COMPARATIVE REVIEW OF MECHANICAL SLUDGE DEWATERING TECHNOLOGIES

An Analysis of Belt Filter Presses, Centrifuges, Screw Presses, and Rotary Fan Presses for Municipal and Industrial Wastewater Treatment Facilities

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EXECUTIVE SUMMARY

Effective sludge dewatering is essential for achieving operational efficiency and regulatory compliance at municipal and industrial wastewater treatment plants. The most successful technologies provide significant cost savings in the storage, transportation, and safe disposal of waste biosolids.

This paper presents a comparative analysis of four leading mechanical dewatering methods – the belt filter press, centrifuge, screw press, and rotary fan press. This information should assist decision-makers at municipal and industrial organizations, design engineers, and plant managers and operators responsible for optimizing wastewater treatment operations in evaluating their options and selecting the most suitable sludge dewatering technology for their needs.

For a summary of the relative characteristics of the four sludge dewatering technologies reviewed, refer to TABLE 1: SLUDGE DEWATERING SYSTEMS COMPARATIVE SUMMARY.

INTRODUCTION: THE STRATEGIC IMPORTANCE OF SLUDGE DEWATERING

Municipal and industrial wastewater treatment processes produce substantial amounts of biosolids in sludge form that must be treated and dewatered for final disposal or reuse. Sludge generally contains 95% to 99% water. The dewatering process decreases the volume of sludge, turning the dilute residuals into a semi-solid “cake,” which reduces storage, transportation, and disposal costs, and indirectly greenhouse gas emissions, while easing the load on landfill infrastructure.

Increasingly, options for sludge disposal are limited – land application on farms is declining due to stricter regulations and liability concerns, especially for industrial sludges. Landfill acceptance and incineration face increasingly strict environmental regulations and higher fees. Other factors influencing sludge dewatering considerations:

- Environmental regulations set limits on sludge quality by evaluating pathogen levels, vector attraction, and emerging contaminants. Facilities are often required to produce drier, more stable cake to meet Class A and B biosolids standards or to decrease leachate in landfills.

- Economics must make sense – In North America, sludge disposal costs typically range between $40 and $120 per wet ton, depending on distance to disposal sites and local tipping fees. Improving dewatering by even one or two percent of dry solids can save thousands of dollars annually in transport and tipping fees. Over a 15 to 20-year operational period, the choice of dewatering technology can make a multi-million-dollar difference in lifecycle costs.
- Treatment facilities aim to enhance sustainable operations by reusing water and reducing the energy and chemicals used in treatment. Drier cake means less “free water” waste and more filtrate that can potentially be recycled for plant use.
- The wastewater treatment industry faces a shortage of experienced operators to replace those retiring. Modern dewatering equipment should be automated, safe, and easy to learn and operate with minimal oversight. Older, labor-intensive, or finicky technologies can pose reliability risks in understaffed plants. Equipment with high-speed rotating parts or exposed moving components can create a safety concern for operators, whereas enclosed, low-speed systems significantly reduce this risk.

Decision-makers such as utility and industrial managers, consulting engineers, and plant operators must carefully evaluate which dewatering technology best matches their specific sludge characteristics, facility size, budget, operational expertise, and regulatory requirements now and in the future.

COMPARATIVE ANALYSIS OF DEWATERING TECHNOLOGIES

The four technologies discussed in this paper each have long histories. The belt filter press was introduced in the 1970s, while the centrifuge was developed more than 70 years ago. The screw press has been used in pulp, food, and sludge handling for approximately 40 years. The relatively new rotary fan press was introduced around 2000 and is now used by hundreds of municipal and industrial facilities. Each dewatering technology is assessed based on:

1. Performance: Solids capture rate, cake dryness, and throughput
2. Energy and polymer use: Typical kWh/dry ton and polymer consumption
3. Operation and maintenance: Level of operator oversight, reliability, and maintenance intensity
4. Footprint and enclosure: Size requirements, odor, and noise control
5. Lifecycle cost: Capital expense, installation, energy, labor, and maintenance over 20 years.

1. BELT FILTER PRESS

The belt filter press (BFP) is a reliable technology thanks to its simple design and continuous sludge dewatering capability. During operation, sludge is first flocculated with polymer and spread onto a belt where water drains under gravity. It then enters a wedge zone where the sludge is confined between an upper and lower belt, gradually increasing pressure on the sludge. Next, the sludge moves through a series of rollers that further compress the belts together, squeezing out water through shear and pressure. The filtrate (water) passes through the belt fabric and is collected, while the dewatered cake is scraped off at the discharge end. Spray nozzles continuously clean the belts to prevent pore clogging.

BELT FILTER PRESS, COURTESY OR-TEC

PERFORMANCE METRICS

- **Cake Solids**: Cake solids typically range from 15-25% for municipal sludge. Waste activated sludge (WAS) usually produces about 16% solids, while primary sludge can produce 26-35%+ dry cake solids. These levels satisfy most landfill requirements.[1]

[1] https://www.thembrsite.com/belt-filter-presses-sludge-dewatering

- **Solids Capture**: The amount of feed solids retained in the cake is typically in the range of 80-95%,[2] and the filtrate is often recycled. Measuring solids capture is challenging due to the need for continuous wash water applied to the belts.
- **Throughput**: BFPs can process approximately 100-500 lb of dry solids per hour per foot of belt width, depending on feed concentrations and characteristics.[3]
- **Energy Use**: BFPs typically consume 10-25 kWh per dry ton of solids produced, depending upon sludge characteristics and polymer addition.[4]
- **Polymer Use**: Polymer demand ranges from moderate to high, at 4-20 lb per dry ton, with lower usage for primary sludge, blended primary/WAS, and mixed digested sludge.[5] Anaerobically digested and membrane bioreactor WAS requires the highest polymer dosing.
- **Operation and Maintenance**: Although BFPs are mechanically simple and their technology is generally well understood and familiar to in-house operators, they require ongoing monitoring and daily inspections.[6]
    - Routine cleaning is essential for reducing odors and corrosion. Wash water is a significant operating cost because BFPs require a continuous spray on the belts to prevent clogging, and this wash water is often filtered final effluent that must be reprocessed.
    - Operators must ensure that belts track properly and the sludge feed is conditioned correctly. Poor polymer conditioning can cause wet cake or sludge to overflow the belts. Automated sensing of sludge conditions often fails to detect poor flocculation in the sludge mixture in time to prevent spills.
    - Maintenance involves cleaning belts and plows, adjusting belt tension and tracking systems, inspecting the wash water system, lubricating bearings regularly, and replacing worn parts such as belts, rollers, and doctor blades (scrapers).
    - Belt replacement can range from 400 to 12,000 hours, with an average of 2,700 hours. If a belt tears or a scraper fails, the machine must shut down to prevent sludge spillover or "blinding" the belt. Start-up and shutdown of BFPs can be completed within minutes, allowing for intermittent operation for a few hours each day if necessary.

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[2] https://www.waterandwastewater.com/belt-filter-press-for-wastewater-treatment

[3] https://handwiki.org/wiki/Chemistry%3ABelt_filter

[4] https://www.suezwaterhandbook.com/processes-and-technologies/liquid-sludge-treatment/belt-filters/introduction

[5] https://www.wef.org/contentassets/d06e8efba3d14274ade7dfd3258188ed/manual-of-good-practice-for-biosolids-v2011.pdf (Table 5.3)

[6] https://porvoo.com.cn/blog/belt-filter-press-maintenance-complete-process-guide/

- **Footprint and Enclosure**: BFPs generally require a large installation space. The machinery can be several meters long to accommodate gravity drainage and multiple roller stages. Ancillary equipment, such as polymer make-up units, sludge feed pumps, belt wash water pumps, and often a dedicated conveyor or chute for cake discharge, increases the footprint. BFPs are usually installed in open areas or poorly enclosed environments that require odor containment systems, such as hooding or ventilation.

- **Adaptability and Limitations**: BFPs can process several types of sludge, including raw, digested, and mixed. They can handle fluctuations in throughput by adjusting belt speed or the number of presses in use. They work best with sludge that contains some fibrous or primary solids. Handling pure WAS can be challenging for BFPs unless it is mixed with primary sludge or pre-thickened. BFPs require a steady feed rate to prevent issues like belt fouling or insufficient dewatering in the dewatering zones. From an environmental and safety perspective, BFPs are open systems. Without enclosures, they emit odors and aerosolized biosolids into the dewatering area. Using enclosures or odor control hoods can lower these risks but may increase costs and require more space. Noise levels are moderate, mainly from motors, gearboxes, and spray pumps. Operators should be cautious to avoid moving parts and pinch points from rollers, belts, and plows, although guards are typically installed.

- **Cost of Ownership:** BFPs are often a low capital cost per dry ton option, making them attractive for budget-constrained projects. Capital costs in the hundreds of thousands of dollars and operating costs ranging from $15-25 per dry ton, including energy, chemicals, and maintenance,[7] can add up over a 20-year operational period – the total ownership costs rise considerably due to labor oversight and downtime needed for operation and maintenance.

2. CENTRIFUGE (DECANTER CENTRIFUGE)

Centrifuges dewater sludge by spinning rapidly (2,000-4,000 RPM) to separate solids from water using centrifugal force. Sludge is fed into the center of the rotating bowl, flinging the denser solids to the outer edge of the bowl, forming a ring of cake, which is then scrolled to the discharge. The clarified liquid (centrate) flows out through ports at the opposite end of the bowl. Polymer is added to the feed to flocculate fine particles for improved solids capture.

Centrifuges operate as continuous flow units and can handle high throughput within a compact design. They often feature multiple settings to optimize performance, such as adjusting bowl speed to vary the G-force, scroll differential speed to control how quickly solids are removed

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[7] https://sludgedryer.in/sludge-dewatering-techniques/

relative to liquid, feed rate, and pond depth (the liquid level in the bowl). The entire process is enclosed within a steel casing to contain noise, splashing, and odors.

Decanter centrifuges are the preferred choice for large wastewater treatment plants because they can handle high volumes and generate relatively high cake solids.

CENTRIFUGE SYSTEM, COURTESY CENTRISYS CNP

PERFORMANCE METRICS

- **Cake Solids**: Centrifuges can achieve cake solids ranging from 22-35% or higher for primary/WAS mixtures, depending on feedstock and polymer addition.[8] Raw and digested WAS are more challenging, reducing the cake solids to 16%-21+%[9] with proper polymer conditioning.
- **Solids Capture**: Typically, centrifuges can achieve 95-98% capture with optimized polymer dosing.[10]
- **Throughput**: A medium-sized centrifuge used in municipal wastewater applications can produce approximately 0.5-3 dry tons per hour at infeed sludge flows of 100-300+ USGPM.[11,12] Large facilities often operate centrifuges to manage high solids capacities in relatively short run times.

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8 https://www.thembrsite.com/centrifugal-sludge-dewatering
9 https://www.epa.gov/sites/default/files/2018-11/documents/centrifuge-thickening-dewatering-factsheet.pdf
10 https://fwrj.com/techarticles/0619%20tech3.pdf
11 https://www.flottweg.com/fileadmin/user_upload/data/sewage-sludge-references-pdf/Kundebericht-MP-Entwaesserung-KA-Buehl-C4E_eng.pdf
12 https://www.andritz.com/products-en/separation/decanter-centrifuges/decanter-centrifuges

- **Energy Use:** Typical municipal decanter centrifuges employ primary drive motors ranging in size from 50-250 HP and scroll drives motors of 10-50 HP. In municipal pilot tests, energy consumed by the centrifuges deployed ranged from 58-80 kWh per dry ton[13], whereas other studies report around 80-90 kWh per dry ton assuming 2% solids feed sludge[14].
- **Polymer Use:** Due to strong forces and short residence time, polymer application is relatively high to achieve effective flocculation that can withstand centrifugation without breaking apart. Polymer use may vary from 5-30 lb of active polymer per dry ton, using less for undigested primary sludge and more for mixtures and straight WAS sludge.[15] Some operators add coagulants or use two-stage polymer dosing to improve performance.
- **Operation and Maintenance**: Decanter centrifuges require experienced operators for startup, balancing, and maintenance.
    - Starting a centrifuge takes time – the bowl must gradually reach speed, and sludge feed is added carefully to prevent imbalances. Shutting down involves decelerating and flushing to remove solids. As a result, frequent on-off cycles are impractical — centrifuges are usually operated for longer shifts or run continuously for maximum efficiency.
    - Automation is often used to adjust the feed pump speed based on torque, and newer machines will trigger alarms for out-of-range vibration or high torque to prevent damage. For example, if the cake discharge gets clogged, a torque overload will shut down the machine. However, centrifuges may not detect suboptimal conditions that don't threaten the machine. If the polymer stops, centrate solids might increase due to poor capture, but the machine may not alarm since no overtorquing is detected, and it may continue operating while producing inferior quality output. It is important that operators consistently monitor centrate clarity and cake quality, although the machines require minimal supervision when operations are stable.
    - The machines are durable, but the abrasive nature of sludge under high G-force causes significant wear on the rotating assembly (bowl and scroll). These parts must be periodically rebuilt or replaced by specialized technicians at the factory or certified repair facility who can meet stringent tolerances. Rebuilding a centrifuge (replacing the scroll conveyor, bearings, seals, etc.) is a major overhaul, often done every few years of operation. Bearing failures or scroll

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[13] https://www.tampa.gov/sites/default/files/rfq/attached/migrated/6of8-pilot_testing_report_-_final1.pdf
[14] https://www.sciencedirect.com/science/article/pii/S2590174524000746
[15] https://www.epa.gov/sites/default/files/2018-11/documents/centrifuge-thickening-dewatering-factsheet.pdf

damage usually require the machine to be offline for weeks or months, awaiting parts. The risk of such downtime makes redundancy essential.

    - Routine maintenance includes lubrication (these machines often have an oil bath or grease points for bearing and gearbox lubrication), regular vibration monitoring, and periodic replacement of wear plates on the scroll.

- **Footprint and Enclosure**: A decanter centrifuge has a more compact footprint compared to belt filter presses for the same throughput. A single decanter unit with its base and frame may occupy only a few square meters. However, these machines are heavy (the rotating assembly and thick casing can weigh several tons) and generate significant vibrations, so they require a sturdy concrete foundation or platform.
    - Ancillary equipment will include a large drive motor (tens or hundreds of horsepower), a backdrive or scroll motor, lubrication systems, vibration monitoring, and controls. They are often installed on elevated structures to allow gravity discharge of cake into bins or conveyors below.
    - Special consideration must be given to dampen vibration and manage the dynamic loads associated with centrifuges operating at high speeds.
    - Since these machines are fully enclosed, odors, spills, and aerosol concerns are contained. However, they are loud, producing noise levels of 85 to 95 dBA or higher, so soundproof enclosures or installing them in dedicated rooms might be necessary.
- **Adaptability and Limitations:** Centrifuges can process a wide range of sludges, from raw primary to digested biosolids and various industrial sludges, assuming the materials are compatible. They work very well on sludges with solids that are significantly heavier than water. Pure secondary (biological) sludges, which are often light and gelatinous, are harder to dewater, but with proper polymer conditioning, they can still achieve decent results.
    - From a scalability perspective, large plants handling flows exceeding 20 MGD have traditionally favored centrifuges because of their high throughput and space efficiency, which offset the higher CAPEX/OPEX.
    - From a safety perspective, centrifuges are high-energy machines – if a catastrophic imbalance occurs due to a dense object or severe wear, it can cause considerable damage. Guards and interlocks prevent operator contact during operation, and there are no open and accessible belts or moving parts during normal use.

Cost of Ownership: Centrifuges are costly, often exceeding one million dollars per unit when installation, electrical systems, enclosures, and ancillary equipment are included. Over a 20-year lifespan, operating and maintenance expenses – particularly power costs and repairs – can surpass the initial purchase price, making the total lifecycle costs of centrifuges among the highest in the industry.

3. SCREW PRESS

The screw press is a slow-speed, compact, enclosed dewatering technology often preferred by small to medium-sized treatment plants and decentralized installations. Originally adapted from the pulp and paper industry, it has gained strong acceptance in water and wastewater applications over the past several decades.

The device uses a screw auger that typically runs at 1-3 RPM to move and press sludge through a cylindrical screen. Flocculated sludge is fed into a vertical or inclined screened drum containing a rotating screw. The screw pushes the sludge through a gradually narrowing screen, creating pressure that forces water through the screen along the length of the drum, while the solids are carried to the discharge end. A backpressure plate or adjustable cone at the outlet offers extra resistance to form a plug of dewatered cake.

SCREW PRESS, COURTESY HUBER TECHNOLOGY

PERFORMANCE METRICS

- **Cake Solids**: Screw presses typically achieve cake solids levels of 15-25%+,[16,17] with the lower values reflecting WAS dewatering results and the higher end typical of primary sludges or those with fibrous content.
- **Solids capture rates:** Screw presses commonly achieve a solids capture rate ranging from 90-98%.[18] WAS and other sludges with fine biological flocculation can break down when sheared and squeezed by the screw mechanism, allowing more solids to pass through the screen with the filtrate.
- **Throughput**: Screw presses process sludge at a slower rate than centrifuges or BFPs, but they are highly predictable when the sludge and polymer dosing are well matched. Throughput varies with machine size, and typical ranges for small to large machines range approximately 40-2,000 lb per hour of solids,[19] scaling with screw diameter and sludge feed concentrations (0.5-2% solids being common). Screw presses are better suited for smaller treatment facilities.
- **Energy and Chemical Use**: Screw presses are among the most energy-efficient dewatering systems available, typically using 5-18 kWh per dry ton[20,21]. Polymer requirements can be 10-30+ lb per dry ton of solids.[17,22] The higher range is typically associated with oily or filamentous feedstock.
- **Operation and Maintenance**: Since these are low-speed machines, there is minimal wear, and they require little maintenance.
    - Augers and screens typically last five to ten years, depending on how abrasive the feed material is. Repair and replacement downtime is usually brief – generally completed in one day.
    - Cleaning is often done intermittently and automatically with internal spray bars to prevent the screen from blinding.
    - Operation produces minimal vibration and noise (around 60 dBA), making screw presses ideal for indoor or residential-adjacent environments.

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[16] https://www.nihaowater.com/news/screw-press-vs-filter-press-a-comprehensive-guide-to-sludge-dewatering.html

[17] https://sludgedryer.in/belt-filter-press-vs-screw-press-dewatering-the-ultimate-guide-for-efficient-sludge-management/

[18] https://www.newea.org/wp-content/uploads/2020/02/27.-AC20_MBurns.pdf

[19] https://www.andritz.com/products-en/separation/drains-presses/c-press-screw-press

[20] https://www.envirep.com/volute-dewatering-press-dewater-sludge-efficiently/

[21] https://www.mivalt.cz/en/news/dewatering-screw-press-vs-centrifuge-energy-consumption-durability-and-noise-level-comparison

[22] https://www.wwoa.org/images/pdf/presentations/Annual_Conf_Presentations_2015/32_VCW_WWOA_Annual_Meeting_-_Dewatering_Evaluations-_October_2015.pdf

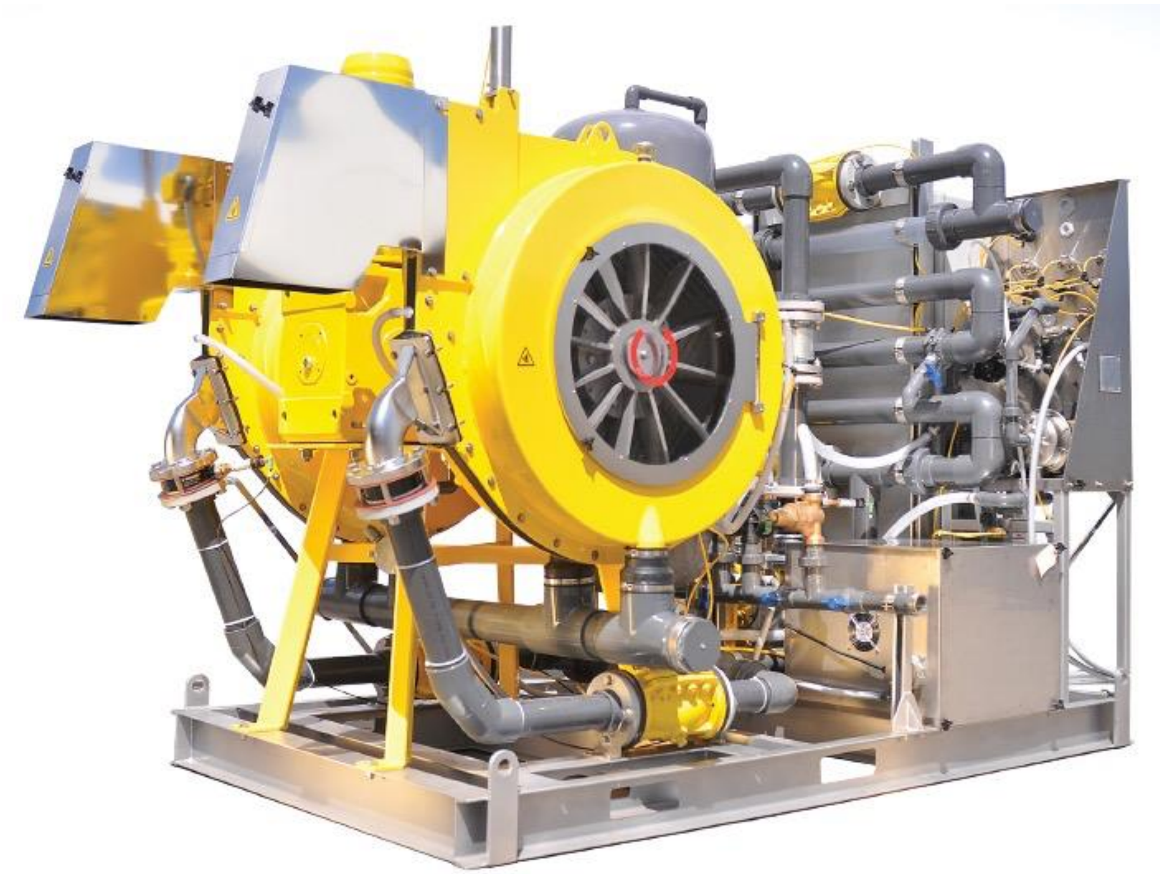
    - Once the press is dialed in and running automatically, remote monitoring can minimize operator oversight. Screw presses can be easily adjusted or turned off and are ideal for intermittent or batch operation lasting a few hours.
- **Footprint and Enclosure**: Screw presses are more compact than BFPs and generally smaller than centrifuges. They are fully enclosed, which significantly reduces odors and mess. They are often installed in small buildings or on mobile skids that include their auxiliary components, such as the polymer system, feed pump, and controls.
- **Adaptability and Limitations**: Screw presses are especially suitable for small to mid-sized treatment facilities to dewater primary or mixed sludges that are easier to process.
- **Cost of Ownership**: Screw presses are ideal for facilities that prioritize simplicity, low cost, and ease of use, even if it means accepting lower throughput capacity, solids capture, and cake dryness compared to belt filter presses or centrifuges.
    - Typical installed costs are much lower than those of belt filter presses and centrifuges. Operating costs may be about half of a BFP over 20 years.
    - Minimal maintenance needs fewer spare parts and less downtime.
    - Reduced operator oversight lessens staffing demands.

4. ROTARY FAN PRESS

The rotary fan press (RFP) is an innovative low-speed dewatering technology that moves sludge through a narrow circular path between two rotating screens, using pressure and friction to extract water. Introduced at the turn of this century, the RFP was designed to bridge the gap between belt filter presses and centrifuges, offering the compact size of a centrifuge with the low energy consumption of a BFP.

Polymer-conditioned sludge is fed into the annular space between two parallel porous screens housed in a drum or cylindrical container. These screens rotate very slowly (often less than one RPM), effectively acting like moving “fan blades” that convey the sludge along. As the sludge progresses through the channel, a pressure differential develops – the inlet side has lower pressure, and the outlet, which is restricted by an adjustable gate, becomes the high-pressure side. Water drains through the screens while the solids concentrate inside. The outlet restrictor gate is adjustable and creates backpressure to form a cake plug of solids. This cake plug, pressing against the screen walls, creates friction that helps squeeze water out.

Periodically or continuously, a scraper or a set of fixed combs cleans the screens from the inside to prevent blinding, and at shutdown, the unit can perform an in-place wash cycle by flushing water while rotating. The entire process is enclosed in a tight housing, preventing odors and mess from escaping.



DUAL-CHANNEL ROTARY FAN PRESS, COURTESY PRIME SOLUTION, INC.

The RFP operates in a semi-continuous mode, where sludge feeds in and cake exits continuously. Due to the slow rotation, the sludge spends a relatively long time being dewatered within the channel, which enhances dryness and improves solids capture. RFPs are often operated in parallel, providing multiple dewatering channels within one unit to increase throughput.

PERFORMANCE METRICS[23]

- **Cake Solids**: Typical cake solid concentrations from primary municipal waste sludge range from 28-38% and 20-32% for primary + secondary mixed sludge. WAS and digested sludges are somewhat more challenging, but the RFP can achieve 15-22% cake.
- **Solids capture**: High, typically 92-98% due to the long dewatering path and gentle handling. This performance remains consistent across municipal, food processing, pulp and paper, and some oil-bearing sludge streams.

[23] https://www.tpomag.com/uploads/downloads/Prime-Solution-Sell-Sheet-RFP_2024_FIN.pdf

    - The resultant one-pass filtrate from RFPs can be clean enough in some applications to be reused as plant wash water or other non-potable needs directly.
- **Throughput**: The modular design of RFP dewatering systems allows scaling as sludge flows increase. Adding more channels to a machine enables RFPs to handle flows similar to those of large centrifuges and process throughputs ranging from 225-6,000 lb of dry solids per hour.
- **Energy and Chemical Use**: With its slow rotation speed and small drive motors, the RFP consumes the least energy among mechanical dewatering options for the same throughput, approximately 4-12 kWh per dry ton.
    - Polymer usage is in the 4-15 lb/dry ton, similar to that of a belt filter press and generally lower than what centrifuges require.
    - Water use is low because the RFP relies on water only for periodic automatic wash cycles, unlike continuous belt showers used for belt filter presses.
- **Operation and Maintenance**: RFPs require very little maintenance and exhibit high uptime. These machines are engineered for fully automated and unattended operation, using a PLC controller with a touch screen. During shutdown, RFPs can automatically run a clean-in-place wash cycle to flush out remaining sludge and clean the screens for the next start. Standard maintenance involves replacing the screen scrapers after extended use and performing periodic oil changes on the drive system. Bearings are sealed either behind the gearbox or outside the sludge channel, preventing grit and slurry from contaminating them.
    - The gearbox is the primary mechanical component, and changing the gear oil every 10,000 operating hours is the main service requirement. This work, and replacing scraper blades, can be completed quickly by in-house staff.
    - There are no belts to align or replace, no high-speed bearings to maintain, and no scrolls or rollers that need regular rebuilding.
    - RFPs can operate even when scraper blades are quite worn and need replacing. In such cases, more frequent wash cycles can keep the screens clear without shutting down the machine. Conversely, belt filter presses and centrifuges must be shut down immediately if a belt or blade fails or if the operation falls out of spec. RFPs allow maintenance to be scheduled at convenient times, significantly reducing their downtime.
    - The RFP control system monitors internal pressure differential to assess operational status. If feed solids decrease or polymer dosing drops, the sludge will not flocculate and offer resistance, causing a pressure drop. This pressure drop will automatically trigger the RFP to shut off or idle instead of running

ineffectively. The RFP safeguards itself from operating out of specifications and prevents messes or off-spec filtrate, making it essentially a “set and forget” system compared to competing technologies.

- **Footprint and Enclosure**: A hallmark of the RFP is its compact footprint, usually a fraction of the size of an equivalent belt filter press and often smaller than a high-capacity centrifuge. RFPs are ideally suited for installation in tight spaces or existing buildings without the need for expansion.
  - Being modular and expandable, additional dewatering channels can often be added to the frame or bolted on to increase throughput without buying an entirely new machine.
  - RFP systems typically include the polymer feed system, a sludge pump, and a sludge thickener upfront (if needed), all skid-mounted or trailer-mounted to simplify installation.
  - Being a fully enclosed system, odor and spill control are built into the design – no extra hooding or ductwork is needed. Additionally, there are no dangerous exposed moving parts.
  - Noise is a negligible factor (approximately 55 dBA) due to the slow rotation, small motor, and gentle dewatering action.
- **Adaptability and Limitations**: The RFP has proven versatile across a wide range of sludge conditions. It is designed to handle tough sludges like WAS that other devices struggle to dewater. RFPs are used to dewater raw and digested sludges (both aerobic and anaerobic), thickened WAS, and various industrial slurries from food processing, pulp and paper, and more. Multi-channel designs and larger diameters up to 48 inches allow modern RFP systems to manage large plant flows by operating in parallel. Major city facilities have successfully operated RFP installations, replacing centrifuges.
- **Cost of Ownership**: While the capital cost of RFPs may be similar to screw presses, the RFP offers better long-term value due to lower energy costs, often higher capture efficiency, and minimal maintenance and downtime. Typical 20-year ownership costs are 25-50% lower than centrifuges and 15-30% lower than belt filter presses, depending on local energy and labor rates.

For a summary of the relative characteristics of the four sludge dewatering technologies reviewed, refer to **TABLE 1: SLUDGE DEWATERING SYSTEMS COMPARATIVE SUMMARY** following.

TABLE 1: SLUDGE DEWATERING SYSTEMS COMPARATIVE SUMMARY

CRITERIA	BELT FILTER PRESS	CENTRIFUGE	SCREW PRESS	ROTARY FAN PRESS
TYPICAL CAKE SOLIDS	**~16%** (WAS) to **~30+%** (primary). Moderate for digested sludge **~18-25%.**	**~22-35%** on mixed primary/digested sludges; **~16-21%+** on WAS.	**~15-25%** for primary/mixed sludges. WAS often limited to high teens without fiber content.	**20-32%** on primary/secondary mix, **15-22%** on WAS.
SOLIDS CAPTURE	**<90%** is common, may be higher with proper polymer conditioning (filtrate often recycled). Can drop to ~75–85% if not optimized.	**95-98%** with proper polymer – produces clean centrate. Pushing for drier cake may reduce capture slightly.	**~90-98%**. Tends to be lower than belt press on WAS, as fine solids can pass through screen if floc breaks.	**92-98%** capture. Exceptional filtrate clarity – often no need to recycle.
THROUGHPUT CAPACITY	**Moderate** – one unit can handle medium flows (e.g. 100-500 lb dry solids/h/ft belt width). Multiple units needed for large plants.	**High** – single unit can handle large flows (e.g. 100–300+ GPM feed). Suited for big facilities (20+ MGD plants).	**Low-Moderate** – lowest per-unit capacity. Often used in small/medium plants or multiple in parallel for higher flows.	**Moderate-High** – modular design allows scaling. Multi-channel units handle significant sludge flows (systems now accommodate 300+ GPM like large centrifuges).
FOOTPRINT	**Large.** Requires extensive floor space for press, sludge conditioning, conveyors. Often a dedicated room; may need odor enclosures.	**Moderate**. Compact machine but needs heavy support structure and vibration isolation. Usually installed on platform with space for maintenance.	**Small**. Very compact skid-mounted unit. Fits in tight spaces, minimal extra infrastructure. Easy retrofit into existing buildings.	**Smallest**. Ultra-compact, low-profile unit. Fits existing spaces without expansion. Can often be added without new building; expandable within same footprint.
ENERGY USE	**Moderate.** Dewatering component requires only a few HP, but continuous wash water requirement adds significantly to energy consumption.	**High.** Large motors (tens to hundreds of HP); high G-force = highest energy consumption and carbon footprint. Significant ongoing power cost.	**Low.** Slow 1-5 HP drive; minimal power needed. One of the lowest energy demands per ton dewatered.	**Lowest.** Small motors (often <10-15 HP total). Most energy-efficient option.
POLYMER USE	**Moderate**. Typically requires polymer dosing (e.g. 4-20 lb/dry ton). Primary sludge needs low polymer, WAS needs the most.	**High.** Often needs higher polymer dose to achieve good capture (5-30 lbs/dry ton). Optimizing polymer is critical for performance.	**Moderate.** Similar to belt filter press for many sludges. May need more polymer for WAS to boost capture. Gentle action can reduce shear on flocs.	**Moderate.** Similar to the belt filter press. Low-shear and long residence can preserve flocs, potentially lowering polymer for equal capture. Polymer demand not significantly different from other options, but excellent capture maximizes its effectiveness.
MAINTENANCE	**Frequent upkeep.** Belts, rollers, and scrapers wear and need regular replacement. Requires daily cleaning of belts, tracking adjustments. Most maintenance can be done by onsite staff, but downtime for belt changes etc.	**Complex and heavy.** Requires specialized maintenance (scroll/bowl rebuilds off-site). Bearings, seals, etc. have limited life under high stress. Unexpected failures can cause months-long downtime for parts.	**Simple and low**. Few moving parts; slow speed causes minimal wear. Occasional screen cleaning, screw/ring wear over years. Maintenance largely handled in-house. Must stop to clean if screen clogs. Overall low downtime.	**Minimal.** Arguably the lowest maintenance of all. No high-wear components; change scrapers periodically, gearbox oil ~10,000 hrs. Bearings sealed/protected. Rare unplanned downtime – maintenance can be scheduled conveniently.

CRITERIA	BELT FILTER PRESS	CENTRIFUGE	SCREW PRESS	ROTARY FAN PRESS
OPERATOR ATTENTION	**High.** Needs frequent monitoring during operation (belt tracking, cake thickness, polymer feed) to prevent upsets. Normally cannot be left unattended for long.	**Medium-High.** Demands skilled operators to adjust settings (speed, torque) for optimal results. Continuous monitoring of centrate and torque. Often staffed or remotely monitored closely.	**Low-Moderate.** Simple start/stop. Can be automated to run with little intervention once dialed in. Lacks advanced sensors – might not detect issues like polymer loss immediately. Periodic checks recommended.	**Low (highly automated).** Designed for unattended operation. PLC controls and sensors (pressure and torque) detect issues and self-correct or shut down safely. Operator typically spends only minutes to start and then the system runs itself. Remote alerts enable off-site monitoring.
NOISE AND VIBRATION	**Moderate noise, low vibration**. Motors/gearbox create some noise, but generally ~70-80 dB range. Little vibration. Often acceptable in general plant area (may require some hearing protection nearby).	**High noise, high vibration**. Loud (often requires dedicated noise abatement). Difficult to converse near running centrifuge. Vibrations necessitate structural isolation. Hearing protection needed for prolonged exposure.	**Low noise, negligible vibration**. Quiet operation – often described as a low hum. No significant vibration due to slow speed. Very operator-friendly acoustically.	**Minimal noise, no significant vibration.** Extremely quiet (one can talk next to it). No vibration issues (slow rotation). Likely the quietest option, improving work environment and eliminating need for soundproofing.
ODOR AND HOUSEKEEPING	**Open system – potential odors**. Unless enclosed or ventilated, odors from sludge on belts can escape. Requires continuous wash water – area can be wet/slippery; needs regular cleaning.	**Enclosed – low odor.** Sealed process keeps odors in; only cake and centrate discharge emit a minor smell. Generally easy to ventilate casing exhaust if needed. Housekeeping confined to occasional centrate spills.	**Enclosed – low odor**. Sludge is enclosed in screen drum; minimal odor release, aside from cake outlet. Little water mess (only some filtrate); area stays clean.	**Totally enclosed – no significant odor**. Sludge is contained within press housing. Odor emissions are negligible; any vent air easily captured. Clean operation – automated wash cycle keeps unit clean.
SAFETY	**Moderate risk**. Exposed moving belts/rollers pose pinch-point hazards; strict precautions needed for maintenance. Spray water and slippery floors can be hazards.	**Moderate risk.** High-speed rotating assembly is enclosed, so low risk during normal operation. However, handling heavy parts for maintenance is a safety concern. Vibration or imbalance events could be dangerous (contained by casing).	**Low risk.** Slow-moving parts inside a closed drum ensures a very low injury potential. Minimal pinch points; just need standard lockout for maintenance (e.g. if opening covers).	**Very low risk.** No high-speed parts, no external motion. Fully enclosed – no operator exposure to moving elements. No risk of high-pressure sprays or flying debris. Minimal safety requirements (basic electrical and mechanical lockout during service).
TYPICAL CAPITAL COST	**Low-Moderate.** Generally, one of the lower upfront costs per volume. Simpler tech, many suppliers. However, large units or full systems (with conveyors, enclosures) add cost.	**High.** Most expensive option initially. High-grade materials, complex fabrication, and installation requirements drive up cost. Often justified only at large scale due to economies.	**Low-Moderate.** Equipment cost is relatively low due to simple design. Competitively priced for small plants. Larger systems need multiple units, increasing total cost (but often less than centrifuges).	**Moderate.** Upfront cost per unit is competitive, similar to or slightly more than belt/screw of equal capacity. However, savings in building size (smaller footprint) can reduce overall project cost.

CRITERIA	BELT FILTER PRESS	CENTRIFUGE	SCREW PRESS	ROTARY FAN PRESS
OPERATING COST	**Moderate.** Low energy cost, but notable ongoing costs for polymer and belt replacements and parts. Labor cost can be significant due to operator attention and maintenance. Overall lifecycle cost considered one of the lowest, but that gap closes if labor is scarce.	**High**. High energy consumption and polymer use drive up costs. Maintenance and parts (bearings, rebuilds) are expensive periodic outlays. Requires skilled labor or service contracts. These factors make centrifuge total OPEX highest of the group.	**Low.** Minimal power use and modest polymer result in a low utility cost. Spare parts usage is low (occasional screw or screen servicing). Labor cost is low since minimal monitoring/maintenance. Overall, very economical OPEX.	**Lowest**. Low energy usage and low wear part replacement frequency make for minimal operation and maintenance costs. Polymer use is similar to others. Labor need is minimal. Rarely any costly repairs. Many cases see major savings by switching to RFP (e.g. lower hauling due to drier cake, less downtime).
BEST APPLICATION	**Mid-sized municipal plants** with combination sludge (primary + WAS) where space is available and operators are on hand. Also suitable for industries with consistent sludge that need a proven, straightforward solution.	**Large wastewater plants** (>20 MGD) that demand high throughput in limited space and have budget for higher OPEX and skilled staff. Good for facilities aiming for maximum solids reduction and already equipped for centrifuge operation.	**Small to medium plants** that value simplicity, low cost, and quiet operation. Ideal for facilities with limited utilities or staffing (e.g. rural municipalities, food processing). Performs best when some fiber or primary solids present (or after aerobic digestion).	**Wide range of plants**, from small to large. Particularly advantageous for plants with mostly WAS or variable sludge, facilities with limited operator staff, and those needing to fit equipment into tight spaces. Often the top choice where energy efficiency and reliability are priorities.
LIMITATIONS	Struggles with thin WAS (may need pre-thickening). Requires continuous cleaning and attention – not ideal if staffing is low. Large footprint might be problematic for space-constrained plants. Filtrate generally recycled due to solids content.	High complexity and cost not justified at small scale. Noise and vibration require mitigation. Downtime impact is huge if only one unit (should have redundancy). Requires steady feed for optimal performance – less forgiving of highly variable sludge without advanced control.	Not well suited for sludge with very fine, incompressible solids (capture drops). Capacity per unit is limited, making it impractical for large flows. Screen clogs halt operation (need maintenance to resolve). Cake solids can be lower on pure WAS.	Single-unit capacity, while improved, still requires multiple channels/units for large flows (though modular design addresses this). Generally, slightly slower throughput per unit than a high-speed centrifuge (offset by parallel operation). Fewer vendors in market (newer tech), so some engineers unfamiliar – must ensure spec is written to include it.

CONCLUSION

Mechanical sludge dewatering technologies for municipal and industrial applications continue to evolve in response to stricter regulations, energy and space constraints, tight budgets, and staffing challenges. No single technology is the most suitable for all situations. In some cases, a hybrid approach or phased implementation of two technologies might be the most practical option. However, industry trends favor solutions that are compact, efficient, easy to operate, and have an attractive total cost of ownership. Of the four technologies reviewed in this paper (belt filter press, centrifuge, screw press, and rotary fan press), the rotary fan press best meets those criteria.

For decision-makers considering a dewatering upgrade or new installation, the next steps should include pilot testing, site visits, reviewing reference projects at similar municipal or industrial sites, developing a detailed lifecycle cost analysis that incorporates energy and maintenance projections, and ensuring bid specifications allow for innovative options like the rotary fan press.

ABOUT PRIME SOLUTION, INC.

Prime Solution, Inc. is a leading American innovator in sludge dewatering technology, recognized for developing the Prime Rotary Fan Press® technology. With more than 30 years of experience in the wastewater equipment industry, Prime Solution has earned a strong reputation for delivering high-performance, operator-friendly dewatering solutions.

With engineering and manufacturing based in Michigan, USA, Prime Solution's products are designed to be Build American, Buy America (BABA) compliant. For municipalities and industries, this domestic manufacturing not only supports American jobs but also simplifies procurement – customers can invest in Prime Solutions' dewatering systems knowing they meet federal funding requirements without the need for waiver applications or extra expenses.

The company offers a range of services, including laboratory sludge testing, pilot demonstrations, full installation support, operator training, and ongoing maintenance programs. These services guarantee that each project, whether a small retrofit or a large multi-unit installation, is successful from the initial setup through long-term operation.

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