New England Water Treatment Technology Assistance Center

University of New Hampshire • Durham, New Hampshire

NE-WTTAC PROJECT SUMMARY REPORT

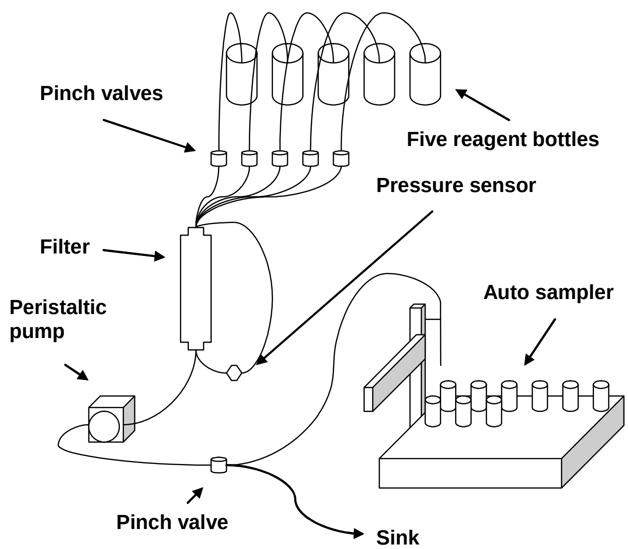
# Enhanced Particle Capture in Slow Sand Filters using a Filter Aid

## Objectives

The main goals of this project were to evaluate the potential use of a highly effective naturally occuring filter aid and to evaluate alternative sources of the ripening agent. The naturally occuring filter aid was obtained by extracting an acid soluble polymer from surface water seston. The filter aid enhances particle removal from raw source waters by modifing the filter media surface properties and appears to be responsible for most of the observed "ripening" of slow sand filters. Previous work demonstrated that the filter aid can be applied at the beginning of a filter run to effect high attachment efficiency. This work builds on previous research that indicates that physical chemical mechanisms are the dominant means of particle removal in at least some slow sand filters. The role of aluminum as a filter aid that naturally effects efficient particle removal in slow sand filters is elucidated.

## Methodology

The experiments were conducted using a computer controlled automated filter test device. Application of the filter aid, *Escherichia coli* challenge to the filter, acid wash, and sampling all were conducted automatically by the test device. The test filter was 2.5 cm in diameter and 15 cm in depth. The filter was filled with glass beads instead of sand as the transparency of glass beads allows us to examine the deposition of filter aid. The glass beads were 0.43 to 0.72 mm in diameter. A pressure sensor was attached to both ends of the filter to record the head loss across the filter. A computer controlled peristaltic pump was connected at the bottom end of the filter to regulate the filter approach velocity, which was between 5 and 12 m/day. The effluent was discharged either to waste or to sample vials in an auto-sampler. *E. coli* removal was measured using the membrane filtration test. Various techniques to coat filter media with the filter aid were evaluated. Early in the research the high concentration of aluminum in the filter aid led to the hypothesis that naturally occurring aluminum may be responsible for slow sand filter ripening. A series of tests were conducted to evaluate the possibility of rapidly ripening slow sand filters with small doses of aluminum.




## Results

The *E. coli* removal efficiency for a filter that received a naturally occurring filter aid extracted from Cayuga Lake seston was plotted as a function of the total amount of aluminum applied to the filter bed. The filter performance was presented as pC* where C* is the dimensionless ratio of effluent *E. coli* concentration divided by the influent *E. coli* concentration and p is a functional shorthand for –log (thus pC* of 3 means 1/1000th of the influent bacteria remain in the effluent). The results suggested that the filter performance was directly proportional to the amount of accumulated aluminum (Figure 1). The concentration of aluminum in the filter feed was 40 µg/L (1.5 µmol/L) as aluminum or approximately 0.44 mg/L as alum.

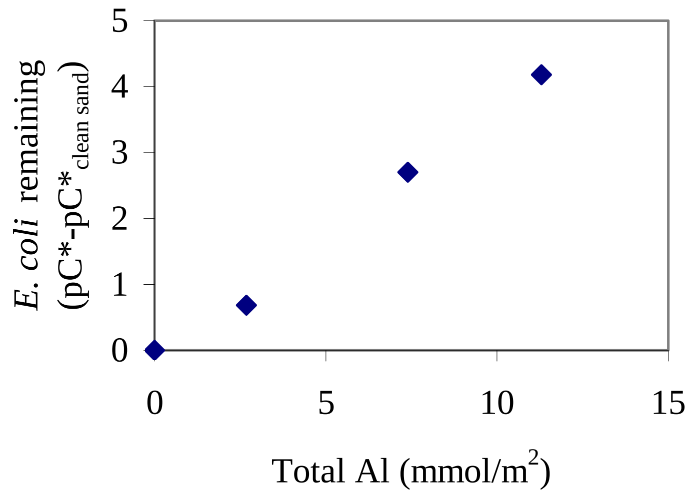



Figure 1. *E. coli* remaining for a filter receiving a Cayuga Lake seston extract filter aid as a function of the amount of aluminum in the filter aid applied to the filter bed. Filter approach velocity was 2.4 m/day and the influent aluminum concentration from the seston extract was 40 µg/L. Adapted from{Weber-Shirk, 2002 #973}.

The hypothesis that the enhanced filter performance caused by the filter aid was due to the naturally occurring aluminum was tested with the filter tester. The approach velocity was set at 12 m/day. Hydrochloric acid (0.1 N) was fed to the filter for two hydraulic residence times to make sure no previously deposited aluminum solid was present. Synthetic raw water (simulating particle free surface water) was applied for two hydraulic residence times to restore neutral pH inside the filter. *E. coli* were then applied for two hydraulic residence times and a sample was collected at two hydraulic residence times after the beginning of the *E. coli* feed. This test permitted determination of the bacterial removal efficiency for a clean filter. Alum was then applied for 0.2 hydraulic residence times at an Al concentration of 1 mmol/L. *E. coli* were introduced for two hydraulic residence times and a sample was collected at two hydraulic residence times after the beginning of the *E. coli* feed. This allowed determination of the bacterial removal efficiency for an aluminum treated filter. Acid was again applied and the above procedures were repeated 9 times except the alum application time was changed from 0.4 hydraulic residence times to 2 hydraulic residence times in increments of 0.2 hydraulic residence times. The results for coliform removal are shown in Figure 2. The head loss for the 120 $mmol/m^2$ accumulated aluminum was less than 4 cm.

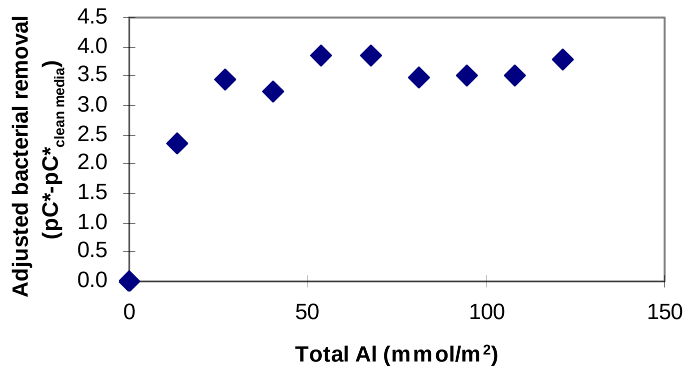



Figure 2 Adjusted bacterial removal (pC*-pC*$_0$) of the filter as a function of the amounts of aluminum applied. There is acid wash between each data point. Filter approach velocity was 12 m/day.

The consistent performance independent of aluminum applied above 30 mmol/m$^2$ may be due to the relatively short column and high approach velocity. Filtration theory would predict no further improvement in particle attachment after the potential collector surfaces are completely coated with the sticky aluminum gel. Thus it is quite possible that 99.99% removal is the theoretical maximum that can be attained with a 15 cm column operating at 12 m/day.

The relationship between head loss and the amount of aluminum applied to the filters was evaluated. The results (Figure 3) suggest that approximately 600 mmol/m$^2$ yields 50 cm of head loss. The application of 600 mmol/m$^2$ is equivalent to 180 g of alum per square meter of filter bed. At a dose of 1.5 μmol/L and an approach velocity of 12 m/day it would take only 33 days to reach 0.5 m of head loss due exclusively to the accumulation of alum. This head loss may be excessive for operating slow sand filters. However, it is reasonable to consider using even lower doses of aluminum since laboratory filter tests suggest that pC* would exceed 6 after about a week of operation at a dose of 1. 5 μmol/L.

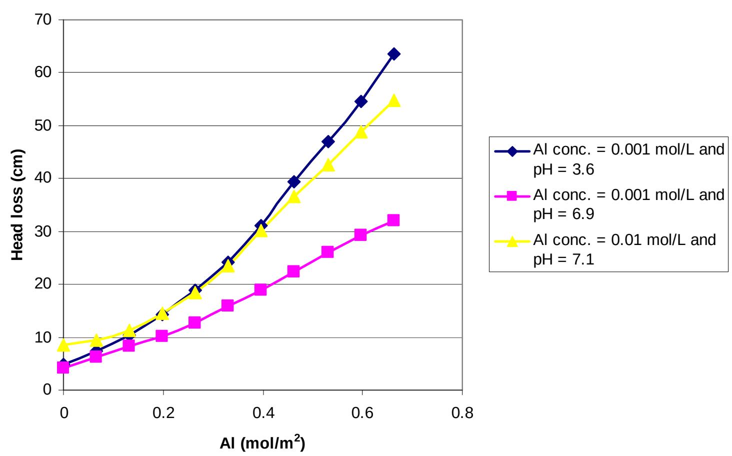



Figure 3 Head losses as a function of the amount of aluminum applied. The experiment was repeated 3 times with different influent conditions.

## Conclusions

Aluminum is a common element in the earth's crust (8% by mass) and thus is ubiquitous in the environment. The natural weather processes release aluminum into surface waters. Aluminum in surface waters may be responsible for a significant fraction of the filter ripening and the particle removal in slow sand filters. In this research we provide evidence that the addition of small amounts of aluminum to slow sand filters causes greatly enhanced removal of E. coli. We also demonstrate that slow sand filter performance can be enhanced over time periods that are only limited by the filter residence time.

## Recommendations

The physical-chemical aspects of particle removal by slow sand filters and the ripening process have been largely ignored perhaps because the gradual ripening suggested a biological process. Now that the potential of physical chemical ripening has been demonstrated further work could address two related topics. First, the role of naturally occuring aluminum in operating slow sand filters could be documented. A reasonable goal would be to assess the relationship between the rate of filter ripening and the aluminum concentration in the source water.

The second and perhaps most important research and development task for slow sand filters could be creating protocols to enhance filter performance with the addition of very low doses of alum. The alum dose would need to be carefully set to avoid clogging the filters.

## Presentations

An article entitled Aluminum in Slow Sand Filtration will be submitted to Water Research.

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## DIsclaimer

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