Wastewater Engineering

Class 4 Solids Separation, Grit removal

Lingling Zhang
Department of Environmental Engineering
University of Science and Technology Beijing

Theoretical analysis

General solids liquid sedimentation separation

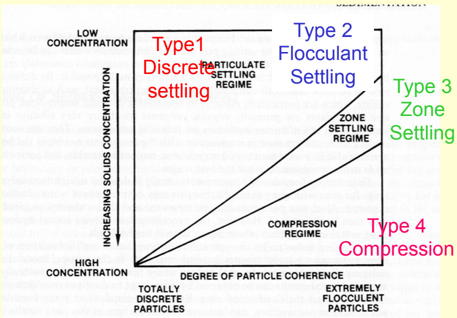


FIG. 1 Effect of particle coherence and solids concentration on the settling characteristics of a suspension.

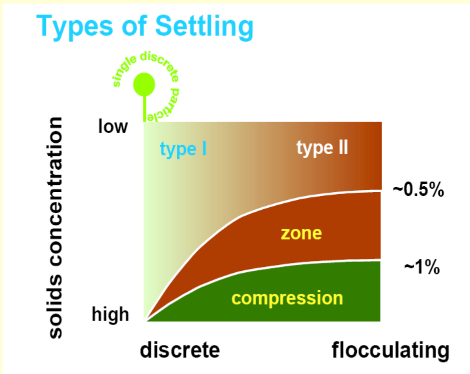
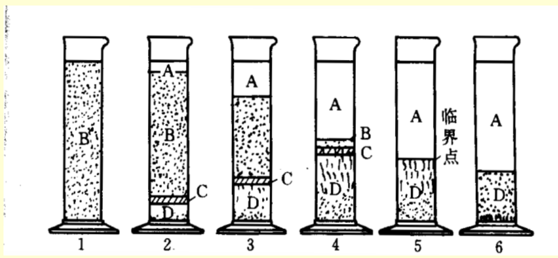


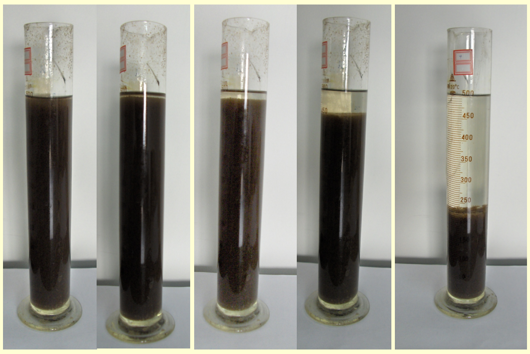
TABLE 6-8
Types of settling phenomena involved in wastewater treatment

Type of settling phenomenon	Description	Application/occurrence	
Discrete particle (type 1)	Refers to the sedimentation of particles in a suspension of low solids concentration. Particles settle as individual entities, and there is no significant interaction with neighboring particles	Removes grit and sand particles from wastewater	Sand or grit removal
Flocculant (type 2)	Refers to a rather dilute suspension of particles that coalesce, or flocculate, during the sedimentation operation. By coalescing, the particles increase in mass and settle at a faster rate	Removes a portion of the suspended solids in untreated wastewater in primary settling facilities, and in upper portions of secondary settling facilities. Also removes chemical floc in settling tanks	Primary sedimentation
Hindered, also called zone (type 3)	Refers to suspensions of intermediate concentration, in which interparticle forces are sufficient to hinder the settling of neighboring particles. The particles tend to remain in fixed positions with respect to each other, and the mass of particles settles as a unit. A solids-liquid interface develops at the top of the settling mass	Occurs in secondary settling facilities used in conjunction with biological treatment facilities	Activated sludge settling
Compression (type 4)	Refers to settling in which the particles are of such concentration that a structure is formed, and further settling can occur only by compression of the structure. Compression takes place from the weight of the particles, which are constantly being added to the structure by sedimentation from the supernatant liquid	Usually occurs in the lower layers of a deep sludge mass, such as in the bottom of deep secondary settling facilities and in sludge-thickening facilities	Sludge Thickening

A—clear water zone; B—hindered settling zone; C—transition zone; D —compression zone



Particles settling process



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In discrete settling, each particle is not affected by other particles, its settling in water is controlled by gravity force only:

For particles in wastewater treatment, Stoke's Law is used in describe the settling velocity of a particle in water

$$V_p = \frac{g\,(\rho_s - \rho)\,d^2}{18\,\mu}$$

Where:
Vp = Settling velocity of the particle
g = gravity acceleration
ρ_s= density of particle
ρ= density of water
μ = viscosity of water

How can one uses the settling velocity of a particle to design a gravity separator ? Using the overflow rate

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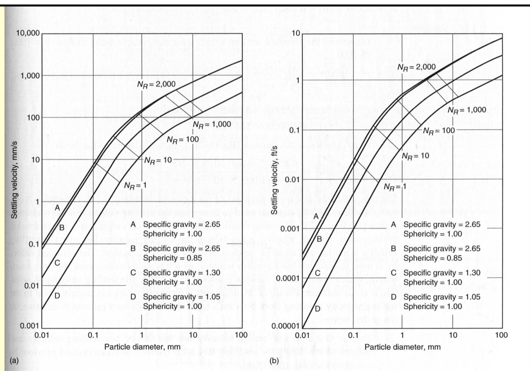
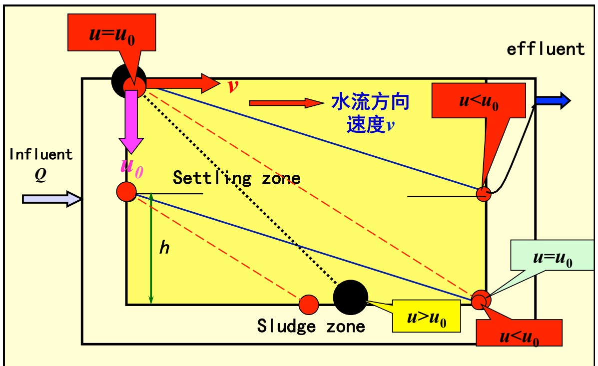


Figure 5-21
Settling velocities for various particle sizes under varying conditions at 20°C: (a) settling velocity in m/s versus particle size in mm, (b) settling velocity in ft/s versus particle size in mm. (Crites and Tchobanoglous, 1998.)



Settling process

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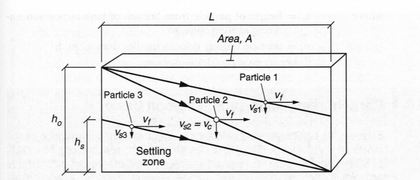

Figure 10-5
Discrete particle trajectories in settling zone rectangular clarifier.

$$v_c = \frac{h_o}{\tau} = \frac{h_o Q}{h_o A} = \frac{Q}{A} = \text{OR} \qquad (10\text{-}16)$$

OR = overflow rate, $m^3/m^2 \cdot h$ (equal to V_c)
A = area of top of basin settling zone, (see Fig. 10-5), m^2
Q = process flow rate, m^3/h
v_c = particle settling velocity such that particle at surface of inlet is removed in sludge zone just before outlet, m/h
h_o = depth of sedimentation basin, m
τ = hydraulic detention time of sedimentation basin, h

For smaller particles with settling velocity < Vc

$$\text{Fraction of particles removed} = \frac{h_s}{h_o} = \frac{h_s/\tau}{h_o/\tau} = \frac{v_s}{\text{OR}} = \frac{v_s}{v_c} \quad (v_s < v_c) \quad (10\text{-}17)$$

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As one can see that the particle removal depends on the particle settling velocity and the basin design overflow rate and not the depth of the basin.

Same surface area

Theoretically, the bottom basin should be able to handle twice amount the flow

Same surface area

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Inclined Plate (tube) Clarifier

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Inclined Plate Clarifier

- Utilize inclined trays to divide the depth into shallower sections, which in turn results in significantly short settling time.
- Typically used for chemically treated water, not used for grit removal or primary settling of municipal sewage due to biological growth problems on the plates.
- Sometimes used to upgrade the existing overloaded primary and secondary clarifiers.
- Tube settlers: use thin-wall tubes in circular, square, hexagonal, or any other geometric shape
- Parallel plate separators: provide a large surface area, thereby reducing the clarifier size. Little wind effect, laminar flow, good for upgrading overloaded horizontal flow clarifiers
- Disadvantages: septic condition, sludge sloughing off, and clogging of inner tubes and channels.

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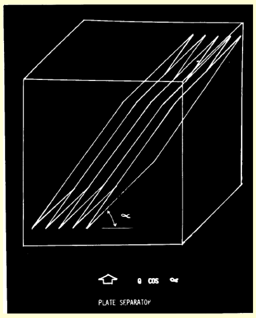
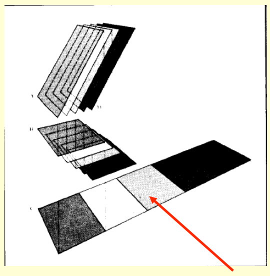
Inclined plate clarifier: use this theory to improve settling – theoretically only for discrete settling but it can be applied in other cases





OR = Q / A

Projected surface area as A for the calculation of OR

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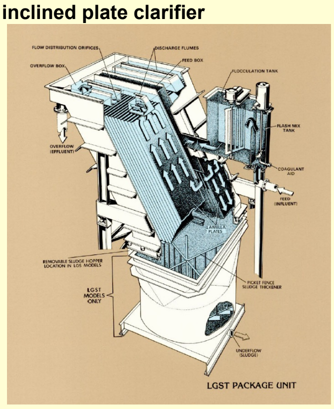
Commercial inclined plate clarifier



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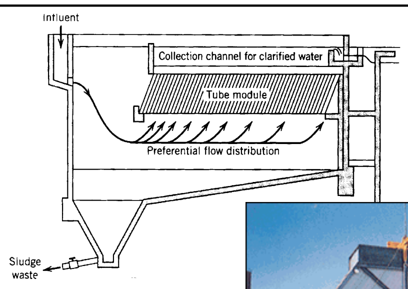
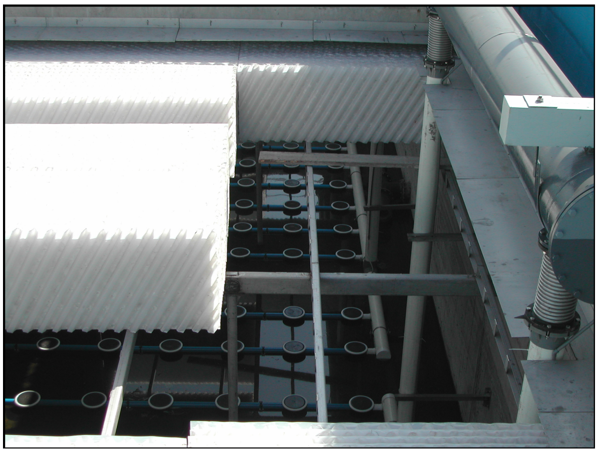


Plate pack assemblies are supplied ready for installation.



Grit Removal System Design

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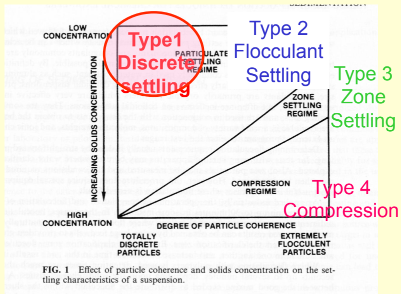
Grit removal



The discrete settling theory, although used in conceptual design of grit removal, is over shadowed by the practical problems of settling solids removal and grit cleaning

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Grit Removal

Grit: consists of sand, dust, cinder, bone chips, coffee grounds, seeds, eggshells, and other materials in wastewater that are nonputrescible and are heavier than organic matter.

Reason for grit removal

- To protect moving mechanical equipment and pumps from unnecessary wear and abrasion
- To prevent clogging in pipes, heavy deposits in channels
- To prevent cementing effects on the bottom of sludge digesters and primary sedimentation tanks
- To reduce accumulation of inert material in aeration basins and sludge digesters which would result in loss of usable volume

Specific gravity

- Grit: 1.3~2.7 (always contain putrefies)
- Organic matter in wastewater: 1.02

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Location of Grit Removal Facility

Location	Advantages	Disadvantages
Ahead of lift station equipment	Max. protection of pumping	Frequently deep in the ground, high construction cost, not easily accessible, and difficult to raise the grit to ground level
After pumping station	Ground level structure – easy to access and operate	Some abnormal wear to pumps
Degritter in conjunction primary sludge	Usually low capital and operation and maintenance costs, cleaner and drier grit	Pumping equipment not adequately protected with

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Velocity-Controlled Grit Channel

- A long narrow sedimentation basin with better control of flow through velocity - used for small plants

Design Factors

- Detention time: 60 sec.
- Horizontal velocity: 0.3 m/sec
- Settling velocity for a 65-mesh material: 1.15 m/min
- Headloss: 30~40% of the max. water depth in the channel
- Grit removal: manual or mechanical

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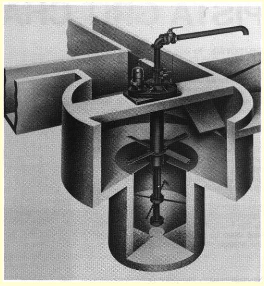
Pista® Grit Removal System

- Operates on the vortex principle.
- Headloss: max. 0.25 inch
- Removal efficiency
  95% of the 50 mesh size grit
  83% of the 80 mesh size grit
  73% of the 140 mesh size grit
- Capacity: 1~70 MGD
- Can be installed above or below ground
- Lower power usage
- Supplied in steel for easy installation and/or attachment to a concrete channel
- Installed in multiples



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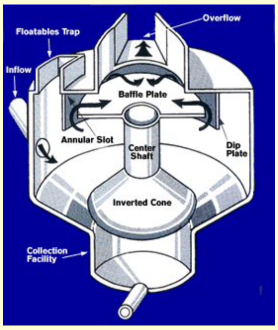
Grit King® Dynamic Separator

- Has no moving parts
- Requires no external power source
- Virtually maintenance free
- Highly efficient w/ min. headloss
- Recovers clean grit
- Self-cleansing
  Designed to operate over a wide range of flows
- Compact, requiring minimal space
- Simple to install and operate
- Easily linked with new or existing plant
- Economical, reduces long term expenditure



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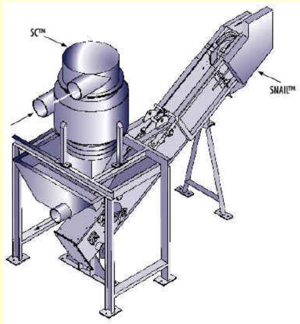
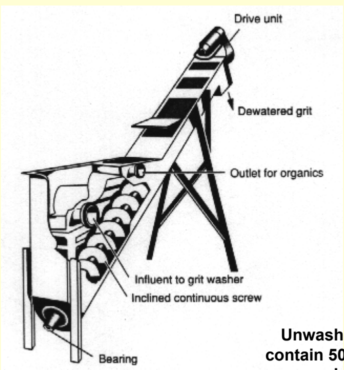
Grit Washing/Sludge Degritting System

- Washing (classifying) and dewatering grit abrasives removed by a headworks grit chamber
- Degritting dilute primary or secondary sewage sludges
- The SC™ uses a very strong free vortex and an accelerated boundary layer to separate abrasives as small as 50 μm sand from organic solids and water and concentrate these abrasives in a slurry stream. Sand is then separated from the slurry stream and dewatered by the total particle capture GRIT SNAIL™.



Grit Separation and Washing Unit

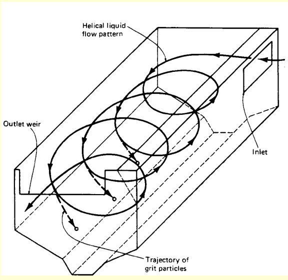


Unwashed grit may contain 50% or more of organic mateirlas

Sand and Grit collection

Aerated Grit Chamber

- Widely used for selective removal of grits by the current induced by air flow and not based on OR
- Create a spiral current within the basin using diffused compressed air
- Designed to remove grit particles having a specific gravity of 2.5 and retained over a 65-mesh (0.21-mm Φ)
- Used for medium to large treatment plants



Aerated Grit Chamber

Aerated Grit Chamber - continued

Advantages
- Can be used for chemical addition, mixing, and flocculation ahead of primary treatment
- Fresh wastewater, thus reduce odors and remove BOD_5
- Minimal headloss
- Grease removal by providing a skimming device
- Remove low putrescible organic matter by air supply
- Remove any desired size by controlling the air supply

Volatile organic compound (VOC) and odor emission
- Due to a health risk, covers may be required or nonaerated type grit chambers may be used.

Aerated Grit Chamber - continued

Design Factors

- **Depth: 2~5 m; length: 7.5~20 m; width: 2.5~7 m; width/depth ratio: 1:1~5:1; length/width ratio: 2.5:1~5:1**
- **Transverse velocity at surface: 0.6~0.8 m/sec**
- **Detention time at peak flow: 2~5 min**
- **Air supply: 4.6~12.4 L/sec·m of tank length (3~8 cfm/ft) - Higher air rate should be used for wider and deeper tanks; provision for air flow control**
- **Inlet structure: Inlet to the chamber should introduce the influent into circulation pattern. > 0.3 m/sec under all flow conditions**
- **Outlet structure: Outlet should be at a right angle to the inlet. > 0.3 m /sec under all flow conditions**
- **Baffles: longitudinal and transverse baffles**
- **Chamber geometry: consider location of air diffusers, sloping tank bottom, grit hopper, and accommodation of grit collection and removal equipment**

Aerated Grit Chamber Design Checklist

- **Design average, peak, and low initial flows**
- **Information on existing facility in case of expansion, site plan, and topographic maps**
- **Type of grit removal facility to be provided**
- **Influent pipe data, and static head, force main, hydraulic grade line if grit removal is preceded by a pumping station**
- **Headloss constraints for grit removal facility**
- **Treatment plant design criteria**
- **Equipment manufacturers and equipment selection guides**

Operation and Maintenance

- Requires well-trained operators
- Maximize grit removal efficiency
- Adjust the air flow to allow grit to settle but prevent organic material from settling
- Use swing type diffusers for easy maintenance

Trouble Shooting Guide
- Rotten-egg odor, corrosion or wear on equipment: increase air supply and inspect the walls, channels, and the chamber for debris
- Low recovery of grit: reduce air supply
- Grit chamber overflow: adjust pump controls
- Reduced surface turbulence: clean diffusers
- High volatile matter content in grit: reduce air supply
- Grey in color, smelly, greasy: increase air supply