Proceedings of the 2nd International Conference on Civil, Structural and Transportation Engineering (ICCSTE'16)
Ottawa, Canada – May 5 – 6, 2016
Paper No. 133

Backwashing Biofilters: Practical Impacts on Dissolved Organic Carbon and Turbidity Removal

Onita Basu, Sarra Ikhlef, Shawn Cleary
Department of Civil and Environmental Engineering/Carleton University
1125 Colonel By Drive, Ottawa, Ontario, Canada K1S 5B6
Onita.Basu@carleton.ca; Sarra.Ikhlef@carleton.ca

Abstract **-** A lab scale study has been conducted to examine the impacts of backwashing on biofiltration performance. The backwash strategies were evaluated based on their impacts on dissolved organic carbon (DOC) removals, biofilters' biomass, backwash water volume usage, and effluent turbidity. Both nutrient limited and non-limited conditions were examined to gain a better understanding on the impact of nutrient conditions on DOC removal. In conjunction with variation in nutrient condition the backwash conditions were systematically altered as well. Backwash conditions examined included water only, 20%, 30% and 40% bed expansions as well as extended terminal subfluidization (ETSW). The overall results found little difference between 20% and 30% in terms of DOC removal while water only and 40% bed expansions resulted in reduced DOC removal. ETSW in all cases was found to be effective in reducing the filter ripening period and hence allowing a filter to be placed into service faster than without ETSW. The backwash procedures investigated in this study showed no consistent impact on biofilters' biomass concentrations as measured by the phospholipids and the adenosine tri-phosphate (ATP) methods. Results from this study provide insight to researchers and drinking water treatment utilities on how to optimize their biological filters for the purpose of optimizing the overall drinking water treatment process.

Keywords**:** Biofiltration, Backwashing, ETSW, Collapse pulsing, DOC removal, Drinking water

1. Introduction

Biological filters are a special type of filters that have the ability to effectively eliminate water contaminants through the accumulation of naturally occurring bacteria on the media in the form of a biofilm. These microorganisms utilize biodegradable organic matter (BOM) as an energy supply and a carbon source through the mediation of oxidation reduction reactions (Urfer et al., 1997). Benefits of biological filtration include; decrease in the formation potential of disinfection by products (DBPs), elimination of taste and odor compounds, reduction in chlorine demand, and decrease in bacterial re-growth potential within the distribution system resulting in a water that is biologically stable (Chaudhary et al., 2007). Biofilters backwashing is performed on a periodic basis to prevent excessive biomass accumulation and headloss buildup, to clean the biofilters, and to restore their removal capacity. An effective backwash will successfully balance the removal of excess biomass while keeping enough attached biomass for subsequent filter runs (Ahmad et al., 1998). In addition to DOC removal, biofilters are also expected to achieve the same level of particle removal that is attained by conventional filters which makes their optimization challenging (Ahmad et al., 1998). Filter ripening sequence, which is a period of increased effluent turbidity that is observed after backwash, is a common problem in drinking water treatment industry (Amburgey and Amirtharajah, 2005). Amirtharajah (1988) stated that about 90% of particles' breakthrough in a well operated filter occurs during the ripening period. Moreover, the main concern about this stage is the potential breakthrough of pathogenic microorganisms such as *Cryptosporidium* and *Giardia* (Colton et al., 1996). As a result, backwashing should minimize the risks that are associated with this period by decreasing its duration and intensity. Over the years, several attempts have been performed in order to optimize biological filters backwashing. Collapse pulsing in particular has been proven to be successful in cleaning conventional filters. However, this backwashing method has shown different degrees of success when employed on biological filters as it sometimes resulted in biological activity deterioration (Liu et al., 2001; Ahmad et al., 1998; Miltner et al., 1995). Other researchers have focused their efforts in minimizing ripening period intensity. The ETSW -which is an additional backwashing step that employs a subfluidization flow rate to gently remove the remnants particles without resulting in the detachment of further particles- has shown some success in minimizing or eliminating the filter to waste time period (Amburgey, 2004). This study aims to investigate the impact of various backwashing regimes, including ETSW and collapse pulsing, on DOC and turbidity removal in a biological filter.

2. Methodology

The experiments were conducted on a laboratory scale system consisting of three dual media filters (GAC and sand) operating in parallel. The flow rate through each column was 100 mL/min to allow for an empty bed contact time of 15 minutes. In order to measure the effluent turbidity prior an inline low range turbidimeter (HACH, Filter Track 660) was used, the device was either attached to biofilter 1(B1), biofilter 2 (B2), or biofilter 3 (B3) depending on the experiment being carried out. Biofilter influent was prepared by mixing dechlorinated tap water with dosing solutions containing different concentrations of carbon and micronutrients. The synthetic water was intended to mimic water coming into a biofilter post coagulation/flocculation/sedimentation. The backwashing experiments were carried out in different phases (Table 1). B2 was operated as the control and had a control backwash strategy (30%Control) that consisted of 6 min of air and water flow combination to achieve collapse pulsing conditions, followed by a high water wash at 30% bed expansion, followed by a 2 min lower water wash at 10% bed expansion. The backwash changes were made on B1 and B3. Phase 1 compared the implementation of a water only backwash (30%W) versus a collapse pulsing backwash (30%Control) under nutrient limited conditions. After that, phase 2 was initiated to study the impact of changing the 30% bed expansion following collapse pulsing to a lower bed expansion (20%) while utilizing the same amount of water volume, 20%SV served for this purpose. Phase 2 also investigated the impact of adding the ETSW to 20%SV. Phase 3 was initiated to study the impact of implementing a higher bed expansion (40%) than the one used in the 30%Control while utilizing a constant water volume, 40%SV served for this purpose. B3 received 40%SV in addition to the ETSW. Phase 4 examined the impact of implementing 20%ST on B1 which adapted a 20% bed expansion but followed the same time duration as 30%Control therefore utilizing less water volume than 30%Control. 20%ST was also tested on B3 but terminated with the ETSW.

3. Results

DOC removals for a water only backwash (with 30% fluidization) and an air assisted backwash (30% fluidization) in which the C:N:P ratio was nutrient limited demonstrated median % DOC removals of 13% when water only backwash was employed and which improved to 21% when collapse pulsing was added to the backwash strategy. This signifies that collapse pulsing is a more efficient backwashing method even under conditions in which biological activity is stressed. A potential explanation for the success of collapse pulsing would be related to biofilm thickness; by the end of the filtration cycle biofilm thickness reaches a critical level that limits the diffusivity of the essential substrate and dissolved oxygen (Simpson, 2008). The combination of air and water provides for greater media collisions and abrasions during backwash (Amirtharajah, 1993). This would result in greater detachment of biomass as compared to a water only backwash which results in a thin active biofilm by the end of the filtration cycle.

Figure 1 compares the % DOC removals associated with each investigated backwash with respect to the control backwash. 20%SV resulted in a median 35% DOC removal which is comparable to the 34% median value observed with 30%Control. These results suggest that employing a low bed expansion while using the same amount of water volume as a higher bed expansion has no significant impact on the DOC removal. 40%SV caused an adverse result with regards to DOC removal ($p<0.05$). The median DOC removal decreased to 24% compared to 30% DOC removal with the 30%Control condition. Figure 2 also shows that backwash water volume savings could be achieved by decreasing the time duration of the 20% bed expansion to follow the same 2 minutes duration as the 30% expansion employed in the control backwash. 20%ST served for this purpose, 20%ST removals are not significantly lower ($p>0.05$) than 30%Control removals with them ranging from 15% to 50% and from 20% to 52% for 20%ST and 30%Control respectively suggesting that under these conditions backwash optimization based on overall productivity could be achieved without compromising DOC removal. Savings of 22% on the use of total backwash water volume could be achieved when employing 20%ST versus employing 30% Control.

Although ETSW lengthens the duration of the backwashing stage and requires a higher quantity of backwash water, the extra water usage and time out of service are compensated by savings after restart when taking into account the overall productivity of the process. In this study, the median % DOC removal for 20%SV was 35% when ETSW was absent and 34% when ETSW was added. Similarly, 40%SV had a median of 24% without ETSW and 22% with ETSW. While the ETSW step for 20%ST gave a median of 33% compared to 36% when ETSW was absent. As a result, the additional flushing stage due to the ETSW procedure does not impair nor improve DOC removal. These findings provide insight on the fact that

ETSW could be optimized for a successful filter ripening sequence elimination without the fear of compromising BOM removal.

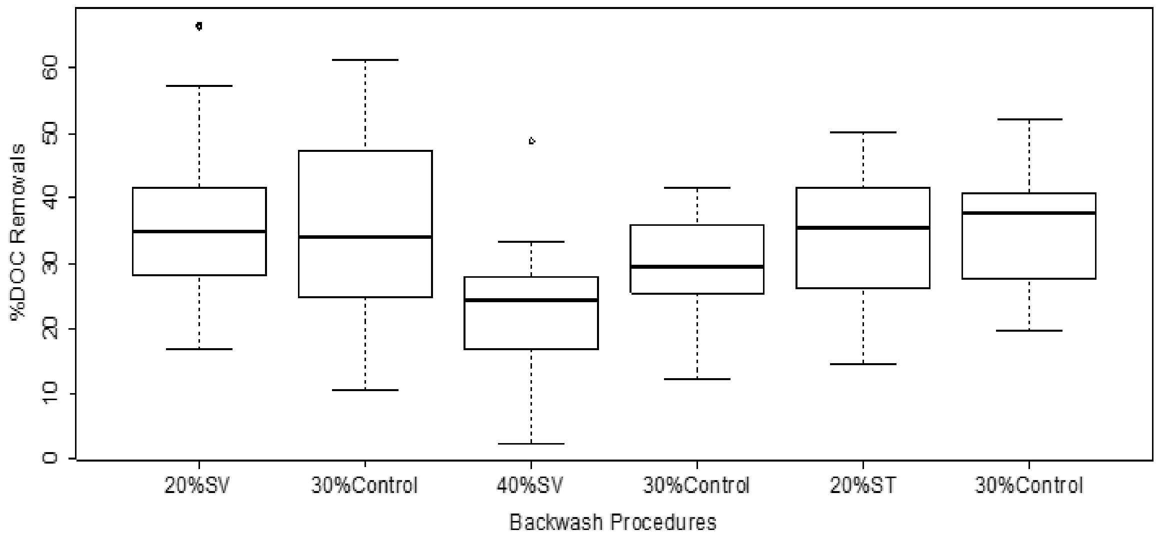

Fig. 1: Backwash procedure influence on DOC removal in non-nutrient limited conditions.

Filter to waste (FTW) was defined as the period starting immediately after restart until effluent turbidity starts improving and reaches 0.3 NTU. In the two experimental trials shown, FTW duration for 20%SV was 75 min in trial 1 and 90 min in trial 2. Similarly FTW duration was 60 min for 30%Control at trial 1 and 75 min at trial 2. These results indicate that both backwashing strategies investigated result in similar biofilter performance and that they are equally effective in meeting the current guideline of 0.3 NTU following the ripening period (Health Canada, 2014). However, it should be noted that neither 20%SV nor the 30%Control showed consistency in terms of FTW duration and the maximum turbidity reached. Similarly, although in general the 40%SV resulted in lower turbidity peaks compared to the 30%Control neither of the two monitored backwashes showed consistency in terms of turbidity peaks and FTW duration. Figure 3 also depict the impact of adding the ETSW on effluent turbidity following restart. Excellent turbidity removal is obtained when the ETSW is employed. The 300 mNTU (0.3 NTU) threshold value is never exceeded in any of the ETSW experiments. Although adding this step requires additional water usage this increase in backwash water volume is offset by the absence of FRS that may take up to two hours and result in wasting treated water.

4. Conclusion

In this study, a lab scale biofiltration system was used to examine the implications of different backwash strategies on DOC removal, backwash water usage, and effluent turbidity. Collapse pulsing conditions improved DOC removals compared to a water only backwash under nutrient limited (13% versus 21%, respectively). 20% and 30% bed expansions resulted in similar DOC removals while a 40% bed expansion resulted in a 6% decrease in DOC removal. ETSW successfully eliminated the filter ripening period while it did not impact the DOC removal when the filters were back in service.

References

[1] R. Ahmad, A. Amirtharajah, A. Al-Shawwa, and M. Peter, "Effects of backwashing on biological filters," *Journal of American Water Works Association*, vol. 90, no. 12, pp. 62–73, 1998.

[2] J. E. Amburgey and A. Amirtharajah, "Strategic filter backwashing techniques and resulting particle passage," *Journal of Environmental Engineering*, vol. 131, no. 4, pp. 535–547, 2005.

[3] J. E. Amburgey, "Optimization of the extended terminal subfluidization wash (ETSW) filter backwashing procedure," *Water Research*, vol. 39, no. 2-3, pp. 314-330, 2004.

[4] A. Amirtharajah, "Optimum backwashing of filters with air scour: a review," *Water Science & Technology*, vol. 27, no. 10, pp. 195-211, 1993.

[5] A. Amirtharajah, “Some theoretical and conceptual views of filtration,” *Journal of American Water Works Association*, vol. 80, no. 12, pp. 36-46, 1988.
[6] D. S. Chaudhary, S. Vigneswaran, H. H. Ngo, W. G. Shim, and H. Moon, “Biofilter in water and wastewater treatment,” *Korean Journal of Chemical Engineering*, vol. 20, no, 6, pp. 1054-1065, 2007.
[7] J. F. Colton, P. Hillis, and C. S. B. Filtzpatrick, “Filter backwash and start-up strategies for enhanced particulate removal,” *Water Research*, vol. 30, no. 10, pp. 2502–2507, 1996.
[8] X. Liu, P. M. Huck, and R. M. Slawson, “Factors affecting drinking water biofiltration: Filtration,” *Journal American Water Works Association*, vol. 93, no. 12, pp. 90-101, 2001.
[9] R. J. Miltner, R. S. Summers, and J. Z. Wang, “Biofiltration performance: part 2, effect of backwashing,” *Journal of American Water Works Association*, vol. 87, no. 12, pp. 64-70, 1995.
[10] D. R. Simpson, “Biofilm processes in biologically active carbon water purification,” *Water Research*, vol. 42, no. 12, pp. 2839-2848, 2008.
[11] D. Urfer, P. M. Huck, S. D. J. Booth, and B. M. Coffey, “Biological filtration for BOM and particle removal: a critical review,” *Journal of American Water Works Association*, vol. 89, no. 12, pp. 83–98, 1997.