Course Number : CE 332
Course Name : Environmental Engineering Lab
Course Credit : 1.50

Experiment No. 12
Chemical Coagulation (Alum Coagulation)

INTRODUCTION

Surface water generally contains a wide variety of colloidal impurities that may cause the water to appear turbid and may impart color to the water. Colloidal particles that cause color and turbidity are difficult to separate from water because the particles will not settle by gravity and are so small that they pass through the pores of most common filtration media. In order to be removed, the individual colloids must aggregate and grow in size so that they can settle by gravity. Chemical agents are used to promote colloid aggregation by destroying the forces that stabilize colloidal particles. The process of destroying the stabilizing forces and causing aggregation of colloids is referred to as chemical coagulation. Coagulation involves reduction of electrical forces of repulsion and promotion of "chemical type" interaction between colloids, which eventually results in settling of the colloids and accomplishes removal of turbidity and color. At higher coagulant doses, "charge reversal" is possible which may result in re-suspension of the colloids. Hence optimum coagulant doses are determined through laboratory model tests where the water to be treated are subjected to a range of doses of a coagulant and the removal efficiencies are observed.

Many authors use the term *"coagulation"* to describe the process by which the charge on particles is destroyed, and the term *"flocculation"* to describe the aggregation of particles into larger units. The chemical used for this purpose is called are called *coagulants*. The most common *coagulants* used in water and wastewater treatment are aluminum and ferric salts such as *alum,ferric chloride* and *ferric sulfate*.

The common metal salt alum (aluminum sulfate) is a good coagulant for water containing appreciable organic matter. The chemical formula used for commercial alum is $Al_2(S0_4)_3 14H_20$. Once dissolved in water, aluminum forms hydroxo-complexes and solids [e.g., $Al(OH)_3(s)$, $Al(OH)^{2+}$, $Al(OH)_{2-}$, $Al(OH)_4$; Eqs. 1-5] and as a result pH of water is lowered, especially if alkalinity of water is low. Theoretically, each mg/l of alum consume approximately 0.50 mg/l (as $CaCO_3$) of alkalinity. For water with low alkalinity, this may result in significant reduction in pH that may interfere with formation of aluminum hydroxide flocs. If the alkalinity is insufficient, coagulant aids such as lime ($CaOH_2$), soda ash (Na_2CO_3), activated silica and polyelectrolytes are used to provide the necessary alkalinity. Iron coagulants operates over a wider pH range and are generally effective in removing turbidity and color from water. However, they are usually more costly.

$$Al_2(S0_4)_3.\ 14\ H_2O\ (alum) = 2Al^{3+} + 3\ SO_4^{2-} \quad (1)$$
$$Al^{3+} + 3\ H_2O = Al(OH)_3\ (s) + 3\ H^+ \quad (2)$$
$$Al^{3+} + H_2O = Al(OH)^{2+} + H^+ \quad (3)$$
$$Al^{3+} + H_2O = Al(OH)_2^{+} + 2H^+ \quad (4)$$
$$Al^{3+} + H_2O = Al(OH)_4^{-} + H^+ \quad (5)$$

Besides the removal of turbidity and color, coagulation with alum and ferric chloride or ferric sulfate is also widely used for removal of heavy metal ions (e.g., lead, arsenic) from water. In this process heavy metal ions are primarily removed by adsorption (and subsequent precipitation) onto coagulated floes of metal (either aluminum or iron) hydroxides. Coagulation with alum and ferric chloride/sulfate have been successfully used for removal of arsenic from water.

REAGENTS

(1) Standard Alum solution.
(2) Standard Arsenic solution (if As removal is to be demonstrated)

APPARATUS

(1) Coagulation (stirring) device
(2) pH meter
(3) Turbidity meter
(4) Glass beakers (1000 ml; 6 nos.)

PROCEDURE

(1) Determine pH and turbidity of the water to be treated. You may be instructed to determine color and arsenic concentration of the water to be treated (if removal efficiencies of these parameters are to be determined).

(2) Fill six 1000 ml beakers each with 500 ml water to be treated.

(3) Add required (as instructed by teacher) coagulant (standard alum solution) to each beaker.

(4) Mix the samples in the beaker with the help of the stirring device. Subject the samples to one minute of rapid mixing followed by 15 minutes of slow mixing (about 40 rpm).

(5) Allow the floes to settle down for about 15 minutes. Observe the characteristics of the floes and the settling rates.

(6) Collect the supernatant from each beaker and measure pH and turbidity of each. You may be instructed to measure color and arsenic concentration of the supernatant samples (if removal efficiencies of these parameters are to be determined).

(7) Plot pH versus alum dose in a graph paper and observe effect of alum dose on pH.

(8) Plot turbidity versus the coagulant (alum) dose in a graph paper. Determine optimum dose of alum from this plot.
(9) Arsenic and color removal efficiencies could also be determined if measurements of color and arsenic concentrations are carried out.

ASSIGNMENT QUESTIONS

(1) What do you understand by coagulation and flocculation? Which coagulants are most commonly used for water and wastewater treatment?

(2) Why addition of alum may result in a drop in pH value. Discuss the effect of alum dose on pH from your experimental results.

(3) What is the primary mechanism by which heavy metal ions are removed during coagulation?