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# Optimizing nitrification in biological rapid sand filters for drinking water production

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**Abstract:** Addition of phosphate or trace metals or better management e.g. in terms of ammonium load can improve the nitrification rate and efficiency in biological rapid sand filters.

**Keywords:** Nitrification; phosphate; tracemetals

## Introduction

Nitrification as a mean to remove ammonium ( $\text{NH}_4^+$ ) is essential in most groundwater based water works, and biological rapid sand filtering is a very wide spread approach. However, the nitrification may not start sufficiently fast in new filters or may not remove ammonium to sufficiently low concentrations to reach guideline values or even worse – the nitrification may be incomplete, leading to accumulation of the toxic intermediate nitrite ( $\text{NO}_2^-$ ). Efficient nitrification in the filters is also imperative to avoid unwanted microbial after growth, oxygen consumption, and formation of toxic nitrite ( $\text{NO}_2^-$ ) in the distribution system.

Although nitrification is a well known process many of the underlying microbial processes in are poorly understood in the drinking water production. This limits the management of the filters and which can result in start-up problems and insufficient removal of the treated compounds. A deeper insight in the composition of the microbial communities (e.g. importance of AOB vs. AOA), the dominant nitrifying guilds, elimination of limiting factors such as micronutrients or tracemetals and an optimal management could all contribute to a better nitrification. The support material also plays a significant role (Gülay et al., 2014).

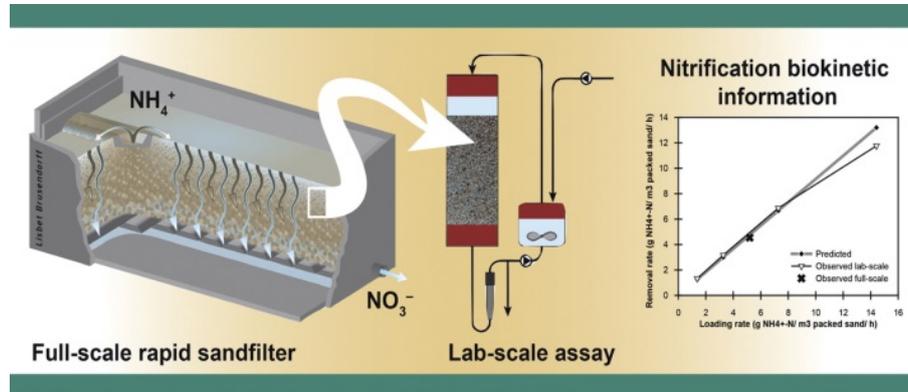
The aim of this research project was to optimize the nitrification in rapid sand filters.

## Material and Methods

The nitrification was studied in laboratory- and pilot-scale packed columns, and in full-scale filters at several water works. To investigate for relation between  $\text{NH}_4^+$  load and  $\text{NH}_4^+$  removal rate, the  $\text{NH}_4^+$  load was increased in short term upshifts in pilot-scale filter columns, operated with sand from a full-scale filter. When equilibrium was reached, the load was shifted down again to prevent alteration of the microbial community.

The effect of phosphate addition was investigated in pilot-scale packed column where the  $\text{NH}_4^+$  loading rate was increased beyond the actual  $\text{NH}_4^+$  removal capacity of the filters. Phosphate was added to one column but not to the control column (Lee, 2014). In a different experiment, phosphate was added to a full-scale filter with incomplete nitrification. Water was sampled over depth of the filter to study the distribution of the added nutrient, and its effect on  $\text{NH}_4^+$  removal. Another study included two laboratory-scale columns (Fig. 1) (Tatari et al., 2013), packed with sand from another

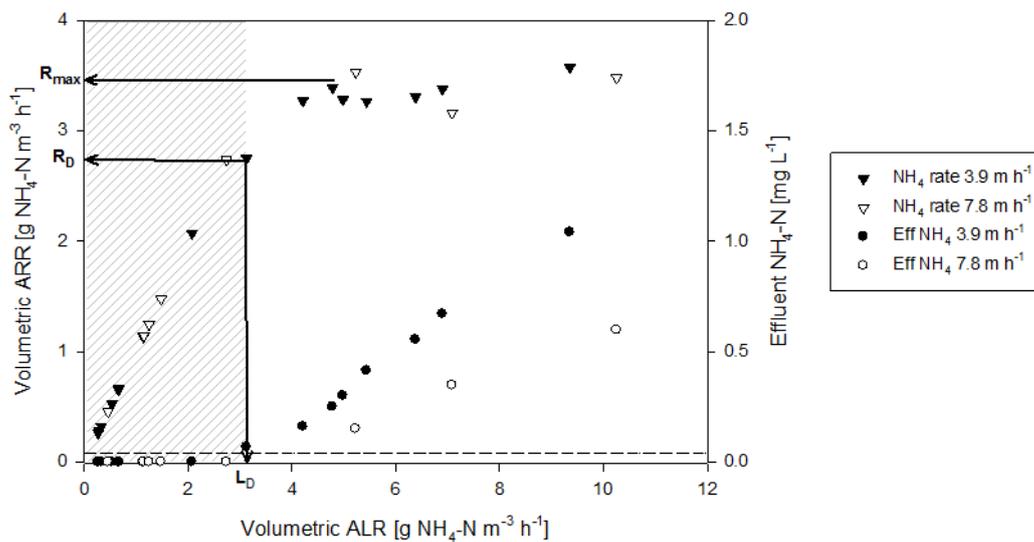
full-scale filter with incomplete  $\text{NH}_4^+$  removal. The  $\text{NH}_4^+$  loading was varied and trace metals were added to one column, whereas the other column was control without addition. Selected trace metals were added to the respective full-scale filter to investigate the effect on full-scale nitrification.



**Figure 1** Depth specific samples of filter material was collected and investigated in the developed small scale columns to reveal biokinetic information on nitrification (Tatari et al., 2013).

## Results and Conclusions

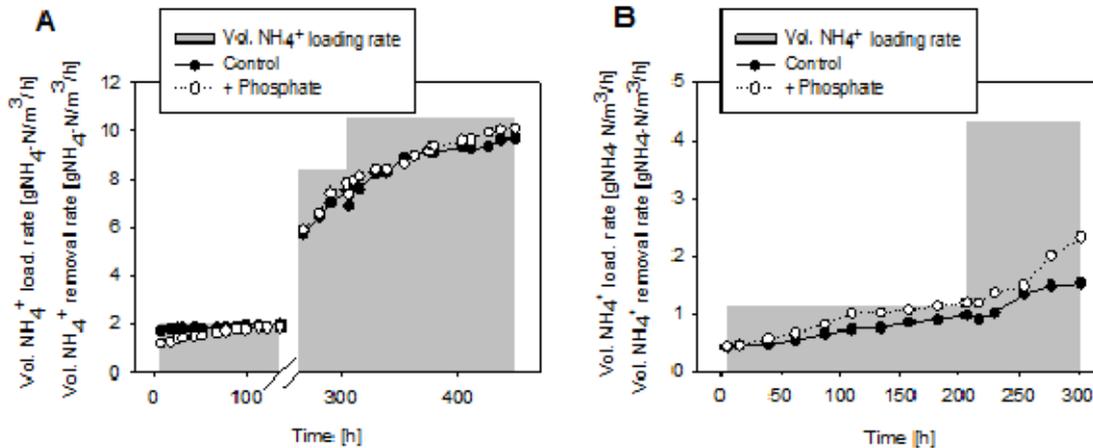
The short term upshifts of  $\text{NH}_4^+$  load revealed that the filters have a substantial capacity in  $\text{NH}_4^+$  removal and are able to deal with dynamic inflow concentrations (Fig. 2). There was no difference in the removal rate whether the load was increased by increased flow rate or increased concentration in the influent (Lee et al., 2014).



**Figure 2** Safe operational window of nitrification (shaded are) where an increase in the ammonium load causes an adequate increase in the nitrification rate (Lee et al., 2014).

With sand from plant A, additional  $\text{PO}_4^{3-}$  did not result in increased removal rates compared to the control for all applied loading conditions.  $\text{NH}_4^+$  removal rate increased over time in both columns (Fig. 3A) whereas with sand from plant B,  $\text{NH}_4^+$  removal was substantially increased when  $\text{PO}_4^{3-}$  was added (Fig. 3B), with 57 %

higher removal at the end of the experiment compared to the control. Packed column lab- and pilot experiments showed that in some cases the addition of  $\text{PO}_4^{3-}$  to poorly performing RSF does clearly improve nitrification. However, it is also suggested that incomplete nitrification in RSF is not necessarily caused by a lack of nutrients (Lee, 2014).



**Figure 3** Applied volumetric  $\text{NH}_4^+$  loading rate and achieved volumetric  $\text{NH}_4^+$  removal rates during the lab-scale experiments with sand from plant A (A) and plant B (B).

In a laboratory-scale column  $\text{NH}_4^+$  removal was higher when trace metals were added, compared to a control, especially at increased  $\text{NH}_4^+$  loading rates. Addition of selected trace metals to a full scale biological rapid sand filter stimulated  $\text{NH}_4^+$  removal rapidly, reducing the filter effluent  $\text{NH}_4^+$  concentration until  $\text{NH}_4^+$  was limiting (Wagner et al., 2014).

Overall, our findings demonstrate the possibility of using phosphorus or trace metals addition to overcome incomplete  $\text{NH}_4^+$  removal, and to increase the  $\text{NH}_4^+$  removal capacity in water works' biological filters.

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