FUNDAMENTALS OF THICKENING AND DEWATERING

What Is the Purpose of Thickening and Dewatering?

A water resource recovery facility's (WRRF's) process is generally separated into the "liquid" train and the "solids" train (see Figure 1). Solids that are allowed to settle in primary and secondary clarifiers are conveyed to solids processing systems. Thickening and dewatering systems remove water from solids and increase the concentration of solids for subsequent processes.

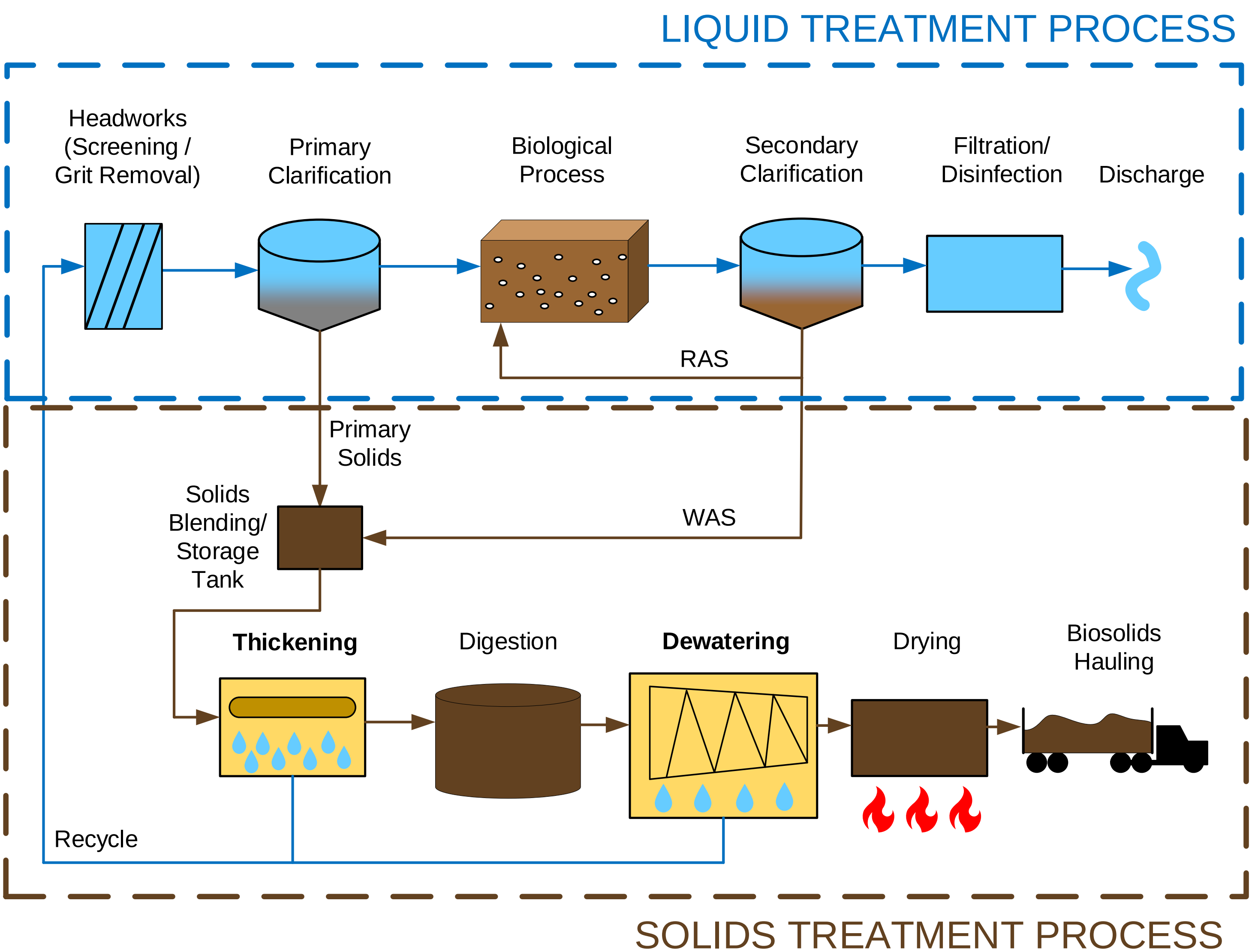

Figure 1. Example of a WRRF Schematic Highlighting the Thickening and Dewatering Processes.
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Note: Not all the process steps depicted in Figure 1 are necessary at all WRRFs. Additionally, not all possible process steps are shown (for example, tertiary treatment may be included to meet stricter discharge limits).

DEFINITION OF TERMS

- Co-thickening—The thickening of primary solids and waste activated solids together (as shown in Figure 1).
- Dewatering—A process that removes water from a thin solids flow stream (for example, 0.5% to 3.5% solids concentration), resulting in a dewatered, semi-solid "cake" product (15% to 40% solids concentration) that can no longer flow like a liquid.
- Polymer—A flocculant that consists of long chains of molecules that create bridges between solids particles when applied to the feed solids entering a thickening or dewatering unit.
- Primary Solids—Solids that are removed from a primary clarifier.
- Recycle Flow Stream—The water that is removed from a thickening or dewatering process and returned to the liquid treatment process. In general terms, this flow stream could also be called the "return flow stream" or the "sidestream." Depending on the thickening or dewatering process, this flow stream may be called, more specifically, "filtrate" (referred to in this fact sheet and the term commonly used to represent this flow stream), "overflow," "underflow," "pressate," or "centrate."
- Return Activated Solids (RAS)—The portion of activated solids that are returned to the biological process.
- Thickening—A process that removes water from a thin solids flow stream (for example, 0.2% to 1.5% solids concentration), resulting in a thickened solids flow stream (2% to 8% solids concentration) that can still flow like a liquid.
- Waste Activated Solids (WAS)—Solids that are removed from a secondary clarifier (sometimes called "final clarifier"). This flow stream is called "activated" because it contains active bacteria generated in the biological process step. This flow stream is called "waste" because it is the portion of activated solids that must be removed to maintain a healthy bacteria population in the biological process.

Thickening

Thickening Basics

- Often, the thickening process is placed on the solids stream discharged from clarifiers. Typically, it is strategically located to reduce the volume required in the downstream process steps (for example, smaller solids storage tanks and/or smaller digesters).
- The most common municipal solids streams that are thickened include primary solids and WAS.
- Co-thickening is the thickening of primary solids and WAS together.
- Although thickening is not a necessary process to meet regulations, it is commonly implemented because of the significant benefits of reduced hydraulic loading, which include:

- Smaller downstream basins and equipment,
- Increased storage or retention time in downstream basins,
- Reduced energy needs (i.e., heat) for processes such as anaerobic digestion, and
- Increased effectiveness of downstream processes (e.g., aerobic and anaerobic digestion).

■ Typical concentrations entering and discharging from the thickening process are as follows:

- Feed solids concentrations to the thickening process generally range from 2000 mg/L (0.2% solids) to 15 000 mg/L (1.5% solids) in typical applications receiving raw primary solids, WAS, or a combination of the two.
- In those typical applications, thickening produces a thickened solids product that generally ranges from 2% to 8% solids concentration (see Figure 2). Unless discharging directly into dewatering equipment, thickened solids must remain flowable and behave as a liquid so it can flow in pipes and be mixed in digesters, or as otherwise required by downstream processes.

Figure 2. Photograph of Typical Thickened Solids at Varying Concentrations (from left to right: 8.25% solids, 6.0% solids, 3.2% solids, and 1.0% solids)
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■ The water separated from the thickened solids is not clean enough for discharge as effluent; it is laden with suspended solids, nutrients, and biochemical oxygen demand (BOD) and requires further treatment. It is typically captured and returned for treatment in the liquid train. Depending on the thickening process, this returned or recycled water stream could be called "filtrate," "overflow," "underflow," "centrate," or "permeate." This stream will be generically referred to as "filtrate" in this fact sheet. It is important to consider the impact of recycle streams from thickening processes, and the constituents of those streams, on the WRRF's processes.

- Recuperative thickening is the process of thickening the contents of a tank (typically a digester) by feeding the tank's contents to the thickener and returning thickened solids to the tank rather than thickening 100% of the tank's feed prior to it entering the tank. This process is used to increase digester capacity and occasionally to operate the thickener equipment under more optimal conditions for better productivity.

What Equipment Is Used for Thickening?

- Types of thickening equipment include the following (organized by thickening mechanism):
    - Sedimentation:
        - By Gravitational Force: Gravity thickeners (or primary clarifiers if used for in-tank thickening)
        - By Centrifugal Force: Decanter centrifuge thickeners
    - Flotation: Dissolved air flotation thickeners (DAFTs)
    - Filtration:
        - Gravity belt thickeners
        - Rotary drum/screw thickeners
        - Membrane thickeners
        - Disc thickeners
        - Volute thickeners
- Many types of thickening processes require the conditioning of the solids with chemicals (e.g., polymer) upstream of the thickening equipment.
    - This helps neutralize the charge and flocculate the solids to aid in the thickening process by producing clearer "filtrate" and thicker solids. Monitoring and optimizing chemical dose are recommended to minimize operating costs.
    - Gravity thickeners, centrifuge thickeners, and DAFTs are generally not required to use polymer but can be used to increase capture of colloidal solids or improve floc strength.
    - Sometimes a decanter centrifuge can be used to either thicken or dewater, with the main difference being that polymer is applied for the dewatering application.
- While the feed solids are thin and able to be handled by a variety of pump types, the thickened solids may reach concentrations that require the use of positive displacement or other pumps designed for higher viscosity fluids.
- Thickening processes using the filtration mechanism require wash water to keep the thickener screening elements clean and functional. Dissolved air flotation and membrane thickeners also require a pressurized air source.
- Depending on the type of feed solids and odor sensitivity at the WRRF, odor control systems may be necessary.
- Table 1 provides an overview of the most common mechanical thickening devices and their typical operational parameters. Note that the operational parameters presented in Table 1 are general and not specific to any WRRF, and it is recommended to consult experts about particular equipment types and anticipated performance depending on a specific WRRF's unique design conditions. Additionally, determining the number and size of units required should account for both hydraulic and solids loading limits.

Table 1. Common Thickeners and Typical Operating Parameters			
Parameter	**Rotary Drum Thickener**	**Gravity Belt Thickener**	**Centrifuge Operated as a Thickener**
Capacity	379 to 1514 L/min (100 to 400 gal/min)	757 to 3407 L/min (200 to 900 gal/min)	114 to 5678 L/min (30 to 1500 gal/min)
Operating Wash Water Requirement	95 to 227 L/min (25 to 60 gal/min)	76 to 227 L/min (20 to 60 gal/min)	N/A (required only during shutdown)
Odor Containment	Yes	No, unless enclosed	Yes
Power Consumption	≈ 0.0013 kW/(L/min) (≈ 0.005 kW/gpm)	≈ 0.0013 kW/(L/min) (≈ 0.005 kW/gpm)	≈ 0.026 kW/(L/min) (≈ 0.1 kW/gpm)
Polymer Requirement [a]	2 to 7 active g/kg (4 to 14 active lb/dry ton) The low end assumes primary solids; the high end assumes anaerobically digested solids.	1.5 to 6 active g/kg (3 to 12 active lb/dry ton) The low end assumes primary solids; the high end assumes anaerobically digested solids.	0 to 4 active g/kg (0 to 8 active lb/dry ton) Although polymer will enhance the performance, it is not necessary for centrifuge thickening, so the low end is zero; the high end assumes co-thickened solids.
Thickened Solids [a]	5% to 12% total solids	4% to 10% total solids	5% to 15% total solids

[a]WEF &ABC (2021).

Dewatering

Dewatering Basics

- The dewatering process is typically located downstream of all solids biological and stabilization processes. It is typically located before composting, drying, or incineration processes or before final reuse/disposal. However, one example of dewatering applied as an intermediate process is as "pre-dewatering" located prior to thermal hydrolysis.
- Although dewatering is not a necessary process to meet regulations, it is often implemented because of the significant benefits associated with volume reduction, which include:
    - Reduction in the size of downstream equipment and storage areas.
    - Reduction in the weight and volume of solids to be transported for reuse or disposal. This has the possibility of saving significant operational costs, such as reducing hauling costs and tipping fees.

- Functionality of the downstream process. Dewatering is sometimes necessary for the effectiveness of downstream processes, such as thermal hydrolysis, drying, incineration, and composting. These processes would not function without upstream dewatering.
- Optimization of downstream processes; for example:
  - Incineration: Cake that is too dry burns too fast and forms "clinkers."
  - Dryers: Cake that is too dry won't form the right size pellet.
  - Composting: Cake that is too wet needs too much amendment.

- A key difference between thickening and dewatering is that dewatering produces a cake which behaves as a semi-solid, not as a liquid.
- Dewatering equipment can be fed solids in a wide range of concentrations and produce what is commonly referred to as "cake solids." For example:
  - Some facilities directly dewater WAS, which is typically between 5000 mg/L (0.5% solids) and 10 000 mg/L (1% solids).
  - Facilities with anaerobic digestion generate solids ranging from 1.5% to 3.5% solids concentration fed to dewatering.
  - Dewatering typically produces a dewatered cake product of 15% to 40% solids concentration (see Figure 3).

Figure 3. Photograph of Dewatered Cake

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- Similar to thickening, the water separated from the dewatered cake solids is not clean enough for discharge as effluent, and it is typically captured and returned for treatment in the liquid train. Depending on the dewatering process, this returned or recycled water stream could be called "filtrate," "pressate," or "centrate," but will continue to be generically referred to as "filtrate" in this fact sheet. It is important to consider the effect of recycle streams from dewatering processes and the constituents of those streams, on the WRRF's processes.

What Equipment Is Used for Dewatering?

- Types of dewatering equipment include the following (organized by dewatering mechanism):
  - Filtration:
    - Belt filter presses
    - Recessed-plate (plate and frame) filter presses
    - Recessed chamber and membrane filter presses
    - Screw presses
    - Volute presses
    - Rotary fan presses
    - Hydraulic piston presses
    - Geotextile tubes
    - Dewatering roll off boxes
  - Sedimentation by centrifugal force: Decanter centrifuges
  - Evaporation: Air drying beds
- Dewatering processes require the conditioning of the solids with chemicals (e.g., polymer) upstream of the dewatering equipment.
  - This helps neutralize the charge and flocculate the solids to aid in the dewatering process by producing clearer "filtrate" and drier solids. Monitoring and optimizing chemical dose are recommended to minimize operating costs.
  - Typically, dewatering requires a notably higher polymer dose than thickening, which is necessary to achieve the significantly higher cake solids concentrations.
- Since feed solids concentrations to dewatering are typically thin (i.e., 1% to 3.5%), the material can be pumped by a variety of pump types, although a low shear positive displacement pump will minimize damage to the larger particles, which helps optimize dewatering equipment.
- The conveyance of dewatered cake requires the use of equipment that can move cake solids, such as the following:
  - Screw conveyor
  - Belt conveyor
  - Cake pumps:
    - Progressing cavity pumps
    - Hydraulic piston pumps
  - Loading vehicles and dump trucks
- Most dewatering processes require wash water to keep the components clean and functional.
- Depending on the type of feed solids and odor sensitivity at the WRRF, odor control systems may be necessary.
- Table 2 provides an overview of the most common mechanical dewatering devices and their typical operational parameters. Note that the operational parameters presented in Table 2 are general and not specific to any WRRF, and it is recommended to consult experts about particular equipment types and anticipated performance depending on a specific WRRF's unique design conditions. Additionally, determining the number and size of units required should account for both hydraulic and solids loading limits.

Table 2. Common Dewatering Equipment and Typical Operating Parameters			
Parameter	**Screw Press**	**Belt Filter Press**	**Centrifuge Operated for Dewatering**
Capacity	19 to 757 L/min (5 to 200 gal/min)	151 to 1136 L/min (40 to 300 gal/min)	19 to 4542 L/min (5 to 1200 gal/min)
Wash Water Requirement	95 to 170 L/min (25 to 45 gal/min)	76 to 227 L/min (20 to 60 gal/min)	N/A (required only during shutdown)
Odor Containment	Yes	No	Yes
Power Consumption	≈ 0.013 kW/(L/min) (≈0.05 kW/gpm)	≈ 0.013 kW/(L/min) (≈0.05 kW/gpm)	≈ 0.053 kW/(L/min) (≈ 0.2 kW/gpm)
Relative Polymer Requirement [a]	2.25x	1x	1.25x
Dewatered (Cake) Solids [b]	12% to 30% total solids	10% to 25% total solids	15% to 35% total solids

[a]The polymer requirement for dewatering equipment can vary greatly (for example, from 6 to more than 40 lb/dry ton), depending on upstream liquid and solids processes, desired cake concentration, polymer product, and other factors. Thus, only a generalized, relative comparison is shown here (for example, screw presses require 2.25 times the amount of polymer as belt filter presses).

[b]These values were adapted from Water Environment Federation & Association of Boards of Certification (2021), Chapter 5, and are intended to indicate relatively generic ranges for municipal solids; however, the performance of any dewatering equipment greatly depends on the qualities of the specific solids being dewatered, and a professional should be consulted to determine actual dewaterability for specific applications. None of the values listed assume lime dewatering, which would increase the resulting cake solids.

Reference

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Suggested Readings

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Filtrate
Gravity belt thickener
Polymer
Recycle flow stream
Return flow stream
Rotary drum thickener
Screw press
Thickening