Sedimentation

California State University: Sacramento

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Objectives

- Process Description
- Sedimentation Basins
- Solids-Contact Clarification
- Sludge Handling and Disposal
- Process Control
- Sedimentation Equipment and Safety

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Process Definition

- To remove suspended solids that are denser than water and to reduce the load on the filters
- Suspended solids
  - Natural state
    - bacteria, clays or silts
  - Modified/preconditioned
    - to form floc
  - Precipitated impurities
    - hardness, iron precipitates formed by the addition of chemicals

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Factors Affecting Sedimentation

- Particle size and distribution
  - larger particles will settle out faster
- Shape of particles
  - smoother circular particles will settle faster
- Density of particles
  - Denser particles settle out better
- Temperature of water
  - Decrease in temperature increases settling time required
- Electrical charge on particles
  - Colloidal particles are generally negatively charged

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Factors Affecting Sedimentation

- Dissolved substances in water
- Flocculation characteristics of the suspended material
- Environmental conditions (e.g. wind effects)
- Sedimentation basin hydraulic and design characteristics (i.e. inlet conditions & basin shape)

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Factors Affecting Sedimentation

- Sand and silt particles > 10 microns can be removed by sedimentation

Source	Diameter of Particle(microns)
Coarse turbidity	1 - 1,000
Algae	3 - 1,000
Silt	10
Bacteria	0.3 - 10
Fine turbidity	0.1 - 1
Viruses	0.02 - 0.26
Colloids	0.001 - 1

1 micron = 0.001 mm

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Currents

- Types
  - Surface currents
    - caused by winds
  - Density currents
    - caused by differences in suspended solids concentrations and temperature differences
  - Eddy currents
    - produced by the flow of the water coming into and leaving the basin
- Can cause suspended particles to distribute unevenly
- Can be reduced with baffled inlets or basin covers

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Detention Time

- 2 definitions
  - The actual time required for a small amount of water to pass through a sedimentation basin at a given rate of flow
  - The theoretical time (calculated) required for a small amount of water to pass through a basin at a given rate of flow
  - Minimum DT = 4 hours
  - Minimum DT, if high-rate settlers installed = 1 hour
- Factors affecting detention time
  - Short circuiting
  - Effective exchange volume
    - Portion of basin through which the water flows
  - Other hydraulic conditions
    - Basin inlet and outlet design

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Sedimentation Basins

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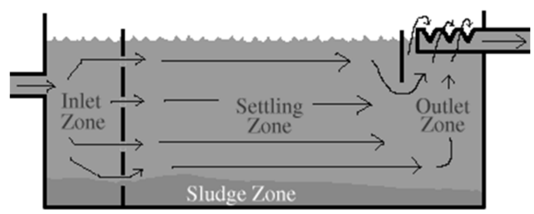
Sedimentation Basins

- 4 zones
  - Inlet zone
  - Settling zone
  - Sludge zone
  - Outlet zone



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Inlet Zone

- Provides a smooth transition from flocculation basin
- Distributes flocculated water uniformly over the entire cross section of the basin
- If properly designed, it will decrease short circuiting
- Over 50% of sludge will settle the first 1/3 of the tank
- Inlet baffle wall will
  - Minimize density currents due to temperature differences
  - Minimize wind currents
  - Minimize tendency of water to flow at the inlet velocity straight through the basin

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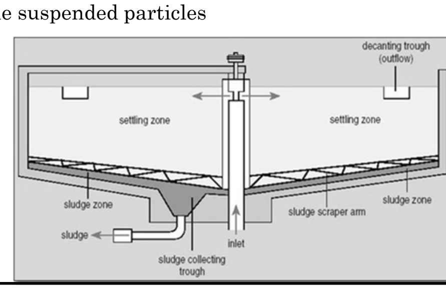
Settling Zone

- Largest portion of basin
- Provides calm, undisturbed storage of the flocculated water to permit effective settling of the suspended particles



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Sludge Zone

- Serves as a temporary storage place for the settled particles
- Located at the bottom of the sedimentation basin
- If sludge becomes too great
  - Decrease effective depth of the basin
  - Cause localized high flow velocities
  - Cause sludge scouring
  - Decrease in process efficiency
- Sludge removed by scraper or vacuum moving along bottom of basin
  - If removal devices do not cover full length of basin, it may have to be drained and flushed to remove the sludge

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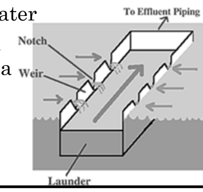
Outlet Zone

- Provides smooth transition from sedimentation basin to settled water conduit or channel
- Can control basin's water level
- Launders are used to uniformly collect settled/clarified water
- V-notch weirs are attached to launders to enable a uniform draw-off of basin water
- If water leaves sedimentation basin unevenly or at too high a velocity, floc can be carried over to the filters



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Basin Types

- Rectangular Basin
- Double-Deck Basin
- Circular and Square Basins
  - Referred to as clarifiers
- High Rate Settlers
  - Placed in basins
- Solids Contact Units

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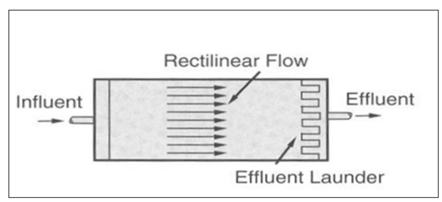
Types of Sedimentation Basins

- Rectangular Basins
  - Flow is in one direction
    - parallel to the basin length
    - called *rectilinear flow*
  - High tolerance to changing water conditions



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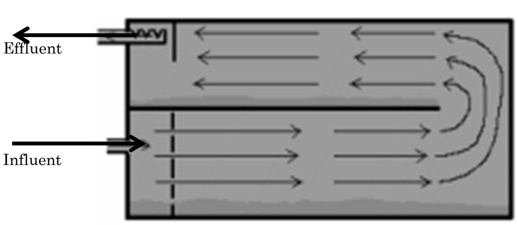
Types of Sedimentation Basins

- Double Deck Basin
  - Stack one rectangular basin on top of another
  - Doubles the effective sedimentation surface area



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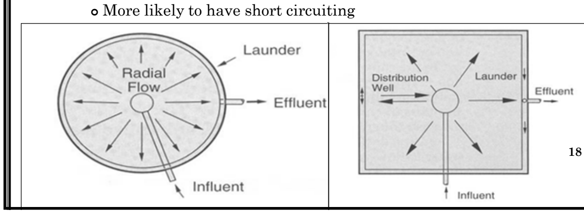
Types of Sedimentation Basins

- Circular and Square Basins (center feed)
  - Often called clarifiers
  - Water flows radially from center to outside
    - Must keep velocity and flow as even as possible
    - Bottom is conical and slopes downward for easier sludge removal
    - More likely to have short circuiting



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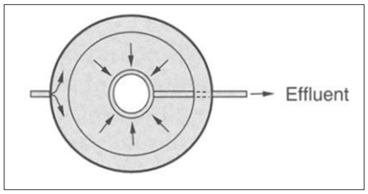
Types of Sedimentation Basins

- Circular Basins (peripheral feed with radial flow)
  - Flow is from the outside edge (periphery) to the center of the basin
  - Design is similar to central feed, radial flow



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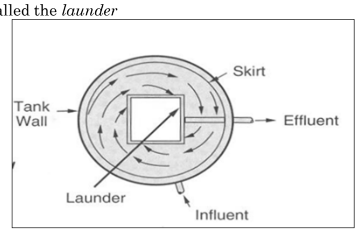
Types of Sedimentation Basins

- Circular Basins (peripheral feed with spiral flow)
  - Water enters at outside edges
  - Flows in a circle around the basin
  - Leaves at the center collector
    - called the *launder*



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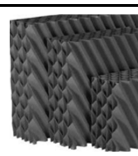
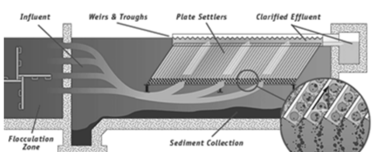
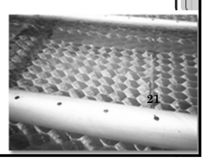
Types of Sedimentation Basins



- High-Rate Settlers aka Tube Settlers
  - Increases settling efficiency of conventional rectangular sedimentation basins
  - Water enters the tubes and flows upward
  - Settled particles collect on surfaces of tubes or settle to bottom of basin
  - Can be tube design or plate design of settlers



JMS Plate Settler system greatly enhances the sedimentation process



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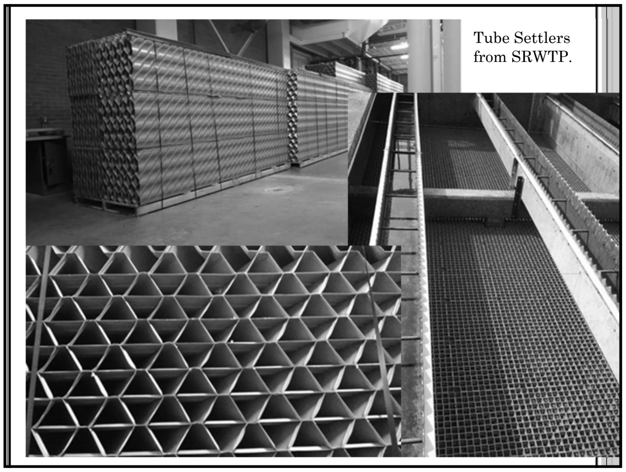

Tube Settlers from SRWTP.

Solids-Contact Clarification

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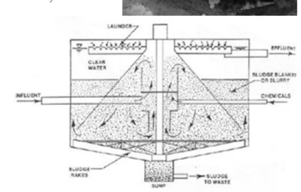
Solids-Contact Units

- Improves overall solids removal process under certain design conditions
- Combine coagulation, flocculation and sedimentation into a single basin
- Water flows upward through a sludge blanket or slurry of flocculated, suspended solids



Solids-Contact Units

- Uniform sludge blanket must be maintained
- Sludge blanket sensitive to changes in water temperature
- Changes in rate of flow should be made infrequently, slowly, and carefully
- Operational factors of importance
  - Temperature
  - Control of chemical dosage
  - Mixing of chemicals
  - Control of sludge blanket
- Perform a drawdown on sludge blanket to check thickness and concentration
  - AWWA: check solids concentration 2 times a day
  - State of TN: check solids concentration every 8 hours (3 times a day)

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Solids-Contact Clarification

- Known as solids-contact clarifiers, upflow clarifiers, reactivators, and precipitators
- Sludge – settled materials from coagulation or settling
- Slurry – the suspended floc clumps in the clarifier
- Internal mechanism consists of 3 distinct processes that function in the same way as conventional treatment
- Sludge produce by the unit is recycled through the process to act as a coagulant aid

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Solids-Contact Clarification

- Advantages
  - Reduced maintenance costs since all 3 processes are in one basin
  - Ability to adjust volume slurry
    - Operator can increase amount of slurry during good periods and remove it during periods when the coag process isn't functioning well
- Disadvantages
  - Requires a high level of operator knowledge and skill
  - Instability during rapid changes in flow, turbidity level, and temperature

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Fundamentals of Operation

- Chemical Dosage
  - Must be sufficient alkalinity
  - Always run jar test before making any changes
- Recirculation Rate
  - Established by speed of impeller, turbine, pumping unit or air injection
  - Entire mass of suspended floc clumps billows and flows within the chamber
    - This recirculating sludge mixes with the raw water and goes through coagulation & flocculation in the reaction zone
- Sludge Control
  - Accumulated sludge on bottom of clarifier (settling zone) is removed via hydraulic means (water pressure)

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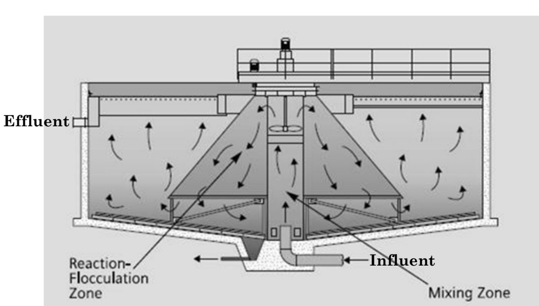
Fundamentals of Operation



Recirculation Zone – where coagulation & flocculation occur

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Sludge Removal

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Sludge Handling

- Sludge must be removed from bottom of basins
  - To prevent interference with the settling process
  - To prevent the sludge from becoming septic or providing an environment for the growth of microorganisms
  - To prevent excessive reduction in the cross-sectional area of the basin (reduction in DT)
- Mechanical sludge removal devices
  - Mechanical rakes
  - Drag-chain and flights
  - Traveling bridges

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Sludge Handling

- Mechanical rakes
  - Used in circular or square basins to push sludge toward a center outlet of sloped basin floor
- Drag-chain & flights
  - Simplest mechanism for rectangular basins
  - Endless chain with scrapers (flights) pushes sludge into a sump
  - Has high operation and maintenance costs
- Traveling bridges
  - Spans width of sedimentation basin and travels along basin walls
  - Sweeps hung from bridge remove sludge from basin floor with suction pumps or by siphon action

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Mechanical Rake

Travelling Bridge

Drag-chain and Flights

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Operation of Sludge Removal Equipment

- Sludge removal frequency depends on
  - Rate of sludge buildup
    - Dependent on amount of suspended material & flock removed
  - Size and capacity of sludge pump
  - Manual removal should be performed twice per year
- Sludge level measured by
  - Sludge blanket sounder
  - Bubbler tube
  - Aspirator
  - Ultrasonic level indicator
- If sludge is too thick and bulks, increase removal frequency
- If sludge is too low in solids (soupy), decrease removal frequency

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Process Control

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Process Control

- Performance of sedimentation basin depends on
  - Settling characteristics of suspended particles
  - Flow rate through basin (surface overflow rate)
- To control settling characteristics of particles
  - Adjust coagulant dose
  - Adjust coagulation-flocculation process
- Flow rate through basin controls process efficiency
  - Higher rate of flow means lower efficiency

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Surface Overflow Rate (SOR)

- Also called Surface Loading Rate (SLR)
  - Measures the amount of water leaving a sedimentation tank per foot of tank surface area
  - gpd/ft^2
- Translates into velocity and is equal to the settling velocity of the smallest particle the basin will remove
  - The faster the water leaves a tank, the more turbulence is created, and the more suspended solids are carried over the weir
    - Only the heavy particles can settle in fast moving water
- The overflow rate is controlled by a change in the flow rate into the tank

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Normal Operating Procedures

- Monitor
  - Turbidity of water entering and leaving the sedimentation basin
    - Entering indicates the load on the sedimentation process
    - Leaving reveals effectiveness of sedimentation
  - Temperature of entering water
    - Colder water means slower settling
- Uneven distribution of floc may indicate raw water quality change or operational problems

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Normal Operating Procedures – Process Actions

- Floc observation
  - Floc should only be visible for a short distance in sedimentation basin
  - If visible for long distance beyond inlet, sedimentation is poor
- Sludge blanket
  - Normal density but close to surface means more sludge should be wasted
  - Light density indicates coag-floc process must be adjusted
  - Floc coming over weir at end of basin indicate density currents, short circuiting, too deep sludge blankets, or high flows
  - Frequent clogging of sludge discharge line indicates too high sludge concentration

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Normal Operating Procedures – Process Actions

- Sludge solids volume analysis - used to determine sludge solids concentration
  - Collect sludge sample and pour known volume into a drying dish
  - Place sample dish in drying oven and evaporate sample to dryness at 103-105°C
  - Weigh remaining solids

$$\text{Sludge solids, \%} = \frac{(\text{Weight of sample, mg})(1\text{ mL})}{(\text{Volume of sample, mL})(1000\text{ mg})} \times 100$$

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Record Keeping

- Influent and effluent turbidity and influent temperature
- Process production inventory
  - Amount of water processed and volume of sludge produced
- Process equipment performance
  - Types of equipment in operation, maintenance procedures performed, and equipment calibration

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Abnormal Operating Conditions – Process Actions

- Measurement of turbidity levels at inlet and outlet of sedimentation basin shows process removal efficiency
- If coagulant dosage increases, sludge removal frequency may also increase
- Decreasing water temperature decreases settling rate and vice versa
- Increased settled water turbidity can lead to premature clogging of filters

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Sedimentation Process Troubleshooting

Source Water Quality Change	Operator Action	Possible Process Changes
Turbidity Temperature Alkalinity pH Color	1. Perform necessary analyses to determine extent of change 2. Evaluate overall process performance 3. Perform jar tests 4. Make process changes 5. Increase frequency of process monitoring 6. Verify response to process changes	1. Change coagulant 2. Adjust coagulant dosage 3. Adjust flash mixer/ flocculator mixing intensity 4. Change frequency of sludge removal 5. Increase alkalinity by adding lime, caustic soda, or soda ash

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Sedimentation Process Troubleshooting

Flocculation Process Effluent Quality Changes	Operator Actions	Possible Process Changes
Turbidity Alkalinity pH	1. Evaluate overall process performance 2. Perform jar tests 3. Verify performance of coag-floc process 4. Make process changes 5. Verify response to process changes	1. Change coagulant 2. Adjust coagulant dosage 3. Adjust flash mixer/ flocculator mixing intensity 4. Adjust improperly working chemical feeder

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Sedimentation Process Troubleshooting

Sedimentation Basin Changes	Operator Actions	Possible Process Changes
Floc settling Rising or floating sludge	1. Observe floc settling characteristics: • Dispersion • Size • Settling rate 2. Evaluate overall process performance 3. Perform jar tests • Assess floc size and settling rate • Assess quality of settled water 4. Make process changes 5. Verify response to process changes	1. Change coagulant 2. Adjust coagulant dosage 3. Adjust flash mixer/ flocculator mixing intensity 4. Change frequency of sludge removal 5. Remove sludge from basin 6. Repair broke sludge rakes

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Sedimentation Process Troubleshooting

Sedimentation Process Effluent Quality Changes	Operator Actions	Possible Process Changes
Turbidity color	1. Evaluate overall process performance 2. Perform jar tests 3. Verify process performance • Coag-floc process • Floc settling characteristics 4. Make process changes 5. Verify response to process changes	1. Change coagulant 2. Adjust coagulant dosage 3. Adjust flash mixer/ flocculator mixing intensity 4. Change frequency of sludge removal

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Types of Equipment

- Sludge removal equipment
- Sludge pumps
- Sump pumps
- Valves
- Flowmeters and gauges
- Water quality monitors
- Control systems

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Sedimentation Equipment and Safety

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Equipment Operation

- Before starting equipment, ensure proper lubrication
- After start up and during operation,
  - Check for excessive noise, vibration, overheating, and leakage
  - Check pump's suction and discharge pressures to make sure they aren't plugged
- Sludge collectors, discharge lines, and troughs should be periodically flushed to maintain a free sludge flow.

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Electrical Equipment

- Avoid electric shock (use protective gloves)
- Avoid grounding yourself in water or on pipes
- Ground all electric tools
- Use the buddy system
- Use a lockout and tag system whenever electrical equipment or electrically driven mechanical equipment is out of service or being worked on

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Mechanical Equipment

- Keep protective guards on rotating equipment
- Do not wear loose clothing around rotating equipment
- Keep hands out of valves, pumps and other pieces of equipment (lock out and tag power switches before cleaning)
- Clean up all lubricant and sludge spills
- Use a lockout and tag systems whenever mechanical equipment is out of service or being worked on

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Open Surface Water Filled Structures

- Use safety devices such as handrails and ladders
- Close all openings and replace safety gratings when finished working
- Know the location of all life preservers
- Use the buddy system

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Valve and Pump Vaults, Sumps

- Be sure all underground or confined structures are free of hazardous atmospheres
- Only work in well-ventilated structures
- Use the buddy system
- Lock or chain valves when working in an area that could be flooded

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Preventive Maintenance

- Keeping electrical motors free of dirt and moisture
- Ensuring good ventilation in equipment work areas
- Checking pumps and motors for leaks, unusual noise and vibrations, overheating, or signs of wear
- Maintaining proper lubrication and oil levels
- Inspecting for alignment of shafts and couplings
- Checking bearings for wear, overheating, and proper lubrication
- Checking for proper valve operation
- Checking for free flow of sludge in sludge removal collection and discharge systems

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Sedimentation
Vocabulary

A. Absorption
B. Adsorption
C. Clarifier
D. Complete Treatment
E. Density
F. Detention Time
G. Dewater
H. Direct Filtration
I. Effluent
J. Influent
K. Launders
L. Overflow Rate
M. Plug Flow
N. Precipitate
O. Representative Sample
P. Sedimentation
Q. Septic
R. Shock Load
S. Short-Circuiting
T. Slurry
U. Supernatant
V. Tube Settler
W. Turbidity

_____ 1. A watery mixture or suspension (not dissolved) matter; a thin, watery mud or any substance resembling it.

_____ 2. To remove or separate a portion of the water present in a sludge or slurry.

_____ 3. The gathering of a gas, liquid, or dissolved substance on the surface or interface zone of another material.

_____ 4. A sample portion of material or water that is as nearly identical in content and consistency as possible to that in the larger body of water being sampled.

_____ 5. A measure of the cloudiness of water.

_____ 6. A type of flow that occurs in tanks, basins or reactors when a slug of water moves through a tank without ever dispersing or mixing with the rest of the water flowing through the tank.

_____ 7. Water or other liquid flowing from a reservoir, basin, treatment process, or treatment plant.

_____ 8. A larger circular or rectangular tank or basin in which water is held for a period of time during which the heavier suspended solids settle to the bottom.

_____ 9. The theoretical (calculated) time required for a small amount of water to pass through a tank at a given rate of flow.

_____ 10. Liquid removed from settled sludge.

_____ 11. Sedimentation basin and filter discharge channels consisting of overflow weir plates and conveying troughs.

_____ 12. A condition that occurs in tanks or basins when some of the flowing water entering a tank flows along a nearly direct pathway from the inlet to the outlet.

_____ 13. A measure of how heavy a substance (solid, liquid, or gas) is for its size.

_____ 14. A condition produced by bacteria when all oxygen supplies are depleted.

_____ 15. A method of treating water consists of the addition of coagulant chemicals, flash mixing, coagulation, minimal flocculation, and filtration.

_____ 16. The taking in or soaking up of one substance into the body of another by molecular or chemical action.

_____ 17. The arrival at a water treatment plant of raw water containing unusual amounts of algae, colloidal matter, color, suspended solids, turbidity or other pollutants.

_____ 18. A device that uses bundles of small-bore tubes installed on an incline as an aid to sedimentation.

_____ 19. A water treatment process in which solid particles settle out of the water being treated in a large clarifier or sedimentation basin.

_____ 20. A method of treating water which consists of the addition of coagulant chemicals, flash mixing, coagulation-flocculation, sedimentation and filtration. Also called conventional treatment.

_____ 21. One of the guidelines for the design of settling tanks and clarifiers in treatment plants;

_____ 22. An insoluble, finely divided substance which is a product of a chemical reaction within a liquid.

_____ 23. Water or other liquid flowing into a reservoir, basin, treatment process, or treatment plant.

Answers

1. T	7. I	13. E	19. P
2. G	8. C	14. Q	20. D
3. B	9. F	15. H	21. L
4. O	10. U	16. A	22. N
5. W	11. K	17. R	23. J
6. M	12. S	18. V	

Review Questions
Sedimentation

1. List as many factors as you can recall that affect particle setting in a sedimentation basin.

2. What types of currents may be found in a typical sedimentation basin?

3. List the four zones into which a typical sedimentation basin can be divided.

4. What is the purpose of the settling zone in a sedimentation basin?

5. What are launders?

6. List three possible shapes for sedimentation basins.

7. Why are rectangular sedimentation basins often preferred over circular basins?

8. During the operation of a solids-contact unit, what items should be of particular concern to the operator?

9. List two advantages of solids-contact units.

10. List the devices that may be used to provide recirculation in a solids-contact unit.

11. Why must accumulated sludge be removed periodically from the bottom sedimentation basins?

12. How can the depth of sludge in a sedimentation basin be measured?

13. The actual performance of sedimentation basins depends on what two major factors?

14. What items should an operator monitor during the normal operation of the sedimentation process?

15. What should be attempted if the sludge line plugs frequently?

16. In the routine operation of the sedimentation process, what types of records should be maintained?

Sedimentation Review Questions
Answers

1. (1) Particle size and distribution, (2) shape of particles, (3) density of particles, (4) temperature of water, (5) electrical charge on particles, (6) dissolved substances in water, (7) flocculation characteristics of the suspended material, (8) environmental conditions, (9) sedimentation basin hydraulic and design characteristics

2. (1) Surface currents induced by winds, (2) density currents caused by differences in suspended solids concentrations and temperature differences, and (3) eddy currents produced by the flow of the water coming into and leaving the basin

3. (1) Inlet zone, (2) settling zone, (3) sludge zone, (4) outlet zone

4. To provide a calm, undisturbed storage place for the flocculated water for a sufficient time period to permit effective settling of the suspended particles in the water being treated

5. Launders are skimming or effluent troughs used to uniformly collect settled water. Adjustable V-notch weirs are generally attached to the launders for controlling the water level in the sedimentation basin

6. Sedimentation basins are available in circular, rectangular, or square shapes

7. Rectangular sedimentation basins are often preferred over circular basins because circular basins are generally more sensitive to short-circuiting and achieve poorer solids removal.

8. Care must be exercised to ensure that a uniform sludge blanket is formed and is subsequently maintained throughout the solids removal process. Other important factors include control of chemical dosages, mixing of chemicals, and control of the sludge blanket.

9. (1) Only one reaction unit to contend with, (2) ability to accumulate slurry during periods of severe taste and odor problems, (3) use slurry accumulation to carry plant when coagulation fails because of increased algal activities

10. Recirculation in a solids-contact unit may be provided by impellers, turbines, pumping units, or by air injection.

11. (1) Prevent interference with the settling process, (2) prevent the sludge from becoming septic or providing an environment for the growth of microorganisms that can create taste and odor problems, (3) prevent excessive reduction in the cross-sectional area of the basin

12. The depth of sludge in a sedimentation basin can be measured with a sludge blanket sounder, a bubbler tube, an aspirator, or an ultrasonic level indicator.

13. (1) the settling characteristics of the suspended particles, (2) the flow rate through the sedimentation basins

14. The operator should monitor the turbidity of the water entering and leaving the basin and the temperature of the water entering the basin.

15. Frequent clogging of the sludge discharge line is an indication that the sludge concentration is too high. If this occurs, try increasing the frequency of operation of the sludge removal equipment.

16. (1) influent and effluent turbidity and influent temperature, (2) process production inventory, and (3) process equipment performance