Chapter II

GENERAL THEORY

2.1 Theory of coagulation

Today, the chemist's definition of coagulation is used as the driving together of colloidal particles by chemical forces. The speedy process and occurs within seconds of the application of the coagulant to the water. Because of this, intense mixing is necessary at the point of chemical application in order to completely uniform chemical distribution and exposure of the fine particles in the water to the coagulant before the coagulation reaction is completed.

In this investigation, the term of coagulation refers to destabilization of colloidal suspension. Therefore, coagulation of colloidal particles can be considered as destabilization of colloidal particles to permit attachment when contact occurs. This is the work of rapid mixing tank.

2.1.1 Destabilization of colloidal particles

Different chemical coagulant can accomplish the destabilization of colloidal particles in different ways, depend on the conditions under which they are used. Some materials can function as coagulants and some coagulants can achieve colloidal destabilization by more than one method. Four distinct methods are presented as follow:

2.1.1.1 Double layer compression, compression of the diffuse layer by the aluminum ions or other metal ions may act as indifferent eletrolytes in the double layer model of the charge particles

2.1.1.2 Adsorption and charge neutralization, adsorption to produce charge neutralization by the adsorption of the hydrolysis products by the surface of the particles may result in the neutralization of the surface charge.

2.1.1.3 Enmeshment in a precipitate, simple enmeshment of the colloidal particles in the hydroxide flocs may result in settlement of suspened particles.

2.1.1.4 Adsorption charge neutralization and interparticle bridging, use synthetic organic polymer as destabilizing agents to charge neutralize and cross linkage of colloidal particles.

2.1.2 Rapid mixing tank

Where a coagulants is used, or in a few of other cases where sequence of application is not critical, rapid mixing may be obtained by injection of the chemicals into a point of high-velocity flow or high-velocity gradient, such as a Parshall flume, hydraulic jump, or in-line blender, static mixer, respectively. More commonly, however, rapid mixing tank are used for completely uniform chemical distribution and exposure of the colloidal particles in the water to the coagulant. Ordinary, rapid mixing tank are fitted with vertical-shaft rotary mixing devices such as paddle agitators or turbines.

Practice in design of rapid mixing tank has been to provide 10 to 30 seconds detention time with relatively high powered mixing devices, to yield velocity gradients in order of magnitude of 300 fps./foot, or more.

2.2 Theory of flocculation

The term flocculation refers to the aggregating of coagulated particles into flocs. Flocculation may be partly a chemical bridging mechanism, enhanced by the use of substances like polymer and/or transport of coagulated particles to increase particle contact and promote floc growth. Flocculation is much slower, and more dependent on time and amount of agitation than coagulation, this is the work of flocculation tank.

2.2.1 Flocculation of coagulated particles

Particle transport to effect interparticle contact and particles aggergation. The rate of aggregation is determined by the rate of collisions occur between coagulated particles and by the effectiveness of these collisions in permitting attachment between coagulated particles. Interparticle contacts, can be accomplished by three separate mechanism which are consist of, thermal motion (Brownian motion), bulk liquid motion (stirring), and differential settling (Weber,1972).

Two separate flocculation mechanism have concern chemists and engineers are indicated as follow:

2.2.1.1 Perikinetic flocculation, the contacts by thermal motion, often termed Brownian motion or Brownian diffusion.

2.2.1.2 Orthokinetic flocculation, the contacts by resulting from bulk fluid (liquid) motion.

a) Velocity gradient flocculation, the contacts resulting from transport induced by stirring

b) Differential-settling flocculation, contacts resulting from settling of the particles more precisely, differential settling. In which a rapidly settling particles are overtaking and colliding with a slowly settling particles.

2.2.2 Flocculation tank

Flocculation is achieved by stirring or agitating the liquid, which consist of coagulated particles. After the coagulant has been introduced and diffused, the minute coagulated particles are brought into contact with each other and with the other coagulated paticles by gently agitation. When flocculation occurs the particles aggregate, increase in size, and are packed to greater density. Generally paddle type agitator are used in a water treatment plant for flocculation. The completeness of the process depends on the characteristic of water and the value of GT, which is ordinary in range of 30,000-150,000. Detention time commomly use for flocculation range from 20 to 60 minutes, and velocity gradients range from 5 to 100 fps. per foot. Too-high velocity gradients will shear floc particles and prevent them from building up to a size that will rapidly settling. Too-low velocity gradients fail to provide sufficient agitation to enable flocculation to become complete, and may fail to achieve the desired compaction.

2.3 Theory of settling

Water works engineers and operators, however think of a settling basin as one in which suspended matter settles without the aid of chemical coagulation, and a sedimentation basins as one in which settling is aided by coagulation. Sedimentation basins may be operated by fill and draw, or by continuous flow, normally almost all plants operate by continuous flow.

Four different types of settling processes are normally recognized in water and wastewater treatment plant design, are presented as follow:

Type I or discrete settling

Type II or flocculant settling

Type III or zone settling

Type IV or compression settling

The distinction arises because of differing physical characteristics of the suspension being settled, which the particles are flocculant or discrete, organic or inorganic, wheather present in high or low concentrations.

2.3.1 Type I settling (discrete settling)

Type I settling is assumed to occur in gravity grit chambers handling wastewater and in basins used for preliminary settling (silt removal) of surface waters. A determination of the settling velocity of the smallest particle to be 100 % removed is fundamental to settle independently and with a constant velocity, a mathematical development is possible. The resulting equations are;

$$V_c = \frac{4\,g\,(\,p_s - p\,)\,d^{1/2}}{3\,C_d} \qquad \text{Newton's Law} \quad (1)$$

$$V_c = \frac{g\,(\,p_s - p\,)\,d^2}{18\,u} \qquad \text{Stoke's Law} \quad (2)$$

Where

d = particle diameter, m. (ft.)

p_s = particle density, kg./m.^{3} (lb./cu.ft.)

p = water density (kg./m.^{3})

C_d = Newton's drag coefficient, dimensionless, dependent on the Reynolds Number and particle shape,

g = acceleration of gravity, m./s.^{2} (ft./sec.^{2}),

V_c = settling velocity of particle in a quiescent liquid, m./s. (ft./sec.) and

u = absolute or dynamic viscosity of water kg./m.s. (lb./sec./ft.)

The following assumptions and simplifications are necessary for apply these equations correctly.

a) Particle concentration is low enough to allow particles to settle independently of each other.

b) The nature of the particles is such that flocculation dose not occur, particles are usually assumed to be inorganic in nature.

c) Particles are assumed spherical in shape.

d) Newton's law is applicable under both laminar and turbulent settling regimes.

e) Stoke's law is a special case of Newton's law, applicable under a laminar flow regime indicated by the Reynolds Number (N_r) less than 0.3, where $N_r = (p\ d\ V_c) / u$

If the flow regime around the particle is known as laminar, Equation 2 can be used directly. However, if this is not the case, Equation 1 is used. The value of the drag coefficient, C_d appearing in Equation 1, is dependent on the value of the Reynolds Number, N_r. Relationship between C_d and N_r that can be described by Equation 3 for $N_r < 10^4$,

$$C_d = 24/N_r + 3/(N_r)^{1/2} + 0.34 \qquad (3)$$

Where

N_r = Reynolds number of the flow regime around the settling particle, and

C_d = drag coefficient of the particle.

2.3.2 <u>Type II settling (flocculation settling)</u>

Type II settling occurs when particles dilution suspension of the particles coalesce or flocculate, during the sedimentation operation, by coalescing, the particles increase in mass and also settle with a faster rate as a result of flocculation. The settling velocities of the aggregates formed change with time, and a strict mathematical solution is not possible. Thus laboratory testing is required to determine appropriate values for design parameters. Type II settling can occur during primary clarification of wastewater, clarification following fixed-film processes and above the sludge blanket in clarifiers following activated sludge treatment. Type II settling can also removes chemical floc in settling tank and clarification of potable water treated with coagulants. However design procedures based on Type III settling are normally used to design these units.

2.3.3 Type III settling (hindered or zone settling)

Type III settling occurs in clarifiers following activated sludge processes and gravity thickeners. While Type III, and Type IV processes may occur to a limited extent in such units, it is Type III that governs design. In suspensions of intermediate concentration, in which interparticle forces sufficient to hinder the settling of neighboring particles. The solids concentration is usually much higher than in discrete or flocculant processes. As a result, the contacting particles tend to settle as a zone or blanket, and maintain the same position relative to each other. As they settle, a relatively clear layer of water is produced above the settling region.

As settling continues, particles near the clarifier bottom become compressed and are in close physical contact. So the hindered settling region contains a gradation of particle concentrations ranging from those found at the interface of the flocculant and hindered settling regions to those found at the top of the compression region. And also occurs in secondary settling facilities used in conjunction with biological treatment facilities.

2.3.4 Type IV settling (compression settling)

In type IV settling particles have reached such a concentration that a structure is formed and furture settling can only occur by compression. Compression takes place from weight of the particles, which are constantly being added to the structure by sedimentation from the supernatant liquid. This type of settling usually occurs in the lower layers of a deep sludge mass such as near the bottom of secondary clarifiers and sludge thickeners.