted in high nitrogen removal even at 120 mg BAC/L.
- Microbial resistance to BAC over time contributed to a stable BNR system operation.
- Use of QACs in poultry processing facilities requires QAC-acclimated BNR systems.

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ABSTRACT

Quaternary ammonium compounds (QACs) are used for sanitation in many poultry processing facilities. This work investigated the fate and effect of a mixture of benzalkonium chlorides (BACs), a class of QACs widely used in commercial antimicrobial formulations, on the biological nitrogen removal (BNR) processes. A laboratory-scale BNR system was operated continuously for 670 days, fed with poultry processing wastewater amended with a mixture of BACs. Initially, the nitrogen removal efficiency deteriorated at a BAC feed concentration of 5 mg/L due to the complete inhibition of nitrification. However, after 27 days of operation, the system recovered and achieved 100% ammonia removal. High nitrogen removal efficiency was achieved even after the feed BAC concentration was stepwise increased up to120 mg/L. Batch nitrification assays performed before, during, and after BAC exposure, showed that rapid microbial acclimation and BAC biodegradation contributed to the recovery of nitrification achieving efficient and stable long-term BNR system operation.

1. Introduction

Poultry processing facilities practice sanitation to keep food contact surfaces clean and pathogen-free. Cationic quaternary ammonium compounds (QACs) are commonly used in industrial sanitizer formulations (Cross and Singer, 1994; Kummerer et al., 2002). The use of sanitizers is likely to increase as poultry processing plant operators face more stringent regulations related to water consumption and conservation, while complying with more strict sanitation rules and wastewater regulations (U.S. EPA, 2004). Sanitizer formulations commonly contain benzalkonium chloride (BAC) homologs of different alkyl chain lengths, mainly C_{12}, C_{14}, and C_{16} (Sutterlin et al., 2008). As cationic surfactants, BACs have high adsorption affinity to anionic surfaces like biomass (Ismail et al., 2010; Ren et al., 2011) and are biodegraded under aerobic conditions (Nishihara et al., 2000; Patrauchan and Oriel, 2003; van Ginkel, 2004; Zhang et al., 2011; Tezel and Pavlostathis, 2012). BAC transformation under anoxic, nitrate reducing conditions was recently reported by means of an abiotic nitrite nucleophilic substitution reaction (modified Hofmann reaction) producing alkyl dimethyl amines (tertiary amines) (Tezel and Pavlostathis, 2009, 2012).

Wastewater generated during sanitation practices in poultry processing facilities is combined with other wastewater streams and typically treated in biological nitrogen removal (BNR) systems comprised of a combination of nitrification and denitrification processes. Achieving efficient BNR is only possible by sustaining the two biological processes and their microbial populations at their optimum physiological and environmental conditions. The poor selectivity and target specificity of BAC will negatively impact the performance of BNR systems due to the susceptibility of BNR microbial populations to BAC. Nitrification was found to be inhibited at BAC concentrations of 2 mg/L (Sutterlin et al., 2008) and

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