Optimizing Filter Conditions for Improved Manganese Control During Conversion To Biofiltration
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PRINCIPAL INVESTIGATORS:
Chance V. Lauderdale, Greg Pope, Kara Scheitlin, John Zwerneman, Mary Jo Kirisits, and Sung Woo Bae

OBJECTIVES

This project sought to build on previous WRF biofiltration research to further validate, optimize, and explore strategies to enhance biofiltration, with a specific focus on enhancing/facilitating the bioacclimation of filter media previously used in a conventional (chlorinated) filtration mode. Special attention was given to accelerating biological acclimation to manganese (Mn) removal while preventing legacy Mn from desorption and release. The overall objective of this study was to identify filter operational strategies for improved Mn control during the conversion to biofiltration, with a specific focus on achieving sustained biofilter treatment performance for Mn removal through both chemically and biologically mediated processes. The ability to monitor and characterize performance degradation or improvement through the conversion was also a critical component of the study.

BACKGROUND

The Trinity River Authority of Texas (TRA) owns and operates the Tarrant County Water Supply Project (TCWSP), which maintains free chlorine residual in the filter influent. The presence of chlorine promotes manganese (Mn) oxidation and precipitation on filter media. Although a portion of Mn precipitate is removed during filter backwashes, a large fraction remains attached to the media. TRA currently applies ozone after sedimentation for disinfection and plans to convert the TCWSP filtration process to a biological mode. This conversion will require moving the chlorine feed point to a location downstream of the filters. The purpose of this process is to provide long-term water quality improvements in terms of taste and odor removal, disinfection, and effluent biostability. However, short-term water quality deterioration may result. The elimination of chlorine residual will cause a decrease in filter feed oxidation-reduction potential (ORP) that may result in a temporary or potentially intermittent release of Mn into the plant-finished water. The TCWSP may experience Mn breakthrough for several months while filter...
biological activity is acclimated sufficiently for Mn treatment. Such a release of Mn would likely create color, turbidity, and taste and odor issues, resulting in customer complaints. TRA currently complies with an internal Mn effluent goal of 20 µg/L and will seek to do so during and after conversion to biofiltration, allowing only small levels of Mn breakthrough.

Previously considered options to mitigate the release and/or effects of Mn prior to operating in a biological mode include media replacement or chemical wash. Implementation of these alternatives is costly. The potential of biofiltration as a sustainable Mn treatment process necessitates the development of a feasible method for the conversion of conventional chlorinated filters to biological filters with minimal impacts to treatment performance or finished water quality. The identification of such a strategy may:

1) Improve water quality
2) Reduce the conversion costs (i.e., avoid media replacement)
3) Reduce disinfection by-products through reduced free chlorine usage and the biological removal of disinfection byproduct precursors
4) Provide utilities with a “green” treatment technology reliant on the natural processes responsible for Mn cycling

This work seeks to validate and refine available operational modifications for the biofiltration process that will yield sustained and robust attainment of a wide range of utility performance goals, including sustained Mn treatment. This project will also provide valuable information on enhancement strategies for the management of Mn release and bioacclimation of filter media.

**APPROACH**

The project approach was developed to identify an effective biofilter conversion strategy at the TCWSP while maintaining Mn removal objectives and all other finished water quality goals. Filter media were collected from the full-scale chlorinated anthracite filters at the TCWSP and installed into a four-column filtration pilot skid. The pilot skid was operated in parallel with the full-scale conventional filters (i.e., fed settled and ozonated water). Upon startup, the filters were operated under a biological mode (without chlorination application). The test plan implemented various biofilter acclimation and operational optimization strategies, including nutrient enhancement, pH optimization (above neutral pH), and substrate enhancement. A control filter column was always in parallel operation with the test filters. The filters were operated for approximately five months before the media was replaced with “new” media from the full-scale filters. The media change out allowed for two distinct testing phases to determine whether biofilter conversion would be most effective during summer/fall (Phase I “warm weather,” temperatures ranging from 18–29 ºC) or winter/spring (Phase II “cold weather,” temperatures ranging from 11–22 ºC). Various hydraulic, treatment performance (including Mn removal), and microbial tracking parameters were monitored throughout the study to investigate the influence of seasonal water quality changes and operational strategies on biofilter conversion effectiveness.
RESULTS/CONCLUSIONS

This research was tailored to address issues that may arise during the conversion from conventional filtration to biofiltration at the sponsoring utility, but it is applicable to the drinking water industry as a whole. A nutrient/pH biofilter enhancement strategy was identified and validated through months of pilot testing that may allow the successful conversion of conventional chlorinated filters to biofilters without jeopardizing Mn treatment or filter hydraulics. These findings may allow utilities concerned with maintaining an effective Mn treatment barrier to consider a conversion to biofiltration with potential tools to support this transition. Specific observations for the best performing biofilter acclimation enhancement strategies are as follows:

Mn Removal Performance

Under warm weather conditions (Phase I), all biofilters tested under enhancement conditions outperformed the control biofilter across both the acclimation period (three weeks, as determined by steady-state DOC removal) and the following 4.5 months of steady state operation. The biofilter influent Mn concentrations averaged 0.07 mg/L, which was treated by the nutrient-enhanced, nutrient/pH-enhanced, and nutrient/pH/substrate-enhanced biofilters to mean Mn effluent concentrations less than 0.025 mg/L. The control biofilter showed an average Mn breakthrough of 0.045 mg/L during this time. Peak Mn loadings up to 0.2 mg/L were removed to less than 0.02 mg/L by all enhanced biofilters, while the control exhibited a Mn breakthrough exceeding 0.08 mg/L, well over the Secondary MCL of 0.05 mg/L. Overall, statistically significant improvements over control levels (p < 0.001) were observed for both total and dissolved Mn using all combinations of enhancement strategies.

Background levels of Mn were too low to adequately evaluate Mn removal performance during the “cold weather” conditions of Phase II. However, simulated Mn spiking events indicated poor Mn removal performance for all acclimating test and control biofilters.

Hydraulic Performance

The nutrient/pH-enhancement strategy resulted in up to a 57% decrease in 24-hour headloss accumulation relative to the control, while the nutrient-enhanced biofilter showed an approximate 22% reduction in head accumulation relative to control conditions. Nutrient- and pH-shutoffs occurred during Phase 1, and validated the observation of improved hydraulic performance using the enhancement strategy. While the nutrient/pH/substrate-enhanced biofilter generally showed superior performance with respect to water treatment, a significant degradation in hydraulic performance was observed in the column after approximately 1–2 weeks of operation (>300% increase in 24-hour terminal headloss). Extended filter run testing (48 and 72 hours as compared to the typical 24-hour runtime) generally resulted in continued relative differences in hydraulic performance between filters.

Microbial Activity and Communities in Biofilters

Microbial tracking was performed throughout the study. Environmental scanning electron microscopy-energy dispersive X-ray spectroscopy (ESEM-EDS) was performed on media samples from the full-scale conventional (chlorinated) filters and pilot-scale biofilter columns to compare
the abundance and structure of biofilms and deposits on media. Media Mn contents were also measured for each biofilter column. Microbial community and other genetic analyses were performed throughout pilot testing on select samples.

In general, biofilters with both nutrient addition and pH adjustment exhibited better Mn removal performance than either the control or the nutrient-enhanced biofilter. Similarly, ESEM-EDS analysis indicated that higher Mn content was generally present in the nutrient and pH adjusted biofilter than either the control or the nutrient-enhanced biofilter. Next-generation sequencing and principal coordinate analysis indicated that a different microbial community was present in each phase of the study (Phase 1, June 2012–November 2012 vs. Phase 2, November 2012–April 2013).

Full-Scale Process Integration and Economic Assessment

A full-scale process integration assessment was developed based on the optimal conditions for the most feasible effective strategy identified during pilot testing. This included conceptual infrastructure, operational, and general process changes necessary for a conversion to biofiltration with the identified enhancement strategy. Of the tested enhancement strategies, nutrient supplementation and pH adjustment were most promising for full-scale implementation. Substrate enhancement was not selected for further evaluation due to the significantly poorer hydraulic performance observed relative to the other strategies tested. Implementation for the participating utility requires minimal capital improvements, including a new phosphoric acid chemical system and minor changes to the existing caustic feed system. Chemical costs would increase with the addition of phosphoric acid; however, there would be no net change in caustic use by the utility. The total estimated conceptual capital cost for the recommended enhancements was $205,000. The total operational costs for these enhancements are approximately $1.08/MG treated.

APPLICATIONS/RECOMMENDATIONS

The results and analyses presented in this report provide methodology for converting conventional filters to biofilters that can be implemented at full-scale water facilities for enhanced Mn removal performance. The presented microbial tracking data provides an initial assessment of the biofilm and microbial community characteristics associated with process recommendations. Ultimately, these microbial analyses may provide links between process performance and community activity and composition.

All of the biofilter enhancement strategies tested in this study were shown to provide some benefit to biofilter acclimation and/or water treatment—and hydraulic—performance. Results demonstrated that enhancement of acclimation and minimization of Mn release from conventional chlorinated filters is possible with biofilter augmentation strategies tailored to site-specific conditions. While this research was tailored to address potential issues that may arise during this conversion from conventional filtration to biofiltration at the sponsoring utility, it is also applicable to the drinking water industry as a whole. This research will augment the existing body of knowledge pertaining to biological drinking water treatment, as the relatively new concept in the gains momentum among U.S. water utilities.

The next phase of this work will include full-scale demonstration testing of the conversion to biofiltration at the sponsoring utility. The enhancement strategies to be applied at the full-scale will include phosphorous supplementation and pH adjustment. Additional investigations should
also be considered for further characterizing the role of source water quality on biofilter performance. Significant opportunities for further biofilter optimization may be realized once understanding of the role(s) of source water temperature, Mn concentrations, and seasonal microbial communities in biofilter Mn-acclimation are achieved.

RESEARCH PARTNERS

- Tailored Collaboration Partner: Trinity River Authority

PARTICIPANTS

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