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Nitrification rates in fluidized-bed filters

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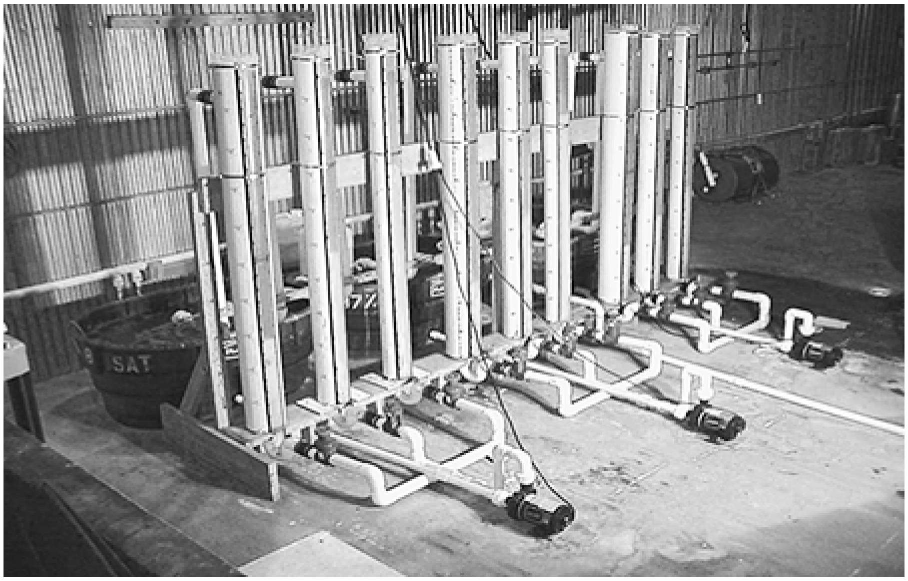
Testing monitored ammonia inflow concentration and loading rate, nitrite, nitrate, hydraulic loading, head loss and biofilm thickness

Many biofilter configurations are used to improve water quality, and their performance varies dramatically with loading and management.

For fluidized-bed filters, good biofilm management addresses the needs of nitrifying bacteria in terms of water quality, nutrient transport, and biofilm sloughing. Ammonia and nitrite conversion rates are used to evaluate of biofilter performance. Also, models of the biofilm are useful for biofilter design, because they can predict the expected thickness of a biofilm from the substrate concentration.



General view of the three-replicate biofiltration system.

Filter performance tested

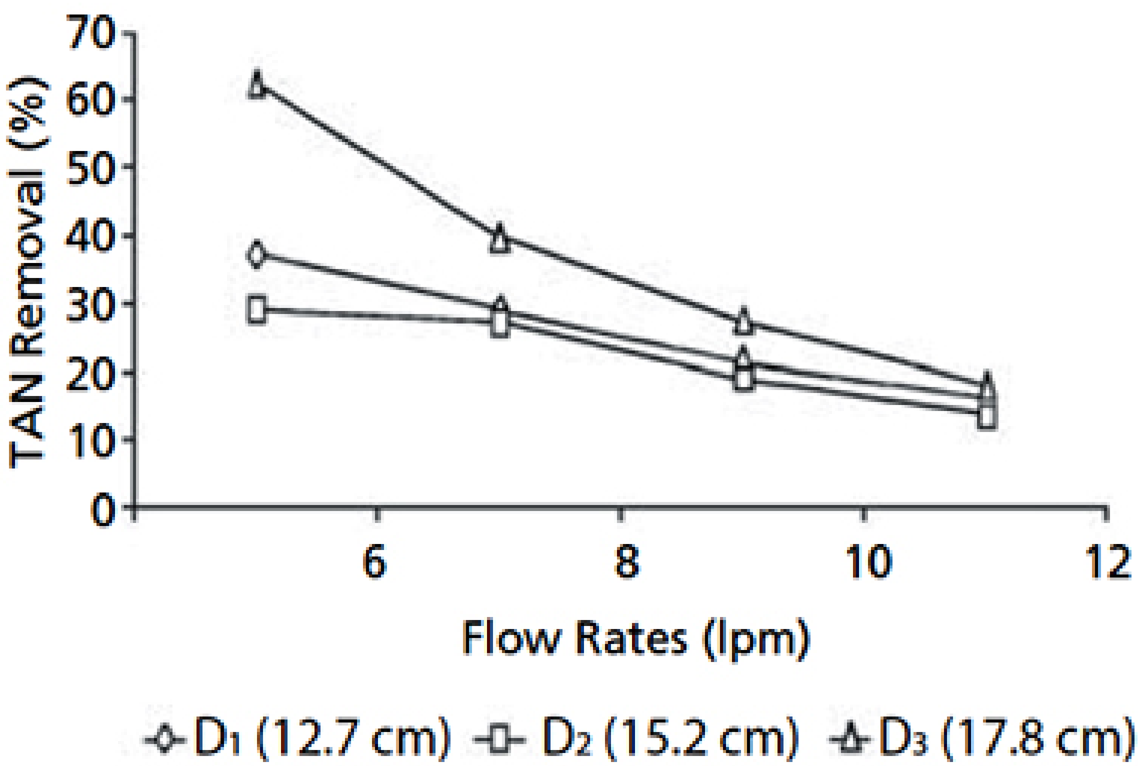


Fig. 1: Avg. TAN removal per pass in part 1 of the study. The ammonia feed is constant (180 mg per square meter per day), and the flow rate through the biofilters is increased from 6 to 12 Lpm.

A study by the author evaluated the nitrification performance of three fluidized-bed filters. Each filter contained 10 liters of ABS (acrylonitrile, butadiene, and styrene) plastic bead media, with cylindrical shape of 2- to 4-mm diameter and length. Three bed height-to-diameter ratios were used with column diameters of 12.7, 15.2, and 17.8 cm. The biofilters were connected in parallel to a reservoir containing 500 liters of water.

The systems were allowed to acclimate using a solution of ammonia and other nutrients. To evaluate filter performance, testing monitored ammonia inflow concentration, ammonia loading rate, nitrite, nitrate, hydraulic loading, head loss and biofilm thickness.

Water flow

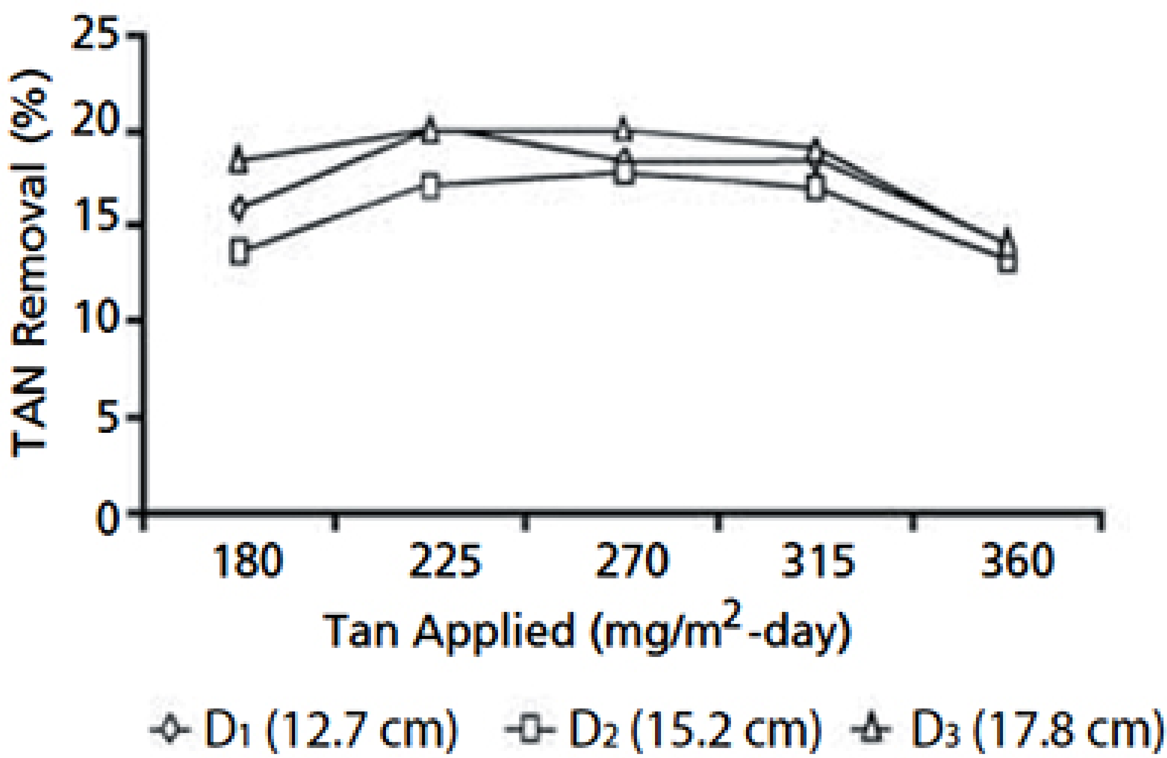


Fig. 2: Avg. TAN removal per pass in Part 2 of the study. The flow rate is constant (12 Lpm) and the ammonia feed through the biofilters is increased from 180 to 360 mg/m2-day.

Four flow rates ranging 6 to 12 liter per minute were tested for each biofilter type, at a constant ammonia feed level of 180 milligrams per square meter per day. The 17.8-cm-diameter biofilter (D_3) showed the highest ammonia removal rate at a flow rate of 6 liter per minute, followed by the 12.7-cm (D_1) and 15.2-cm (D_2) filters.

Increased flow rate decreased the difference in ammonia and nitrite removal rates among the biofilters. The increased flow rate also reduced the ammonia level in the system from 0.6 to 0.5 milligrams per liter, but did not affect nitrite concentrations.

Ammonia feed rates

The effects of five ammonia feed rates of 180 to 360 milligrams per square meter per day were tested at a flow rate of 12 liter per minute. Maximum ammonia removal was observed at ammonia loadings of 270 milligrams per square meter per day. Ammonia and nitrite removal rates differed between biofilters, but the differences were smaller than those regarding flow variation.

Ammonia accumulated in the tanks at 0.5 to 1.0 milligrams per liter as ammonia loading increased, although nitrite concentration remained relatively constant. This indicated that in plastic bead systems, there is a limitation in nitrification rate with increasing ammonia concentration that results in ammonia accumulation. However, the results showed that nitrification performance improved by 17 percent as the flow rates were increased.

Biofilm development

Biofilm thickness increased with ammonia loading, but decreased with increased hydraulic loading rate. Fig. 3 shows an electron micrograph of the cross-section of a bead covered with biofilm. Biofilm thicknesses observed in this study were less than those predicted using a biofilm model.

Fluidization

Fluidizing a column means pumping against head loss at the bottom plate, in the beads, and in the water column. Head loss varied with flow rate and degree of media fluidization, ranging from 4.6 cm in biofilter D1 at 6 liters per minute to 1.8 cm in biofilter D3 at 12 liters per minute. The percentage of bed expansion increased linearly with water velocity for each biofilter.

There was only a small density difference between the media, biofilm, and water. Hence, there were no significant changes in fluidization level as biofilm accumulated or was sheared off, suggesting the fluidization of plastic beads is more constant over a range of biofilm thicknesses than in sand biofilters.

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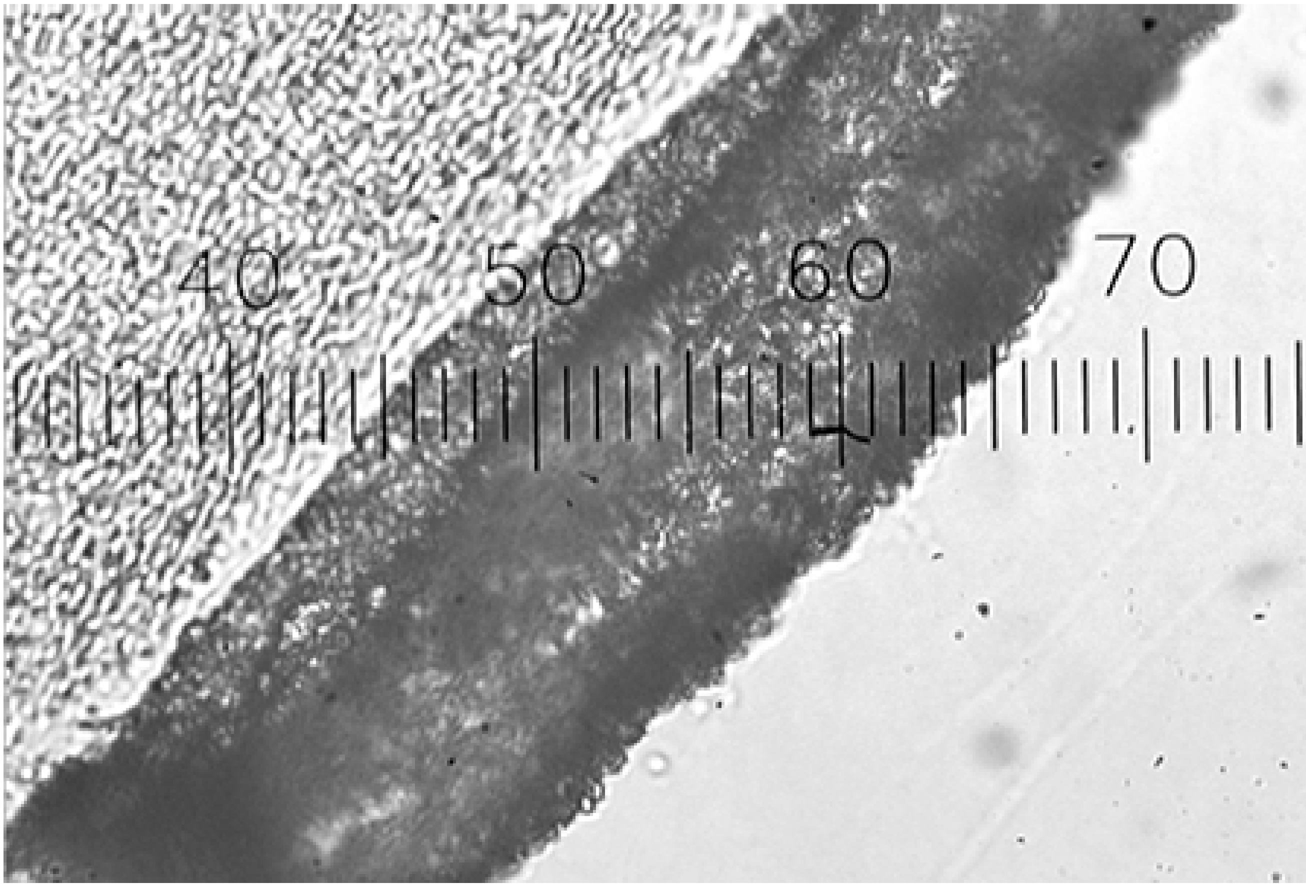

Fig. 3: Cross-section of a nitrifying biofilm attachment to a plastic bead surface. Scale: 1 unit = 4 µm.

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