SOLIDS CAPTURE IN THICKENING AND DEWATERING PROCESSES

Optimizing Thickening and Dewatering

- Optimizing thickening or dewatering (solids separation) equipment involves monitoring multiple important parameters, including
  - Solids loading (kg/h or lb/hr),
  - Hydraulic loading (L/min or gpm),
  - Chemical (i.e., polymer) dosage (active g/kg, kg/tonne, or lb active/dry ton),
  - Discharge solids (percent solids), and
  - Solids capture (percent).
- Operators are often asked to find ways to produce drier discharge solids, reduce hydraulic loading, reduce chemical dosage, and reduce operating times, all with the ultimate goal of reducing operational costs.
- The challenge is that all of these parameters are intricately linked. It is not possible to adjust for one without affecting the others. Optimizing the system becomes a balancing act where all parameters must be acknowledged (see Figure 1).

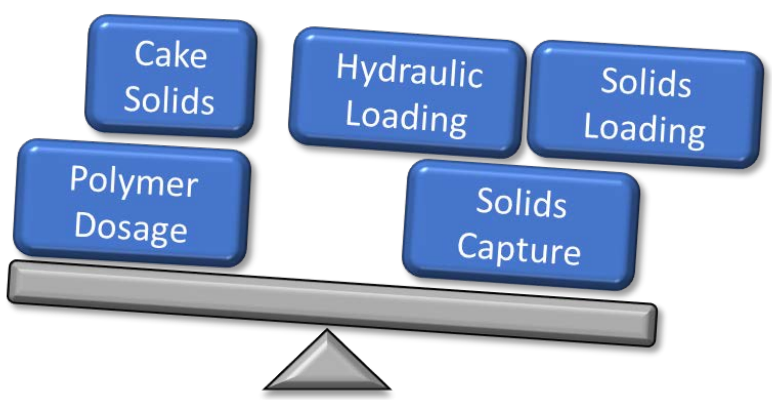

Figure 1. Optimization of Thickening and Dewatering Processes Is a Balancing Act
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- Solids capture is often overlooked as a parameter that can have a significant impact on the optimization of thickening and dewatering. It can also help improve the overall performance of the water resource recovery facility (WRRF).

What Is Solids Capture?

- Solids capture is the percentage of solids in the feed flow that ends up in the discharge (thickened/cake) solids. In other words, it is an indication of how "clean" the solids separation equipment is operating.
- Water separated from the discharge solids in the solids separation equipment is typically captured and returned for treatment in the liquid train. Depending on the process, this recycled water stream (also known in general terms as "return" or "sidestream") could be more specifically called filtrate, overflow, underflow, pressate, centrate, or permeate. This stream will be generically referred to as "filtrate" in this fact sheet, which is a common term used to represent this flow in the industry.
- Below is a generic diagram of the solids path through a WRRF with good solids capture (see Figure 2). If a large portion of the solids are not removed (low solids capture), then the exit path becomes a loop instead (as shown in Figure 3).

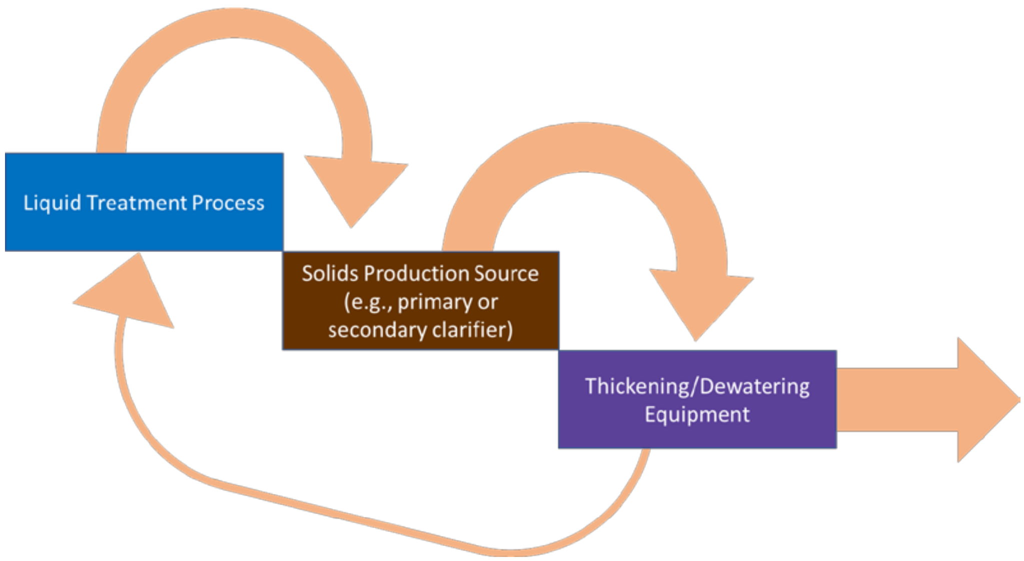

Figure 2. Diagram of Good Solids Capture
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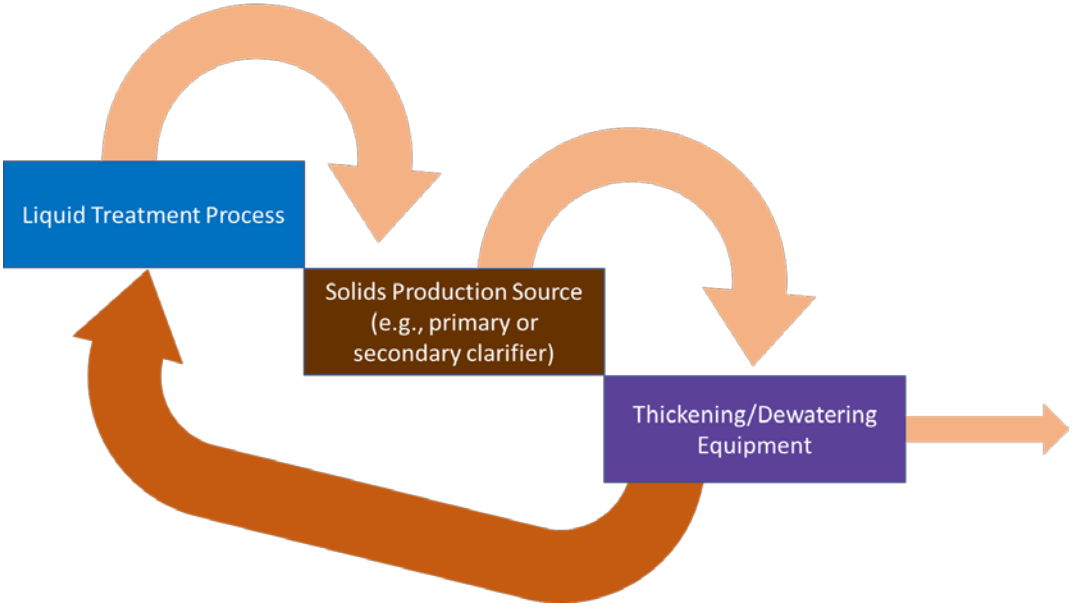

Figure 3. Diagram of Poor Solids Capture
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- The typical industry standard for solids capture is 90% for thickening equipment and 95% for dewatering equipment. This number has gone up over recent years as technologies and polymers have improved. When too many solids are being returned to the head of the plant (poor solids capture), the solids capture percent may be as low as 60% to 80%.

Why Is Solids Capture Important?

- Getting the solids removed efficiently the first time around saves money and headaches throughout the WRRF. If there is poor solids capture, solids will get recycled through the entire treatment process multiple times, requiring energy for pumping and re-treatment. As the solids are recycled, the particles become smaller and more difficult to settle. This causes additional chemical costs to aid settling; greater labor costs for additional equipment cleaning; and often causes other performance, operation, and maintenance issues within the WRRF.
- Often, the act of achieving high solids capture will automatically yield better results in the other areas of the WRRF.
    - When seeking to optimize the thickening or dewatering process, blindly focusing on one parameter, like polymer dose, can lead to adverse effects on the rest of the operations. For example, simply turning down the polymer dose without consideration of the other parameters will often lead to lower discharge (thickened/cake) solids, lower solids loading capability, and more solids recycled back to the liquid train for reprocessing.
    - Likewise, an attempt to increase discharge solids simply by turning up the torque (centrifuges) or pressure (belt filter presses and other filter presses) on the equipment will often yield detrimental effects on solids capture and maintenance costs.
    - However, focusing on solids capture to truly optimize the process as a whole can result in reducing polymer usage in addition to increasing the discharge solids.

- If WRRFs have been operating with poor solids capture, once an improvement is made to the solids capture, it typically takes several months for the recirculating solids to be removed because the entire WRRF is literally being "cleaned out."
    - When solids capture is poor, it is often the "fines," or other specific smaller particles that are not bound up well in the flocculated structure formed by the polymer. Those same smaller solids particles will be more difficult to capture the second time they go through the thickening/dewatering equipment, and the third time around, and the fourth, and so on.
- Small WRRFs are not exempt from this concern. Poor filtrate quality becomes especially important at smaller WRRFs where thickening and/or dewatering may only take place one or two days per week. In these cases, the filtrate returned to the head of the WRRF, in a short, concentrated burst, represents a larger percentage of the overall influent flow. Avoiding these spikes in overall solids, biochemical oxygen demand, and nutrient loading to the facility is a benefit of maintaining high solids capture levels.

Calculating Solids Capture

Full Equation

Equation 1 is the most complete calculation that can be used to determine percent solids capture (WEF Residuals and Biosolids Solids Separation Subcommittee, personal communication, 2021).

$$Percent\ Solids\ Capture\ (\%) = \frac{D}{F} \times \frac{F - (R \times \frac{Q+W}{Q})}{D - (R \times \frac{Q+W}{Q})} \times 100 \qquad (1)$$

Where:

Q = Flowrate to the thickening or dewatering equipment (gpm)

W = Wash water flowrate (gpm) plus polymer dilution water flowrate (gpm)

F = Feed solids concentration (percent total suspended solids by weight)

D = Discharge (thickened or dewatered) solids concentration (percent total suspended solids by weight)

R = Recycle flow stream (i.e., filtrate) solids concentration (percent total suspended solids by weight)

Note: Percent total suspended solids is measured as mg/L of total suspended solids and converted to percent by weight by dividing by 10 000.

When calculating percent solids capture, one must consider the types of solids being measured. Filters and centrifuges remove suspended solids. The dissolved solids are not removed by these devices. Ideally, the feed, discharge, and filtrate should be analyzed for suspended solids. Practically, laboratory methods are not able to provide this analysis with reasonable effort for higher solids samples, and total solids are measured instead. This skews the result but still provides comparative data.

For example: A feed solids concentration of 0.5% total solids that may contain 0.2% dissolved solids and 0.3% suspended solids is significant mathematically because 0.2%

dissolved solids of 0.5% total solids is 40%. If the feed solids concentration is 5% total solids and dissolved solids is 0.2%, the dissolved solids are only 4%, and the error may be considered reasonable. For cake, measuring total solids is acceptable because, for example, a 20% solid with 0.2% total solids results in minimal (1%) error.

Here is a sample percent solids capture calculation:

- If the flow rate to a rotary drum thickener *(Q)* is 1290 L/min (340 gpm),
- the wash water flowrate is 20 gpm and dilution water to create the polymer solution is 15 gpm, so the sum of these two flow rates *(W)* is 133 L/min (35 gpm),
- the feed solids concentration *(F)* is 0.75% total suspended solids,
- the discharge solids concentration *(D)* is 6% total solids,
- the filtrate solids concentration *(R)* is 300 mg/L, or 0.03% total suspended solids,
- then, using the equation provided, the solids capture is calculated to be 96.1%.

Simplified Equation if Flow Data Are Unavailable

Equation 2 is a simplified version of Equation 1 based on laboratory analysis only and can be applied to represent solids capture if flow information is not available. Equation 2 is the version provided by the Association of Boards of Certification (ABC) in the Formula/Conversion Table for use on ABC operation certification exams and is adapted from Equations 2.16 and 5.5 of *Wastewater Treatment Fundamentals II—Solids Handling and Support Systems* (WEF & ABC, 2021).

$$Percent\ Solids\ Capture\ (\%) = \frac{D}{F} \times \left[\frac{(F - R)}{(D - R)}\right] \times 100 \qquad (2)$$

Where:

F = Feed solids concentration (percent total suspended solids by weight)

D = Discharge (thickened or dewatered) solids concentration (percent total suspended solids by weight)

R = Recycle flow stream (i.e., filtrate) solids concentration (percent total suspended solids by weight)

(See notes under Equation 1, which are also relevant for Equation 2.)

Alternate Laboratory Method

Another basic method to track solids capture is to use the basic laboratory test tube centrifuge. Results can be obtained in 5 minutes or less by spinning similar volumes of the feed and the filtrate in separate tubes to compare the relative volumes of solids in each. The photo in Figure 4 shows filtrate on the left and feed solids on the right after laboratory centrifugation. The filtrate with no visible solids in the tip of the tube indicates greater than 99% capture. Although not as accurate as the equations, these spin tests provide quick feedback for equipment optimization.

Figure 4. A Laboratory Centrifuge Can Provide a Quick Indication of Solids Capture
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How Can Solids Capture Be Improved?

Document and Create Data Trends

- When optimizing full-scale thickening or dewatering, it is often best to document and create trends and take it step-by-step.
- First, make a data table or a spreadsheet and write down all of the settings and parameters that are associated with the operation of the solids separation equipment. This could include many data points, but make sure to incorporate at least the following:
  - Feed solids concentration,
  - Feed flowrate,
  - Discharge (thickened/cake) solids concentration,
  - Polymer flowrate,
  - Polymer concentration, and
  - Wash water flowrate (if applicable).
  - Operating parameters associated with the particular solids separation equipment should also be recorded. For example:
    - For belt filter presses, this includes the belt speeds and belt tension.

    - For centrifuges, this includes bowl speed, pond depth, differential speed, and torque.
    - For screw presses, this includes screw speed, inlet pressure, and cone pressure.

- Calculate the solids capture and include this information in the data table as the results.
  - As described in the previous section, calculating the solids capture will require the measurement and documentation of the suspended solids concentration of the filtrate.
  - It may be beneficial to also include a space in the data table to document a description and/or photos of the observation of the filtrate. See Figure 5 for a dramatic comparison of dirty versus clean filtrate. Other description words for poor quality filtrate could include the following: cloudy, gray color, polymer smell, or sticky feel.

Figure 5. Visibly Poor Filtrate (on Left) Compared to Visibly Clean Filtrate (on Right)
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- The act of recording all of the settings and results will often reveal a trend that points toward better optimization. It is not uncommon for there to be seasonal variations in the performance of solids separation equipment based on changes to the characteristics of the solids produced by the WRRF.
- Once the baseline data of the existing system is established, small changes (<10% at a time) to operational parameters can be implemented and results documented.

- The challenge is to only make one change at a time to determine the effect of changing only one variable and to let that change reach steady-state operating conditions before sampling and taking measurements.

Ideas Beyond Adjustments to Equipment Operations

- More significant changes can be implemented if the above approach does not produce satisfactory results. For example:
  - Consider physical/mechanical modifications to the solids separation equipment, such as tightening or changing the belt, selecting a different screen size for a belt or screw presses, or adjusting the weir height on a centrifuge.
  - Evaluate the frequency of intensive cleanings or other preventative maintenance. For example, the belt on a belt filter press can be cleaned periodically with a cleaning solution such as bleach. However, performance of the belt filter press may go down if the frequency of these cleanings is too often or too seldom.
  - Evaluate new and different polymers, which may allow the difficult, finer solids to be more effectively flocculated into larger, denser solids and more readily captured. If using dry polymer, evaluate the potentially greater effectiveness of emulsions, polymers with higher cationic charges and molecular weights, or branched and cross-linked polymer products. Conduct bench scale polymer trials to short-list a selection of products, and set up full-scale, side-by-side trials (if possible) to compare different polymer products in your equipment.
  - When evaluating polymers or optimizing existing polymers, be sure your polymer preparation equipment is functioning properly.
  - Find out from experts the recommended mixing and conditioning tactics to improve flocculation and solids separation. This may lead to the implementation of alternate polymer injection points to allow operational flexibility in the contact time of the polymer with the feed solids, improved injection and sludge/polymer mixing devices, or modifications to the polymer solution concentration or polymer aging system.
  - Consistency is key. The more consistent the feed solids and polymer solution flowrates can be, the easier it is for the thickening or dewatering process to be optimized. Variations in feed solids flow, percent solids concentration, or type of feed solids material can contribute to equipment running inefficiently. Adding a large well-mixed blend tank for blending solids streams can help maintain consistency in feed solids.
  - Remember that, because polymer molecules are designed to interact with solids molecules, polymer feed rates should be proportional to the solids loading rate, not the hydraulic loading rate.
  - If external materials, such as septage or grease, are added, the best solution is to slowly meter these materials in over a longer period instead of in surges. Once the certain feed characteristics are consistent, it is easier to optimize thickening and dewatering processes for the best performance. Also, centrifuges and filters don't like grease because it easily floats out with the centrate and clogs filter pores, so if grease is already separated, it is best to keep it out of your solids separation equipment.

Conclusions

- Spending a day or two every few months to focus on solids capture will pay off in the long run to optimize overall plant performance and save overall costs.
- For complete thickening or dewatering performance optimization, it is recommended that operators start by adjusting the solids separation equipment to obtain the cleanest possible filtrate and then look to optimize a single performance parameter while keeping other parameters as constant as possible.
- It is recommended that equipment settings be monitored and recorded while modifying and testing different operating parameters to find optimal settings and to use digital technology (e.g., photographs, videos, data logging) to document the results for future use.

Reference

Water Environment Federation & Association of Boards of Certification. (2021). *Wastewater treatment fundamentals II: Solids handling and support systems.* Water Environment Federation.

Suggested Readings

Bauer, H., Fritz, E., & Hanson, J. (2021). *Fundamentals of thickening and dewatering.* https://www.accesswater.org/

Bauer, H. & Kim, Y. (2020). *Understanding polymer for thickening and dewatering processes.* https://www.accesswater.org/?id=-10027753&fromsearch=true#iosfirsthighlight

Water Environment Federation; American Society of Civil Engineers; & Environmental and Water Resources Institute. (2018). *Design of water resource recovery facilities* (6th ed.); WEF Manual of Practice No. 8/ASCE Manuals and Reports on Engineering Practice No. 76. Water Environment Federation.

Water Environment Federation & Association of Boards of Certification. (2018). *Wastewater treatment fundamentals I: Liquid treatment.* Water Environment Federation.

Water Environment Federation, Water Environment Research Foundation, & U.S. Environmental Protection Agency. (2012). *Solids process design and management.* Water Environment Federation.

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