Comprehensive Evaluation of Dewatering Alternatives for the City of Fort Myers

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The City of Fort Myers (City) owns and operates two wastewater treatment facilities: the Central Advanced Wastewater Treatment Facility (AWWTF) and the South AWWTF. The City treats wastewater from its service area and from surrounding Lee County through an interlocal agreement. Approximately 50 percent of the wastewater treated at the Central and South AWWTFs is produced by Lee County.

The Central AWWTF is an 11-mil-gal-per-day (mgd) facility. Wastewater entering the Central AWWTF is treated in a five-stage Bardenpho process prior to being distributed to the reclaimed water system for land application (R-001) or discharged to the Caloosahatchee River. The high-level disinfection system of the facility can produce up to 6 mgd of reclaimed water. The existing solids handling process includes aerobic digestion of secondary waste activated sludge (WAS) and alum chemical sludge, followed by dewatering using belt filter presses. The dewatered biosolids cake is hauled to the Lee-Hendry County Landfill for composting or disposal.

The South AWWTF is a 12-mgd facility. Wastewater entering the South AWWTF is treated using the Bardenpho process prior to being discharged to the Caloosahatchee River. The existing solids handling process includes aerobic digestion of secondary WAS and alum chemical sludge, followed by dewatering using belt filter presses. The dewatered biosolids cake is hauled to the same landfill for composting or disposal.

The existing dewatering facilities at the Central and South AWWTFs are approximately 30 years old and are in need of replacement. The current dewatering handling facilities utilize the addition of polymer to the feed sludge prior to being pumped to the belt filter presses. Significant advancements in dewatering technology have been made since the 1980s, allowing the production of cake with higher solids content than can be achieved with the existing belt filter presses. Dewatering technologies, including belt filter presses, centrifuges, and screw presses, were evaluated on a present-worth life cycle cost basis. A pilot study was also conducted at the South AWWTF to collect actual field data on the performance of the units.

Dewatering Pilot Evaluation

Dewatering of biosolids is a critical step in biosolids processing, impacting downstream treatment processes and transportation costs. Projecting the performance of biosolids dewatering equipment at a specific treatment facility is difficult to do based on sludge characteristics alone. Pilot testing of dewatering equipment is commonly conducted to compare dewatering technologies and to refine the expected performance of each technology. An on-site pilot testing program was conducted at the South AWWTF to provide a comparison among belt filter presses, centrifuges, and screw presses. Objectives of the pilot testing program included:

- Providing a comparison of the dewatering performance of each technology on feed sludge from the South AWWTF.
- Optimizing process parameters used to project annual operating costs associated with biosolids dewatering.
- Evaluating alternative polymers for use with the new dewatering technologies.

The South AWWTF was chosen for pilot testing as its dewatering equipment has priority to be replaced over the Central AWWTF, and in the experience of the City, sludge at the South AWWTF is typically more difficult to dewater than sludge at the Central AWWTF. In addition to the determination of the solid content of the biosolids cake produced by each alternative dewatering technology, pilot testing was also conducted to evaluate polymer dosage, throughput, power, and solids capture.

The dewatering technologies were pilot tested separately during the months of July and August 2014 for approximately two to three days each. The data and results collected from each pilot test at the South AWWTF were compiled and examined to characterize the expected performance of each technology. The specific manufacturers selected for pilot testing were chosen based on availability of pilot equipment. Other manufacturers offer similar quality equipment that can be expected to perform in a similar manner, as discussed previously.

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Pilot Test Layout and Methodology

The pilot testing trailers were set up south of the South AWWTF blower building between the aerobic digesters and the screening and grit removal building. Feed sludge was obtained from the aerobic digester through a pump-out connection. Both potable water and reclaimed water connections were located near the trailer for washdown and polymer makeup. Electricity was provided from a connection to a motor control center (MCC) for one of the City's blowers. Filtrate or centrate was discharged into the wetwell of an in-site lift station near the trailer. Dewatered biosolids cake was collected in a dumpster and hauled to the landfill at the end of every day. Samples were collected and analyzed by the City's laboratory on-site at the South AWWTF.

A pilot test sampling and analysis protocol was created and distributed to the dewatering equipment manufacturers in late June 2014. The dewatering equipment vendors were requested to follow a standard pilot testing sequence, which consisted of polymer screening, dewatering unit optimization, polymer optimization, and finally, system stress testing. Polymer screening was intended to include evaluating different polymers to identify those that were most effective in dewatering the feed sludge at the South AWWTF. At the option of the dewatering vendor, polymer screening could be completed off-site prior to pilot testing or on-site during the week of testing. The centrifuge and belt filter press manufacturers chose to collect sludge samples prior to testing to conduct off-site analysis. The screw press manufacturer did not evaluate polymers prior to arriving at the South AWWTF.

The dewatering optimization step was intended to consist of initial test runs to identify the most effective settings of the dewatering unit. These settings include items such as belt filter press belt pressure and speed, centrifuge pond depth, and screw press operating pressure. Following optimization of the dewatering unit, the polymer optimization step was intended to consist of dewatering sludge with the polymers identified during the polymer screening stage at varying dosages. The final stage of the pilot testing was intended to be system stress testing where the feed sludge flow rate is steadily increased to observe the impact of increased throughput on cake solids.

Pilot unit operators were expected to document dewatering unit settings, sludge flow rate, polymer type and dosage rate, power draw, and other process variables throughout testing.

Feed Sludge Characterization

Samples of the feed sludge were taken periodically during the pilot testing period and analyzed for total suspended solids (TSS) and volatile suspended solids (VSS). The feed sludge characteristics were very consistent throughout the pilot testing period. A summary of the feed sludge characteristics is presented in Table 1.

It is important to note that due to the nature of the pilot testing process, simply averaging the data is not adequate to gauge the full-scale performance of the dewatering unit. The pilot testing process is intended to optimize the performance of the units by testing different variables to determine the impact on cake solids. The performance of the dewatering unit at each data point must be independently evaluated to accurately assess the performance.

Belt Filter Press

The belt filter press was pilot tested from July 28, 2014, to Aug. 1, 2014. The pilot unit trailer is shown in Figure 2.

A sludge sample was collected from the South AWWTF prior to the start of pilot testing, and evaluated to select polymers for pilot testing. Three polymers were selected for testing: BASF Zetag 7878FS40, Polydyne C-6266, and Polydyne C-9530. The BASF polymer was tested over three runs and Polydyne C-6266 was tested over nine runs, as was Polydyne C-9530. Polymer doses ranged from 13.8 to 32 pounds active polymer per ton dry solids (lbs/ton). While all of the polymers yielded good dewatering results in the range of 15.9 to 20.7 percent cake solids, the Polydyne C-6266 polymer was found to be the most effective polymer for the belt filter press in terms of dewatering performance.

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Table 1. Feed Sludge Characterization

Parameter	Number of Samples	Range	Average
Total Suspended Solids (mg/L)	13	8,380-9,160	8772
Volatile Suspended Solids (mg/L)	3	3,100-3,160	3133

Table 2. Partial Belt Filter Press Test Results

Run Number (Per Vendor)	Sludge Loading Rate (lbs/hr/m)	Polymer Dose (lbs/ton)	Cake Solids (% solids)
9	640	20.2	19.56
10	645	21.2	18.84
11	886	15.9	16.56
12	886	21.5	15.92
Projected Performance	**750**	**18-22**	**17-19**

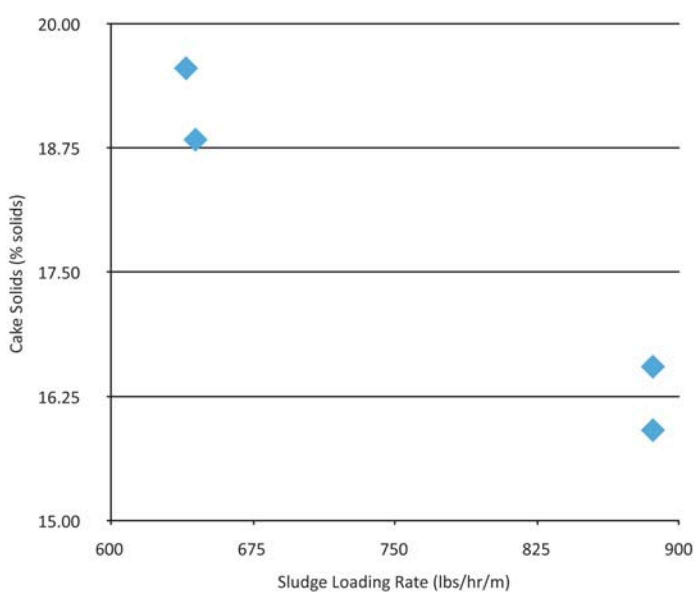

Figure 2. Belt Filter Press Pilot Unit

Figure 3. Belt Filter Press Throughput Versus Cake Solids

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All of the test runs yielding over 20 percent solids were obtained using Polydyne C-6266 polymer. Three out of the five dewatering results reporting above 20 percent solids required high polymer doses ranging from 27 to 32 lbs /ton. Polymer doses of approximately 20 lbs/ton produced similar cake solids, while resulting in a substantial savings in polymer. The pilot test report recommends an expected polymer consumption rate of 28-30 lbs/ton.

The sizing of a belt filter press is based on the solids loading per meter of belt width. In this manner, the results obtained from the 0.6m pilot unit can be scaled up to the 2m units proposed for full-scale installation. Throughput testing was conducted simultaneously with the polymer optimization testing. The majority of the test runs were conducted at lower solids loading rates than the design value of 750 pounds per hour per meter (lbs/m/hr), and the expected performance presented in the pilot study report was based on a solids loading of 300-500 lbs/hr/m. While the pilot unit was not tested at the exact loading rate, four tests were conducted that were used to estimate the performance of the belt filter press. As these four runs bracket the design solids loading rate of the proposed belt filter presses and the polymer dose was roughly the same in three of the four runs, these results are representative of the expected results of a full-scale pilot unit. Sludge loading rate versus cake solids for these four test runs is presented in Figure 3.

The linear relationship between cake solids and sludge loading rate was used to estimate the performance of the belt filter press at the design sludge loading rate of 750 lbs/hr/m. A cake solids concentration of 17.9 percent would be expected based on the curve presented in Figure 3. Some variability in the performance of the dewatering equipment is to be expected due to variations in the feed sludge, and a range of 17 to 19 percent is reasonable to expect for a full-scale installation. Data used in estimating the performance of the belt filter press and the projected full-scale performance are presented in Table 2.

Centrifuge

The centrifuge was pilot tested Aug. 11-14, 2014, and is shown in Figure 4.

The centrifuge vendor conducted polymer screening prior to pilot testing. Three polymers were identified for on-site testing: Polydyne C-6242, BASF 8868FS, and Polydyne SE-1026 (the polymer currently used at the City's AWWTFs). Polymer optimization tests were conducted with each of the three polymers at a sludge feed rate of 65 gpm. All polymers began testing at a high dosage (55 to 60 lbs/ton) and reduced thereafter to create the polymer optimization curve. The BASF 8868FS polymer was found to be the most effective in terms of dewatering performance, significantly outperforming the Polydyne SE-1026 currently used at the plant.

After the polymer optimization tests, throughput testing was conducted using the BASF 8868FS polymer. The sludge flow was increased while monitoring the cake dryness to determine where throughput begins to limit the dewatering results. The results of the throughput testing and the projected performance of the full-scale unit are presented in Table 3.

The centrifuge manufacturer reports expected performance of 19 to 22 percent cake solids at a polymer dose of 25 to 29 lbs/ton and at a sludge loading rate of 1,500 lbs/hr in a full-scale unit. Upon review of the data presented in the pilot test report, these ranges are representative of the expected performance of a full-scale installation.

Energy consumption of the centrifuge was monitored using a power meter during each of the test runs. An average of 120 kWh/ton was used to estimate the energy consumption of the full-scale centrifuge installation. Energy consumption data are presented in Table 4.

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Figure 4. Centrifuge Pilot Unit

Table 3. Centrifuge Throughput Test Results

Run Number (Per Vendor)	Sludge Loading Rate (lbs/hr)	Polymer Dose (lbs/ton)	Cake Solids (% solids)
18	237	26.2	21.8
19	342	26.4	21.8
20	395	28.9	21.8
21	529	28.7	19.7
Projected Performance	**1500**	**25-29**	**19-22**

Table 4. Centrifuge Energy Consumption Data

Parameter	Number of Samples	Range	Average
Energy Consumption (kWh/ton)	19	105-172	121

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Screw Press

The screw press was pilot tested Aug. 18-21, 2014. The screw press vendor chose not to collect a sample of sludge prior to pilot testing for polymer screening and instead relied on the Polydyne polymer vendor to recommend the type of polymer to be used in testing. The dewatering vendor recommended using Polydyne SE-1026, the same polymer used by the City at the AWWTFs. Another Polydyne product, Clarifloc C-6262, and a number of Ashland Chemical products were also tested throughout the week.

Ashland Chemical polymers K-279 FLX, K-275 FLX, and K-274 FLX were tested over a total of seven runs and yielded poor dewatering results. The polymer currently used at the AWWTFs, Polydyne SE-1026, was tested five times, yielding relatively poor dewatering results. The Polydyne Clarifloc C-6262 polymer was found to be the optimal polymer for the screw press.

Due to the large number of polymers tested on-site and the size of the pilot unit, only five runs were completed using the optimal polymer. Two of these runs were conducted at low solids loading rates, and high polymer doses skewing the results. The remaining three results were conducted at the rated solids loading capacity of the unit (320 lbs/hr). These results were considered typical of the expected full-scale performance. The screw press test results and expected performance of the full-scale unit are presented in Table 5. Note that the cake solids values presented in the screw press pilot test report are the values reported by the equipment vendor. The cake solids values presented in this report are the values obtained by the City laboratory, which were typically lower than the vendor-reported values.

Although not specified in the pilot test report, the screw press vendor reported an expected performance of 17.5 to 19 percent solids at a polymer dose of 28-32 lbs/ton. The expected performance of the units is near the lower end of this range based on the observed performance. Overall, the screw press produced a cake solids similar to the belt filter press at a higher polymer consumption. The pilot test report indicates that the poor results may have been in part due to the age of the City's Polydyne SE-1026 polymer and the fact that plant water was used for polymer makeup for all of the test results in lieu of potable. A potable water source was available for polymer makeup and it is not clear why it was not used by the screw press vendor.

Energy consumption of the screw press was monitored using a power meter during the majority of the test runs. An average of 2.8 kWh/ton was used to estimate the energy consumption of the full-scale screw press installation. Energy consumption data are presented in Table 6.

Table 5. Partial Screw Press Test Results

Run Number (Per Vendor)	Sludge Loading Rate (lbs/hr)	Polymer Dose (lbs/ton)	Cake Solids (% solids)
3	320	28	16.96
4	320	24	16.68
5	320	24	18.84
Expected Performance	**1500**	**24-28**	**16-18**

Table 6. Screw Press Energy Consumption Data

Parameter	Number of Samples	Range	Average
Energy Consumption (kWh/ton)	11	2.3-4	2.8

Table 7. Projected Biosolids Cake Solids Content

Parameter	Belt Filter Press	Centrifuge	Screw Press
Range of Expected Performance (% Solids)	17-19	19-22	16-18
Design Value (% solids)	18	20.5	17

Table 8. Projected Polymer Dosing Rates

Parameter	Belt Filter Press	Centrifuge	Screw Press
Range of Expected Performance (lbs/ton)	18-22	25-29	24-28
Design Value (lbs/ton)	20	27	26
Polymer Type	Polydyne C-6266	BASF Zetag 8868FS	Clarifloc C-6262

Note: Numbers presented are in lbs active polymer/ton dry solids.

Pilot Test Summary and Conclusions

A detailed discussion of the data collected during the pilot testing is presented. Due to the process of optimizing the dewatering equipment with many variables, including throughput, polymer dosage, and polymer type, some data were not included in the performance considerations. Other factors impacting performance are discussed in other equipment specific sections of the report.

One of the key parameters is the cake dryness attainable by each dewatering technology. The solids content values presented are based on the optimized polymer type and their performance during pilot testing. As previously discussed, cake solids content can directly impact treatment and transportation costs; the higher the percent solids, the less disposal and transportation costs there will be. Solids content of the biosolids cake produced using each dewatering technology is presented in Table 7.

Each dewatering technology experimented with multiple polymers to determine the optimal performing polymer based on the cake dryness results. Over the course of the pilot testing, only the Andritz centrifuge and the Schwing Bioset screw press tested the polymer (Clarifloc SE-1026) currently in use at the plant. Compared to the other polymers tested, the Clarifloc SE-1026 did not perform as well.

The optimal polymers for the Andritz centrifuge and Schwing Bioset screw press were BASF Zetag 8868FS and Polydyne Clarifloc C-6262, respectively. An optimal polymer for the belt filter press was not reported; however, based on the data, the optimal polymer appeared to be Polydyne C-6266. In addition to the optimal polymer, an optimal dose was identified during the pilot test. An optimal polymer dose increases the stability of the flock, resulting in increased water release and cake dryness. Overdosing polymer can result in overflocculation, hindering dewatering results. The expense of polymer can also outweigh the benefits of a marginal increase in solids content achieved. Polymer dose ranges based on the optimal polymers mentioned are presented in Table 8.

Solids capture generally exceeded 95 percent during the pilot testing, and is expected to remain high during full-scale operation. Average solids-capture values with each technology are presented in Table 9.

Very high solids capture rates have become the industry standard in dewatering. The equipment pilot tested at the South AWWTF is no exception; at design loading rates, the solids capture of the units can be expected to be in excess of 95 percent.

Throughput of dewatering equipment is a function of both hydraulic loading and solids loading. Biosolids dewatering equipment should provide adequate throughput to meet solids production within the desired operating schedule. The throughput must also be balanced with the required solids retention time to achieve sufficient cake solids content. Table 10 presents the required number of proposed units to achieve the design throughput. All dewatering equipment was sized to require three units at the Central AWWTF and two units at the South AWWTF to achieve the 1,500 lbs/hr throughput.

Energy consumption of the full-scale dewatering units was estimated based on the results of the pilot tests for the centrifuge and screw press. As the belt press vendor did not report measured energy consumption, the rated motor horsepower was used to estimate energy consumption. The belt filter press motors are small, and although the projected energy consumption is conservative, it has minimal impact on the project operation and maintenance costs. The projected energy consumption for each dewatering technology is presented in Table 11.

Table 9. Reported Solids Capture

Belt Filter Press (% TSS)	Centrifuge (% TSS)	Screw Press (% TSS)
95	97	97

Table 10. Units Required for Design Throughput

	Design Throughput (lbs/hr)	Required Number of Units
Belt Filter Press	1500	Central AWWTF – 2 South AWWTF – 3
Centrifuge		
Screw Press		

Table 11. Projected Energy Consumption

Parameter	Belt Filter Press	Centrifuge	Screw Press
Energy Consumption (kWh/dry ton)	6	121	2.8

Note: Belt Filter Press is based on motor Hp.

Table 12. Summary of Dewatering Alternative Performance

	Belt Filter Press	Centrifuge	Screw Press
Number of Units – Central AWWTF	3	3	3
Number of Units – South AWWTF	2	2	2
Capacity of Units	1,500 lbs/hr	1,500 lbs/hr	1,500 lbs/hr
Projected Cake Solids	18%	20.5%	17%
Projected Active Polymer Consumption	20 lbs/ton	27 lbs/ton	26 lbs/ton
Connected Motor Horsepower	6	150	12
Capital Cost – Central AWWTF	$2770000	$3520000	$3750000
Present Worth Cost – Central AWWTF	$28100000	$29400000	$31500000
Capital Cost – South AWWTF	$2175000	$2625000	$2825000
Present Worth Cost – South AWWTF	$16000000	$16700000	$17900000
Capital Cost – Central & South AWWTF	$4945000	$6145000	$6575000
Present Worth Cost – Central & South AWWTF	$44100000	$46100000	$49400000

Summary of Dewatering Alternatives

A summary of the sizing, performance, and projected costs of each dewatering alternative is presented in Table 12.

The total present-worth cost estimates are based upon the City's current practice of composting biosolids cake. Hauling and disposal costs represent the majority of the annual operations and maintenance costs, and any change in the method of disposal of biosolids cake or renegotiation of the current contract with Lee County has the potential to significantly impact the total present-worth cost of each alternative, as shown in the sensitivity analysis.

Recommended Alternative

Centrifuges are recommended for installation at the Central and South AWWTFs. Centrifuges and belt filter press have comparable present-worth costs over the 20-year evaluation period. However, centrifuges offer the highest noncost score, are best able to fit within the confines of the existing building, and provide the highest cake solids. Centrifuges are also proposed for the City's future East Water Reclamation Facility, allowing a common spare-parts inventory to be shared among the three facilities.