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An agency of the Government of Ontario

CWAE Centre de Walkerton pour l'assainissement de l'eau
Un organisme du gouvernement de l'Ontario

Pilot Testing Report:

Chloride Sulfate Mass Ratio Bench-Scale Testing

Walkerton Clean Water Centre

Research & Technology

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Executive Summary

Background

A city in Ontario has a drinking water system that supplies drinking water to more than 10,000 people. Water for the system is obtained from both groundwater and surface water sources. The focus of this study is exclusively the treatment of the surface water.

The surface water treatment plant is a direct filtration plant incorporating coagulation with aluminum sulphate (alum), flocculation, and dual media filtration. There is no sedimentation stage. The system uses chlorination for both primary and secondary disinfection.

The Centre previously conducted a bench-scale review of treatment coagulants in early 2021 for this system, which concluded that PAX-XL 1900 may be a better coagulant than alum in terms of treated water pH adjustment requirements, performance, and lower levels of residual aluminum. However, the use of PAX-XL 1900 was noted to potentially change the chloride to sulphate mass ratio (CSMR). A higher CSMR may lead to corrosion issues in the distribution system (WRF, 2010). Due to these findings, phase 2 of the study was aimed to focus on exploring the CSMR values using different coagulant products, to better understand potential effects they may have on the system

Objectives

The overall objective of this bench-scale testing project was to assess the CSMR for the system's current coagulant, alum, and other coagulants that were determined in the first part of the study to perform well for this water source, aluminum chlorohydrate (PAX-XL 1900) and acidified alum (Clar+ion A10).

Secondary objectives include the following:

1) To determine the effect of the selected coagulants on treated water pH;

2) To determine the effect of the selected coagulants on treated water alkalinity;
3) To determine the effect of the selected coagulants on treated water residual aluminum levels; and
4) To determine the optimum dose of each selected coagulant by using a coagulant charge analyzer (CCA) by obtaining a value of 0 mV.

Approach

Raw water was collected on-site at the surface water treatment plant before coagulant addition. Containers were then shipped to the Centre. Upon arrival at the Centre, raw water containers were refrigerated until the bench-scale testing was conducted using a Phipps and Bird jar tester.

Three jar tests were conducted for each coagulant mimicking the treatment plant, employing rapid mixing (100 RPM for 1 minute), and flocculation (20 RPM for 7.5 minutes followed by 10 RPM for 7.5 minutes) at room temperature.

Key Findings

The following conclusions can be drawn from this bench-scale study:

1) Acidified alum, Clar+ion A10, provided the lowest CSMR values at various dosages, followed by alum and then PAX-XL 1900.
2) All three coagulants had a similar effect on treated water pH up to a 10 mg/L dose. These values were within the operation guideline set for Ontario.
3) All three coagulants had a similar effect on treated water alkalinity up to a 10 mg/L dose. These values were within the operation guideline set for Ontario.
4) PAX-XL 1900 provided the lowest level of residual aluminum in the treated water when compared the other coagulants tested.

5) When a CCA was used to determine optimum dosages of each coagulant tested, the results were approximately 21.0, 21.5 and 3.3 mg/L for alum, Clar+ion A10 and PAX-XL 1900, respectively.

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1.0 Introduction

A city in Ontario has a drinking water system that supplies drinking water to more than 10,000 people. Water for the system is obtained from groundwater and surface water sources. The focus of this investigation is the treatment of the surface water. The surface water treatment plant is a direct filtration plant incorporating coagulation with alum, flocculation, and dual media filtration. There is no sedimentation stage. The system relies on chlorination for both primary and secondary disinfection.

The Centre completed a bench-scale review of coagulants in early 2021 for the system, which concluded that PAX-XL 1900 may be a better coagulant than alum in terms of treated water pH adjustment requirements, performance, and lower levels of residual aluminum. However, the use of PAX-XL 1900 might change the chloride to sulphate mass ratio (CSMR) which is currently 0.38 using alum at the system's surface water treatment plant (WTP). It is important to keep CSMR less than 0.5 (WRF, 2010). A higher chloride to sulfate ratio may lead to corrosion issues in the distribution system which requires a study of chloride to sulfate mass ratio (WRF, 2010).

2.0 Objectives

The overall objective of this bench-scale testing project was to assess the CSMR for the system's current coagulant, alum, and other coagulants that were determined in the first part of the study to perform well for this water source, aluminum chlorohydrate (PAX-XL 1900) and acidified alum (Clar+ion A10).

Secondary objectives include the following:

1) To determine the effect of the selected coagulants on treated water pH;
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3) To determine the effect of the selected coagulants on treated water residual aluminum levels; and
4) To determine the optimum dose of each selected coagulant by using a coagulant charge analyzer (CCA) by obtaining a value of 0 mV.

3.0 Materials and Methods

3.1 Raw Water Collection and Shipping

Raw water was collected on-site at the system's WTP before coagulant addition, using 20 L plastic containers. Containers were then shipped to the Centre. Upon arrival, the raw water containers were placed in a refrigerator until the following day when bench-scale testing was conducted using alum, PAX-XL 1900, and Clar+ion A10.

3.2 Jar Testing

Jar testing was conducted using a 6 paddle Phipps and Bird jar tester. Details of the jar testing procedure are summarized below in Table 1.

Table 1: Jar Test Conditions

Experiments	Coagulant	Doses Applied (mg/L)	Jar Test Conditions			
			Rapid mixing	Flocculation		Temperature (˚C)
1 - 9	PAX XL 1900	2, 4, 6, 8, 10	100 RPM for 1 min	20 RPM for 7.5 mins	10 RPM for7.5 mins	21
	Alum	2, 4, 6, 8, 10				
	Clar+ion A10	2, 4, 6, 8, 10				

3.3 Water Quality Analysis

Samples were collected from each jar following the second stage of flocculation and filtered through a 0.45 µm filter to estimate the performance of direct filtration. For each sample, general water quality parameters including turbidity, pH, alkalinity, true and apparent colour, aluminum, DOC and UV absorbance at 254 nm were analyzed. Samples of sulfate were sent to an external lab for analysis.

4.0 Results and Discussions

4.1 Chloride to Sulphate Mass Ratio

Figure 1 shows trends of the CSMR observed for various dosages (n=3) during jar testing for all coagulants. The CSMR of raw water was determined to be 1.17 for alum which was linearly reduced to 0.57 at a 10 mg/L dose. The CSMR for the WTP was 0.38 when a 5.9 mg/L alum dose was applied. The CSMR for the alum jar test was 0.73 when dosed 6 mg/L of alum. This value was 1.92 times higher in the jar tests than measured in the WTP.

The declining trend observed for CSMR for Clar+ion A10 was similar to that obtained for alum. The CSMR trend for PAX-XL 1900 was different from the other coagulants tested and increased with the increasing dosages. The CSMR was 2.01 for the 10 mg/L dose of PAX-XL 1900. Overall, the Clar+ion A10 coagulant provided the lowest CSMR values at various dosages, followed by alum and then PAX-XL 1900.

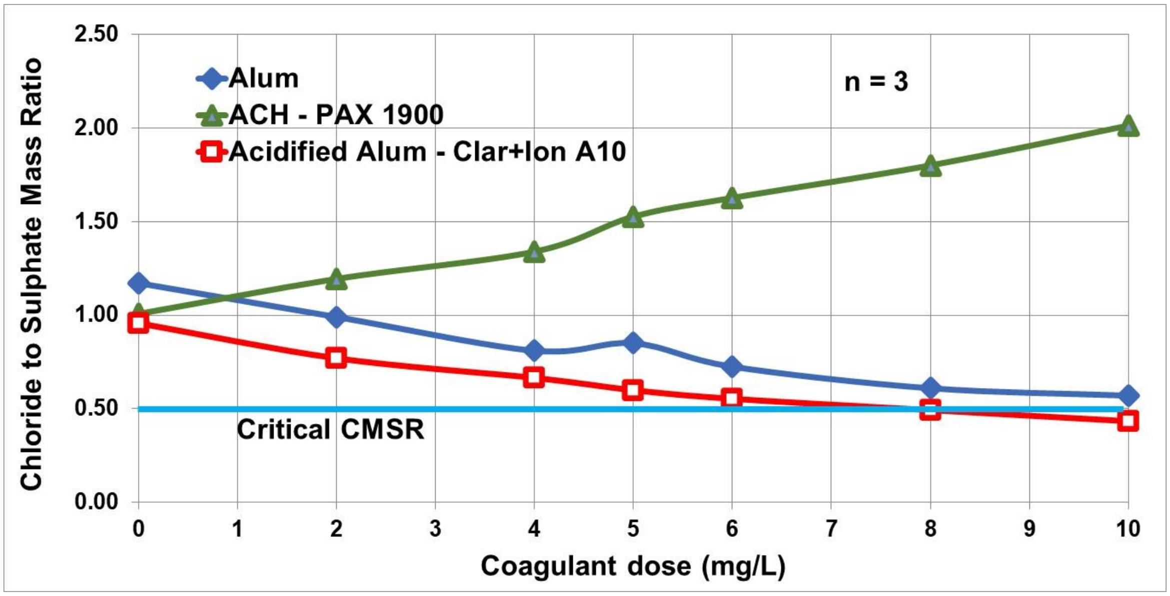

Figure 1. CSMR trends for all three coagulants

4.2 pH

The pH trends for all three coagulants are presented in Figure 2. The pH of the treated water when dosing alum, Clar+ion A10 and PAX-XL 1900 decreased except for pH of the Clar+ion A10 2 mg/L dose. It should be noted that the pH range of raw water was 7.30 to 7.47 while the pH for all treated waters dosed with 10 mg/L of all three coagulants was 7.18 to 7.20. Overall, all three coagulants demonstrated similar trends and showed approximately the same pH for 10 mg/L doses.

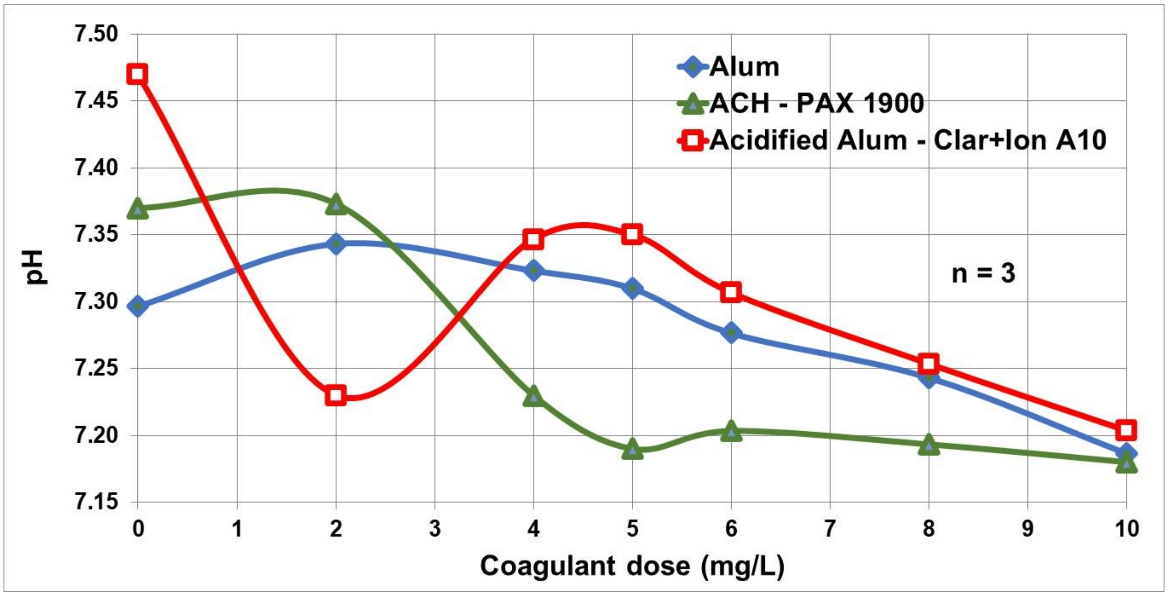

Figure 2. pH trends for all three coagulants

4.3 Alkalinity

Figure 3 shows alkalinity trends for all three coagulants. Generally, alkalinity values decreased as the dosages of coagulant increased. For all coagulants, alkalinity levels were 39 to 40 mg/L for 10 mg/L doses.

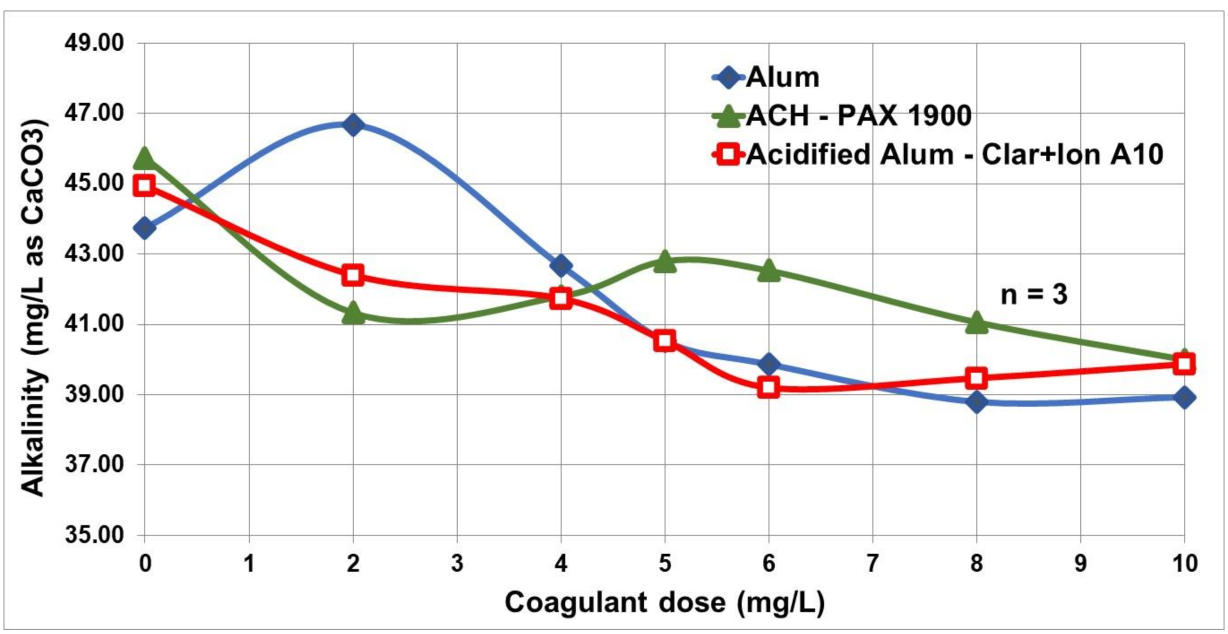

Figure 3. Alkalinity trends for all three coagulants

4.4 Residual Aluminum

Figure 4 presents dissolved residual aluminum levels for all coagulants. Residual aluminum was decreased from 0.186 mg/L for a 2 mg/L dose to 0.07 mg/L for 10 mg/L dose when using alum. When using Clar+ion A10, the residual aluminum first increased from 0.13 mg/L at a 2 mg/L dose to 0.18 mg/L at a 4 mg/L dose, but then followed a similar trend as alum and decreased to 0.06 mg/L for a 10 mg/L dose.

At the 6 mg/L dose selected to mimic the conditions of the WTP, which was dosing 5.9 mg/L at the time of this bench-scale testing, residual aluminum levels were comparable at 0.116 in the Clar+ion A10 jar test and 0.10 mg/L at the WTP.

PAX-XL 1900 showed a different trend compared to alum and Clar+ion A10 coagulants. Residual aluminum levels were ranging from 0.02 to 0.035 mg/L for all PAX-XL 1900 dosages. In short, PAX-XL 1900 provided the lowest level of residual aluminum when compared to the other coagulants.

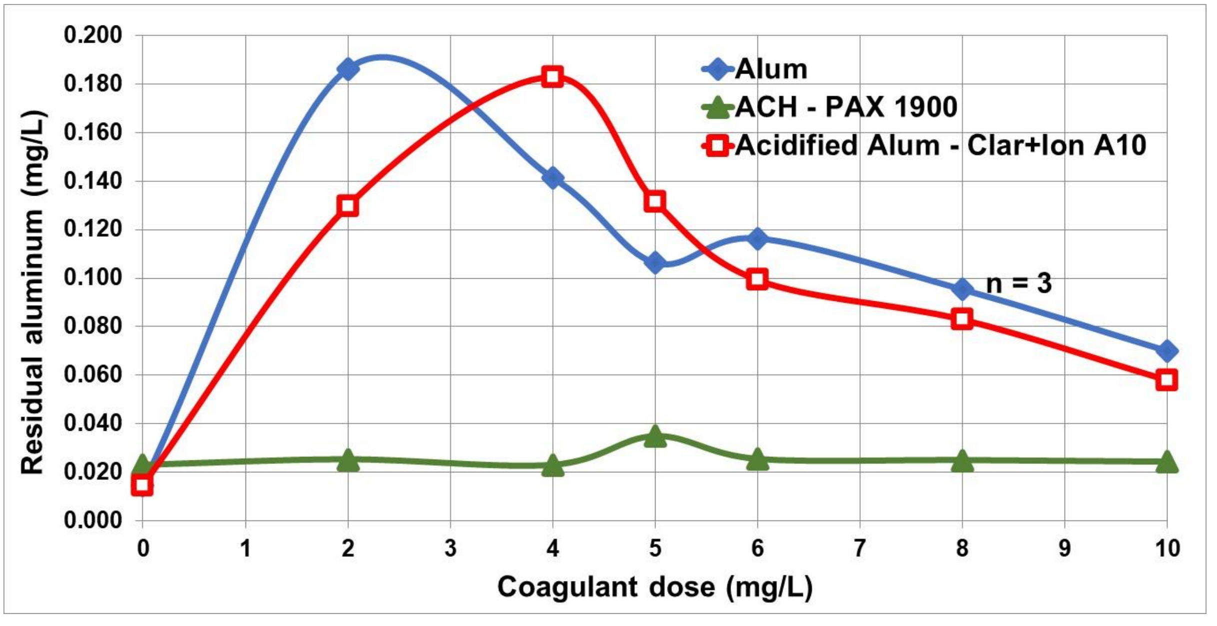

Figure 4. Residual aluminum trends for all three coagulants

4.5 Coagulant Charge

Coagulant charge, measured by a coagulant charge analyzer (CCA), shows the overall charge of raw water and coagulant at a specific condition. A coagulant is considered in an optimum state when its coagulant charge reaches 0 mV. Coagulant charge values for all coagulants are presented below in Figure 5. The coagulant charge was 0 mV when alum and Clar+ion A10 dosages were approximately 21.0 mg/L and 21.5 mg/L, respectively. However, these dosages seem high because currently the WTP uses only 5.9 mg/L alum. PAX-XL 1900 showed a 0 mV charge when a dose of 3.3 mg/L was applied, which appears reasonable considering the current WTP dosage of 5.9 mg/L alum.

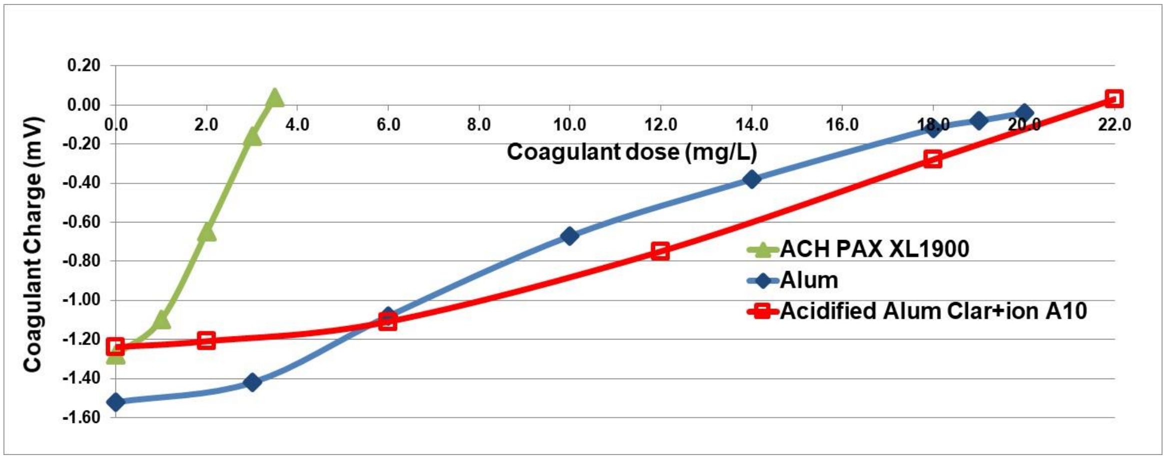

Figure 5. Coagulant charge values for all three coagulants

5.0 Conclusions

The following conclusions can be drawn from this bench-scale study:

6) Acidified alum, Clar+ion A10, provided the lowest CSMR values at various dosages, followed by alum and then PAX-XL 1900.
7) All three coagulants had a similar effect on treated water pH up to a 10 mg/L dose. These values were within the operation guideline set for Ontario.
8) All three coagulants had a similar effect on treated water alkalinity up to a 10 mg/L dose. These values were within the operation guideline set for Ontario.
9) PAX-XL 1900 provided the lowest level of residual aluminum in the treated water when compared the other coagulants tested.
10) When a CCA was used to determine optimum dosages of each coagulant tested, the results were approximately 21.0, 21.5 and 3.3 mg/L for alum, Clar+ion A10 and PAX-XL 1900, respectively.

6.0 References

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