Sedimentation

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Photo Credit: Virginia Department of Health

Objective

In this lesson we will answer the following questions:

- How does sedimentation fit into the water treatment process?
- What zones are present in a sedimentation basin?
- How is sedimentation sludge disposed of?

Reading Assignment

Along with the online lesson, read Chapter 5: Sedimentation, in your textbook Operation of Water Treatment Plants Volume I .

Lecture

Introduction

Purpose

Sedimentation is a treatment process in which the velocity of the water is lowered below the suspension velocity and the suspended particles settle out of the water due to gravity. The process is also known as **settling** or **clarification**.

Most water treatment plants include sedimentation in their treatment processes. However, sedimentation may not be necessary in low turbidity water of less than 10 NTU. In this case, coagulation and flocculation are used to produce **pinpoint** (very small) floc which is removed from the water in the filters.

Location in the Treatment Process

The most common form of sedimentation follows coagulation and flocculation and precedes filtration. This type of sedimentation requires chemical addition (in the coagulation/flocculation step) and removes the resulting floc from the water. Sedimentation at this stage in the treatment process should remove 90% of the suspended particles from the water, including bacteria. The purpose of sedimentation here is to decrease the concentration of suspended particles in the water, reducing the load on the filters.

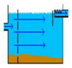
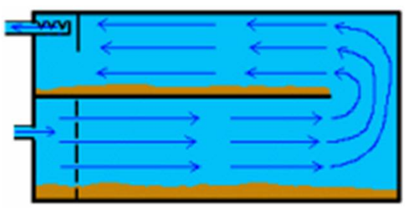
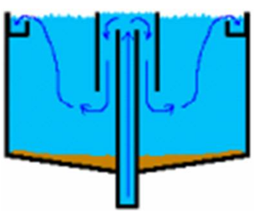
Sedimentation can also occur as part of the pretreatment process, where it is known as **presedimentation**. Presedimentation can also be called **plain sedimentation** because the process depends merely on gravity and includes no coagulation and flocculation. Without coagulation/flocculation, plain sedimentation can remove only coarse suspended matter (such as grit) which will settle rapidly out of the water without the addition of chemicals. This type of sedimentation typically takes place in a reservoir, grit basin, debris dam, or sand trap at the beginning of the treatment process.

While sedimentation following coagulation/flocculation is meant to remove most of the suspended particles in the water before the water reaches the filters, presedimentation removes most of the sediment in the water during the pretreatment stage. So presedimentation will reduce the load on the coagulation/flocculation basin and on the sedimentation chamber, as well as reducing the volume of coagulant chemicals required to treat the water. In addition, presedimentation basins are useful because raw water entering the plant from a reservoir is usually more uniform in quality than water entering the plant without such a holding basin.

The rest of this lesson will be concerned with sedimentation following coagulation and flocculation. We will consider types of sedimentation basins and parts of a typical sedimentation basin, as well as the disposal of sludge. Then, in the next lesson, we will learn to design a sedimentation basin and will consider some problems which may affect sedimentation basins.

Types of Basins

Three common types of sedimentation basins are shown below:

	Rectangular basins are the simplest design, allowing water to flow horizontally through a long tank. This type of basin is usually found in large-scale water treatment plants. Rectangular basins have a variety of advantages - predictability, cost-effectiveness, and low maintenance. In addition, rectangular basins are the least likely to short-circuit, especially if the length is at least twice the width. A disadvantage of rectangular basins is the large amount of land area required.
	Double-deck rectangular basins are essentially two rectangular sedimentation basins stacked one atop the other. This type of basin conserves land area, but has higher operation and maintenance costs than a one-level rectangular basin.
	Square or circular sedimentation basins with horizontal flow are often known as **clarifiers**. This type of basin is likely to have short-circuiting problems.

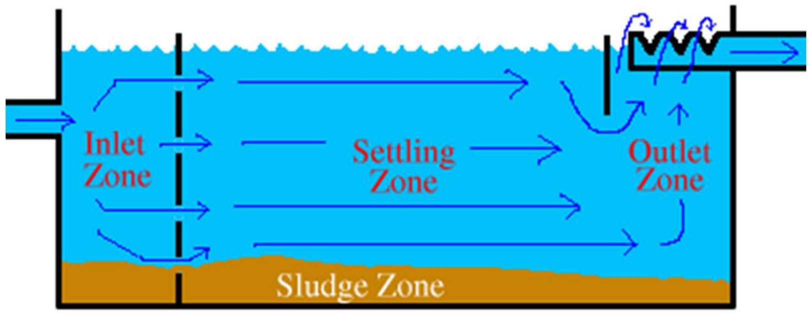
A fourth type of sedimentation basin is more complex. **Solids-contact clarifiers**, also known as **upflow solids-contact clarifiers** or **upflow sludge-blanket clarifiers** combine coagulation, flocculation, and sedimentation within a single basin. Solids-contact clarifiers are often found in packaged plants and in cold climates where sedimentation must occur indoors. This type of clarifier is also often used in softening operations.

Zones

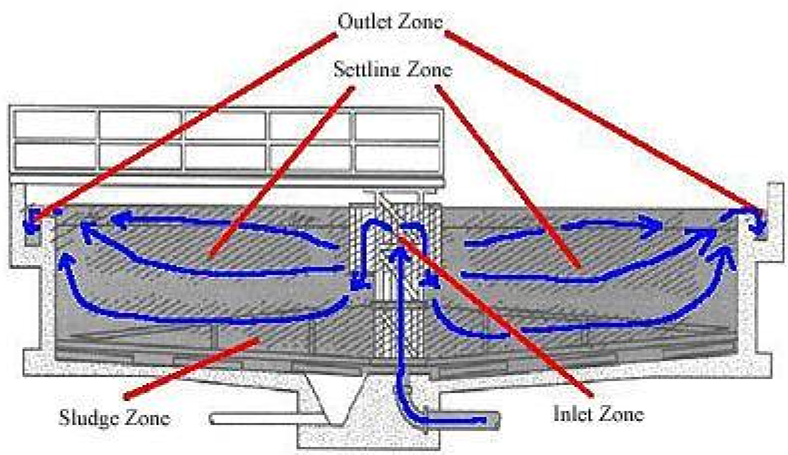
Introduction

All sedimentation basins have four zones - the inlet zone, the settling zone, the sludge zone, and the outlet zone. Each zone should provide a smooth transition between the zone before and the zone after. In addition, each zone has its own unique purpose.

Zones can be seen most easily in a rectangular sedimentation basin, such as the one shown below:



In a clarifier, water typically enters the basin from the center rather than from one end and flows out to outlets located around the edges of the basin. But the four zones can still be found within the clarifier:



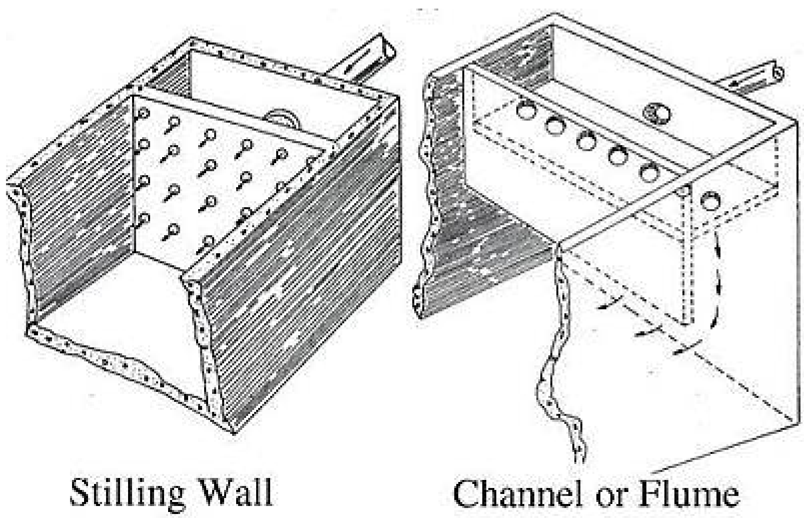
Inlet Zone

The two primary purposes of the inlet zone of a sedimentation basin are to distribute the water and to control the water's velocity as it enters the basin. In addition, inlet devices act to prevent turbulence of the water.

The incoming flow in a sedimentation basin must be evenly distributed across the width of the basin to prevent short-circuiting. **Short-circuiting** is a problematic circumstance in which water bypasses the normal flow path through the basin and reaches the outlet in less than the normal detention time. We will discuss short-circuiting in the next lesson.

In addition to preventing short-circuiting, inlets control the velocity of the incoming flow. If the water velocity is greater than 0.5 ft/sec, then floc in the water will break up due to agitation of the water. Breakup of floc in the sedimentation basin will make settling much less efficient.

Two types of inlets are shown below. The **stilling wall**, also known as a **perforated baffle wall**, spans the entire basin from top to bottom and from side to side. Water leaves the inlet and enters the settling zone of the sedimentation basin by flowing through the holes evenly spaced across the stilling wall.



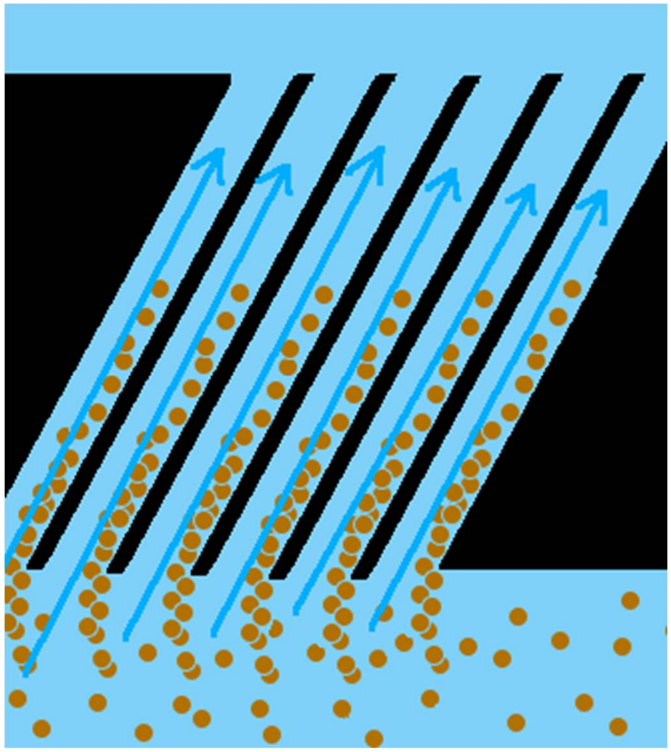
From: Water Works Operator's Manual

The second type of inlet allows water to enter the basin by first flowing through the holes evenly spaced across the bottom of the channel and then by flowing under the baffle in front of the channel. The combination of channel and baffle serves to evenly distribute the incoming water.

Settling Zone

After passing through the inlet zone, water enters the settling zone where water velocity is greatly reduced. This is where the bulk of floc settling occurs and this zone will make up the largest volume of the sedimentation basin. For optimal performance, the settling zone requires a slow, even flow of water.

The settling zone may be simply a large expanse of open water. But in some cases, tube settlers and lamella plates, such as those shown below, are included in the settling zone.



Tube settlers and lamella plates -
Water flows up through slanted tubes or along slanted plates.
Floc settles out in the tubes or plates and drifts back down into the lower portions of the sedimentation basin. Clarified water passes through the tubes or between the plates and then flows out of the basin.

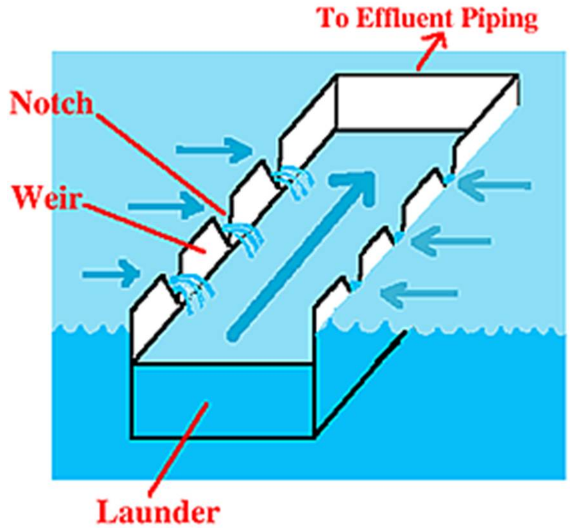
Tube settlers and lamella plates increase the settling efficiency and speed in sedimentation basins. Each tube or plate functions as a miniature sedimentation basin, greatly increasing the settling area. Tube settlers and lamella plates are very useful in plants where site area is limited, in packaged plants, or to increase the capacity of shallow basins.

Outlet Zone

The outlet zone controls the water flowing out of the sedimentation basin - both the amount of water leaving the basin and the location in the basin from which the outflowing water is drawn. Like the inlet zone, the outlet zone is designed to prevent short-circuiting of water in the basin. In addition, a good outlet will ensure that only well-settled water leaves the basin and enters the filter. The outlet can also be used to control the water level in the basin.

Outlets are designed to ensure that the water flowing out of the sedimentation basin has the minimum amount of floc suspended in it. The best quality water is usually found at the very top of the sedimentation basin, so outlets are usually designed to skim this water off the sedimentation basin.

A typical outlet zone begins with a baffle in front of the effluent. This baffle prevents floating material from escaping the sedimentation basin and clogging the filters. After the baffle comes the effluent structure, which usually consists of a launder, weirs, and effluent piping. A typical effluent structure is shown below:

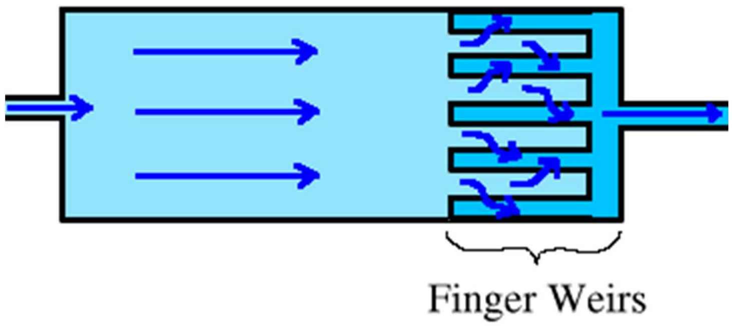


The primary component of the effluent structure is the **effluent launder**, a trough which collects the water flowing out of the sedimentation basin and directs it to the effluent piping. The sides of a launder typically have weirs attached. **Weirs** are walls preventing water from flowing uncontrolled into the launder. The weirs serve to skim the water evenly off the tank.

A weir usually has notches, holes, or slits along its length. These holes allow water to flow into the weir. The most common type of hole is the V-shaped notch shown on the picture above which allows only the top inch or so of water to flow out of the sedimentation basin. Conversely, the weir may have slits cut vertically along its length, an arrangement which allows for more variation of operational water level in the sedimentation basin.

Water flows over or through the holes in the weirs and into the launder. Then the launder channels the water to the **outlet**, or **effluent**, **pipe**. This pipe carries water away from the sedimentation basin and to the next step in the treatment process.

The effluent structure may be located at the end of a rectangular sedimentation basin or around the edges of a circular clarifier. Alternatively, the effluent may consist of **finger weirs**, an arrangement of launders which extend out into the settling basin as shown below.



Sludge Zone

The sludge zone is found across the bottom of the sedimentation basin where the sludge collects temporarily. Velocity in this zone should be very slow to prevent resuspension of sludge.

A drain at the bottom of the basin allows the sludge to be easily removed from the tank. The tank bottom should slope toward the drains to further facilitate sludge removal.

In some plants, sludge removal is achieved continuously using automated equipment. In other plants, sludge must be removed manually. If removed manually, the basin should be cleaned at least twice per year, or more often if excessive sludge buildup occurs. It is best to clean the sedimentation basin when water demand is low, usually in April and October. Many plants have at least two sedimentation basins so that water can continue to be treated while one basin is being cleaned, maintained, and inspected.

If sludge is not removed from the sedimentation basin often enough, the **effective** (useable) volume of the tank will decrease, reducing the efficiency of sedimentation. In addition, the sludge built up on the bottom of the tank may become **septic**, meaning that it has begun to decay anaerobically. Septic sludge may result in taste and odor problems or may float to the top of the water and become scum. Sludge may also become resuspended in the water and be carried over to the filters.

Sludge Disposal

Sludge Composition

The sludge which is found in the bottom of a sedimentation tank is primarily composed of water. The solids in the sludge are mainly excess coagulant, such as alum. Alum sludge has a solids concentration of only about 1% when automatically removed from the basin, or about 2% if manually removed. (The greater solids concentration of manually removed sludge is due to a small amount of gravity thickening.)

Many options exist for disposal of sedimentation sludge. Here we will discuss disposal in streams, sanitary sewers, lagoons, and landfills.

Disposal in Streams and Sewers

In the past, sludge and backwash water was typically released into streams and other bodies of water. However, this practice is becoming much less common and is now well regulated. Backwash water and sludge can only be released into streams if a discharge permit has been granted by the NPDES. The NPDES further requires extensive daily monitoring of the water quality when the sludge is being discharged.

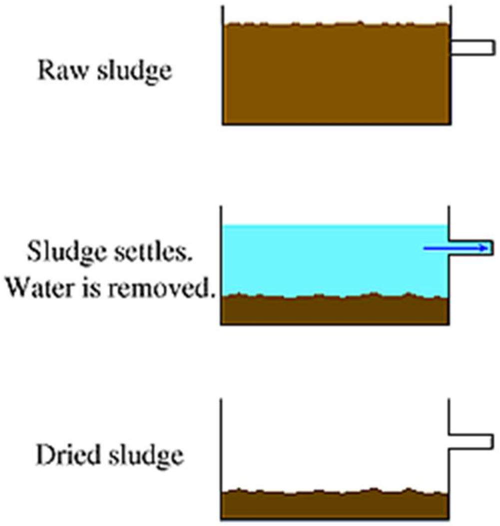
Alternatively, sludge may be piped directly to the sanitary sewer. However, this disposal option also has its disadvantages. Sludge can cause sewer blockages. In addition, fees charged by the wastewater treatment plant can be expensive. Releasing sludge into the sewage lines in large batches makes treatment of the wastewater problematic, so sludge is typically released slowly over a long time period, which requires a large holding tank at the water treatment plant.

Thickening Sludge

Most of the other alternatives require transporting sludge away from the treatment plant. Sludge is typically dried before it is trucked away since the greater volume of wet sludge makes it much more expensive to transport. This drying process is known as **dewatering** or **thickening**. Alum sludge is difficult to thicken, but a variety of devices have been developed to thicken the sludge, some of which are explained below.

In many cases, the sludge is treated by the addition of polymers to aid in the dewatering process. Alternatively, the sludge can be heated or frozen and thawed to increase the solids concentration. Treating the sludge to aid in thickening is known as **conditioning** the sludge.

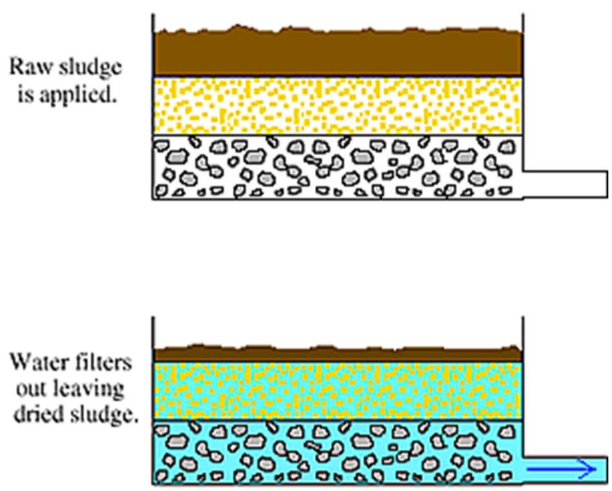
Once the sludge has been conditioned, it may be thickened in a lagoon, drying bed, or one of several other devices.



Lagoons, which are small-volume storage ponds, are the simplest device used to thicken sludge. These lagoons are filled with sludge and the solids are allowed to settled due to gravity to the bottom of the lagoon while the clear water is pumped off the top.

After a few months, gravity and evaporation will have reduced the sludge to a 30-50% solid state. The sludge can then be covered with soil and left on site, or may be trucked to a landfill off-site.

Drying beds are often used to thicken sludge destined for a landfill more quickly than the sludge would be thickened in a lagoon.



A **drying bed** is similar in design to a sand filter, with a layer of sand underlain by a layer of gravel. The sludge is applied to the top of the sand and the water percolates down through the sand and gravel and is drained away. When the sludge is sufficiently dry, it is carefully removed from the top of the sand and is trucked to a landfill. When sludge is preconditioned with chemicals, dewatering in a drying bed may take only a few days or weeks.

Other processes used to thicken sludge include filter presses, belt filter presses, centrifuges, and vacuum filters. These processes result in sludge with a solids content ranging from 30 to 50%.

Review

Sedimentation is a process used to remove suspended particles from water using gravity. Sedimentation may take place in a presedimentation device such as a reservoir, grit basin, debris dam, or sand trap; or sedimentation may follow coagulation/flocculation and take place in a rectangular sedimentation basin, a double-deck rectangular basin, a clarifier, or a solids-contact clarifier.

Sedimentation basins typically have four zones - the inlet zone which controls the distribution and velocity of inflowing water, the settling zone in which the bulk of settling takes place, the outlet zone which controls the outflowing water, and the sludge zone in which the sludge collects. Sludge may be disposed of a in sewer or stream or may be conditioned and then thickened in a lagoon, drying bed, filter press, belt filter press, centrifuge, or vacuum filter before being transported to a landfill.

References

Alabama Department of Environmental Management. 1989. *Water Works Operator Manual*.

Kerri, K.D. 2002. *Water Treatment Plant Operation*. California State University: Sacramento.

Ragsdale and Associates. Version III. *New Mexico Water Systems Operator Certification Study Guide*. NMED Surface Water Quality Bureau. Santa Fe.