WATER TREATMENT

SKAA 2912

FLOCCULATION

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INTRODUCTION

- Objective:

  To provide an increase in the number of contacts between coagulated particles suspended in water by gentle and prolonged agitation

INTRODUCTION

- Flocculation theories come from the observations of:
  - Small particles undergo random Brownian motion due to collisions with fluid molecules – **particle-particle collisions**
  - Stirring water containing particles creates **velocity gradients** that bring about particle collisions

Flocculation process relies on turbulence to promote collisions between destabilized particles to form large and dense flocs

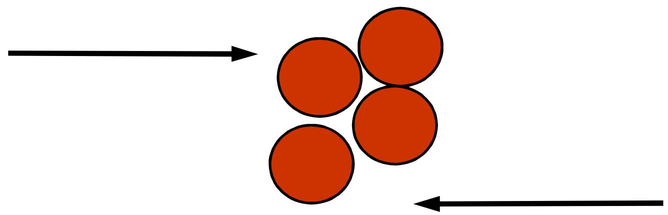
- Flocculation mechanisms:
  - Microscale (perikinetic) flocculation
  - Macroscale (orthokinetic) flocculation
  - Differential settling

INTRODUCTION

- Flocculation mechanisms:
  - Microscale (perikinetic) flocculation
    - For small particles < 0.1 µm
    - Primary mechanism: **Brownian movement**
    - Form flocs ranging from 1 to 100 µm

INTRODUCTION

- Flocculation mechanisms:
  - Macroscale (orthokinetic) flocculation
    - For small particles > 1 µm
    - Mixing causes **velocity gradients** that causes collisions between suspended materials
    - Can result in floc breakup due to shear forces in the water



INTRODUCTION

- Flocculation mechanisms:
  - Differential settling
    - Flocculated particles (different sizes) settle via **gravitational forces**. Because of the different in sizes, they have **different settling velocities** which causes particles to collide and form larger flocs; thus, promoting flocculation

TYPES OF MIXING

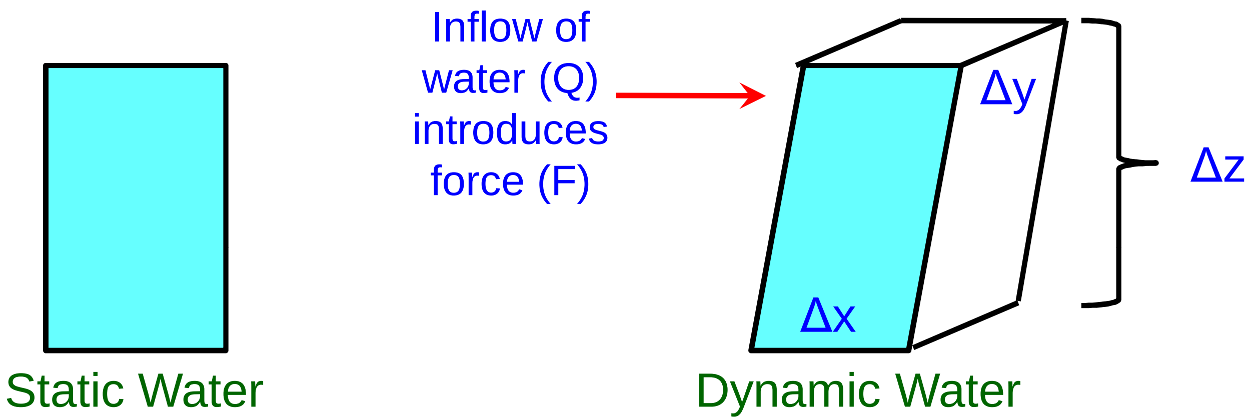
- Agitation
  - To promote processes (flocculation)
  - To maintain particles in suspension
  - For mass transfer (aeration)
- Blending

  To combine two or more liquid streams to achieve specific level of uniformity (e.g. coagulation, chlorination, pH control, fluorination)

The fundamentals of the mixing theory are based on turbulence concept because wastewater treatment processes take place in turbulent flow.

FLUIDS DYNAMIC

- Shear stress in fluids



The distribution of force at the x-y plane is known as **shear stress** where

$$\tau_{xy} = \frac{\text{Force}}{\text{Area}} = \frac{F}{\Delta x \Delta y} \longrightarrow F = \tau_{xy} \Delta x \Delta y \longrightarrow F = \mu \frac{dv}{dz} \Delta x \Delta y$$

Fluid is a moving entity, therefore

$$\tau_{xy} = \mu \frac{dv}{dz}$$

μ = dynamic viscosity of water, kg/m.s
dv = velocity gradient
dz = the change in height

FLOCCULATION THEORY

- Root-Mean-Square (RMS) Velocity Gradient (Camp and Stein, 1943)

Flocculation speed α Velocity gradient

↑

Controlled by the power (P) per unit of volume (V)

$$\frac{P}{V} = \frac{Force \times Velocity}{\Delta x \Delta y \Delta z}$$

P = power of mixing input to entire mixing vessel, W (1 W = 1 kg. m^2/s^3)

V = volume of the mixing vessel, m^3

Substituting force and velocity

$$\frac{P}{V} = \frac{\mu \frac{dv}{dz} \Delta x \Delta y \times \frac{dv}{dz} \Delta z}{\Delta x \Delta y \Delta z} \rightarrow \frac{P}{V} = \mu \left(\frac{dv}{dz}\right)^2 \rightarrow \frac{dv}{dz} = \sqrt{\frac{P}{\mu V}} = \overline{G}$$

↑ RMS velocity gradient, s^{-1}

FLOCCULATION THEORY

- To design the flocculation tank, Camp Number ($\overline{G} \times t$) is used.

$$\overline{G} = \text{RMS velocity gradient, s}^{-1}\ (20 - 75\ \text{s}^{-1})$$

$$t \quad = \text{time, s}\ (10 - 60\ \text{min})$$

$$\overline{G}t = 12\,000 - 27\,0000$$

TYPES OF FLOCCULATORS

Mechanical	Hydraulic
Advantages: •Flexibility of control and reliable •Reduction in amount of chemicals used •Less head loss •Better floc formation if properly adjusted •Flocculators can be maintained or replaced without shutting down the basin	**Advantages:** •Simple to construct and operate •Less chance of short-circuiting •No moving parts •Can produce very large flocs
Disadvantages: •Low velocity around the shaft •Dead spaces in corners and possibility of short circuiting •High operation and maintenance cost	**Disadvantages:** •Cannot be easily adjusted •Increase head loss •Little flexibility
Examples: Horizontal paddles Vertical paddles Vertical turbines	Examples: Baffle type mixing basin

TYPES OF FLOCCULATORS

Paddle flocculators

- Frequently employed in conventional treatment systems and the removal of solids are by sedimentation
- Rotational speed should start at the lowest speed to avoid failures of flocs formation during startup

To move the paddles in the flocculator, power is needed

$$P = \text{Force} \times \text{Velocity}$$

Force exerted can be converted into energy to move the paddle

$$E = \text{Force} \times \text{Distance}$$

$$E = \frac{1}{2}(\text{mass})(\text{velocity})^2$$

$$\text{Force} \times \text{Distance} = \frac{1}{2}(\text{mass})(\text{velocity})^2 = \frac{1}{2}\text{Density} \times \text{Volume} \times (\text{velocity})^2$$

TYPES OF FLOCCULATORS

Paddle flocculators

$$\text{Force} = \frac{1}{2}\text{Density} \times \text{Area} \times (\text{velocity})^2 = \frac{1}{2}\rho A v^2$$

The force exerted on the paddles will be affected by the resistance due to water. Therefore, the power imposed on the paddle should consider the drag coefficient, C_D)

$$F_D = \frac{1}{2} C_D \rho A_p v_p^2$$

↓

$$P = \text{Force} \times \text{Velocity} = \frac{1}{2} C_D \rho A_p v_p^3$$

Length:Width Ratio	C_D
1	1.16
5	1.20
20	1.5
Flat blades	1.8
>>20	1.9

TYPES OF FLOCCULATORS

Paddle flocculators

Drag coefficient, C_D, are based on the length to width ratio

Length:Width	C_D
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TYPES OF FLOCCULATORS

Baffle type flocculators

Design Criteria

Parameter	Value
Velocity	10 – 30 cm/s
Minimum width of the channel	45 cm
Depth of flow	1.0 m
Detention/residence time	20-30 minutes
Clear distance between baffle end and wall	1.5 times distance between baffles
Minimum tanks	2 tanks

REFERENCES

- Crittenden, J.C., Trussell, R.R., Hand, D.W., Howe, K.J., Tchobanoglous, G. (2012). *Water Treatment: Principles and Design*, 3rd Edition, USA: John Wiley & Sons.