Filter Media Treatment

Created by Monroe Weber-Shirk, last modified by Po-Hsun Lin on Dec 20, 2011

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Abstract

The post sedimentation addition of polyaluminum chloride (PACl) was investigated as a means to enhance particle removal efficiency in rapid sand filtration. The process modification was evaluated in laboratory studies and at the Cornell Water Filtration Plant (CWFP). PACl was continuously metered into CWFP filter influent to increase concentrations by 0.06 to 4.2 mg/L (as aluminum) during the filter-to-waste stage of the filter operation cycle to accelerate filter ripening. Lower influent PACl concentrations ranging from 0.056 to 0.43 mg Al/L were also continuously applied during filtration. In comparison to a control filter that received no PACl addition, the ripening time required decreased with PACl dose, and the incremental improvement in particle removal during filtration increased with PACl dose. The addition of 0.056 mg Al/L of PACl (the lowest concentration tested) significantly reduced initial filter ripening time at the CWFP from 10 hours to 2.5 hours, and effluent turbidity in the test filter over the 77 hour filter run was lower than the control filter by an average of 17%. Incremental head loss increase caused by the PACl feed was dose dependent and was negligible for the lowest dosage tested.

Method of application in Drinking Water Treatment Plants

The filter media treatment process was conducted in one of the rapid filters at the CWFP. An electrical metering pump (PULSAtron Series MP) proportionally controlled by the CWFP flow-paced computer system was employed to inject PACl. The PACl injection port was in the settled water pipe before the water reached the test filter. The filter media treatment process included two stages: (1) A high concentration of liquid PACl was applied to settled water during the filter-to-waste stage of operation for 13 min. (2) After filter-to-waste when the filter was placed in operation, a lower concentration of PACl was continuously injected during filter run. PACl addition was terminated when the test filter head loss reached 115 cm (45 inch) according to the standard operating procedure for the facility, but the filter was not backwashed until the filtered water volume reached 1.5 million gallons, filter online time reached 90 hours, or filter water quality deteriorated. Different concentrations of PACl were applied at both stages to evaluate the effect of PACl on filter ripening and long term performance. Table 2 provides details of PACl concentrations used in each trial. The PACl concentrations reported at each stage were dependent on the plant flow rate during filter-to-waste (0.9 mm/s or 240 gpm) and the average flow rate during filtration.

A control filter in the CWFP was operated simultaneously with the test filter to compare the filter performance, head loss accumulation, and aluminum concentration in the filtered water.

Table 2. Summary of full-scale experiments

Trial	PACl used during FTW *† (mg Al/L)	PACl used in Filtration (mg Al/L)	PACl metering time (hr)	Total Al mass used (g/m^2)	Incremental head loss ** (cm)	Average filtration rate (mm/s)
1	0	0	0	0	-10	1.28
2	4	0.43	32.5	59.6	80	1.11
3	4.2	0.19	65.9	52.2	65	1.13
4	0.23	0.19	60	44.9	71	1.09
5	0.14	0.12	70	34.9	63	1.15
6	0.06	0.056	77	19.2	30	1.23

*FTW: Filter to waste
† The test PACl was 5.5% Al by mass and the PACl density was 1260 kg/m3
**Incremental head loss = final head loss in test filter – final head loss in control filter

Results of Filter Media Treatment

Figure 2 shows the effluent turbidities of the test filter with filter media treatment and the control filter for an entire filtration run (trial 4). The PACl concentrations (as aluminum) applied are presented in Table 2. The effluent turbidity of the test filter dropped from 0.064 to 0.046 NTU in 2 hours while the turbidity of the control filter increased initially and then declined to 0.054 NTU after 13 hours. Thus, the time for ripening of the test filter was significantly decreased through PACl addition. The filter performance of the test filter was better than the control filter by an average of 23% during the entire filter run. Operation of the CWFP is constrained to daytime intervals. Arrows in Figure 2 above the line for the control filter show the points in time when operation of the plant stopped, and the run time shown on the x-axis does not include times when the plant was not operating. Turbidity spikes appear in both filters on each occasion that operation resumed, and were likely due to particle detachment from the media grains in response to the onset of flow. Turbidity spikes in the test filter were significantly less than the control filter, and the recovery time of the test filter to the previous effluent turbidity was significantly shorter than for the control filter. Between the 55 to 56th hour a large spike occurred in settled water turbidity (data not shown) because of a malfunction of the CWFP plant PACl pump (the PACl pump for the test filter was still functioning). This influent turbidity spike resulted in effluent turbidity spikes from both filters. However, the transient increase in turbidity in the test filter was significantly smaller than the control filter. Collectively these results indicate that the filter media treatment process can significantly accelerate filter ripening, reduce the turbidity spikes when restarting the plant, effectively improve the filter performance, and make the filter less sensitive to fluctuations in influent turbidity. After 60 hours of operation addition of PACl to the test filter was terminated. Improved performance by the test filter (i.e., effluent turbidity below that of the control) continued after the PACl feed was terminated, but particle removal slowly began to approach that of the control. This result demonstrated that the filter media treatment process modified the filter media to enhance the ability to capture particles and that sustained improvement was dependent on continued addition of PACl as a filter aid.

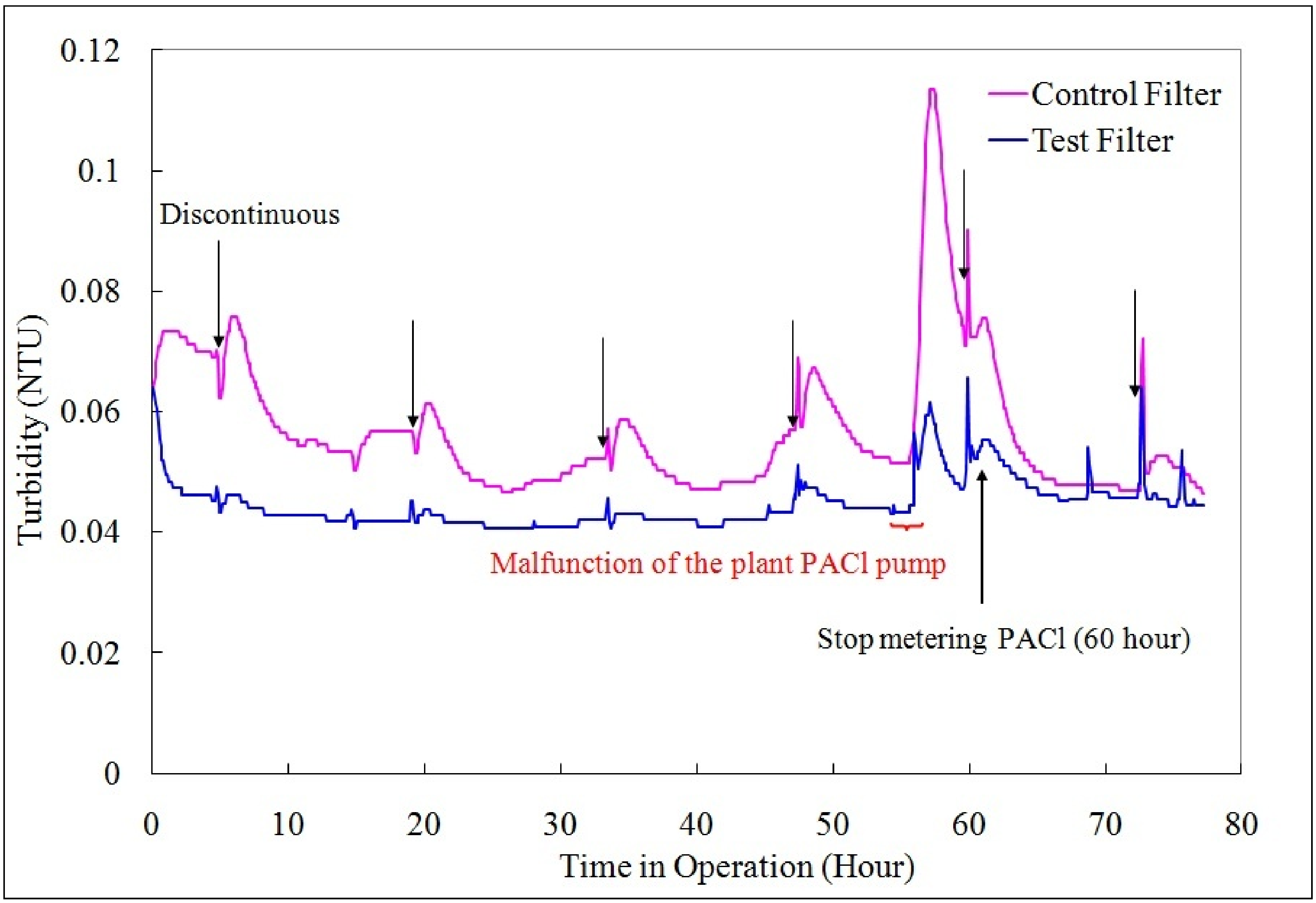

Figure 2. Effluent turbidities of the test and control filters for trial 4. Arrows above the control filter line show points at which daytime plant operation was terminated.

The incremental difference in turbidity between the test and control filters normalized by the average settled water turbidity in each trial is shown in Figure 3 as a function of the aluminum concentration resulting from PACl addition to the filter influent. The test filter that did not receive the filter media treatment (i.e., no PACl addition) performed the same as the control filter. For the test at the lowest concentration (i.e., 0.056 mg Al/L, trial 6), the test filter performance over the 77 hour filter run was better than the control filter by an average of 17% (raw data not shown). Although differences in raw water quality occurred between the comparison experiments, a trend is evident between the incremental improvement achieved during filtration and the PACl concentration.

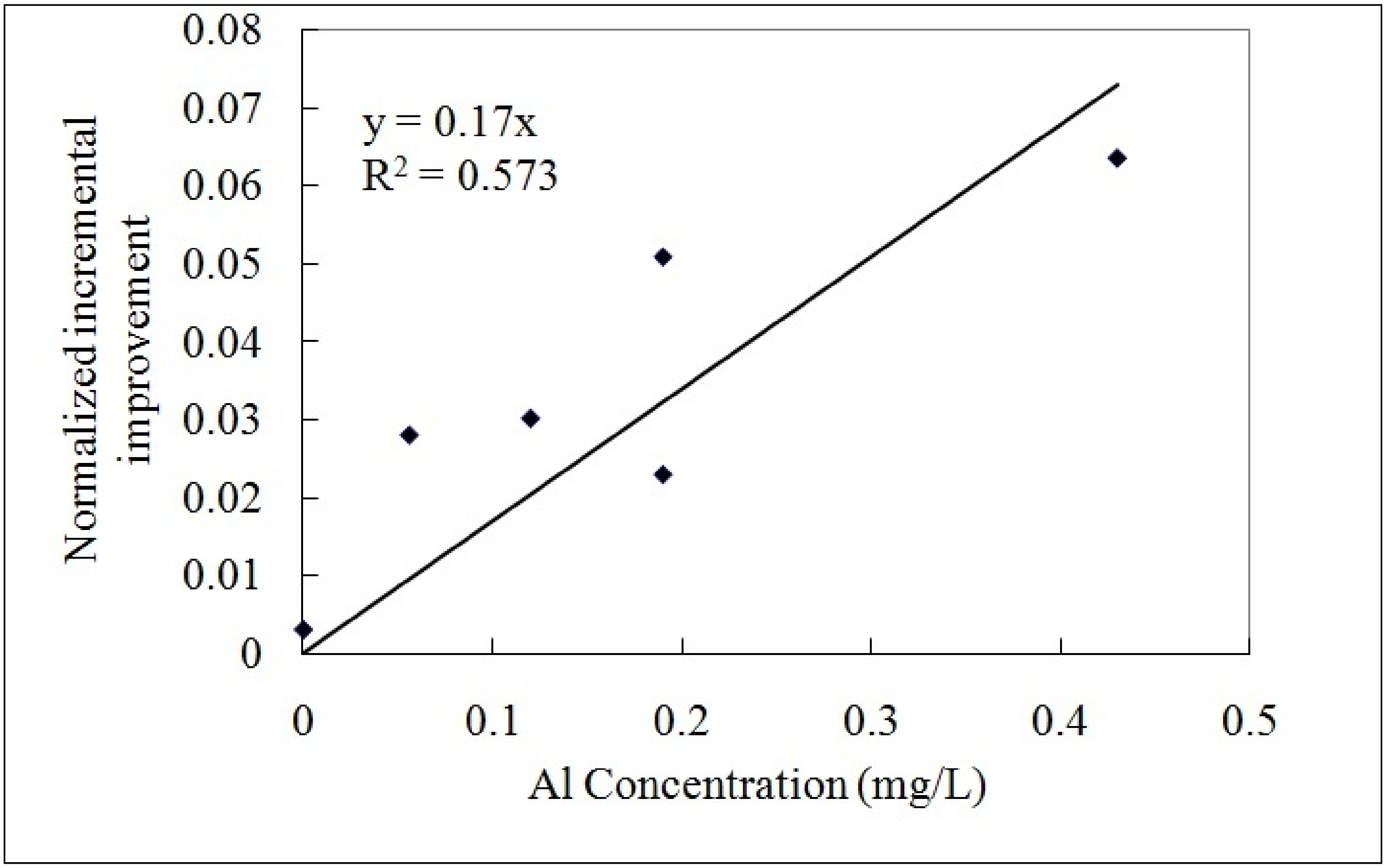

Figure 3. Normalized incremental turbidity improvement of the test and control filters as a function of increased aluminum concentration resulting from PACl addition to the filter influent.

Advantages of Filter Media Treatment

Application of the filter media treatment with PACl to the CWFP filter successfully accelerated filter ripening and enhanced turbidity removal by modifying the filter media. In the test with the lowest PACl concentration (i.e., 0.056 mg Al/L, trial 6), the filter ripening time was reduced from 10 hours to 2.5 hours, and the test filter performance over the 77 hour filter run was better than the control filter by 17%. PACl treatment facilitated rapid performance recovery after the treatment plant shutdowns. Treated filters displayed decreased sensitivity of the filter to turbidity spikes in the filter influent indicating that treatment provided protection against process upsets. The experimental results show that the incremental improvement of turbidity removal increased with PACl concentration, and the initial filter ripening required an application of between 0.5 and 3.5 g/m2 of aluminum. The difference in the rate of head loss increase between the control and test filters was proportional to the applied aluminum concentrations. Application of the highest aluminum test dose (0.43 mg Al/L) did not result in aluminum concentrations in the filtered water above the EPA secondary standard.

The filter media treatment process was easy to implement, and provided improved particle removal and an additional barrier against treatment upsets at a full-scale conventional water treatment plant. PACl addition can effectively improve filter performance for conventional water treatment plants at negligible incremental cost and without requiring significant modifications. The performance of the CWFP is excellent and the PACl-mediated improvement to the baseline low effluent turbidity suggests that treatment plants with higher effluent turbidities may reduce the occurrence of treatment violations through PACl addition. The CWFP has implemented the PACl filter media treatment process as its normal operating procedure.

Economic Analysis

The incremental cost of filter media treatment was estimated to be 4.70E-4 USD/m3 of filtered water based on the liquid PACl cost of 0.5 USD/L (2 USD/gallon) and an application rate of 0.06 mg/L as aluminum (slightly above the lowest dose used in this study). Filter media treatment can be accomplished with a single metering pump for an entire water treatment plant with all filter influent receiving a constant dose. Installation of the required PACl injection line from the existing PACl stock tanks to a point somewhere between the sedimentation tank effluent and the filter influent should be relatively straight forward. This economic analysis does not consider the possibility of using improved particle capture in filters as an opportunity to reduce the coagulant dose used before sedimentation.

Facilities Currently Using the Technology

The CWFP has implemented the PACl filter media treatment process as its normal operating procedure. This technology makes the operators easier to run the plant.

For more information

For more information please contact Po-Hsun Lin

Documents

Enhanced Filter Performance by Fluidized-Bed Pretreatment with Al(OH)3(am): Observations and Model Simulation
Po-Hsun Lin, Leonard W. Lion, and Monroe L. Weber-Shirk, Journal of Environmental Engineering 1, 389 (2011).

Enhanced Particle Capture through Aluminum Hydroxide Addition to Pores in Sand Media
Po-Hsun Lin, Leonard W. Lion, and Monroe L. Weber-Shirk, Journal of Environmental Engineering 1, 284 (2011).

Comparison of the Ability of Three Coagulants to Enhance Filter Performance
Po-Hsun Lin, Leonard W. Lion, and Monroe L. Weber-Shirk. Journal of Environmental Engineering 137, 371 (2011).

No labels