ABSTRACT

Nitrous oxide (N_2O) is an unwanted byproduct from biological nitrogen removal in wastewater treatment, because it is a strong green house gas and major stratospheric ozone depletion substance. N_2O emissions from biological nitrogen removal can contribute substantially to the carbon dioxide (CO_2)-equivalent footprint of wastewater treatment. The majority of these N_2O are produced by ammonia oxidizing bacteria (AOB) and denitrifiers via nitrifier nitrification (NN), nitrifier denitrification (ND), and heterotrophic denitrification (HD) pathways. Many efforts have been done to characterize the production of N_2O in wastewater treatment system. However, the fundamental knowledge about pathways and controls of N_2O production is limited, and mainly challenged by difficulties in distinguishing these different pathways in a complex microbial community. In this thesis, batch incubation studies, lab-scale investigations and full-scale monitoring of the dynamics of N_2O production are combined with the $^{15}N/^{18}O$ stable isotope labeling approach to provide a better understanding of N_2O production mechanisms.

In **Chapter 2** pathways of N_2O production and their dependence on environmental parameters (DO, NO_2^- and NH_4^+) in nitritation-anammox biomass were investigated in short-term incubations. Under low NO_2^- condition, NN was the dominant production pathway of N_2O at 0.2 mg L^{-1} DO. However, ND was induced by external NO_2^- addition and became as major N_2O production pathway with 0.7 mM NO_2^- addition.

Dynamics of N_2O in a lab-scale partial nitritation reactor was studied by online dissolved N_2O monitoring combined with ^{15}N stable isotope labeling (apply $^{15}NH_4^+$/ $^{15}NO_2^-$ to the reactor) to reveal the mechanisms of N_2O production (described in **Chapter 3**). N_2O production was completely dominated by ND.

Chapter 4 focuses on full-scale plant. A novel $^{15}N/^{18}O$ dual labeling method was established to study the dynamics of N_2O production pathways in a full-scale activated sludge plant. The results showed that the oxic phase was the major source of N_2O production with more than 5 times higher accumulation rates than in the anoxic phase. NN and ND contributed roughly equal at 3 mg L^{-1} DO, while ND was the dominante source at 1mg L^{-1} DO.

The studies demonstrated that $^{15}N/^{18}O$ stable isotope labelling is a robust approach to distinguish different N_2O production pathways in biological nitrogen removal plants, and it can contribute to the development of operational strategies to minimize N_2O emissions. All three pathways (NN, ND, and HD) were active in nitrogen removal processes, each responding differently to changes in the operational conditions. NN can be a significant N_2O source in nitritation-anammox and activated sludge system. It can contribute with up to ~100% of the total N_2O production. However, ND is the predominate source of N_2O in the partial nitritation process, due to high NO_2^- concentrations together with low concentrations of DO. HD was a minor source of N_2O under oxic conditions in all tested nitrogen removal processes, while promoted when DO was absent or organic carbon was present. The relative importance of NN and ND to total N_2O production was mainly determined by DO level and NO_2^- concentration.