

Relating dynamic conditions to the performance of biological rapid sand filters used to remove ammonium, iron, and manganese from drinking water

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Relating dynamic conditions to the performance of biological rapid sand filters used to remove ammonium, iron, and manganese from drinking water

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Abstract

Biological rapid sand filters are used throughout the world to remove both particulates and dissolved compounds from drinking water and is a proven and effective treatment technique for providing safe and secure drinking water. However, experience has shown that some filters have problems consistently meeting regulatory guidelines for compounds like ammonium and reduced forms of iron and manganese. These compounds can cause biological instability in the distribution system and can lead to many problems including the growth of pathogens and aesthetic problems (taste, odor, and color). When problems occur in these filters, current solutions are often based on rules of thumb and guess work rather than on firm scientific principle. The goal of this research is to characterize the underlying processes that control the biological performance of biological rapid sand filters in order to link filter management to performance. This can be used to optimize operating conditions such as flow rate, loading conditions, and time between backwash cycles, to ensure that water quality guidelines are continuously met and so the filters are operated as efficiently as possible.

Pilot scale biological rapid sand filter columns were set up at Islevbro water works, a drinking water plant in west Copenhagen, to determine how operating conditions and substrate loading affect the performance of the filters. Two columns were run in parallel and fed with influent water from the water works. The sand in the pilot columns was taken from one of the full scale filters and matches the depth profile of the full scale filter.

The pilot columns were initially operated for 2 and a half months at similar operating conditions as the full scale filter to validate the performance of the pilot columns. After this, a series of short term ammonium load shift experiments were performed in one of the columns to determine the maximum nitrifying capacity of the filter. Ammonium was dosed until steady state was established (between 6 and 8 hours) and water samples were collected with depth to determine the ammonium and nitrite removal throughout the depth of the column. These experiments were also performed at two different flow rates and various times after backwashing to determine if these conditions influenced the nitrifying capacity of the filter. Water samples were also collected with depth for Iron and manganese to determine the effects of flow and increased ammonium loads on the removal of these compounds. Media samples were also collected with depth and qPCR analysis was done to determine the density and distribution of ammonium oxidizing bacteria (AOBs) in the columns.

The results showed that the columns were able to remove significantly more ammonium than under normal loading conditions and that the capacity does not change as a function of flowrate or time after backwash. The columns did see increased nitrite above regulatory limits in the effluent during the load shift experiments. Iron and manganese removal were not affected by increased ammonium loads and the density and distribution of AOBs closely follows the ammonium removal in the filter. The results show the filters are able to safely operate under increased flow rates and ammonium concentrations and that the time after backwash does not dramatically effect nitrification in the filters.

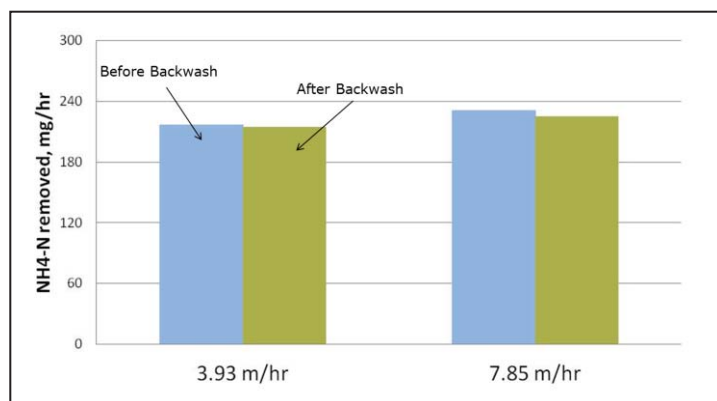


Figure 1: Ammonium removal (mg NH₄-N/hr) in pilot columns at normal flow (3.93 m/hr) and double the normal flow (7.85 m/hr) both before and after backwash

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