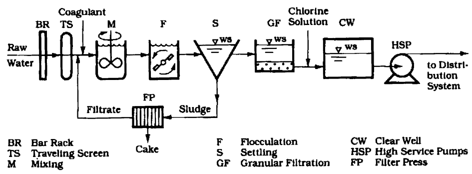
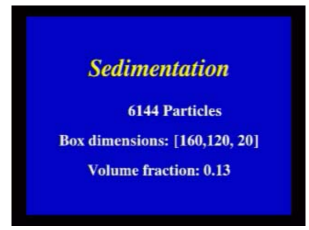
Treatment Processes



Screening → Aeration → Prechlorination →
Sedimentation ← Flocculation ← Coagulation

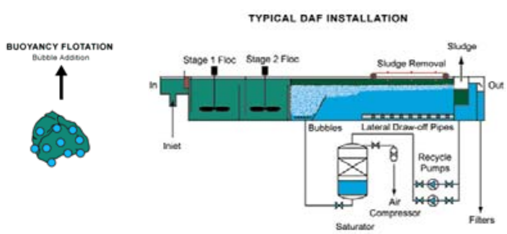
Sedimentation

Sedimentation is the **downwards movement of an object** relative to its surrounding medium, due to the force of gravity.



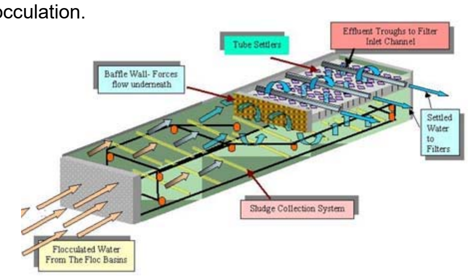
Sedimentation

Dissolved-air flotation (DAF) is a method whereby bubbles are produced by the reduction of pressure in a water stream saturated with air.



Sedimentation

The purpose of sedimentation is to remove preexisting solids, as well as the precipitates formed in coagulation and flocculation.



Sedimentation

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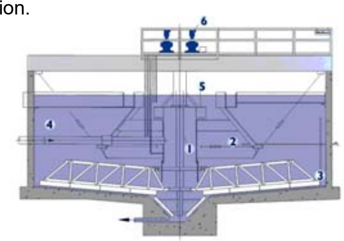
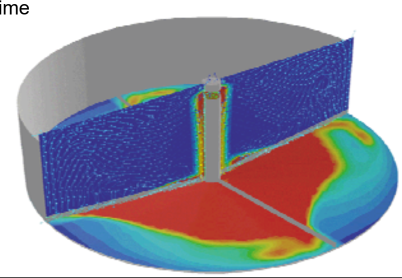


Sedimentation

Model of a circular settlement tank with sludge scrapers was used to estimate the distribution of particulate concentration over time



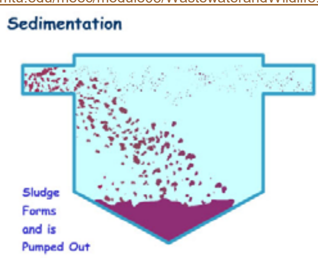
Sedimentation

Sedimentation

Sedimentation

Click HERE for animations about sedimentation

http://techalive.mtu.edu/meec/module03/WastewaterandWildlife.htm



Sedimentation

- Sedimentation is the accumulation through gravity of particulate matter at the bottom of a fluid.
- This natural process is frequently used to separate contaminants from air, water, and wastewater.
- There are four types of settling:
  - discrete
  - flocculant
  - hindered
  - compression

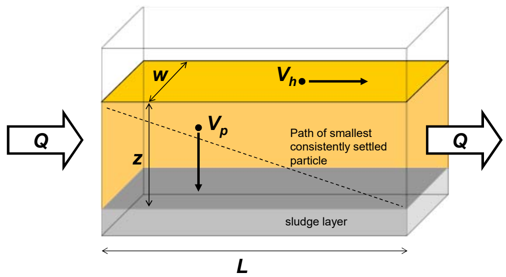
Sedimentation

- ***Discrete*** - Individual particles settle independently, neither agglomerating nor interfering with the settling of the other particles present. This occurs in water with a low concentration of particles.
- ***Flocculant*** - Particle concentrations are high enough that agglomeration occurs. This reduces the number of particles and increases average particle mass. The heavier particles sink faster.

Sedimentation

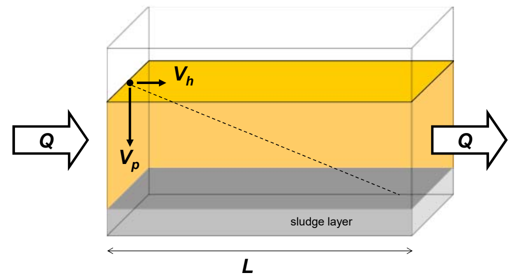
- ***Hindered*** - Particle concentration is sufficient that particles interfere with the settling of other particles.
- ***Compression*** - In the lower reaches of clarifiers where particle concentrations are highest, particles can settle only by compressing the mass of particles below.

Sedimentation



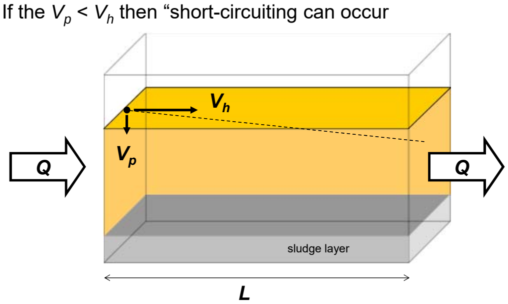
Sedimentation

If the $V_p > V_h$ then settling can occur



Sedimentation

If the $V_p < V_h$ then "short-circuiting can occur



Sedimentation

The horizontal velocity, $\boldsymbol{V_h}$, of a particle can be approximated by considering the flowrate, ***Q***, and the cross-sectional flow area of the tank.

$$Q = V_h A \quad \Rightarrow \quad V_h = \frac{Q}{A}$$

$$V_h = \frac{Q}{wz}$$

Sedimentation

The residence time of water in the sedimentation tank can be approximated as:

$$V_h = \frac{Q}{wz} \quad \Rightarrow \quad V_h \Rightarrow L/t$$

$$t = \frac{Lwz}{Q}$$

Sedimentation

Estimate of the residence time of water in a small sedimentation tank where ***Q*** = 1 liter/min, ***L*** = 6 in., ***w*** = 6 in., and ***z*** = 10 in. (dimensions of a tank in the lab).

$$t = \frac{Lwz}{Q} = \frac{6\,\text{in.}(6\,\text{in.})10\,\text{in.}}{1{,}000\,\text{ml}/\text{min}}$$

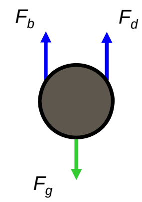
$$t = \frac{360\,\text{in.}^3\,\text{min}}{1000\,\text{ml}}\left[\frac{16.39\,\text{ml}}{\text{in.}^3}\right] = \boxed{5.9\text{ min}}$$

Sedimentation

- Discrete settling, can be analyzed by calculating the settling velocity of the individual particles contained within the water.
- The forces acting on a particle are:
  - gravity in the downward direction,
  - drag acting in the upward direction as the particle settles
  - upward buoyancy due the water displaces by the particle

Sedimentation

The forces acting on a settling particle are:



F_g is the force due to gravity
F_d is the drag force
F_b is the buoyant force

$$F_g = F_d + F_b$$

Sedimentation

The gravitational force can be expressed as:

$$F_g = m_p g$$

Using the density and volume of the particle yields:

$$F_g = \rho_p V_p g$$

where: ρ_p is the density of the particle, lb-mass/ft.^{3},
V_p is the volume of the particle, ft.^{3}, and
g is the gravitational constant, ft./s^2

Sedimentation

The drag on the particle can be calculated by the drag equation from fluid mechanics

$$F_d = \frac{1}{2} C_d A \rho_w v^2$$

where C_d is the drag coefficient, dimensionless,
A is the particle cross-sectional area, ft.^{2},
ρ_w is the density of water, lb-mass/ft.^{3},
v is the velocity, ft./sec.

Sedimentation

The buoyant force acting on the particle is:

$$F_b = m_w g$$

Substituting the particle volume and density of water, yields:

$$F_b = \rho_w V_p g$$

where: ρ_w is the density of water, *lb-mass/ft*^{3},

Sedimentation

By balancing the forces acting on a settling particle and using the relationships for F_g the force due to gravity, F_d the drag force, and F_b the buoyant force, the following relationship can be developed:

$$\rho_p V_p g = \frac{1}{2} C_d A \rho_w v^2 + \rho_w V_p g$$

Sedimentation

Solving for the settling velocity, ***v***, results in:

$$v = \sqrt{\frac{2(\rho_p - \rho_w)V_p g}{C_d A \rho_w}}$$

If the particle is assumed to round and the formulas for area and volume of a sphere are used:

$$v = \sqrt{\frac{4(\rho_p - \rho_w)d_p g}{3C_d \rho_w}}$$

where $\boldsymbol{d_p}$ is the diameter of the particle

Sedimentation

At low Reynolds numbers (for N_{Re}, < 1) C_d, can be approximated by:

$$C_d = \frac{24}{N_{Re}}$$

For Reynolds Numbers is transition flow, 1 < N_{Re} < 10,000, the drag coefficient for spheres is:

$$C_d = \frac{24}{N_{Re}} + \frac{3}{\sqrt{N_{Re}}} + 0.34$$

For turbulent flow, N_{Re} > 10,000, the relationship for the drag coefficient for spheres is:

$$C_d = 0.4$$

Sedimentation

The Reynolds Number is: $N_{Re} = \dfrac{\rho v d}{\mu}$

where ***u*** is the absolute viscosity of the water, lb-force-sec./ft.^{2} (at 50^{0}F, $\boldsymbol{\mu}$ = 2.73(10^{-5}) lb.-sec./ft.^{2}).

For N_{Re}, < 1 the particle settling velocity can be estimated as a function of the properties of the particle and water, and the particle diameter, or

$$v_p = \frac{(\rho_p - \rho_w)d^2 g}{18\mu}$$

Sedimentation

This relationship is known as Stokes' law, and the velocity is known as the Stokes velocity.

$$v_p = \frac{(\rho_p - \rho_w)d^2 g}{18\mu}$$

The vertical velocity of water in a settling basin is often described as the ***overflow rate (OFR)***.

It is usually expressed as gal./ft.^{2}-day (m^3/m^2-day).

Sedimentation

The overflow rate is calculated in the following way:

$$OFR = \frac{Q}{A}$$

where: ***OFR*** is the overflow rate, gal./ft.^{2}-day,
Q is the flowrate, gal./day, and
A is the clarifier area, ft.^{2}.

Treatment Processes

Any Questions?