Monitoring of coagulation performance and determination of coagulant dosage using a pilot in-line filter

Water Science & Technology **Vol 53 No 4–5 pp 411–417** © IWA Publishing 2006

S.G. Kim*, K.J. Choi*, H.J. Son*, Y.C. Jun*, J.B. Rhee, I.S. Shon**, Y.D. Lee*** and S.H. Kim******

*Busan Water Quality Institute, 421-1, Maeri Sangdong Gimhaisi Kyungnam, Republic of Korea
(E-mail: *sgkim0822@hanmail.net*)

**Civil Engineering Department, Pukyong National University, Republic of Korea

***Civil and Environmental Engineering Department, Cheju National University, Republic of Korea

****Civil Engineering Department, Kyungnam University, Republic of Korea

Abstract A rapid method using the pilot in-line filter to detect any change in coagulation performance was proposed in this study. This method attempted to detect a change in coagulant dosage and mixing intensity by evaluating the filtrate quality of the in-line filter, which took the rapidly mixed water. Since the response time of this method was less than 10 min, it could be valuable to monitor the coagulation performance. The in-line filter was found more useful without underdrain. The in-line filter was more sensitive to a change in filtrate quality without underdrain than with underdrain. A new method, which combines a jar test with the in-line filter, was proposed to determine the coagulant dosage. This method reflected the actual plant situation more accurately than a jar test.

Keywords Coagulant dosage; jar test; particle counter; pilot in-line filter; turbidity

Introduction

Coagulation should be properly and effectively controlled in order to produce good quality water because it is the first step in conventional treatment. A mistake at the first step often leads to the production of poor quality water. Many factors can influence coagulation efficiency: raw water qualities, mixing conditions, coagulant dosage, etc. Among these, determination of the proper coagulant dosage is most important. Mixing intensity and time are important, but once they are decided at the design stage, it becomes difficult to change these conditions. On the other hand, coagulant dosage should be decided constantly in order to reflect the continuous change in raw water qualities. Coagulant performance should be continuously monitored because stoppage of coagulant addition could result in serious water quality degradation, such as leakage of cryptosporidium oocysts. Deciding whether the added coagulant dosage is correct is often decided by examining the settled water quality. There was also a study to attempt to evaluate a change in coagulant dosage by using the filtrate turbidity rather than raw water turbidity (AWWA, 1980). This means that 3–4 hours or more are necessary in order to detect any problem in coagulation process at the treatment plants. Therefore, a rapid method to detect any change in coagulation performance is necessary. A new method is proposed in this study. This method is expected to act as an alarm to detect any problem in coagulation process such as stoppage of coagulation addition and mixing speed. Applicability of this method was evaluated in this study.

Most water treatment plants currently rely upon a jar test to decide coagulation dosage. Operators usually run a jar test everyday, and decide the day's coagulant dosage based the settled water quality. Since the final step of conventional water treatment is filtration, a jar

doi: 10.2166/wst.2006.147

test is not appropriate for this purpose. Therefore, Bowers *et al.* (1982) used a small column to determine the coagulant dosage. The filtrate quality could be a better parameter to evaluate the coagulation performance. Therefore, a new method has been proposed to decide the coagulant dosage. This method combines a jar test with an in-line filter. Applicability of this method was evaluated in this study. The proposed method was compared to a jar test in order to determine the appropriate coagulant dosing method.

Materials and methods

Experiments

Figure 1 shows the pilot in-line filter used to monitor coagulation performance. The in-line filter was installed at the pilot plant at Water Quality Institute of Busan city waterworks. There are three trains at this plant and each train can treat 100 m^3/d. These trains employ different sedimentation: rectangular sedimentation basin (No. 1), solids contact unit (No. 2), pulsed blanket type clarifier (No. 3). The in-line filter was attached to the train No. 3. Rapid mixing time was 1.2 min, and detention time of pulsed blanket type clarifier (No. 3) was 190 min at the pilot plant. The filtration rate was 105 m/d. As shown in Figure 1, rapidly mixed water was fed into the in-line filter (diameter 40×500 mm). The in-line filter was operated at the similar filtration rate (96 m/d). A difference between the in-line filter and the filter lay in the underdrain. The in-line filter was installed without underdrain, while the filter was with an underdrain (detention time of 6.8 min). A particle counter, which was attached to these filters, counted the filtrate particle numbers.

Figure 2 shows the test apparatus used to determine the coagulant dosage. PACl (poly aluminium chloride) was added during rapid mixing at 130–180 r.p.m. Slow mixing

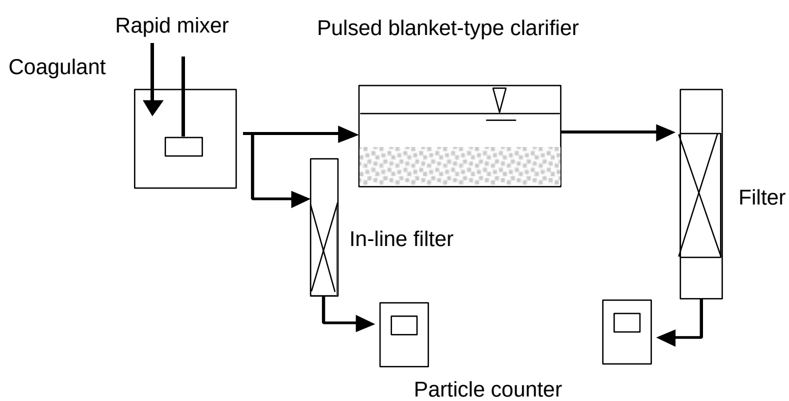

Figure 1 The pilot in-line filter and the pilot plant at Busan Water Quality Institute

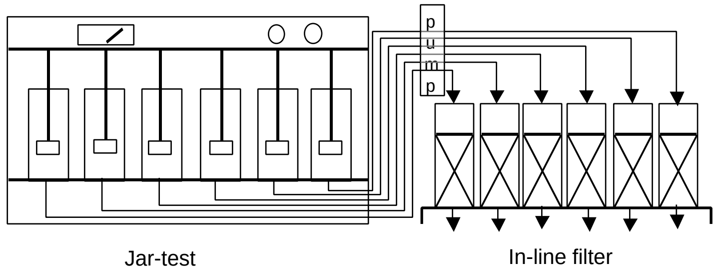

Figure 2 Test apparatus used to determine the coagulant dosage

followed 1 min of rapid mixing at 40 r.p.m. While slow mixing was provided for 15 min, water was fed into the in-line filter (3 × 3 × 6 cm) at 60 mL/min. The filtrate was then transferred into a reservoir (90 mL). The reservoir was designed for the excess filtrate to overflow. The filtrate within the reservoir was used for the examination of water quality.

Raw water used in this study was from Nakdong river. This river is a raw water source for the water treatment plants at Pusan city. Water quality was monitored using particle counter (Met One, Pacific Scientific Instruments) and turbidity meter (2100AN, Hach). Particles were divided into four groups based on their sizes: $>2\,\mu m$, $3-5\,\mu m$, $5-7\,\mu m$, $7-10\,\mu m$. The pH meter was 710A from Orion. Alkalinity was measured based on *Standard Methods* (1998).

Results and discussions

Effect of underdrain

It was suspected that the pilot in-line filter could reflect a change in filtrate water quality more sensitively without underdrain than with underdrain. It is because underdrain could provide a opportunity to mix the backwash water with the filtrate. Figure 3 compares the filtrate water qualities without (No. 1) and with underdrain (No. 2). According to Figure 3, underdrain affected the filtrate water quality. The filtrate turbidity decreased with time for the filter No. 1, but increased for filter No. 2. When the filter No. 1 was back into operation after backwash, the filtrate turbidity and particles rapidly increased due to dislodged particles. Before the filter maturing solids remained at the filter media (especially bottom) were released at the beginning of the operation. This was reflected on the filtrate turbidity instantly.

The filtrate turbidity of filter No. 2 gradually increased. The initial turbidity was low because the backwash water stored at the underdrain was released at the beginning of the operation. The underdrain acted as a reservoir and held a portion of the backwash water. The particle count data were also similar. A relatively long period was required for a filter with underdrain to stabilise. Cleasby and Baumann (1962) state that 30–40 min are usually required for the filtrate turbidity to stabilise. This result indicates that the

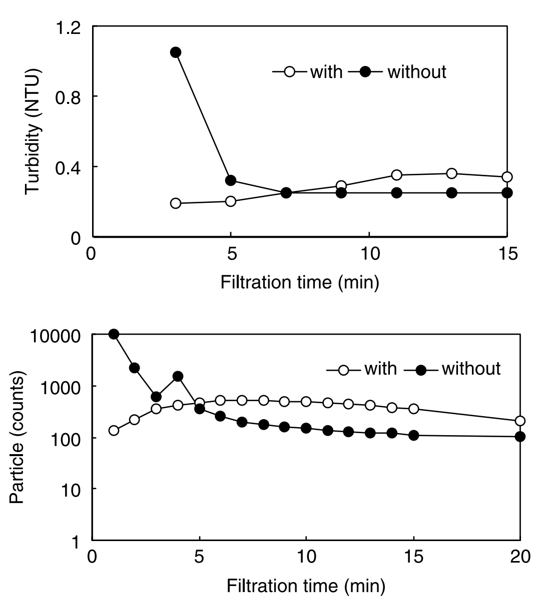

Figure 3 Comparison of the filtrate turbidity and particles with and without underdrain

underdrain is unnecessary for a quick response to a change in the filtrate quality. Since the pilot in-line filter is expected to act as a rapid method to detect any change in coagulation performance, it was installed without underdrain in this study.

Change in coagulant dosage

Figure 4 shows a change of total particles $> 2\ \mu m$ in filtrate as the coagulant dosage was varied. Addition of PACl at 20 mg/L removed most of particles $> 5\ \mu m$. Particles $< 5\ \mu m$ passed through the pilot in-line filter, but the number decreased with operation. The time needed for the in-line filter to respond to the stoppage of coagulant addition was short. The particle count of the filtrate started to increase 5 min after addition of PACl was terminated. Suthaker *et al.* (1998) defined the stabilisation stage of filter when the filtrate turbidity decreased. This result indicates the in-line filter reached the stabilisation stage in about 5 min. The time needed to respond to a change in coagulant dosage was also short. When PACl dosage was increased to 40 mg/L, it took 7 min for the particle count of the filtrate to decrease. The number of particles reduced with increasing coagulant dosage. More than 100 particles/mL were measured at 20 mg/L of PACl. Increasing to dosage to 40 mg/L and 60 mg/L reduced the number to around 10 particles/mL. These results clearly showed that the pilot in-line filter could be useful to detect any change in coagulant dosage in treatment plants. The filter responded the change in less than 10 min. It was sensitive enough to detect a change in the coagulant dosage. Turbidity was as sensitive as particle count. When residual turbidity was measured instead of particle count, similar results were obtained, as shown in Figure 5. Although Bridgeman *et al.* (2002) said that there is no relationship between turbidity and particle count, the relationship was found in this study. They changed at the same pattern.

Change in coagulant conditions

Figure 6 shows an effect of mixing intensity on coagulation performance. Rapid mixing was provided at various speeds (300, 600, 900 and 1,200 rpm). The particle count of the filtrate was measured in order to examine any effect of mixing intensity. The filtrate reached a stable condition after 5 min and reached the steady-state at 15 min. The effect of rapid mixing was noted on the particle count. More particles were detected at higher speeds. This result indicates that the pilot in-line filter was sensitive enough to detect any change in mixing speed. Therefore the pilot in-line filter would be useful in determining the proper mixing speed.

Figure 7 shows an effect of coagulant dosing point. The dosing point was moved from the water surface to the mixer. The change in the dosing point could not affect the

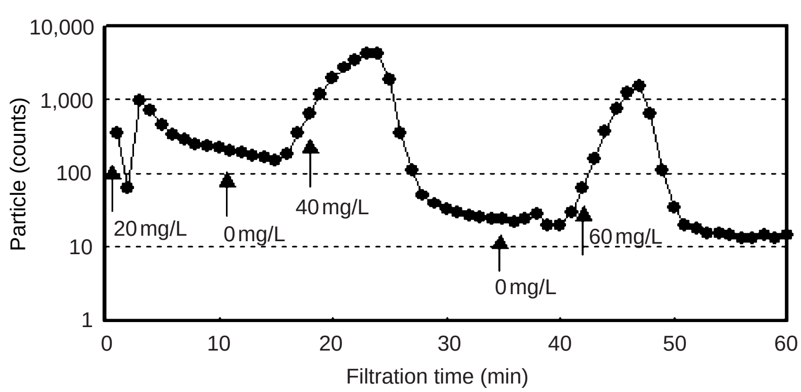

Figure 4 Particle count of the filtrate with a change in the coagulant dosage

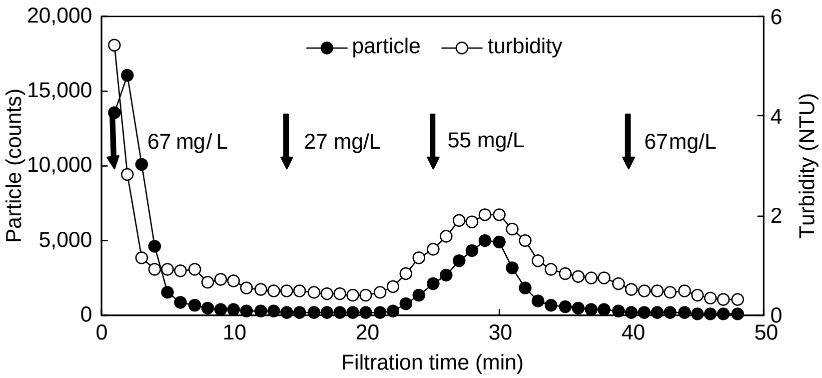

Figure 5 Residual turbidity and particle count of the filtrate with a change in the coagulant dosage

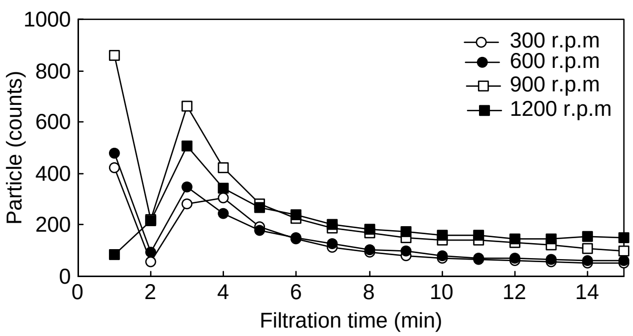

Figure 6 Particle count of the filtrate with a change in mixing speed

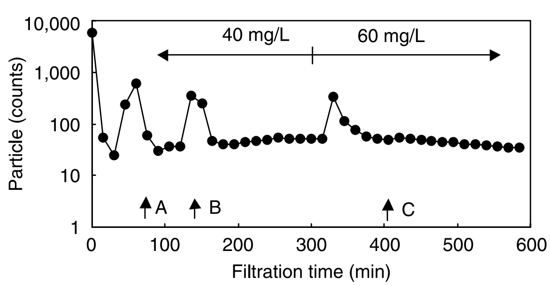

Figure 7 Particle count of the filtrate with a change in coagulant dosing point and dosage

particle count of the filtrate. This might be caused by back mixing at the rapid mixing chamber (Chichuan *et al.*, 2002). However, the number of the particles slightly increased when the concentration of PACl was decreased to 40 mg/L.

Determination of coagulant dosage

Figure 8 compares three experimental results for highly turbid water: settled (Case I), filtered after settling (case II), and in-line filtered (case III) Turbidity of raw water was 61 NTU, alkalinity was 41 mg/L and pH was 7.3. Coagulant dosage is usually determined by comparing the settled water qualities from a jar test. On the other hand, the filtrate was used to evaluate the treatment performance (such as coagulation) on site. Therefore, settled water was filtered in order to reflect the full-scale plant situation more accurately.

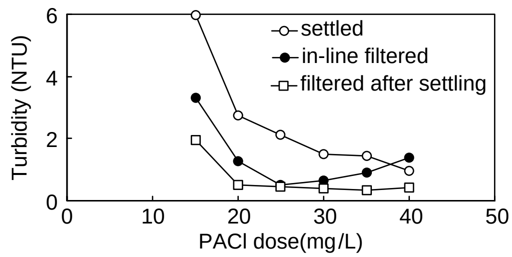

Figure 8 Comparison of three water qualities for highly turbid water

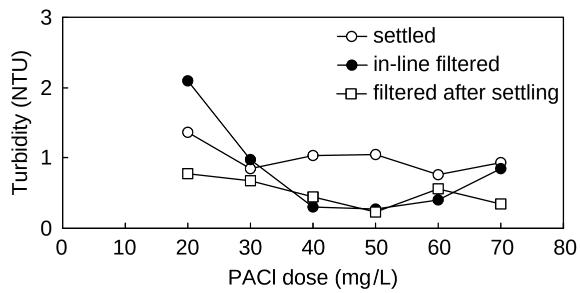

Figure 9 Comparison of three water qualities for lowly turbid water

The in-line filtered indicates the treated water using a new method. As mentioned earlier, this method combines a jar test with an in-line filter. The water qualities of cases I and III were compared based on the water quality of case II in order to examine the effectiveness of the in-line filter for determination of coagulant dosage.

The residual turbidity of case II reached the minimum value after addition of PACl at 20 ppm. The residual turbidity of case I kept decreasing up to 40 p.p.m, while that of case III reached the minimum at 25 p.p.m. The in-line filter was more sensitive to a change in coagulant dosage. Slight overdose of coagulant resulted in an increase of the residual turbidity. Experiments were repeated with lowly turbid water (Figure 9). Turbidity of raw water was 6.8 NTU, and alkalinity and pH were similar to those of highly turbid water. Lowly turbid water required more coagulant than highly turbid water. The residual turbidity of case II reached the minimum value at 50 p.p.m. The residual turbidity of Case I showed two minimum points at 30 and 60 p.p.m., while that of case III reached the minimum value at 40 p.p.m. This result indicates that a new method reflected the actual situation more accurately than a jar test.

Conclusions

A rapid method using the pilot in-line filter to detect any change in coagulation performance was proposed in this study. The in-line filter could be useful to detect any change in coagulant dosage. Since the in-line filter was sensitive enough to detect any change in mixing speed, it would also be useful in determining the proper mixing speed. The response time was less than 10 min. The in-line filter was found more useful without underdrain. The in-line filter was more sensitive to a change in filtrate quality without underdrain than with underdrain. A new method, which combines a jar test with the in-line filter, was proposed to determine the coagulant dosage. This method reflected the actual plant situation more accurately than a jar test.

References

AWWA Committee Report (1980). The status of direct filtration. *J. AWWA*, **72**(7), 405–411.

Bowers, D.A., Bowers, A.E. and Newkirk, D.D. (1982). Development and evaluation of a coagulant control test apparatus for direct filtration. Proc. AWWA Water quality Technology Conference, Nashville.

Bridgeman, J., Simms, J.S. and Parsons, A. (2002). Practical and theoretical analysis of relationships between particle count data and turbidity. *AQUA*, **51**(5), 263–271.

Chichuan, K., Chihpin, H. and Jill, R.P. (2002). Coagulation of high turbidity water: Effects of rapid mixing. *AQUA*, **51**(2), 77–85.

Cleasby, J.L. and Baumann, E.R. (1962). Selection of sand filtration rates. *J. AWWA*, **54**(5).

Standard Methods for the Examination of Water and Wastewater (1998). APHA/AWWA/WERF, Washington, DC, USA.

Suthaker, S., Smith, D.W. and Stanley, S.J. (1998). Optimization of filter ripening Sequence. *AQUA*, **47**(3), 107–118.

Wagner, E.G. and Hudson, H.E. (1982). Low-dosage, high-rate direct filtration. *J. AWWA*, **74**(5), 256–261.