New England Water Treatment Technology Assistance Center
University of New Hampshire ▪ Durham, New Hampshire
NE-WTTAC
PROJECT SUMMARY

The Role of the Schmutzdecke in E. Coli Removal in Slow Sand and Riverbank Filtration

Objectives

The exact role that the interface layer or schmutzdecke exerts in microbial removals in both SSF and RBF systems has not been well-defined. The need to establish or re-establish a schmutzdecke layer after filter cleaning or riverbed scouring events needs to be ascertained, so that appropriate operational methods can be implemented, if required.

The specific objectives of this research included:

1. Ranking the relative importance of various media characteristics and operational conditions on biofiltration removals of Escherichia coli bacteria.
2. Assessing the effect of a sudden removal of the schmutzdecke on pathogen removal in the event of scouring or cleaning and a filter's ability to recover from such an event as a function of temperature.
3. Assessing removal mechanisms associated with the schmutzdecke biofilm. Specifically, determining whether the extracellular polymeric substances (EPS) excreted by the schmutzdecke biofilm enhance the “stickiness” of filter media.
4. Estimating the potential influence of protistan predation as a pathogen removal mechanism.

Methodology

A series of studies was conducted on laboratory scale sand columns under varying operational and design conditions with spiked concentrations of E. coli.

First, a screening study was conducted to determine the design and operational parameters of most importance for optimal removal in the schmutzdecke (Objective 1). The results of the screening study were also compared to results obtained by other researchers at laboratory, pilot, and full scale in order to verify that the lab scale apparatus used for the present research satisfactorily represented larger systems. In light of the results of the screening study, a subsequent study focused on the effect of specific parameters: empty bed contact time and media size (Objective 1).

Next, larger filters were simulated by connecting the lab scale filter columns in series in order to model RBF scouring and SSF cleaning (Objective 2). Then, the results of all the previous studies were analyzed for trends correlating biofilm status in the schmutzdecke and E. coli removal (Objective 3). Other biological removal mechanisms - release of exotoxins and protistan predation - were investigated with specifically designed studies (Objectivw 3). Preliminary examination of protistan predation found it to hold promise as a significant removal mechanism, but also generated many questions. In addition, very little previous research on predation in SSF and RBF was available, so more emphasis was given to predation in the final studies (Objective 4).

Results

Results confirmed that E. coli removals in slow-rate biological filters occur primarily at the interface and are related to schmutzdecke ripening state, empty bed contact time, biological activity, temperature, and protistan abundance. Using a suite of analyses characterizing the biofilm growing on the schmutzdecke, no connection was found between the preexisting extent of biological ripening and a filter's ability to recover from a scouring or scraping event that removed the schmutzdecke. Biological activity, as measured by CO_2 respiration in the top 2.5 cm, as well as protistan abundance in the top 0.5 cm of the schmutzdecke did, however, correlate positively to E. coli removal. The role of predation deserves further investigation, and filters should be operated in such a way as to enhance biological activity and protistan abundance in the schmutzdecke.

Conclusions

1. Filter Characteristics Assessment:
   - EBCT appeared to be more important than HLR, size, or biological ripening.
     - Above an EBCT of 30 minutes, E. coli removal did not significantly improve.
     - Majority of bacteria removal occurred in top 7 cm, but some challenge organisms penetrated beyond schmutzdecke.
2. Evaluation of Schmutzdecke Removal:
   - Scraping or scouring dramatically reduced bacterial removal efficiency, but filter recovered in < 4 days.
     - Water temperature affected extent of recovery.
     - Cold filters (80°C) achieved a significantly lower ultimate removal efficiency than warm filters (240°C).
   - Most initial attachment of E. coli occurred in schmutzdecke.
   - Captured E. coli detached from schmutzdecke after challenge was stopped.
3. Role of Schmutzdecke Biofilm:
   - Strong correlation between bacterial removal and biological activity.
   - Assessment of EPS by total carbohydrate and total protein did not provide strong correlation indicative of biologically mediated attachment.
   - Inactivation or death caused by toxins in schmutzdecke was not observed.
4. Role of Protists:
   - Protistan predation may play critical role either by grazing to limit detachment or by interception in pore water, but neither mechanism was confirmed.
   - Draining filters did not immediately decrease number of protists in schmutzdecke.
   - Protists can be seeded onto operating filters.

Recommendations

- Compare removal of other challenge microorganisms to E. coli.
- Investigate other biofilm characteristics besides gross measures of biomass and EPS and gather more data to improve correlations.
- Examine effect of desiccation on protists by allowing filters to sit after draining.
- Improve experimental methods for examining effect of seeding with protists.

Principle Investigators

Dr. M. Robin Collins, Ph.D., P.E.

Presentations

4th International Slow Sand and Alternative Biological Filtration Conference. Mülheim an der Ruhr, Germany, May 2006.

American Water Works Association (AWWA) 125th Annual Conference. San Antonio, TX, June 2006.

New England Water Works Association (NEWWA) 125th Annual Conference. Danvers, MA, September 2006.

Publications

Unger, M. and M.R. Collins (2006). "Assessing the role of the schmutzdecke in slow sand and riverbank filtration." In Recent Progress in Slow Sand and Alternative Biofiltration Processes, R. Gimbel, N.J.D. Graham, and M.R. Collins, eds. IWA Publishers: London.

Unger M. and M.R. Collins (2006). "Assessing the role of the schmutzdecke in slow sand and riverbank filtration." Proceedings, AWWA Annual Conference, San Antonio, TX.

Disclaimer

This project was funded by the U.S. Environmental Protection Agency grant number X3155801-2.
Mention of specific trade names herein does not imply endorsement on the part of the USEPA or the University of New Hampshire.