New approaches to improve the removal of dissolved organic matter and nitrogen in aquaculture

Reducing the environmental impact of aquaculture requires that waste treatment practices are further improved. Currently applied treatment technologies achieve good solids removal and nitrification. Yet discharge of nitrogen (N) and organic matter (OM) from fish farms is still often an important issue constraining aquaculture development, especially in sensitive areas. Possibilities for efficient end-of-pipe treatment exist for large intensive recirculating aquaculture systems (RAS), while smaller and especially the technically less advanced fish farms, struggle to reduce nutrient discharge further due to the lack of cost-effective and easy applicable treatment methods for removing dissolved N and OM. The purpose of this PhD thesis was to assess the problem of removing dissolved N and OM in the context of the large differences in system intensity between farms, and to devise new, simple methods for removing dissolved N and OM from aquaculture effluents of technically less advanced farms in particular. The work split in two parts. The first part focused on the turnover of dissolved N-compounds (Paper I) and dissolved organic matter (DOM) (Paper II) and in aerobic biofilters operated at increasing long-term waste loadings. The second part examined the potential of using anoxic denitrifying woodchip bioreactors for removal of nitrate from aquaculture effluent (Paper III-V). Investigations within the first part showed that the effectiveness of biofilters, as determined by their areal removal rates, for removing DOM and degrading ammonia, nitrite and urea, increased with increasing long-term waste loading. The findings sustained/suggested that DOM to (some extend) can be removed by biofiltration, and that biofilters therefore may be applied for removing DOM from aquaculture effluents. The studies furthermore showed that degradation of urea contributes to the ongoing nitrification activity in aquaculture biofilters, and that the transition zone from first order (substrate dependent) to zero order (substrate independent) degradation of ammonia and nitrite was elevated with increasing long-term biofilter loading up to a certain threshold. The latter indicated that the removal capacity of biofilters operated at lower loadings is easily exceeded, and that they may not respond very well to sudden increases in total ammonia nitrogen (TAN) concentrations.

In the second part of the thesis, a field study documented the start-up performance of a pilot-scale, denitrifying woodchip bioreactor at a commercial outdoor fish farm (Paper III). Nitrate removal was immediate after bioreactor start-up and was accompanied by short-term leaching of nutrients and organic matter from the woodchips. The study demonstrated that woodchip bioreactors are able to remove nitrate from dilute aquaculture effluents under commercial conditions. The obtained nitrate removal rate (7.06±0.81 g NO3-N/m3/d at ~8°C) was, however, relatively low, signifying that a quite large reactor would be required for complete removal of NO3-N at commercial farms. Laboratory studies were therefore carried out to test whether removal rates in woodchip bioreactor could be improved. Paper IV demonstrated that simultaneously changing the hydraulic retention time and adding bicarbonate to the inlet water of laboratory-scale woodchip bioreactors improved N removal. Moreover, the study indicated that sulfur-based autotrophic denitrification is potentially important to the overall N removal in woodchip bioreactors. A subsequent laboratory study demonstrated that higher N removal rates could be achieved in mixotrophic denitrification reactors containing mixtures of woodchips, sulfur granules and seashells (Paper V).

12 Altogether, the woodchip studies sustained that denitrifying woodchip bioreactors may represent an alternative and simple method for removing nitrate from dilute/low-organic-strength aquaculture effluents for which application of, for example, heterotrophic denitrification reactors needing input of organic carbon sources is generally not feasible.

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