ENE 806 Project Report 2

COAGULATION AND FLOCCULATION: COLOR REMOVAL

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Abstract

Natural organic materials are one of the main components that cause the color in surface water. In this study, we treat both natural water and the tap water spiked with humic substance with different alum dosage to compare the removal efficiency of both humic substances and turbidity in either cases. By the aid of jar test apparatus, we used various alum dosages from 0 and 200 mg/L. Furthermore, after determining the optimum alum dosage for natural river water, the optimum pH value for color removal was studied by varying the range from 4.5 to 8.5. Based on what we found in the experiments, with the same lime dosage the removal efficiency of humic substances and turbidity in natural water is not as high as that in the tap water containing only humic substances. Furthermore, the optimum color removal condition for natural water was determined to be 120 mg/L alum dosage with pH 6.5.

Summary

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1. Introduction

The requirement of water quality is increasing during the time, therefore the aesthetic quality of water should be improved by water treatment plant before being used. The color of water is an indication of the organic content, including humic and fulvic acids, the presence of natural metallic ions such as iron and manganese, and turbidity (Crittenden and Montgomery Watson Harza (Firm) 2005). Furthermore, different source of water will have its own color due to the location, time and the main components existed. For example, some surface waters may have color as a result of organic materials leached from organic debris, such as leaves, needles of conifers, and wood in various stages of decomposition. Some streams and rivers that drain areas of red clay soils may be reddish during flood stages because of colloidal clays in suspension that cause turbidity. Some surface waters and groundwaters may have color due to the presence of certain metallic ions, such as iron and manganese. Water with iron will be brownish to reddish, whereas waters with manganese will be brownish to blackish (Reynolds and Richards 1996)

The presence of natural organic content (NOM) have big impact on aesthetic quality, as NOM imparts a yellowish tinge to water that many people find unpalatable (Crittenden and Montgomery Watson Harza (Firm) 2005). Therefore, the content of NOM in water is an indicator of the true color in water, since the true color is caused by dissolved species and is used to define the aesthetic quality of water. On the other hand, turbidity is another indicator, since turbidity increases the apparent color of water which is caused by the presence of suspended particles, which may range in size from colloidal to coarse dispersions, and they reduce the clarity of the water (Reynolds and Richards 1996).

To treat this aesthetic problem in water and wastewater engineering practice, the addition of electrolytes is of major significance to destruct the colloidal stability and they are called coagulant (Casey 1997). Alum ($Al_2(SO4)_3.18H_2O$) was found to have relative higher coagulating power of a number of electrolytes because it is a trivalent salt (Casey

1997).Their primacy as coagulants is due to their effectiveness in destabilizing the predominantly negatively charged colloids found in natural waters.

The predominant action of alum ($Al_2(SO4)_3.18H_2O$) is that, when it is added to water, this compound dissociates in the Al^{3+} trivalent ion. This ion then hydrates to form an aquometal complexes which then pass through a series of other hydrolytic reactions which allowed the formation of different kinds of mononuclear species (in this case, hydroxo-alum). Because those mononuclear species are highly positively charged, they can interact with the negatively charged clay or silica particles in the water, and thus coagulate them by a purely electrostatic action. In modern language, the Al^{3+} reduced the repulsive ψ potentials between the particles (Reynolds and Richards 1996). Furthermore, the product of the coagulation between these particles and hydroxo-alum complexes has low solubility levels in the pH range of normal use.

To ensure uniform dispersions of the coagulant a rapid mixing system is required at the beginning, following by a more gentle agitation required to establish velocity gradients of a magnitude suitable for flocculation (Casey 1997). Then, these big flocs were allowed to settle down for a couple of hours by the force of gravitation.

Since each water (from different source) will have its own material content, people always try to find the optimal dosage of coagulant according to both economic and efficient aspects. For example, in water treatment practice the required coagulant dose generally falls within the range 2-8 $mg \cdot L^{-1}$ as metal ion. In wastewater treatment practice coagulant concentrations up to 40 $mg \cdot L^{-1}$ (as metal ion) have been used (Casey 1997). So the coagulant dose really depends on the required treatment extent and the purpose of treatment.

When the issue of the coagulant dosage is solved, the optimum pH range for coagulation is also a undergoing topic. Hatfield found the optimum pH range for color removal to be 6.1 to 6.3, but it worth to be noted that the value for maximum floc formations depends upon the anion present in the solution, such as SO_4^{2-}, Cl^-, etc (Hatfield, W.D., J Am

Water Works Assoc, 11, 554 (1924)). For another example, in the presence of oxalate ion, the pH value changes to be 8.5 to 9.5, whereas in the presence of chromate ion, a much broader range of coagulation from pH 5 to 10 was found. (Faust, Hunter et al. 1967)

In this report, we tested the optimum alum dosage as well as pH range to treat Red Cedar River located in Michigan State University Campus. And also we compared the treatment efficiency of alum for the tap water spiked with humic substances alone for comparison.

2. Material and methods

The water was obtained from Red Cedar River in front of the main library of MSU. We did not spike additional humic substance into the river. On the other hand, we prepared another concentrated humic acid solution (Lot num: 01816AA, Aldrich) with the same absorption value as the river water (Genesys 2 spectrophotometer, Spectronic, Thermo Scientific, Waltham, MA). The coagulant we chose is aluminum sulfate octadecahydrate ($Al_2(SO4)_3.18H_2O$, 98+% A.C.S., Sigma-Aldrich). The stock solution was 10 mg/mL and we added with different volume to get various alum dosage. Note that those volumes ranging from 0 to 40mL were assumed as negligible in comparison with the volume of the water in the beakers (2L).

A standard curve of humic acid concentration vs absorbance was done with concentrations ranging from 0 to 40 mg/L. The calibration curve can be found in Figure 1

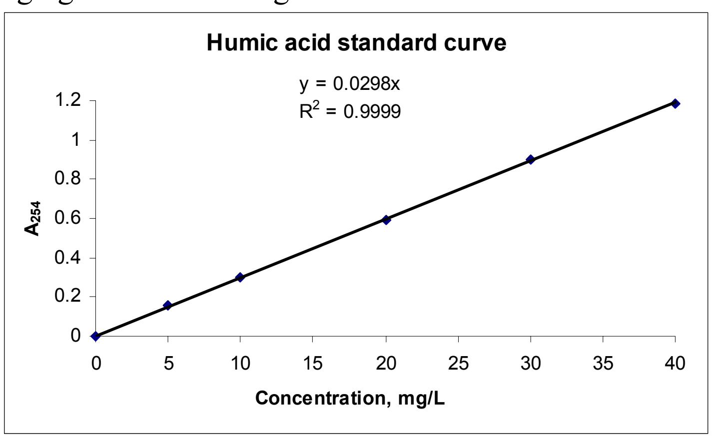

Figure 1: calibration curve for the absorbance of humic acid with wavelength 254 nm.

Turbidity was measured with a turbidimeter (2100A, HACH, Loveland, CO) and the values were expressed in nephelometric turbidity units (NTU). The turbimeter was calibrated with standards every time before the measurement. A pH meter (SA 720, Orion, Thermo Scientific, Waltham, MA) was used to control the pH value before and after the coagulation experiments. The traditional Jar test device (Phipps&bird Stirrer, Richmond, VA) was used to do the coagulation test.

Each beaker contained 2 L of river water or humic acid spiked tap water. After adding appropriate volume of the alum stoke solution, the water was mixed at 160 rpm for 2 min, 70 rpm for 15 min, 30 rpm for 35 min and settled for 2 hours. Then the top layer of water in each beaker was collected with a Pasteur pipette and measured in terms of absorbance, turbidly and pH.

In a first experiment, river water, or humic acid spiked tap water was treated for coagulation as explain above, with different concentrations of alum ranging from 0 to 200mg/mL.

In a second experiment, river water pH was adjusted at different pHs between 4.5 and 8.5 with sulfuric acid 1N (the amount of sulfuric acid added to adjust the pH are described in table 1). Once the pH adjusted, the same treatment of coagulation as above was used and initial and final absorbance and turbidity were measured.

pH	4,72	5,47	6,00	6,46	7,00	7,44	8,23
H_2SO_4 (1N) addition (ml)	10,20	9,00	7,60	5,00	2,80	0,90	0,00

Table 1: Adjustment of pH by adding of different volumes of sulfuric acid

3. Results and discussion

3.1. Determination of optimal alum dosage in natural Red Cedar River and in humic acid spiked tap-water.

In those experiments, water (Red Cedar River water or humic acid spiked tap water) has been treated with different concentrations of alum ranging between 0 and 200 mg/L. In both cases, the pH of the water has been adjusted with sulfuric acid at 7.3. The final absorbance (at 254 nm) and the final turbidity have been measured and then, have been plotted as a function of the alum concentration (see figure 2).

As we can see on this graph, the absorbance at 254 nm is decreasing when the amount of alum is increased and this, both for the river water and for the humic acid spiked water. At the same time, this absorbance tends to increase weakly for an alum dosage higher than 150mg/L and this, more particularly for the river water. However, the absorbance of the humic acid spiked water tends to decrease really faster (with the amount of alum) than the river water since the minimum alum dosage (used in this experiment) appears to be efficient to remove more than 80% of the absorbance. The decreasing of the river water color seems to be the more efficient (with a bit less than 80% removal) with a higher alum concentration ranging between 120 and 200 mg/L.

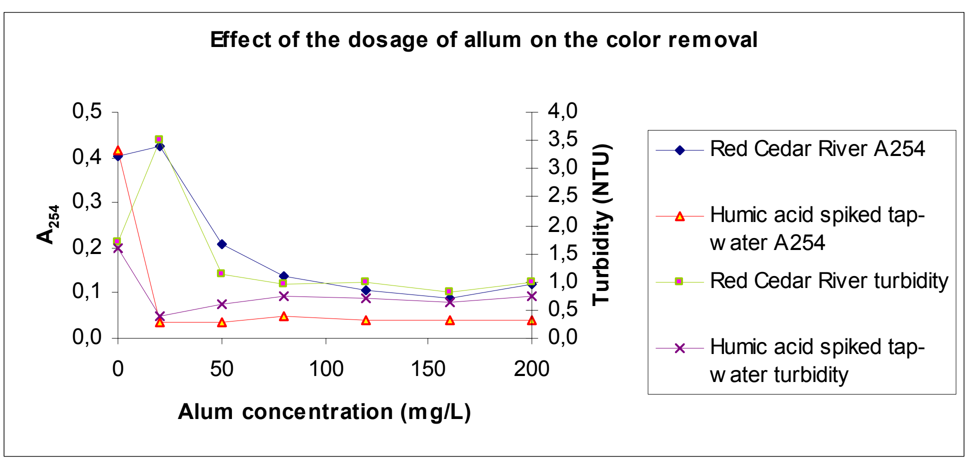

Figure 2: Effect of the dosage of alum on the color removal for river water and humic acid spikes tap-water

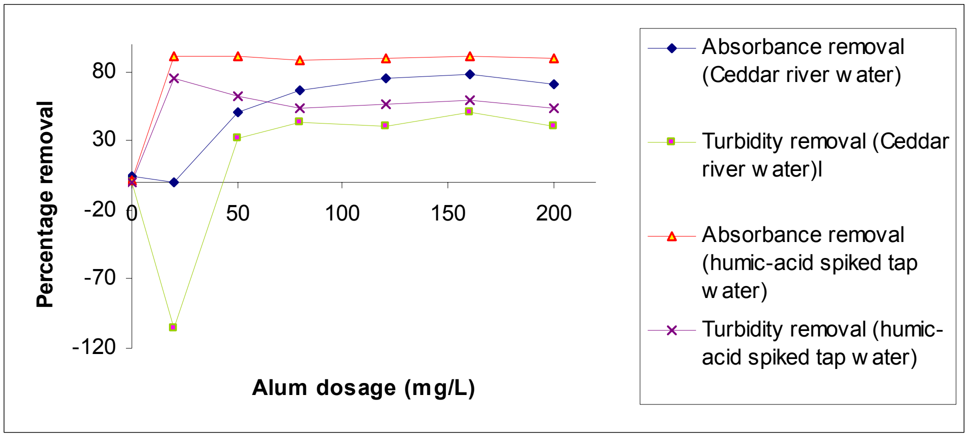

Figure 3: Effect of the alum dosage on the color removal efficiency for river water and humic acid spikes tap-water

3.2. Determination of the color removal optimal pH

This experiment has only been done for the river water with the optimal concentration of 120 mg/L of alum. Since we want to use the less amount of alum as possible (for economic reasons) and the best efficiency as possible we decided to use the alum concentration of 120mg/L.

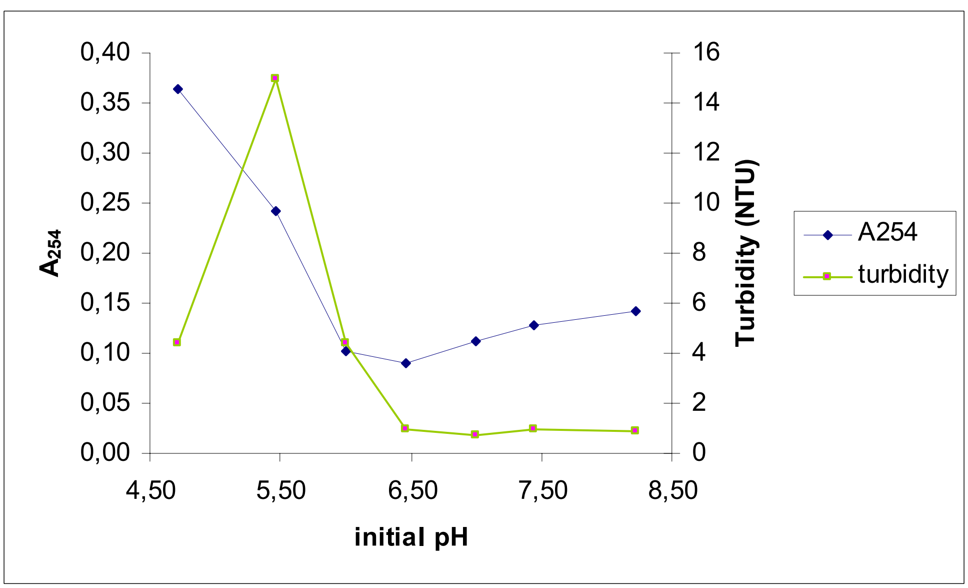

Figure 4: Effect of initial pH on the color removal for river water and humic acid spikes tap-water

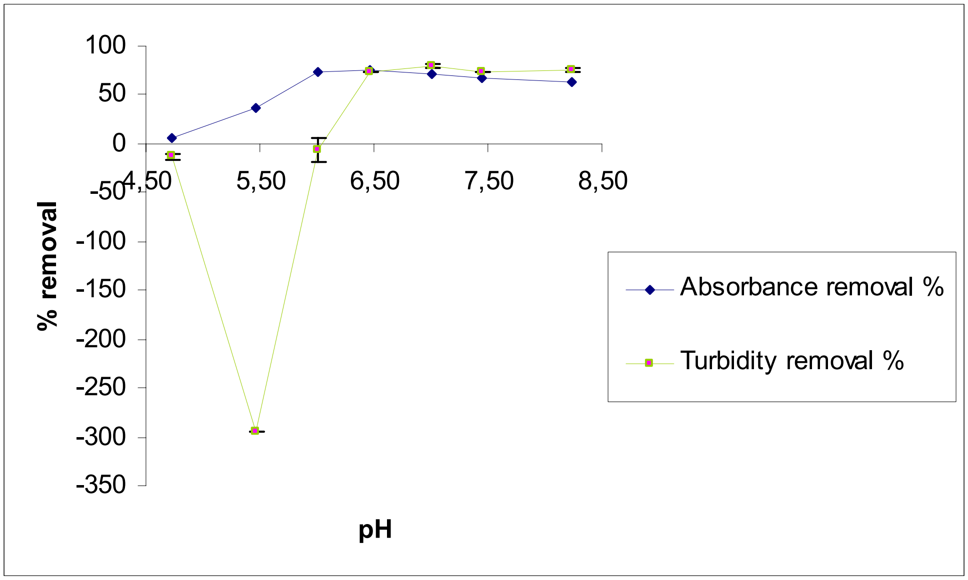

Figure 5: Effect of pH on the color removal efficiency for river water and humic acid spikes tap-water

We can see on those graphs that the pH which allows the best either color and turbidity removal is around 6.5. At this pH the color removal is more than 76% when the turbidity removal is around 73%.

We also saw a drop of around 0.5 to 1 unit of pH for all the initial pH tested except for the initial pH of 4.5, for which the final pH is the same. (See appendix 2).

The probable reason why, with different pHs the color is different, is that the color-producing substances in water behave inconsistently. pH adjustment may cause a change in the ionization of the color molecule with corresponding effects on bond lengths and configurations and thus light absorption.

4. Conclusions

During the study of the color removal efficiency with different alum dosage for two types of water, nature water and tap water are not showing exactly the same trend. As for the tap water spiked with humic substances, the removal rates for humic substances and turbidity gave best results with even the lowest alum dosage (20%). On the other hand, the nature water experienced a different situation. When the alum dosage applied was over 100 mg/L, the removal rates were getting better and 120 mg/L of alum dosage is the optimum one with higher removal efficiency and relatively lower cost. With this fixed optimum dosage, the optimum pH for the color and turbidity removal of natural water was found to be 6.0 – 6.5.

5. References

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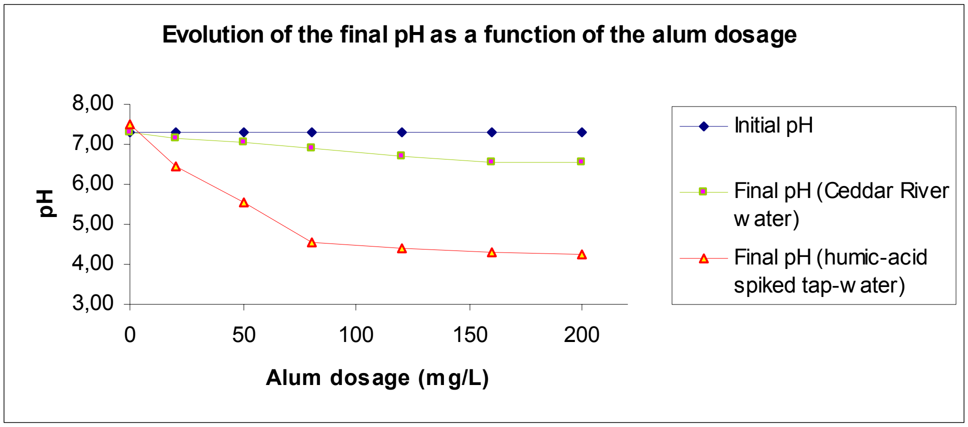
Crittenden, J. and Montgomery Watson Harza (Firm) (2005). Water treatment principles and design. Hoboken, N.J., J. Wiley.

Faust, S. D., J. V. Hunter, et al. (1967). Principles and applications of water chemistry; proceedings. New York,, Wiley.

Reynolds, T. D. and P. A. Richards (1996). Unit operations and processes in environmental engineering. Boston, PWS Pub. Co.

6. Appendix

Appendix 1: Evolution of the final pH after color removal as a function of the alum dosage



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Appendix 2: Evolution of the final pH after color removal as a function of the initial pH