Population Dynamics of Nitrifying Bacteria in Biological Wastewater Treatment

PÄR LYDMARK

Department of Cell and Molecular Biology, Microbiology, Göteborg University, Medicinaregatan 9C, Box 462, SE-405 30, Göteborg, Sweden

The increased eutrophication of rivers, lakes and seas has raised the demands on wastewater treatment plants (WWTPs) for the removal of the nutrients phosphorus (P) and nitrogen (N). While P is mostly treated chemically, N is removed by biological processes involving several different groups of bacteria. One of the processes involved is nitrification, in which N in the form of ammonium is converted to nitrate in two consecutive steps mediated by ammonia-oxidizing bacteria (AOB) and nitrite-oxidizing bacteria (NOB). Since both AOB and NOB are relatively slow-growing and sensitive bacteria, the nitrification processes at many WWTPs are unstable and not working as efficiently as desired. The microbiological factors behind these fluctuating performances are, however, to a large extent unknown.

Diversity studies of nitrifying population dynamics in WWTPs are important building blocks in the overall process of improving strategies for stable and efficient nitrification, since observations indicate that plants with lower diversity are more prone to process failure. The aim of this thesis was to characterize the microbial communities responsible for nitrification in WWTP biofilms and activated sludge systems, and by full-scale operation or pilot plant experiments reveal how the observed populations responded to environmental factors such as ammonium concentration gradients, ammonium starvation and different sludge age in terms of population abundance, nitrifying activity and physical distribution within biofilms.

The results presented show that a high diversity of coexisting subpopulations within the *Nitrosomonas oligotropha* lineage can be found together with other AOB populations such as the *N. communis* and *N. europaea* lineages in full-scale WWTPs. Moreover, their different distribution in the studied systems with respect to time, reactor sections and biofilm orientation clearly indicated that physiological differences between closely related nitrifiers may be more pronounced than earlier expected.

When coupled to measurements of nitrification rates, the population dynamic studies presented indicates that large variations in nitrifying capacity not only are due to the community structure, but also to the physiological status of the nitrifying community. For example, different schemes of nutrient pulses resulted in very different nitrification rates in pilot plant nitrifying trickling filters in much shorter time-scale than seen for population changes. Moreover, this thesis includes results indicating that AOB populations experiencing fluctuating ammonium concentrations may be better adapted to utilize occasional peaks of ammonium in the surrounding water, than AOB constantly fed with high substrate concentrations. As discussed, this may be due to both biofilm thickness and intracellular differences reflected by the fluctuating conditions. Such data can be of great importance when optimizing the operational schemes for nitrification in full-scale WWTPs, and may in the long run lead to a more stable nitrifying process.

Keywords: Nitrification, wastewater, ammonium, AOB, NOB, biofilm, *Nitrosomonas*.

Göteborg 2006 ISBN 91-628-6792-X