Overcoming Obstacles with a Difficult-to-Handle Sludge: Centrifuge Piloting at Miami's Central District Wastewater Treatment Plant

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As part of the consent decree project for Miami-Dade's Central District Wastewater Treatment Plant (CDWWTP), the program management and construction management (PMCM) team conducted pilot testing of centrifuge thickening prior to anaerobic digestion and centrifuge dewatering postanaerobic digestion. The pilot dewatering testing used digested biosolids from the digester, receiving mechanically thickened biosolids at high solids input concentration after steady state operation was achieved. The pilot testing established performance criteria used for the design-build documents and associated process performance guarantee.

The CDWWTP, located on Virginia Key, is the oldest existing sewer treatment plant operated by the Miami-Dade Water and Sewer Department and was originally constructed in 1956. The CDWWTP is a high-purity oxygen-activated sludge secondary treatment facility with a permitted capacity of 143 mil gal per day (mgd) or 22,555 cu meters per hour (m^3/h). The plant has two separate liquid processing streams: Plant 1 was rated at 60-mgd average daily flow (ADF) (9,464 m^3/h) and Plant 2 was rated at 83-mgd ADF (13,091 m^3/h).

The CDWWTP produces only waste activated sludge (WAS). The WAS is mixed with polymer in the piping and sent to eight 55-ft-diameter (16.8-meter) gravity thickeners with a 13-ft (4-meter) side-water depth. Both Plant 1 and Plant 2 contain four gravity thickeners, which thicken the solids to 2 to 4 percent total solids (TS) before being stabilized in twenty-four 105-ft-diameter (32-meter) anaerobic digesters, each with a nominal operating volume of 1.5 mil gal (MG) (5,700 cu meters) that are operated under two-stage mesophilic conditions. The digesters are currently being upgraded from primary-secondary to single-stage operation.

Plant 1 consists of two digester clusters, each with four digesters, and Plant 2 consists of four digester clusters, each with four digesters. The digested biosolids are further dewatered using Alfa Laval DS 706 centrifuges that achieve greater than 25 percent TS. The sludge fed to the centrifuges is currently conditioned using a dry-polymer-type system. Ferric sulfate is also added to the dewatering feed, primarily for struvite control.

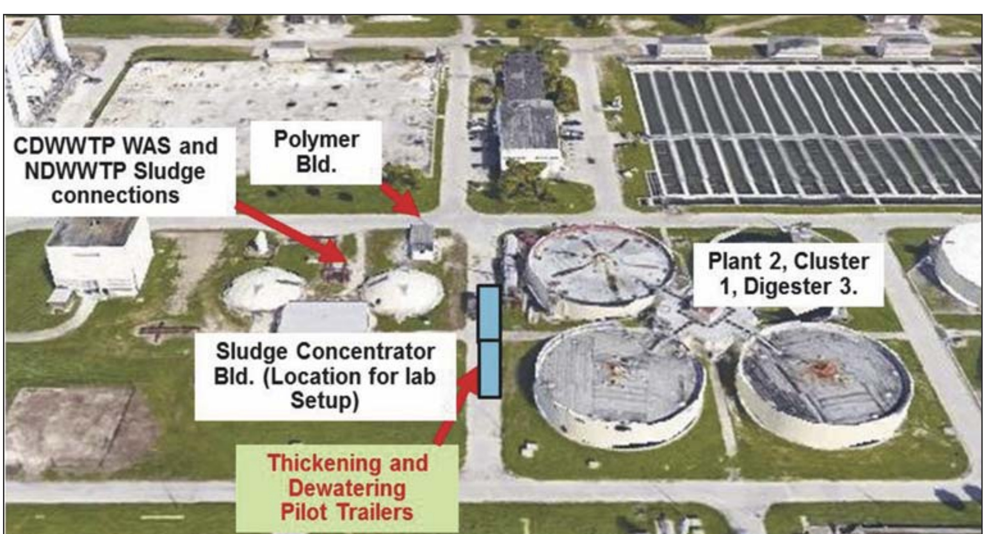

Figure 1. Site Plan Showing Centrifuge Pilot Installation at Central District Wastewater Treatment Plant on Virginia Key

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The CDWWTP also receives primary sludge and WAS from the North District Wastewater Treatment Plant (NDWWTP). The sludge transfer building at NDWWTP houses four sludge transfer pumps with variable speed drives. The pumps are used to pump sludge through two 16-in. force mains, which are parallel for about 10 mi before they join at an interconnection. From the interconnection, sludge can be directed to the sewage collection system of CDWWTP (Force Main 2) or to an extension of one 16-in. force main that continues another 6 mi, where it then discharges to the gravity sludge thickeners located at Plant 2 of CDWWTP (Force Main 1). The sludge from NDWWTP contains an exorbitant amount of rags, plastics, and grit, which have historically been problematic for CDWWTP sludge thickening operations. Screening of NDWWTP sludges will be implemented to remedy this operational challenge.

The CDWWTP is replacing the existing gravity thickeners with new centrifuge thickeners that are expected to improve the performance and increase the capacity in the existing digestion complex. The existing dewatering centrifuges are also near the end of their useful service life and the design includes replacing the system with a new centrifuge dewatering complex.

Pilot Study Overview and Objectives

To better establish performance criteria for the new thickening and dewatering centrifuges, a fivemonth centrifuge thickening, digestion, and centrifuge dewatering pilot study was conducted at CDWWTP from May to September 2016. The pilot study was set up to simulate future thickening, digestion, and dewatering operating conditions to establish thickening and dewatering performance criteria. Figure 1 shows a plan view layout of the site and identifies the locations for the centrifuge thickening and dewatering pilot trailers; Figure 2 provides photos of the pilot testing trailers provided by Centrisys, which were selected after a competitive bidding process. The PMCM team oversaw the piloting effort with outstanding support from the CDWWTP operations and maintenance staff.

Periodic samples collected throughout the pilot operation were all analyzed for TS. The PMCM team regularly monitored the volatile solids (VS) content of the thickened sludge fed to the digester and digested biosolids samples, the digested biosolids pH was measured, and the centrate samples were also analyzed for total suspended solids (TSS). College interns from Florida International University and University of Miami were trained to perform the sampling and laboratory analysis throughout the duration of the pilot-testing period.

Figure 2. Photos of Pilot Equipment: Thickening (left) and Dewatering (right)

Figure 3. Thickening Polymer Injection Point

Thickening Pilot Testing

The thickening pilot operation was based on feeding three different sludges to the pilot centrifuge thickener:

- CDWWTP: WAS-only
- NDWWTP: Primary and WAS
- CDWWTP: WAS + NDWWTP Primary and WAS

The purpose of the thickening pilot operation was to determine the optimum polymer design conditions and performance of the centrifuge thickening. The overall target for the centrifuge thickening performance, as stated in the basis of design and specifications, was to thicken the WAS to 5.5 percent TS, while maintaining greater than 95 percent solids recovery. Determining the necessary polymer dose to achieve this performance is also important. Parameters that were adjusted for the centrifuge thickening included the pool depth, bowl speed, and differential scroll speed.

Thickening Pilot Setup

Thickening in the pilot unit was tested without polymer, with emulsion polymer, and with dry polymer. The pilot unit was set up to allow injection of polymer at two locations, as illustrated in Figure 3, either directly into the bowl of the unit (internal injection) or in the sludge feed line upstream of the centrifuge inlet (external injection). Polymer flow was measured during each sampling event using a calibration column located on the pilot trailer.

The emulsion polymer used for testing was PRAESTOL® K144-L, a cationic, high-molecular-weight emulsion polymer. Two different dry polymers were also tested, including the dry polymer currently used in CDWWTP's gravity concentrators (SNF Polydyne Clarifloc SE-1138) and the dry polymer currently used in CDWWTP's dewatering centrifuges (SNF Polydyne Clarifloc SE-1141).

Thickening Pilot Testing: Central District Wastewater Treatment Plant Waste Activated Sludge

For the CDWWTP WAS-only thickening operation, the system was set up and operated with emulsion polymer, with dry polymer, and without polymer. Polymer curve tests were conducted by maintaining a constant volumetric throughput of sludge feed to the centrifuge, while changing the polymer dose. With the exception of changing the polymer dose, all other parameters on the centrifuge remained the same for each polymer curve test. After generating the polymer curves, the unit was operated for several days at a constant flow rate, with optimized settings to test the stability of operation throughout the course of a day.

The testing showed that the centrifuge, operating on CDWWTP WAS-only, could reliably thicken the WAS from 0.9 to 1.3 percent TS to 5 to 6 percent TS, and achieve greater than 95 percent solids recovery. Testing was conducted using both dry and emulsion polymers. The dry polymer required 3 to 4 pounds per dry ton (lb/DT) or 1.5 to 2 grams per dry kilogram (g/kg) active dosing, compared to 0.6 to 3 lb/DT (0.3 to 1.5 g/kg), based on the emulsion. It was also possible to thicken the sludge to 5 to 6 percent TS without the use of polymer, but this reduced hydraulic throughput by about 25 percent to allow solids recoveries to remain above 95 percent. Examples of the polymer curve data and extended operation data that were collected are provided in Figure 4.

Thickening Pilot Testing: North District Wastewater Treatment Plant Primary and Waste Activated Sludge

When pilot operation initially began in May 2016, the 6-mi, 16-in. line from the interceptor that allowed NDWWTP sludge to be fed to CDWWTP gravity thickeners was out of service, so pilot testing of NDWWTP sludge could not begin until it was brought back into service. In addition, the amount of debris and grit in the sludge from NDWWTP, which has historically been problematic for CDWWTP operations, was exacerbated during the piloting period since the primary sludge degritters at NDWWTP were out of service for a replacement.

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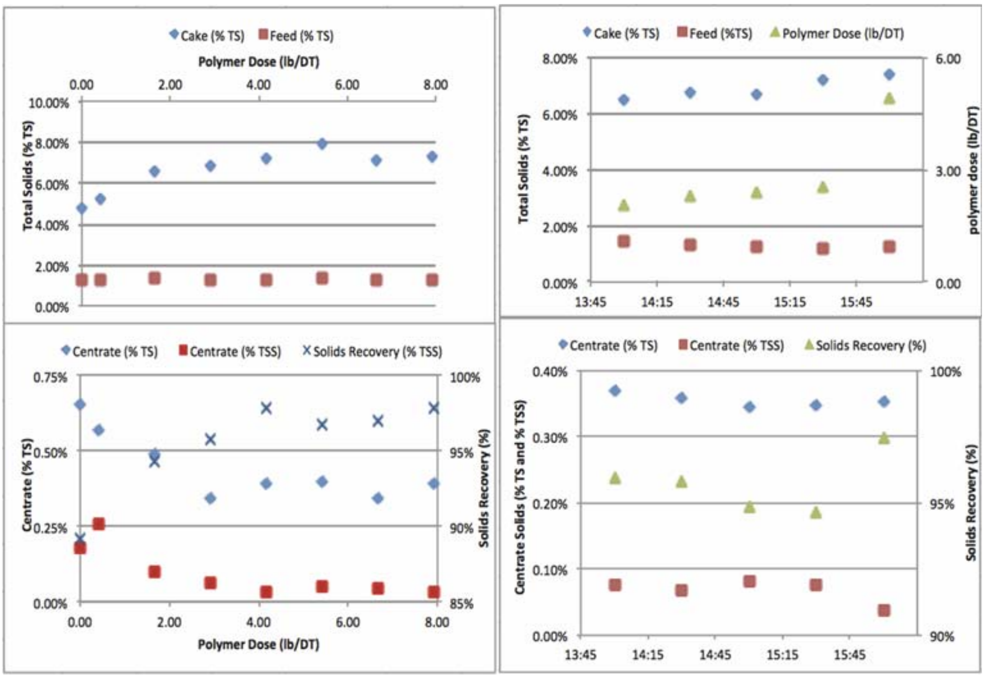

Figure 4. Dry Polymer Curve and Extended Operation Data: Central District Wastewater Treatment Plant, Waste Activated Sludge-Only

Figure 5. Central District Wastewater Treatment Plant Screens for North District Wastewater Treatment Plant Sludge

Figure 6. Central District Wastewater Treatment Plant and North District Wastewater Treatment Plant Blend Tank

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In order to provide a solution to minimize the impact of rags and grit for an interim period before the consent decree projects were to be implemented, water and sewer department operations personnel installed two Lakeside Raptor® Screens, shown in Figure 5 on the receiving pipe for NDWWTP sludge. The unit contains a screening system and an aerated grit chamber that provides removal of both rags and grit to a dumpster. The NDWWTP sludge from the screens was directed to one of CDWWTP's gravity concentrators.

Testing of NDWWTP sludge started at the end of June 2016, and testing ultimately continued through mid-September 2016. During the testing period, daily plant records for NDWWTP sludge production and transfer operations were provided to the PMCM team, which included information of flow to Force Main 1 and the solids concentration. The preliminary design for the NDWWTP sludge concentration was 0.75 percent TS average, with a range from 0.5 to 1 percent TS, but the data collected showed that the NDWWTP concentration was typically less than 0.5 percent TS.

Initial testing was conducted mostly on NDWWTP primary sludge, since a large proportion of the WAS was directed to Force Main 2 to the influent of CDWWTP due to limitation in the piping. On Aug. 29, 2016, after some piping modifications were made, all NDWWTP sludge began going through Force Main 1, and this mode of operation remained throughout the duration of the pilot that concluded on Sept. 15, 2016. The combination of thin sludge and the high proportion of primary sludge made thickening in the pilot centrifuge very difficult.

Although the CDWWTP WAS-only sludge was easily able to thicken in the pilot centrifuge, the NDWWTP primary sludge and WAS, which was more dilute, was difficult to handle and thicken reliably. After testing the NDWWTP primary sludge and WAS alone using multiple parameters, stable operation could not be maintained. Initial attempts to blend NDWWTP primary and WAS with CDWWTP WAS using an in-pipe blending system were also unsuccessful.

Because of the difficulties with the NDWWTP primary and WAS operation, a separate frac tank and recirculation pump was rented to allow a buffer for the NDWWTP primary and WAS, and for better control of blending the CDWWTP WAS and NDWWTP primary and WAS. When the NDWWTP sludge was blended with CDWWTP sludge in the blend tank (shown in Figure 6), stable operation could be maintained in the centrifuge, and greater than 5.5 percent TS-thickened sludge, with greater than 95 percent solids recovery, could be achieved. The dry polymer required 1.5 to 3 lb/DT (0.75 to 1.5 g/kg) ac-

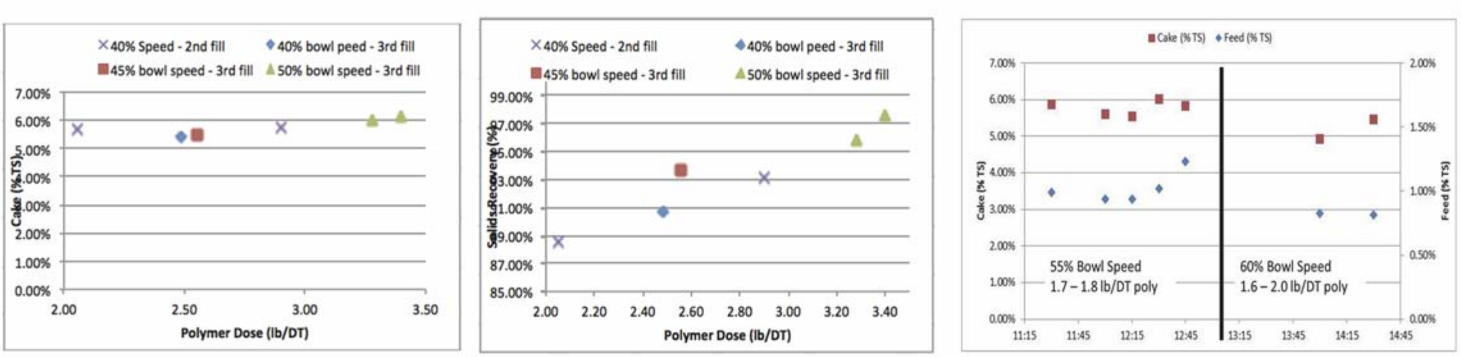

Figure 7. Central District Wastewater Treatment Plant and North District Wastewater Treatment Plant Polymer Curve and Extended Operating Testing Data

tive dosing, compared to 2 to 3 lb/DT (1 to 1.5 g/kg), based on the emulsion.

The testing showed that including a blend tank to mix the CDWWTP and NDWWTP sludge would be important for future operation to be successful. Example data collected for thickening the CDWWTP and NDWWTP sludge blend are provided in Figure 7.

The setup used during the pilot had several limitations with regard to capacity, tank mixing, and flow metering that should not be issues in a full-scale system. Because of the limitations, there were some variations noted for day-to-day operation. In addition, during the time of testing, the feed pump on the pilot centrifuge was wearing out and close to failure due to excessive wear on the stator from grit. Because of these issues, it was not possible to conduct an extended operation run for more than two to three hours at a time.

Continuous Thickening Pilot Operation

Centrifuge-thickened sludge was fed to Plant 2, cluster 1, digester 3 (the test digester) to simulate future high-rate single-stage mesophilic anaerobic digestion conditions and to increase the solids content of the digested biosolids for the dewatering pilot operations. Near-continuous operation began in mid-June and the team maintained continuous operation through mid-August, but performance testing on CDWWTP and/or NDWWTP sludge continued to be conducted during normal workday hours, with operation switching to CDWWTP WAS-only for overnight and weekend operations.

A manifold was set up to allow switching between the NDWWTP and CDWWTP sludges and was also used initially to blend them. Mechanical problems with the unit, specifically the thickened cake pump, limited the throughput and the operation time. The stator in the thickened sludge pump had to be replaced several times throughout the duration of the pilot.

For the stable period (shown in Figure 8), the thickened solids content to the digester averaged

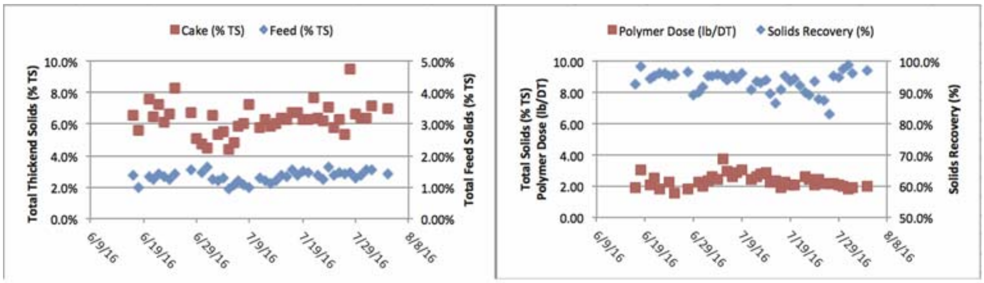

Figure 8. Continuous Thickening Operation

6.3 percent TS (with a 2.3 lb/DT [1.15 g/kg] active polymer dose) and the volatile solids content of the raw sludge being fed to the digester averaged 86 percent VS/TS. The solids content in the test digester was increased to approximately 2.8 to 3 percent TS. For comparison, the rest of the digesters operating at CDWWTP were being fed gravity-thickened sludge at approximately 3.8 percent TS, with a volatile solids content of 83 percent VS/TS; the other operational digesters operated at an average of 2.2 percent TS. The volatile solids reduction (VSR) estimations during this period ranged from 50 to greater than 70 percent, while the digester was approaching a steady state.

Dewatering Pilot Testing

The purpose of the dewatering pilot operation was to determine the optimal design conditions and performance of the dewatering centrifuge using the thickened biosolids fed from the test digester. The overall target for the centrifuge dewatering performance as stated in the basis of design specifications was to dewater the thickened digested biosolids to greater than 24 percent TS, while maintaining greater than 95 percent solids recovery. The necessary polymer dose to achieve this performance is also important to determine (and the draft specifications indicate) that an active polymer dose should be less than 25 lb/DT.

Metcalf and Eddy's *Wastewater Engineering Treatment and Reuse* (5th edition) lists 22 to 25 percent TS expected for anaerobically digested WAS and primary sludge, where the polymer consumption is expected to be 15 to 30 lb/DT active polymer dose, and solids recoveries are expected to be 95 percent or greater. The CDWWTP currently doses ferric sulfate at a rate of 1.9 gal per 1000 gal of sludge ahead of the centrifuges for struvite control. This practice is planned to continue in future operations, so a temporary ferric dosing system was also included with the pilot.

Dewatering Pilot Testing: Setup

For the dewatering pilot, the system was set up and tested with both emulsion and dry polymer, as well as ferric sulfate conditioning, which is similar to the current CDWWTP dewatering operation. The majority of the testing was conducted using the plant's dry polymer, which is more representative of the future design; however, some limited testing was also conducted using emulsion polymer to provide a comparison.

The initial dewatering operation was dedicated to optimizing the machine for the site-specific operation. Adjustable parameters included the pool depth, bowl speed, and differential scroll speed. The pool depth was adjusted manually through adjustment of the outlet weir plate and throughout all of the dewatering operation. The system was operated with the B weir plate, which corresponds to the second-deepest pool depth. For most of the dewatering operation, the centrifuge

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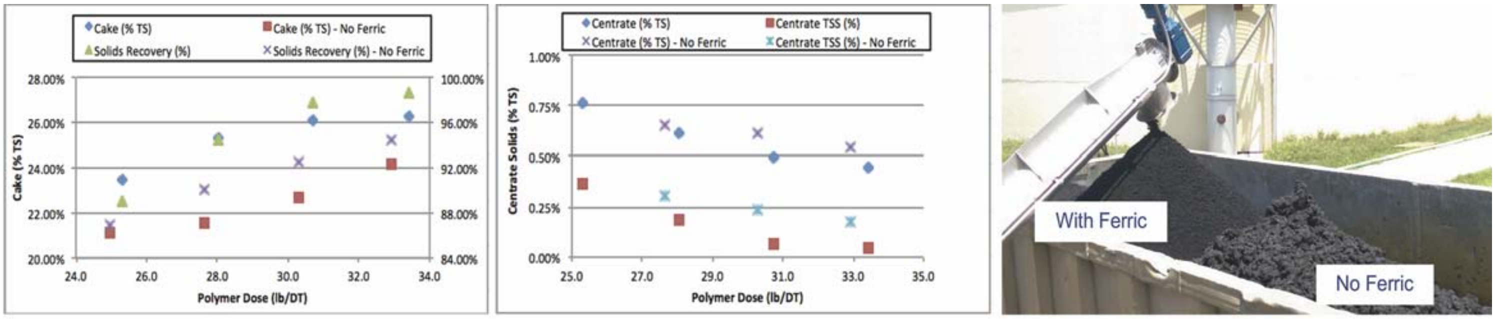

Figure 9. Central District Wastewater Treatment Plant Dewatering Polymer Curve Testing With and Without Ferric Sulfate (data, left; photo of cake, right)

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also operated at the highest bowl speed of 3,350 revolutions per minute (rpm). It was also found that injecting polymer directly into the feed tube was the best injection point, compared to other polymer injection locations tested.

Initial testing started with emulation polymers on Aug. 11, 2016. Three cationic, high-molecular-weight emulsion polymers were tested in order to determine the top polymer type for further testing. The emulsion polymers were able to achieve 21 to 26 percent TS, with greater than 95 percent solids recovery, but required higher polymer doses than were listed in the specifications (>30 lb/DT [15 g/kg]). Since the emulsion polymer dosing requirements were high compared to the specification requirements, and the basis of design is for a dry polymer, only limited further testing was conducted using emulsion polymer.

The dry polymer used for all of the dewatering testing was Polydyne Clarifloc C-SE-1141, which is currently used for CDWWTP dewatering centrifuges. This dry polymer testing used for the duration of the pilot was optimized to start performance testing on Aug. 17, 2016.

Dewatering Pilot Testing: Polymer Curve Testing

Polymer curve tests were conducted by maintaining a constant volumetric throughput of digested biosolids feed to the centrifuge, while changing the polymer dose to measure the impact. With the exception of changing the polymer dose, most of the other parameters on the centrifuge remained the same for each polymer curve test.

Poymer curve tests were conducted primarily on dry polymer with feed tube polymer injection. Testing was mostly done with ferric sulfate dosing, but testing without it was also done as a comparison; the data for this comparison are shown in Figure 9. The cake solids ranged from 23.5 to 26.3 percent TS with the addition of ferric sulfate; without the addition, the cake solids were 3 to 4 percent points lower, ranging from 21 to 24 percent TS. The difference in solids content was visibly noticeable, as can be seen in Figure 9. Without the addition of ferric sulfate, the solids recovery was also noticeably worse than the operation with ferric sulfate.

Dewatering Pilot Testing: Extended Operation Results

In addition to polymer curve tests, the dewatering centrifuge was operated for two days at a constant flow rate to test the stability of operation throughout the course of a day. Two tests were conducted at 80 gal per minute (gpm) (18.2 m^3/h) using dry polymer. Throughout the course of the test, it was desired to maintain constant settings; however, periodic adjustments were made based on visual observations of both the dewatered solids concentration and the centrate quality. The pilot field staff collected samples during these trials approximately once every 30 minutes to one hour, depending on the total duration of the particular test.

One extended run using dry polymer is shown in Figure 10. Performance during this run was stable, with dewatered cake solids averaging 25 percent TS and solids recoveries averaging over 98 percent for all samples collected. The feed during this run was consistent, averaging 3 percent TS. The differential speed was held at 3 rpm during the five hours of operation and the power consumption averaged about 0.19 kW (kilowatt)/gpm (0.83 kW/[m^3/hr]). The polymer concentration during this run averaged 0.8 percent and the active polymer dose averaged 25.8 lb/DT (12.9 g/kg).

The results of the dewatering pilot indicate that the centrifuge dewatering unit will be able to achieve a total cake solids of >24 percent TS and solids recovery requirements of >95 percent. The testing showed that >24 percent TS cake could be achieved with 25 lb/DT (12.5 g/kg) active dosing of dry polymer and a ferric sulfate dose equal to 1.9 gal ferric sulfate per 1,000 gal of sludge. Testing conducted without the use of ferric sulfate conditioning showed that the dewatering performance was reduced by 2 to 4 percent TS in cake solids and that the solids recovery percentages were lower. The centrifuge could achieve 26 to 28 percent TS with emulsion polymer, but the polymer dosages are higher and almost double than the desired maximum of 25 lb/DT (12.5 g/kg) active.

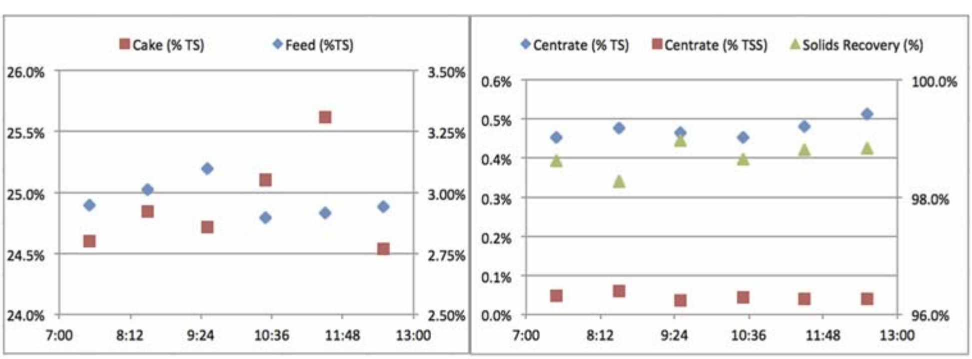

Figure 10. Extended Operation Using Dry Polymer

Conclusions

The CDWWTP WAS-only thickening testing showed that the centrifuge, operating on CDWWTP WAS-only, could reliably produce solids at 5 to 6 percent TS and achieve greater than 95 percent solids recovery. Testing was conducted using both dry and emulsion polymers. The dry polymer required 3 to 4 lb/DT (1.5 to 2 g/kg) active dosing, compared to 0.6 to 3 lb/DT (0.3 to 1.5 g/kg), based on the emulsion. It was also possible to thicken the sludge to 5 to 6 percent TS without the use of polymer, but this reduced hydraulic throughput by about 25 percent to allow the solids recoveries to remain above 95 percent.

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Because of the difficulties with NDWWTP primary and WAS operation, a separate tank was rented to allow a buffer NDWWTP primary and WAS, and for better control of blending the CDWWTP WAS and NDWWTP primary and WAS. When NDWWTP sludge was blended with CDWWTP sludge in the blend tank, stable operation could be maintained in the centrifuge, and greater than 5.5 percent TS thickened sludge, with greater than 95 percent solids recovery, could be achieved. The dry polymer required 1.5 to 3 lb/DT (0.75 to 1.5 g/kg) active dosing, compared to 2 to 3 lb/DT (1 to 1.5 g/kg), based on the emulsion. The testing showed that including a blend tank to mix the CDWWTP and NDWWTP sludge is important for future operation to be successful.

Near-continuous operation began in mid-June and the team maintained continuous operation through mid-August, but mechanical problems with the unit, specifically the thickened cake pump, limited the throughput and the operation time. For the stable period, the thickened solids content to the digester averaged 6.3 percent TS (with a 2.3 lb/DT [1.15 g/kg] active polymer dose) and the volatile solids content of the raw sludge being fed to the digester averaged 86 percent VS/TS. The solids content in the test digester was increased to approximately 2.8 to 3 percent TS. For comparison, the rest of the digesters operating at CDWWTP were being fed gravity-thickened sludge at about 3.8 percent TS, with a volatile solids content of 83 percent VS/TS and the other operational digesters operating at an average of 2.2 percent TS. The VSR estimations during this period ranged from 50 to greater than 70 percent, while the digester was approaching a steady state.

Overall, the pilot testing was used to set the necessary performance criteria for a design-build package. The testing also showed the importance of including a blend tank to be able to successfully manage and thicken the primary and WAS from NDWWTP. The pilot results highlight the importance of piloting to determine operational difficulties and to refine design performance criteria.

Acknowledgments

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