

Balancing operator input and cost - a case study for dewatering technology selection

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ABSTRACT

Sludge dewatering technology selection study was performed for the Salt Lake City Water Reclamation Facility (SLCWRF). The SLCWRF upgrade to biological nutrient removal will be in the footprint of the existing sludge drying beds. Evaluation included centrifuges, belt filter presses (BFPs), and screw presses. A unique feature of the evaluation was to ensure that operation and maintenance staff provided input. The evaluation incorporated a triple bottom line assessment using a Sustainable Return on Investment and a sustainability review. Results showed that screw presses and centrifuges rank higher than BFPs, using economic and non-economic criteria. Although centrifuges scored highest on monetary factors, screw presses scored highest on nonmonetary factors. Based on operator feedback (preference and safety concerns), potential risks associated with pathogen regrowth of centrifuge cake, increased centrifuge cake odors, and site visit input from other facilities with full-scale dewatering systems, screw presses were selected.

KEYWORDS

Biosolids, Dewatering, Operations, BNR

INTRODUCTION & BACKGROUND

The Salt Lake City Water Reclamation Facility (SLCWRF) currently feeds anaerobically digested biosolids to open air drying beds for dewatering and drying. As part of the future biological nutrient removal (BNR) upgrade to the WRF, the new BNR system will replace the current trickling filter and activated sludge system, in the area currently occupied by the sludge drying beds. In order for the drying beds to be decommissioned; design, construction, and implementation of mechanical dewatering is required to maintain continued sludge and biosolids processing and management. The new BNR is designed to meet a Phase 1 Capacity of 56 million gallons per day (mgd) annual average day flow (AAF). A potential future Phase 2 expansion would increase the capacity to 84 mgd AAF.

METHODOLOGY

A dewatering alternative analysis was conducted as an initial design step to select the dewatering technology that will be used as the basis of design. Three of the most commonly used wastewater biosolids mechanical dewatering technologies, belt filter press, centrifuge, and screw press, were compared. The dewatering alternative analysis presented includes the following steps:

Site visits by the SLCWRF operation and maintenance (O&M) staff to several local dewatering installations conducted on July 26 and July 27, 2018.

- Bench scale preliminary testing by equipment suppliers – samples were collected for jar and bench scale testing by four belt filter press suppliers, five centrifuge suppliers, and four screw press suppliers, to allow them to provide input on expected dewatering performance and polymer consumption. Samples were collected between June and August 2018.
- Dewatering pilot testing for a centrifuge, two types of screw presses, and a belt press was conducted from August 27 to September 21, 2018. The main purpose of the pilot testing was to allow the O&M staff to gain operational experience with the different dewatering technologies, to be able to better compare the options.
- Operator survey and ranking document issued following completion of the site visits and pilot testing, and the results of the survey were factored into the analysis.
- Triple Bottom Line analysis and Sustainable Return on Investment (sROI) analysis

During the kick-off meeting for the dewatering alternatives analysis, a list of qualitative (non-monetary) criteria was presented. The criteria were sent to the SLCWRF's O&M and engineering staff, to comment on the criteria and assign weight factors for each. After review and feedback, the criteria factors were confirmed, and additional criteria were added. Each criterion was assigned a weight score, where 1 represented the least important to the SLCWRF staff and the Design team, and 5 represented the most important to the same group. The criteria and weight factors are shown in Table 1. The criteria are grouped as Technical, Operator Considerations, and Social and Environmental.

Table 1: Mechanical Dewatering Alternative Analysis Qualitative Criteria

Qualitative Criteria	Weight (1–5)
Technical	
Expected performance (percent total solids)	4.5
Footprint requirements	2.8
Water requirements	3.5
Reliability and experience at other BNR + MAD facilities	4.6
Operator Considerations	
Reliability (operator perspective)	4.6
Ease, flexibility and complexity of operation	4.1
Ease of maintenance	4.1
Cost of spare parts/consumables/specialty tools	3.7

Qualitative Criteria	Weight (1–5)
Accessibility to vendor maintenance (local/regional/national)	4.0
Social and Environmental	
Odor potential within building	3.9
Operator/maintenance safety	4.7
Product quality (odor/pathogen potential in cake)	3.9
Hydrogen sulfide control/resilience	3.8

Note:

BNR = biological nutrient removal; MAD = mesophilic anaerobic digestion

The inputs for scoring were based on vendor-provided data, experience from other facilities, input from the July site visits, and input from the September pilot testing.

RESULTS

Sludge Loading and Dewatering Design Criteria

For sizing purposes, the dewatering equipment was assumed to operate at future design maximum month conditions 24 hours per day, 5 days per week. This was used to set the design mass loading rates in pounds per hour (lb/hr) and design hydraulic loading rates in gallons per minute (gpm) for the dewatering system, as shown in Table 2. The system also would be sized to include a fully redundant unit, and all scenarios would include at least three units installed, in case one unit is down for a major rebuild. During detailed design, the loading rates were adjusted based on BNR Biowin™ modeling and the design was adjusted to be based on maximum week conditions.

Table 2: Design Dewatering Biosolids Loadings with BNR

Criteria	Phase 1	Phase 2
Mass loading rate, pound per hour	4,240	6,360
Hydraulic loading rate, gallons per minute	314	470

The preliminary sizing resulted in requiring four belt filter presses initially (with space to expand to six), three centrifuges initially (with space to expand to four) or four screw presses initially (with space to expand to six).

Dewatering Technology Overview

The dewatering technology evaluation focused on belt filter presses, centrifuges, and screw presses. The advantages and disadvantages of each evaluated technology are summarized in Table 3.

A belt filter press (BFP) is a continuously fed solids dewatering device that uses the principals of chemical conditioning, gravity drainage, and mechanically applied pressure to dewater sludge.

Mechanical pressure is applied to sludge, sandwiched between two tensioned belts, by passing those belts through varying diameter rollers. For a given belt tension, as the roller dimension decreases, increasing pressure is exerted on the sludge, removing more water.

The common type of centrifuge used for dewatering municipal sludge is a solid-bowl centrifuge, which consists of a long bowl that is mounted horizontally and tapered at one end. Sludge is introduced continuously into the spinning bowl of the unit, and the solids concentrate along the perimeter of the spinning bowl. An internal helical scroll, spinning at a slightly different speed, moves the accumulated sludge toward the tapered end, where additional solids concentration occurs as the solids back up behind the lip at the discharge end of the unit. The dewatered material is discharged through a chute, located at the bottom of the unit. Centrifuges operate as continuous feed units that remove solids by a scroll conveyor and discharge liquid over the weir. The conical-shaped bowl helps lift the solids out of the liquid, allowing them to dry on an inclined surface before being discharged.

Screw presses dewater solids by using one or more rotating screws that are installed within perforated screen troughs. This allows gravity drainage of water (filtrate) through the screen at the beginning of the inlet end of the unit. As the solids are conveyed along the unit, the frictional forces create gradually increasing pressure that is caused by the outlet restriction weir, producing dewatered cake that is discharged from the end of the unit. The screw press contains a helical screw inside a cylinder, formed from perforated sheets, longitudinal bars, or a series of rings.

Table 3: Dewatering Technology Advantages and Disadvantages

Technology	Advantages	Disadvantages
Belt Filter Press	<ul style="list-style-type: none"> • Well established/proven technology at medium to large facilities • Moderate dewatering performance • Low energy consumption • Lower polymer consumption than other technologies • Upsizes well for medium to large facilities • Enclosed systems are available (but are not always operator-friendly; and are often left open) • Low speed and low noise • Low shear, low odor in final solids • No reported fecal coliform reactivation and regrowth 	<ul style="list-style-type: none"> • Higher labor requirements than some other dewatering technologies • Large footprint required • Requires large amount of wash water • Open design can generate extensive odors resulting in higher odor control costs • Requires periodic replacement of belts and rollers • Lower solids recovery when compared to centrifuges • Not as clean an operation compared to other technologies
Centrifuge	<ul style="list-style-type: none"> • Well established/proven technology • Good dewatering performance (drier cake than other technologies) • Smaller footprint • Upsizes well for medium to large facilities 	<ul style="list-style-type: none"> • High electrical/energy consumption • Can require specialized maintenance by outside personnel • Two redundant units sometimes recommended as maintenance

Technology	Advantages	Disadvantages
	<ul style="list-style-type: none"> • Can be automated; requires minimal operator attention • Enclosed technology (easier to clean and contain odors) • Little to no wash water requirements • Available in large capacity requiring fewer units 	<ul style="list-style-type: none"> • often requires longer down time than other technologies • Relatively high polymer consumption compared to BFP • Special structural considerations—high speed and vibration • Relatively high noise level • High shear can lead to higher odor • Fecal coliform reactivation and regrowth potential
Screw Press	<ul style="list-style-type: none"> • Proven technology • Moderate dewatering performance • Low energy consumption • Low maintenance requirement • Easily automated • Enclosed technology reduces odors • Low wash water requirements 	<ul style="list-style-type: none"> • Larger capacity units are newer to the market than centrifuges and BFPs • Many design variations with individual vendor units; competitive bidding more challenging • Potential for high polymer use • Long sludge retention times in press make optimization more challenging • Some models do not empty sludge on shutdown

Dewatering Technology Site Visits

As part of the evaluation process SLCWRF O&M and AECOM staff visited water reclamation facilities in the Salt Lake City area. This allowed the O&M staff to see potential dewatering technologies in operation and engage with the O&M staff at those facilities, to better understand the differences between the various dewatering technologies. Site visits were conducted to four sites, as summarized in Table 4.

Table 4: Summary of SLCWRF Dewatering Site Tours

Date of Visit	Plant Location	Dewatering Technology
July 26, 2018	North Davis	Belt Filter Press (Alfa Laval Winklepress)
July 26, 2018	Central Davis	Screw Press (FKC)
July 26, 2018	South Valley Water Reclamation Facility	Belt Filter Press (Ashbrook) and Komline-Sanderson Dryer
July 27, 2018	Jordan Basin Water Reclamation Facility	Centrifuge (GEA / Westfalia)

The tours provided the O&M staff with the opportunity to see first-hand examples of the various dewatering equipment being proposed for the New WRF. To compile SLCWRF staff feedback, input was requested via a questionnaire given to those who made the visits. The questionnaire asked for a ranking of the following items:

- Reliability;
- Ease, flexibility and complexity of operation;
- Ease of maintenance;
- Odor potential within the building; and
- Operator/maintenance safety.

Figure 1 shows the O&M staff ranking.

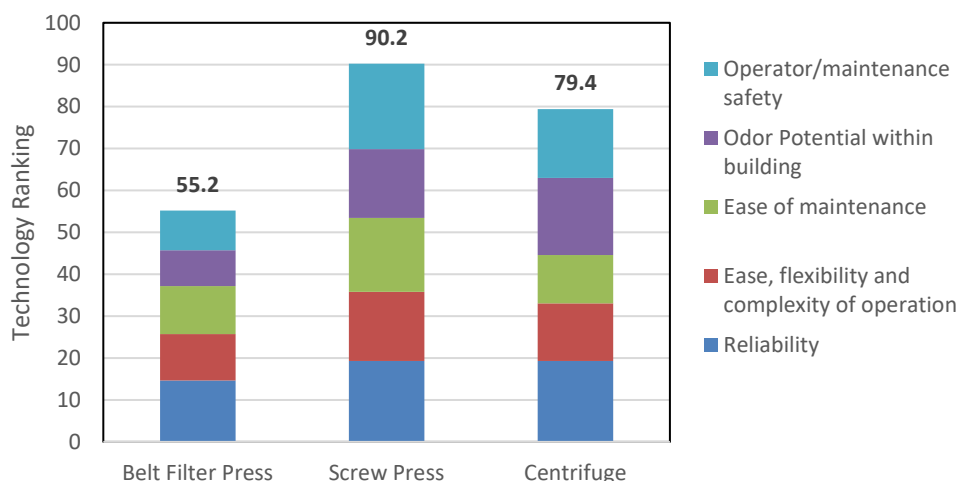


Figure 1: Dewatering Site Visit O&M Staff Ranking

The O&M staff was also asked to generally rank the technologies based on the tour where 1 represents the most favored technology and 3 represents the least favored technology. The results of this survey along with reasons provided by the O&M staff for the ranking are shown in Table 5. The results show that there is a clear preference from the SLCPU O&M staff for the screw press technology.

Table 5: Summary of Overall SLCWRF Operation and Maintenance Staff Dewatering Technology Ranking

Technology	Average Ranking	Reasons Provided for Ranking
Belt Filter Press	2.8	<ul style="list-style-type: none"> • Easy to operate but was messy and odorous with a lot of exposed moving parts and a belt which seemed to have a higher chance to be maintenance heavy and unsafe to be around. • Belt problems; lots of down time • Belt alignment issues; many moving parts • Poor odor control; lots of maintenance • Too many moving parts • Tight areas for maintenance seems like it would create maintenance and safety issues, belt tracking issues
Screw Press	1.0	<ul style="list-style-type: none"> • Fairly simple to operate but had some fine tuning to deal with in relation to flow and polymer feed, was more contained and less messy, parts were slow moving and didn't require overly specialized knowledge to repair; however, limited in size • Easy to maintain and operate • Fully enclosed; less moving parts • Maintenance upkeep is easy • Quality of cake • Simple system for both operations and maintenance
Centrifuge	2.5	<ul style="list-style-type: none"> • Very clean compared to other technologies, needed some fine tuning with polymer and flow but seemed simple to operate afterwards, much larger in size and capacity, parts were contained and safe to be around; however, fast moving parts require specialized knowledge of maintenance, which could put us in long downtimes if repairs are needed and power costs were large • Hard to get parts • Very loud, high speed moving parts • Loud and noisy • Power hungry • Expensive vendor maintenance, long lead time for parts from across the pond

Bench and Pilot Testing

To better predict dewatering performance with alternative dewatering technologies, a series of bench scale tests were conducted by various dewatering technologies' manufacturers. Testing was conducted with BFPs, centrifuges, and screw presses.

Following the bench scale testing, dewatering pilot testing also was performed at the SLCWRF. Pilot dewatering units testing included a centrifuge, a horizontal screw press, a belt press, and an inclined screw press. The main purpose of this pilot testing was to familiarize the O&M staff with different mechanical dewatering technologies, to provide input for final technology selection. The test results also were considered to determine dewatering performance criteria. However, the results demonstrated dewatering for the existing biosolids characteristics, which consisted of anaerobically digested primary and trickling filter/activated sludge. Biosolids characteristics are expected to change with the addition of the biological nutrient removal system. Each pilot unit testing was scheduled for a week. A summary of averages and ranges of data results are shown for each unit in Table 6.

Table 6: Summary of Pilot Testing Results

Unit	Average			Range		
	Polymer Rate (lb/dt)	% Solids	Solids Capture Rate (%)	Polymer Rate (lb/dt)	% Solids	Solids Capture Rate (%)
Centrifuge (Flottweg)	21	25	99.7	15.6–27.6	21–27	99.5–99.9
Horizontal Screw Press (FKC)	26	23	99.5	21.4–35.5	20–25	99–99.7
Inclined Screw Press (Huber)	24	23	96	14.34–29.9	21.3–25.4	80.6–99.9
Belt Press (BDP)	11	21	99	7.6–20.9	17.2–23	97–99.5

Note:

lb/dt = pounds per dry ton solids

Based on the sampling results, the centrifuge performed the best in terms of dewatering total solids performance. Both screw presses performed similarly and required more polymer dose rates than the centrifuge. The belt press required the least amount of polymer dose rates of all the units but produced the lowest cake solids. The results in terms of performance were in line with what typically is expected for these types of mechanical dewatering units. During testing, staff observed that the cake produced from the pilot centrifuge had much stronger odor than that from the BFP or screw press.

O&M staff feedback was compiled on the pilot testing observations through a survey where 1 represents the lowest (or worst) score and 5 represents the highest (or best) score. The results showed that the O&M staff preferred the screw press technology over the BFP and Centrifuge technologies. The results of this survey were consistent with the site visit surveys that were conducted.

Figure 2 shows the total scoring for each technology. Similar to the site visit survey, the results of the analysis show a clear preference by the O&M staff for screw presses, with a slightly higher preference for the horizontal screw press over the inclined screw press.

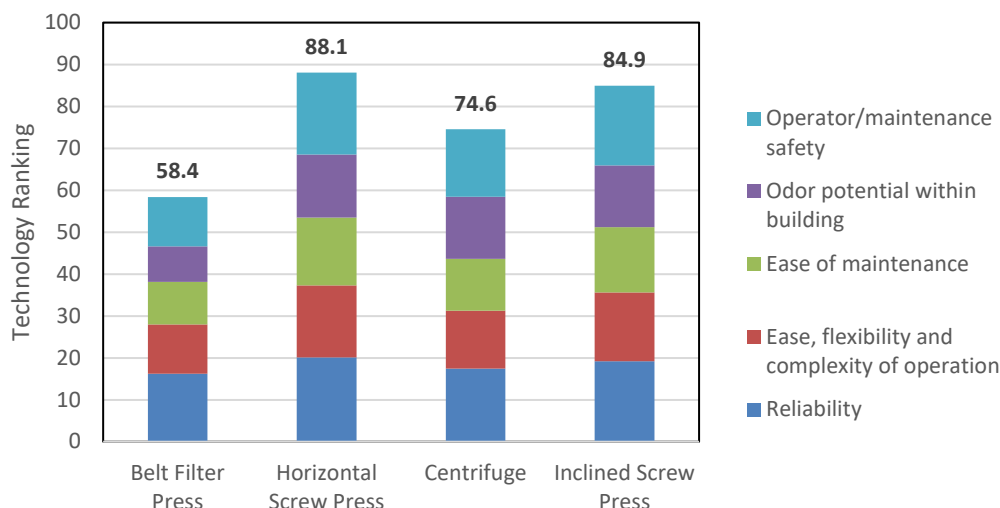


Figure 2: Dewatering Pilot Testing O&M Staff Ranking

Capital and Operating Cost

The different dewatering technologies were evaluated for the full-scale facility based on sizing, capital cost, performance criteria, footprint, and impact on odor control. The comparison was quantified with an annual operating cost estimate.

The preliminary sizing was based on four belt filter presses initially (with space to expand to six), three centrifuges initially (with space to expand to four) or four screw presses initially (with space to expand to six). The Class 4 opinion of probable construction costs ranged from \$24.0 million (centrifuges) to \$31.0 million (belt presses) with screw presses in the middle at \$28.7 million.

The annual operating costs were also estimated and a breakdown for the first year of operation (year 2020) is shown in Figure 3. Performance assumptions were based on vendor input, bench scale testing, on-site pilot testing, and experience from other facilities. The dewatering performance is expected to diminish after the BNR system is online because of documented impacts that biological phosphorus removal has on dewatering (Kopp et al. 2016; Higgins et al. 2017).

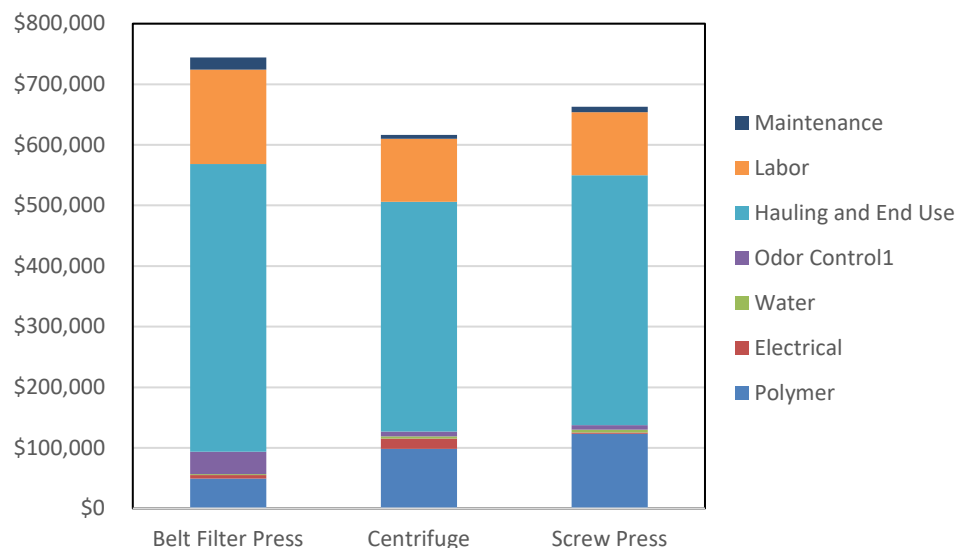


Figure 3 – Annual Operating Cost – Year 2020

The results show that hauling and end use were the largest component of annual operating cost. For the analysis it was assumed that the Class B biosolids would go to ET Technologies to make a soil blend for landfill cover (current outlet) but alternative Class B beneficial use options are also being explored. The next two largest components of the annual operating cost were polymer and labor.

DISCUSSION

Sustainable Return on Investment Analysis

The dewatering alternatives analysis considers not only the capital and operating costs of the options, but also the comparative benefits and costs to the owner and the community. The triple bottom line (economic, social, and environmental) costs and benefits are important considerations in the alternatives analysis because the alternatives may result in different social and environmental impacts. The social and environmental costs and benefits that were monetized in the dewatering alternatives analysis included greenhouse gas emissions; criteria air pollutants; safety impacts from truck trips; and roadway maintenance costs. In addition to the capital and annual operating outlays required by the options, the options would result in different social and environmental impacts.

The lifecycle cost impact analysis used a 25-year operations period, beginning at completion of project construction, and a conventional 3 percent discount rate, discounting all values to 2019. To coincide with construction, all dollars were escalated to 2020 dollars, using an escalation rate of 2.2 percent per year. The analysis used constant dollars to avoid uncertainty associated with inflation over the period of analysis. The results of the life-cycle cost and sROI analysis are shown in Figure 4.

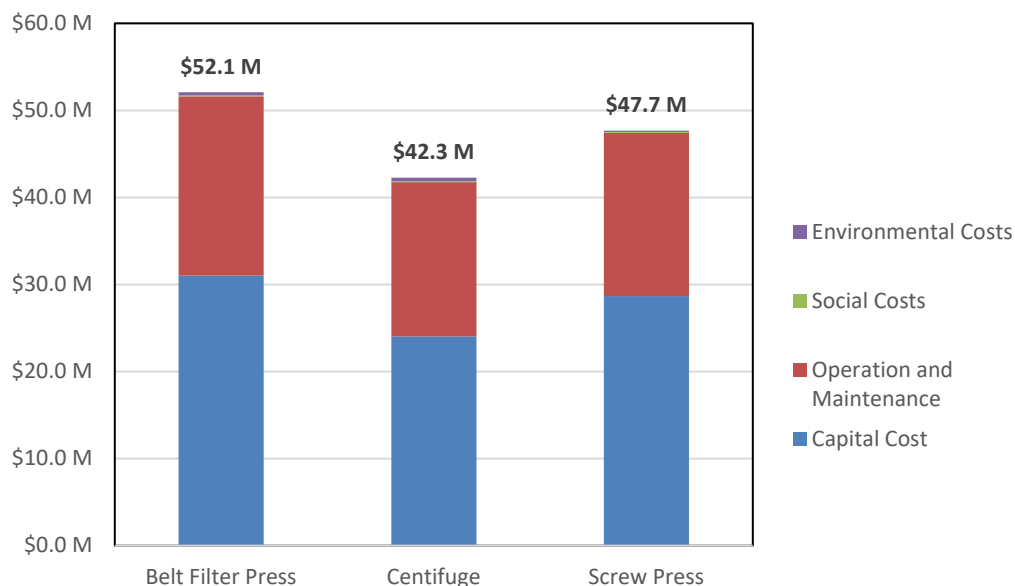


Figure 4: Dewatering Alternatives Analysis Lifecycle Cost

The results of the analysis showed that centrifuges offer the lowest total life-cycle costs, and this is due to having both the lowest capital cost (fewer units and smaller building) and providing the best dewatering performance in terms of driest cake. Screw presses and BFPs would be approximately 13 and 23 percent more expensive, respectively, on a life-cycle cost basis, compared to centrifuges. For this level of analysis, the expected accuracy of the cost estimates is within 10 to 20 percent.

Because the sROI analysis was based on several major assumptions, some sensitivity analyses also were conducted. Sensitivity analyses were conducted using an alternative screw press that would only require three units initially (with space to expand to four). Requiring only three units initially with space to expand to four would reduce the building size, and these differences reduced the lifecycle cost difference to less than 10 percent when compared to centrifuges. An additional sensitivity analysis was conducted, assuming all options achieved the same dewatered solids concentration, and this did not change the economic rankings of the alternatives.

The results of the analysis are shown in Figure 5. The results show that screw presses received the highest overall score and had the highest technology ranking based on combined social/environmental, operator considerations, and technical criteria.

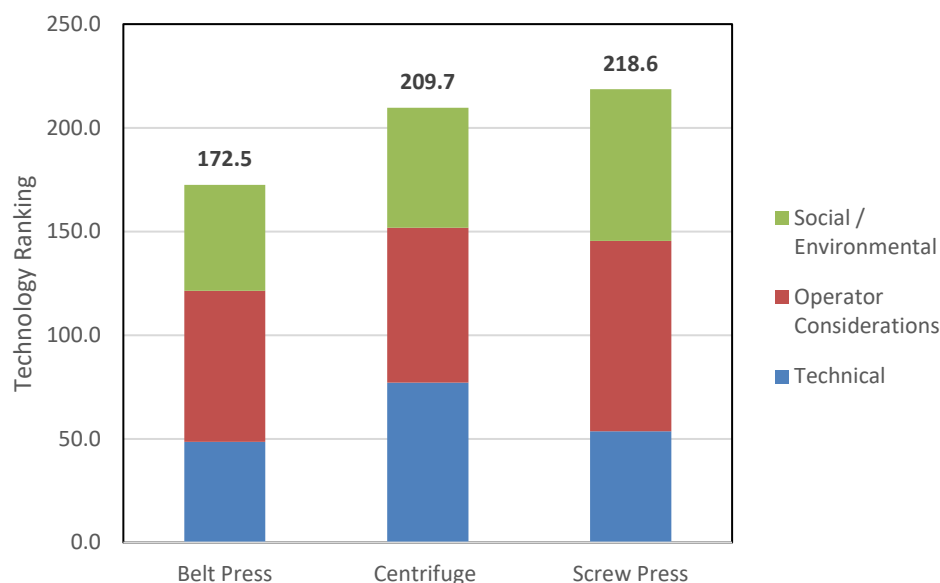


Figure 5: Dewatering Alternatives Analysis Qualitative Ranking

The results of the analysis showed that both screw presses and centrifuges rank higher than BFPs, using both economic and non-economic criteria. Centrifuges offer a more compact option that would reduce building size and would be expected to produce the driest dewatered biosolids. However, centrifuges have the potential to produce a more odorous product (which was observed during the pilot testing) and have a higher risk for pathogen regrowth as noted in current research literature (Chen et al. 2011, WERF 2015). The pathogen regrowth risk is of greater concern if a Class A digestion process is implemented at some point in the future. Screw presses offer the simplest system in terms of O&M and is the preferred technology of the SLCWRF O&M staff. Screw presses are larger units than centrifuges, and less operational experience exists with this technology at similarly sized facilities, however, newer and larger facilities are implementing use of screw presses.

CONCLUSIONS

Although centrifuges scored highest in economic factors, screw presses scored highest in non-economic factors. Based on operator preference, operator safety concerns associated with the centrifuges, the potential risks associated with biological pathogen regrowth of centrifuge cake, increased cake odors associated with the centrifuge cake, and site visit input from operators at facilities with full-scale dewatering systems, the Design team selected screw presses as the dewatering technology for the New WRF.

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