

## CHAPTER 3

## CHEMICAL COAGULATION AND FLOCCULATION

3-1 General Considerations

A definition of the difference between coagulation and flocculation is needed because the terms are often used interchangeable. Coagulation involves the reduction of surface charges and the formation of complex hydrous oxides. Coagulation is essentially instantaneous in that the only time required is that necessary for dispersing the chemical coagulants throughout the liquid. Flocculation, which is discussed in a subsequent section, involved the bounding together of the coagulated particles to form settleable or filterable solids by agglomeration. This agglomeration is hastened by stirring the water to increase the collision of coagulated particles. Unlike coagulation, flocculation requires definite time intervals to be accomplished. (Culp, 1971).

The removal of oxygen demanding and turbidity producing colloidal solids from wastewaters is often referred to an intermediate treatment, since colloids are intermediate in size between suspended and dissolved solids. The most common and practical method of removing these solids is by chemical coagulation (Newmerow, 1963).

Chemical coagulation is a process of destabilizing colloids, aggregating them, and building them together for ease of sedimentation. It involves the formation of chemical flocs that absorb,

entrap, or otherwise bring together suspended matter, more particularly, suspended matter that is so finely divided as to be colloid.

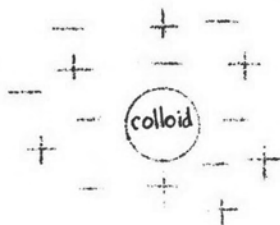
The chemicals most commonly used are alum,  $\text{Al}_2(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O}$  copperas,  $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$  and ferric chloride,  $\text{FeCl}_3$ . Aluminum sulfate appears to be more effective in coagulation carbonaceous wastes, while iron sulfate are more effective when a considerable quantity of proteins is present in the wastes. (Newmerow, 1963).

The process of chemical coagulation involves complex equilibria among a number of variables including colloids of dispersed matter, water or another dispersing medium, and coagulating chemicals. There must be driving forces including, similar to the electrical phenomenon, to cause the interaction of these three variables. (Newmerow, 1963).

### 3-2 Coagulation by Neutralization of the Electric Charges

This can be accomplished by :

1. Lowering the zeta potential of the colloids (See figure below)



(STABLE COLLOID)

Zeta potential is the difference in electrical charge existing between the stable colloid and the dispersing medium.

2. Neutralizing the colloidal charged by flooding the medium with an excess of oppositely charged to electrons, usually hydrous oxide colloids formed by reaction of the coagulant with ions in the water. The coagulant colloids also become destabilized by the reaction with foreign, oppositely charged colloids, and produce hydrous oxide, which is a floc forming material.

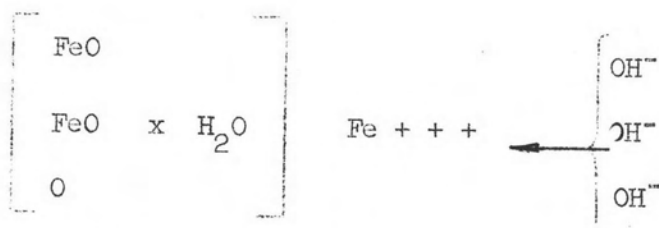
From the standpoint of electrical charges, there are two predominant types of colloids in wastewater.

1. Colloids naturally present, including several proteins, starches, hemicelluloses, polypeptides, and other substances, all possess negative charged (mostly lyophobic in nature).

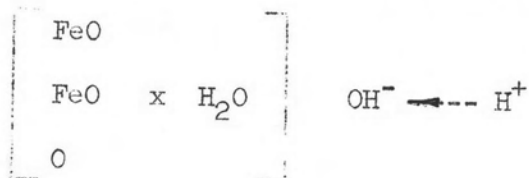
2. Colloids artificially produced by coagulants, usually the hydroxides of iron and aluminium (mostly lyophilic in nature) are mainly positivity charged ions.

In most scientific circles it is believed that the charge on colloidal particles is due mainly to the preferential adsorption of ions, usually  $H^+$  or  $H^-$ , from the dispersing medium. The charge may also be due, in part, to the direct ionization of a portion of its structural groups, such as  $NH_2^+$  and  $COO^-$ .

Hydrous aluminum and iron oxides, as well as other metal sols, can acquire both positive and negative charges:

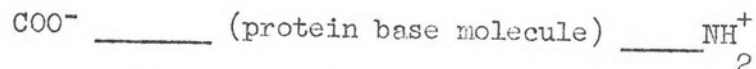


Excess Fe + + + makes colloids positively charged



Excess OH<sup>-</sup> makes colloids negatively charged

However, a colloid can acquire a charge by means other than adsorption. When a protein is dissolved in solution, it can be schematically illustrated as follows:



It may become necessary to add up all the positive NH<sub>2</sub><sup>+</sup> groups and the negative COO<sup>-</sup> groups to ascertain the final ionic charge of the solution, because of the inherent charge brought about by direct ionization of groups within the molecule itself (Newmerow, 1963).

### 3-3 Aluminum Coagulation

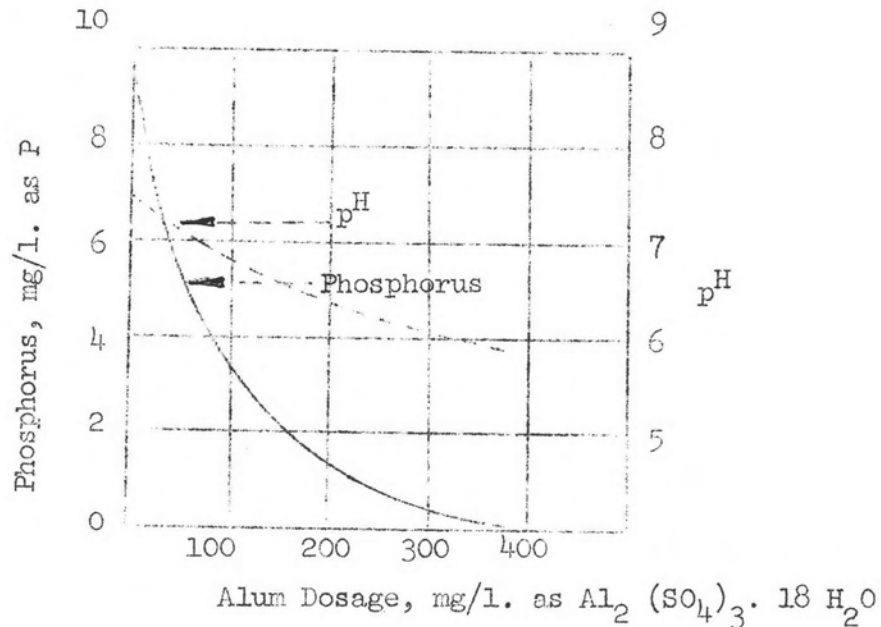
When aluminum is added to wastewater in the presence of alkalinity, the following hydrolyzing reaction occurs:



This is a classical reaction used in explaining the coagulation process in water treatment plants. The aluminum hydroxide floc is

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a voluminous, gelatinous floc providing clarification. In the presence of phosphates, the following reaction also occurs:



The above two reactions compete for the aluminum ions. At pH values above 6.3, the phosphate removal mechanism is either by incorporation in a complex with aluminum or by adsorption on aluminum hydroxide floc. If the hydrolyzing reaction did not compete with the phosphate would be stoichiometric, with 0.87 lb. of aluminum required for each pound of phosphate. In practice, the aluminum to phosphate ratio is on the order 2-3 depending on concentration the final phosphate concentration desired and the chemical characteristics of the particular wastewater requirements. (Culp, 1971).

Sodium aluminate ( $\text{NaAlO}_2$ ) is an alternate source of aluminum ion which is usually a poor coagulant in soft wastewater and a fair-to-good coagulant in hard waters. Parallel jar tests of sodium aluminate and alum will quickly determine if sodium aluminate is an attractive alternate. (Culp, 1971).

Alum is available in either dry or liquid form. It is available in dry form as either ground, powder, or lump form in bags, barrels, or car-loads. (Culp, 1971).

### 3-4 Iron Coagulation

The dominant reaction product between the phosphate ion and the ferric ion at  $\text{p}^{\text{H}}$  value above 7 is believed to be  $\text{Fe PO}_4$  with a solubility product of about  $10^{-23}$  at  $25^{\circ}\text{C}$ . The colloidal particle size of the formation of a well-flocculating hydroxide precipitate which includes the  $\text{Fe PO}_4$  particles and acts as an efficient adsorbent for other phosphorus compounds. Experience has shown that efficient phosphorus removal requires the stoichiometric amount of iron (1.8 mg/l. Fe per mg/l. of P) to be supplemented by at least 10 mg/l. of iron for hydroxide formation. Typically, the iron requirements for municipal wastewater are 15-30 mg/l. as Fe to provide phosphorus reductions of 85-90 percent: The use of 0.3-0.5 mg/l. of anionic polymer is required to produce a clear supernatant (Wakasch, 1968).

If iron salts are used for wastewater coagulation, a small amount of base usually sodium hydroxide or lime, is required to neutralize the acidity of these strong acid salts in soft waters.

### 3-5 Coagulation Control by Jar Test

The jar test is a laboratory procedure which affords a rapid means to determine the effects of chemical treatment on wastewater. It consists of a series of six stirring paddle which can be rotated at a variable controlled speed to mix contents of liter beakers as shown in Figure 4. This permits the simultaneous treatment and observation of six samples under identical mixing conditions in order to determine the relative merits of various chemical treatment, or to determine the optimum dosage of a particular chemical. (Culp, 1971).

In making jar tests it is desirable to duplicate in so far as possible actual full scale plant conditions. It is common to start the mixer at say 40-80 rpm., in this research used 75 rpm. for rapid mix about 3 minutes, then reduce the paddle speed to 25 rpm. for slow mix about 27 minutes. At the end of the slow mix period, the paddles are then removed from the jars and the floc is to settle to the bottom of the beakers is about 30 minutes. Measurements of turbidity, color,  $p^H$ , alkalinity, chemical oxygen demand and suspended solids before and after for comparing a good criterion to use.

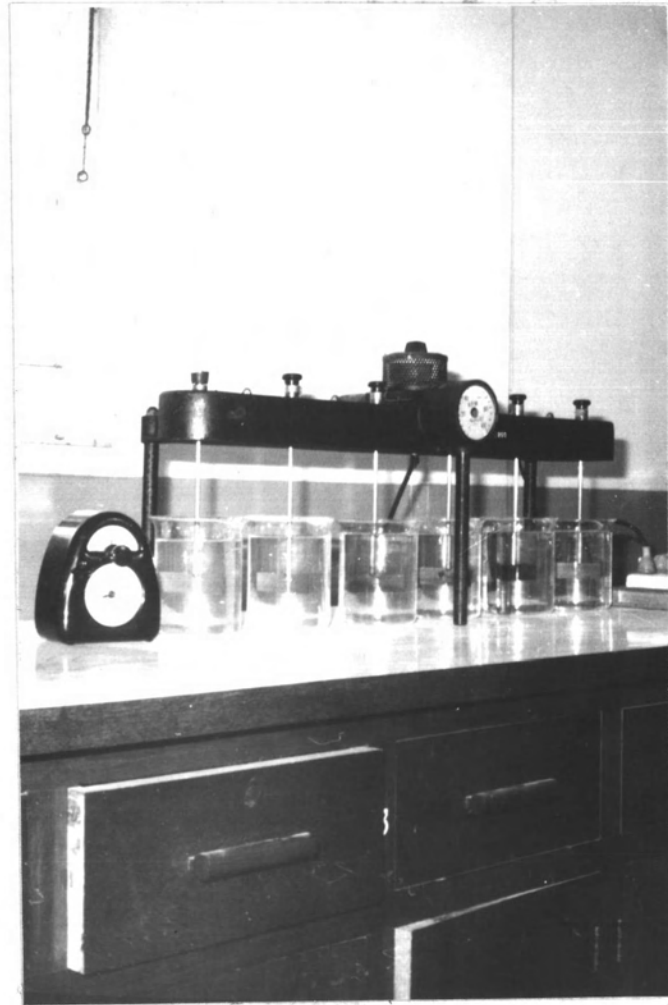


FIGURE 4 COAGULATION CONTROL BY JAR TEST.