Biosolids Dewatering Alternatives for Orange County

Michael Scullion, K. Richard Tsang, Larry Tunnell, William Hurley, and Mark Burgess

Dewatering is a critical step in biosolids processing. Producing a drier biosolids cake can result in a significant cost savings to many of the utilities in central Florida that rely on contract hauling and land application of their biosolids. Belt filter presses have long been the dewatering technology of choice; however, the next generation of biosolids dewatering technologies offers promising results.

Water Reclamation Facilities in Orange County

Orange County Utilities (OCU) operates three water reclamation facilities (WRF): the Northwest WRF, the South WRF, and the Eastern WRF. Each currently uses belt filter presses for dewatering of secondary waste activated sludge (WAS). None of the WRFs have primary clarifiers. The 7.5-mgd Northwest WRF utilizes a modified Ludzack Ettinger (MLE) process train with secondary WAS stored in a series of aerated sludge holding tanks prior to dewatering. The Eastern WRF consists of a 19-mgd, five-stage Bardenpho process train, and a parallel 5-mgd, three-pass step-feed process train. Secondary WAS is typically sent directly to the belt filter presses for dewatering. Two old dissolved air flotation (DAF) tanks located at the Eastern WRF are no longer in operation. Although they can be used for sludge holding, there is insufficient capacity for extended storage in the DAF tanks. At the 43-mgd South WRF, the three process trains consist of a 20.5-mgd step-feed process train, 15-mgd MLE process train, and a 7.5-mgd oxidation ditch. The WAS at the South WRF is thickened on gravity belt thickeners prior to being treated in anaerobic digesters. Anaerobically digested sludge is dewatered by belt filter presses and conveyed into trucks for land application or disposal.

Dewatering of biosolids is a critical step in biosolids processing, impacting downstream treatment processes and transportation costs. Over the previous three years, dewatered solids contents have ranged from 13 percent at the South WRF to 16 percent at the Eastern WRF. Newer dewatering technology can be expected to significantly improve the performance of the existing belt filter presses. Production of a drier biosolids cake would reduce the volume of biosolids to be treated and transported, resulting in a significant savings. As the performance of dewatering technologies is largely site-specific, an on-site pilot testing program was conducted to provide a comparison of alternative dewatering technologies. In addition to a determination of the solid content of the biosolids cake produced by each alternative dewatering technology, the pilot testing also evaluated polymer dosage, throughput, power consumption, and solids capture.

Continued on page 20

Michael Scullion, P.E., is project manager, and Mark Burgess, P.E., BCEE, is vice president, with CDM Smith in Maitland. K. Richard Tsang, Ph.D., P.E., BCEE, is senior vice president with CDM Smith in Raleigh, N.C. Larry Tunnell, P.E., P.G., is chief engineer—utilities engineering division, and William Hurley, P.E., is manager—water reclamation division, at Orange County Utilities in Orlando.

Centrifuge pilot unit

Linear electro-dewatering pilot unit

Continued from page 18

Methodology

Alternative dewatering technologies were evaluated to select technologies that offered increased capacity and greater solids content than the existing belt filter presses. Technologies selected for the evaluation included centrifuge, screw press, rotary fan press, and linear electro-dewatering.

Pilot Testing Schedule

Pilot testing was conducted between Jan. 25 and March 19, 2010. Table 1 provides an overview of the pilot testing schedule.

The pilot testing schedule was developed to allow side-by-side comparison of the alternative dewatering technologies as much as possible, based on equipment availability. Since centrifuges and screw presses are established methods for biosolids dewatering, the technologies were selected for side-by-side comparison with the existing belt filter press units. The rotary fan press was pilot-tested after the centrifuge and screw press testing had been completed; however, the belt filter presses were in operation allowing a side-by-side comparison of the performance of the two technologies. Biosolids cake produced by the belt filters presses at each of the three WRFs was processed on the electro-dewatering unit. Due to scheduling conflicts, pilot testing of dewatered biosolids cake produced by the centrifuge, screw press, and rotary fan press was not possible.

Sampling and Analysis

Prior to commencement of pilot testing, a sampling and analysis protocol was developed to standardize collection and analysis of samples during the pilot study. Samples of feed sludge, filtrate, and biosolids cake were collected by OCU at regular intervals during the pilot testing. Sampling intervals were selected to allow for changes in operating conditions of the pilot units with adequate time for the units to reach equilibrium and produce a consistent biosolids cake. As part of the pilot testing program, the existing belt filter presses were operated and sampled at the same time as the alternative dewatering technologies.

Table 1. Orange County Biosolids Dewatering Pilot Program Schedule

Equipment Pilot Tested	OCU Facility	Dates Conducted
Centrifuge and Screw Press	Northwest WRF	Jan. 25-28, 2010
Centrifuge and Screw Press	South WRF	Feb. 1-4, 2010
Centrifuge and Screw Press	Eastern WRF	Feb. 8-11, 2010
Linear Electro-Dewatering	All WRFs	Feb.15-25, 2010
Rotary Fan Press	South WRF	March 12-16, 2010
Rotary Fan Press	Eastern WRF	March 18-19, 2010

Linear electro-dewatering sludge cake

Samples were split, with the equipment manufacturers conducting their analysis onsite, while OCU samples were shipped to its central laboratory for analysis. Feed sludge was tested for total and volatile solids, and pH. The solids content of the dewatered sludge cake and the filtrate was also measured.

Centrifuge Testing Methodology

The centrifuge technology utilizes high rotational speed to create a centrifugal force, pressing solids against the wall of the centrifuge bowl. Solids are removed from the centrifuge by a scroll rotating at a different speed than the bowl, while liquid level is controlled by adjustable weir plates that are adjusted to maintain a pond depth suitable for sedimentation of solids inside the centrifuge.

Samples of feed sludge collected from the WRFs were sent to the centrifuge manufacturer for preliminary sludge characterization and polymer testing the week prior to beginning the pilot testing program. Throughout the pilot study, the centrifuge manufacturer followed a set procedure for optimization of their equipment: establishment of the pond level, polymer testing, and finally, development of a throughput curve.

Screw Press Testing Methodology

The screw press technology consists of a series of U-shaped screen segments surrounding an inclined screw. Feed sludge enters the base of the unit, with the screen openings decreasing in size as the sludge travels up the screw. The slow rotation of the screw creates backpressure that forces water out of the sludge. A cone at the discharge end of the screw can be adjusted to provide additional backpressure to aid dewatering.

The screw press manufacturer did not evaluate the feed sludge prior to the beginning of the pilot testing. Upon arriving at the site, feed sludge was jar-tested with eight to ten polymers that the operator had on hand to evaluate the settling characteristics. Based on the results of the jar tests, one to two polymers were selected for further evaluation during the pilot testing period. The screw press manufacturer's testing protocol consisted of adjusting sludge feed rate, polymer type, dose and solution strength, screw speed, and discharge pressure based on the experience of the operator to obtain a drier cake.

Linear Electro-Dewatering Testing Methodology

The linear electro-dewatering technology has recently emerged onto the market, with a limited number of municipal installations. Building upon the limits of conventional mechanical dewatering, the linear electro-dewatering process uses an electric field to extract additional water from biosolids cake. An add-on process following mechanical dewatering, linear electro-dewatering is capable of producing a final solids content of 30 to 50 percent.

The linear electro-dewatering pilot unit consists of three separate components: the electro-dewatering unit, a separate electrical and control skid, and a high-pressure booster pump. Biosolids cake is manually loaded into the inlet hopper of the machine, where it is rolled out into a thin layer on the belt for dewatering. As the belt moves forward, electrodes are lowered to make contact with the sludge layer, while applying minimal pressure. Current is applied to the sludge layer, inducing an electrical field that draws water down through the belt through electro-osmosis. After a preset period of time, the electrodes rise, the belt moves, and a scraper blade is used to remove sludge from the belt. The backwash pumps deliver a high-pressure spray to the underside of the belt for cleaning during the discharge process, prior to the next batch entering the machine. At 10 to 20 percent inlet cake solids, the linear electro-dewatering unit used in the pilot tests has a throughput of 200 to 300 pounds per hour.

The linear electro-dewatering process is intended to operate at a constant voltage, with the thickness of the sludge layer adjusted to optimize conductivity and throughput of the unit. In order to further improve conductivity, the manufacturer utilizes a propriety dewatering aid referred to as electro-dewatering agent (EDA). Dosage rates for EDA were not reported by the manufacturer; however, its use was not required for biosolids cake from the South WRF, and limited quantities (less than five gallons) were used during the pilot testing of biosolids cake from the Northwest and Eastern WRFs. The second process variable with the electro-dewatering unit is treatment time, which directly impacts throughput as the linear electro-dewatering unit operates as a batch process.

Bench-scale testing was conducted prior to the pilot testing on biosolids cake from the existing belt filter presses of the WRFs, as well as cake produced by the centrifuge and screw press at the South WRF. Baseline sludge layer thicknesses and dewatering times developed

Continued on page 22

Continued from page 21

during the bench-scale testing were used as a starting point for the pilot testing.

Rotary Fan Press Testing Methodology

The rotary fan press technology utilizes two parallel wedgewire filter screens rotating at a slow speed to push feed sludge through the unit. A restrictor arm on the discharge of the press provides backpressure, which forces water out through the rotating screen elements.

The testing of the rotary fan press occurred after the testing of the other alternative dewatering technologies had been completed. Thus, side-by-side comparison of the rotary fan press was possible only with the existing belt filter presses.

The rotary fan press manufacturer conducted preliminary sludge analysis on-site prior to testing. Anaerobically digested feed sludge at the South WRF was dosed with sulfuric acid or ferric sulfate in addition to polymer in some of the pilot test runs due to the presence of struvite. At the Eastern WRF, polymer alone was used for preconditioning of the feed sludge prior to dewatering. The rotary fan press pilot trailer contained two dewatering units to allow testing with both a 1-in. and 1.5-in. channel width. Rotary fan press performance was evaluated by varying throughput, feed pressure, polymer dosage, and polymer type.

Results and Discussion

The sampling and analysis protocol developed prior to the testing program ensured that appropriate data were collected to allow for performance comparison. Parameters including solids content of the dewatered biosolids cake, polymer dosing rates, solids capture, energy consumption, and throughput provide a basis for comparison of dewatering performance.

Table 2. Alternative Dewatering Technology Feed Sludge Characteristics

OCU Facility	Solids Content	Volatile Solids	pH
Northwest WRF	1.0 to 1.5 percent	82 to 84 percent	7.0
South WRF	3.0 percent	70 to 74 percent	7.5
Eastern WRF	0.9 to 1.0 percent	88 to 90 percent	6.7 to 6.9

Table 3. Biosolids Cake Solids Content

OCU Facility	Centrifuge	Screw Press	Belt Filter Press	Rotary Fan Press
Northwest WRF	23.0 percent	21.4 percent	13.7 percent	N/A
South WRF	20.2 percent	17.1 percent	13.0 percent	13.7 percent
Eastern WRF	20.5 percent	20.3 percent	15.1 percent	17.2 percent

Samples of feed sludge, filtrate, and sludge cake

Feed Sludge Characteristics

Feed sludge samples were collected regularly during the pilot testing period and analyzed for solids content, volatile solids, and pH. Characteristics of the feed sludge at each WRF are presented in Table 2.

Cake Solids Content

One key dewatering parameter is cake dryness attainable by each technology. The existing belt filter presses at each WRF were operated under typical conditions and sampled regularly throughout the pilot testing period. The Eastern WRF produced the highest average solids content of the three facilities at 15.1 percent. No single sample from any of the belt filter presses reached 16 percent solids. The rotary fan press produced cake solids marginally better than the belt filter presses. When optimized, the screw press produced solids content above 17 percent at each of the facilities. Biosolids cake from the centrifuge exceeded 20 percent at each WRF. Solids content of the biosolids cake produced using each dewatering technology is presented in Table 3.

It should be noted that the solids content values presented in Table 3 for the centrifuge and screw press are the maximum values achieved during the course of the pilot study. These values reflect the optimization of the process over the week-long test period. The values for the belt filter presses presented are average values; however, the solids content of the cake produced by the belt filter presses was very consistent (± 1 percent of the average) over the course of the pilot testing period. Based on the data collected during the pilot study, use of a centrifuge or screw press as an alternative dewatering technology can be expected to significantly outperform the existing belt filter presses. A summary of 2008 biosolids production rates at each OCU facility, and the reduction in volume that could be expected to be achieved with an alternative dewatering technology, are presented in Table 4.

Based on data collected during pilot testing, upgrading the existing belt filter presses to centrifuges or screw presses would result in a 26 to 32 percent reduction in the amount of biosolids cake produced by OCU. At 2008 biosolids production rates, this amounts to a reduction of 76 to 93 wet tons per day. Biosolids production would be reduced by up to 164 wet tons per day based on 2025 projections by incorporating a more efficient dewatering technology. Significant reductions in the operations and maintenance costs associated with contract hauling and land application of biosolids due to the reduced volume have the potential to offset capital costs associated with replacement of the existing dewatering equipment.

The linear electro-dewatering unit is a unique add-on dewatering technology with the potential to enhance the existing belt filter presses or to operate in unison with new mechanical dewatering equipment. Due to availability of equipment, the electro-dewatering pilot testing was only able to be conducted on biosolids cake produced by OCU's existing belt filter presses.

The performance of the electro-dewatering unit was promising, with over a 100 percent increase in solids content of biosolids from all three OCU facilities. Solids content of biosolids cake treated by the electro-dewatering unit far exceeded anything that could be produced using traditional mechanical dewatering technologies alone, as shown in Table 5.

Initial biosolids cake concentrations from the belt filter presses, which represent the feed concentration to the electro-dewatering unit, are also shown in Table 5. The initial solids content of the biosolids cake from the Northwest and Eastern WRFs are higher than the values reported in Table 3, partially due to the fact that the cake was collected overnight and trucked to the South WRF the following morning for testing. Fresh biosolids cake was delivered each day during the pilot testing to minimize additional air drying of the material prior to testing. Temperatures during the pilot testing period were unseasonably low for central Florida, helping to minimize evaporation and changes in solids content of the cake during the day.

The linear electro-dewatering unit was able to further increase the solids content of the cake produced by the belt filter presses to at least 30 percent. Longer treatment times can produce higher concentrations; however, the technology operates as a batch process where treatment time is directly related to throughput. Table 5 provides solids content for the minimum and maximum treatment times used during the pilot tests. The electro-dewatering process has a practical upper limit to the amount of water that can be removed, after which the additional time and power required to further increase solids content are not cost-effective. However, for the treatment times investigated during the pilot test, there is a linear relationship between treatment time and solids content.

Screw press pilot unit

Table 4. 2008 OCU Biosolids Production and Wet Tonnage after Dewatering

OCU Facility	Facility (Dry Tons per Day)	Belt Filter Press (Wet Tons per Day)	Centrifuge (Wet Tons per Day)	Screw Press (Wet Tons per Day)
Northwest WRF	4.7	34.3	20.4	22.0
South WRF	16.4	126.2	81.2	95.9
Eastern WRF	19.7	130.5	96.1	97.0
Total	40.8	290.9	197.7	214.9

Table 5. Electro-Dewatered Biosolids Cake Solid Content

OCU Facility	Belt Filter Press	Electro-Dewatering Unit (Minimum Time)	Electro-Dewatering Unit (Maximum Time)
Northwest WRF	14.8 percent	34.0 percent (7 min)	39.0 percent (7.5 min)
South WRF	13.0 percent	31.0 percent (8.5 min)	36.5 percent (9.5 min)
Eastern WRF	16.4 percent	34.0 percent (4.5 min)	43.0 percent (6.5 min)

A second process variable with the electro-dewatering unit is thickness of the sludge layer. A thinner layer improves dewatering performance at the cost of throughput. With cake from the Eastern WRF, increasing the layer thickness from 12.5 mm to 15.0 mm produced a 7 percent decrease in the solids content (from 43 percent to 36 percent) with the same six-minute treatment time. Layer thickness can be adjusted to produce the desired throughput; however, there are limitations as an excessively thick layer will have limited conductivity, prohibiting dewatering. Balancing throughput and solids content is required to maximize the effectiveness of the system. The desirable final solids content of biosolids cake is also dependent upon the end use. Biosolids that are to be heat-dried for use as fuel should be as dry as possible prior to hauling to reduce cost. However, if the cake is to be composted, solids content that is too high is not desirable.

Polymer Dosing

In general, the polymers used for the biosolids dewatering pilot study had high to very high cationic charge, with medium molecular weight emulsion polymers at roughly 40 percent active polymer content. Polymer dosages were fine-tuned during pilot testing to develop a range that produced the driest biosolids cake. Typically, increasing the poly-

Continued on page 24

Continued from page 23

mer dosing rate increases solids content; however, above a certain limit, additional polymer can actually hinder dewatering. The expense of polymer can also outweigh the benefits of a marginal increase in solids content achieved with a large increase in dose. Optimal polymer dose ranges are presented in Table 6.

Polymer dosage rates for the rotary fan press were reported as 12 to 16 lbs active polymer per dry ton for both the South WRF and Eastern WRF. The centrifuge and screw press consumed significantly larger amounts of polymer to dewater the digested sludge from the South WRF than sludge from the Eastern or Northwest WRFs. The rotary fan press consumes 30 to 50 percent less polymer than the centrifuge or screw press; however, the reduction in cake solids content offsets this benefit.

Polymer consumption, when operating the belt filter presses, is roughly half of what would be anticipated from a centrifuge or screw press at each facility. Replacing the existing belt presses with a centrifuge or screw press would double OCU's polymer consumption rates, while improving dewatered cake solids content by 5 to 10 percent.

Solids Capture

Solids capture generally exceeded 90 percent during pilot testing. Average solids capture values at each facility are presented in Table 7.

Solids capture for the centrifuge was typically in excess of 95 percent. Lower centrifuge capture rates were observed during pilot testing at the Eastern WRF, particularly when throughput exceeded the rated capacity of the machine. Lower capture rates were observed for the screw press when operating at higher scroll speeds, higher throughput, and increased feed and discharge pressure. The rotary fan press produced solids capture rates above 97 percent over the course of pilot testing.

The linear electro-dewatering manufacturer notes that the lower capture rates observed during pilot testing are typical, as the doctor blade on the unit is not as efficient as a full-scale model and the blade was not set at its optimal position. It should be noted that initial pilot testing of the electro-dewatering unit was completed with a standard conveyor belt. The linear electro-dewatering manufacturer had a belt with smaller openings shipped to the South WRF in an attempt to increase the capture rate. This belt was received on the final day of testing, allowing two test runs to be completed on biosolids cake from the South WRF. Solids capture of each sample exceeded 99 percent.

Table 6. Optimal Polymer Dosing Rates

OCU Facility	Centrifuge (lbs/ton Active Polymer)	Screw Press (lbs/ton Active Polymer)
Northwest WRF	20-24	18-20
South WRF	33-37	30-35
Eastern WRF	19-23	18-24

Table 7. Average Solids Capture at OCU WRFs

OCU Facility	Centrifuge	Screw Press	Electro-Dewatering
Northwest WRF	97.0 percent	94.5 percent	92 percent
South WRF	96.2 percent	94.9 percent	95 percent
Eastern WRF	91.5 percent	96.5 percent	93 percent

Table 8. Projected Biosolids Production

	Northwest WRF	South WRF	Eastern WRF
Feed Sludge Solids Content	1.25 percent	3.00 percent	1.00 percent
2009 Max Month Biosolids Production	18,800 ppd	48,400 ppd	48,300 ppd
2025 Max Month Biosolids Production	26,600 ppd	76,300 ppd	68,200 ppd
2009 Feed Sludge Flow Rate	180,500 gpd	193,500 gpd	579,000 gpd
2025 Feed Sludge Flow Rate	255,000 gpd (530 gpm*)	305,000 gpd (635 gpm*)	818,000 gpd (1,700 gpm*)

* Flow rates represent required flow rate at current feed sludge solids concentrations to complete dewatering in one eight-hour shift per day.

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

Throughput

Throughput of dewatering equipment is a function of either hydraulic loading or solids loading. Biosolids dewatering equipment selected should provide adequate throughput to meet solids production within the desired operating schedule. Dewatering at OCU is typically conducted during one to two shifts per day to match plant staffing. Projected biosolids production for OCU's facilities is presented in Table 8.

The South WRF thickens secondary WAS prior to feeding its anaerobic digesters, decreasing the volume of feed sludge due to solids destruction in the digesters. Feed sludge at the South WRF is thicker, with around 3 percent solids content, while at the Northwest and Eastern WRFs, 1 to 1.5 percent solids is typical. Dewatering equipment at the South WRF would be expected to operate at a lower hydraulic loading rate to maintain the same solids loading rate into the machines.

The dewatering units used for pilot testing were all small-scale, commercially available units. A 36-in. diameter rotary fan press was used during pilot testing. The largest commercially available unit from the rotary fan press manufacturer is a double 48-in. diameter unit. This unit would be anticipated to process 90 gpm of 1 percent solids feed sludge based on observations from the pilot study. Higher throughputs could be obtained with a centrifuge or screw press. The largest screw press units offer capacity equivalent to that of a two-meter belt press, roughly 200 gpm at 1 percent solids feed sludge. While an improvement over the capacity offered by the rotary fan press, the limited throughput of the screw press may limit its application at large WRFs. Centrifuges offer the greatest throughput of any alternative dewatering technology, with units available to process 500 gpm or greater, at 1 percent solids feed sludge. Dewatering throughputs for the linear dewatering unit were estimated based on pilot testing data. The largest linear electro-dewatering unit currently available has an estimated capacity of 1.4 to 2.8 wet tons of solids per hour. Higher throughput offers the benefit of fewer units and shorter run times, reducing capital and operations costs.

Energy Consumption

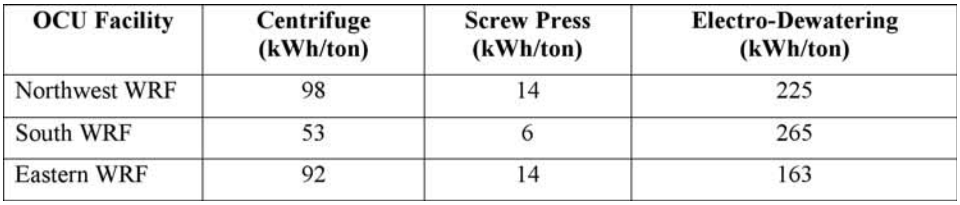
Operations costs associated with energy consumption can have a tremendous impact on biosolids dewatering. Energy consumption data were monitored and recorded by the centrifuge and linear electro-dewatering manufacturers during the pilot testing. The screw press manufacturer reported a maximum electric draw of the screw press, which was used to calculate energy consumption. Energy consumption of the dewatering equipment observed during pilot testing is presented in Table 9. These values only include the energy draw of the dewatering equipment, not energy use associated with pumping or conveyance.

The primary advantage of the screw press is energy consumption that is seven to ten times less than that of a centrifuge with comparable cake solids content. Mechanical dewatering is the most efficient dewatering method;

Continued on page 26

Dewatered sludge cake from South Water Reclamation Facility

Table 9. Energy Consumption of Dewatering Alternatives



OCU Facility	Centrifuge (kWh/ton)	Screw Press (kWh/ton)	Electro-Dewatering (kWh/ton)
Northwest WRF	98	14	225
South WRF	53	6	265
Eastern WRF	92	14	163

Continued from page 25

however, achieving higher solids concentrations requires an alternative technology such as electro-dewatering or heat drying. Energy consumption observed with the linear electro-dewatering pilot unit is less than would be expected with heat drying to reach the same solids content. Linear electro-dewatering has the potential to pair well with heat drying to reduce operations costs.

Conclusions

Pilot testing confirmed that alternative dewatering technologies will outperform OCU's existing belt filter presses. The belt filter presses can also be labor intensive, and are open units leading to spills of partially dewatered biosolids cake from the units. The alternative dewatering technologies tested provide higher solids content, less maintenance, a smaller footprint, and a contained dewatering solution. While selection of an alternative dewatering technology is somewhat dependent upon the final destination of the dewatered biosolids, conclusions can be drawn based on the results of the pilot study.

A rotary fan press offers some improvement in dewatered cake solids content over the existing belt filter presses, with less polymer consumption than that of the centrifuge and screw press. Although the rotary fan presses can be provided with multiple units to a skid, throughput is a limiting factor for facilities on the scale of OCU's WRFs.

The centrifuge and screw press technologies produced the highest dewatered cake solids content in pilot testing. Polymer consumption for the two units was comparable, although significantly greater than that of the belt filter press. Centrifuges offer slightly higher cake solids than the screw press, and the highest throughput available, with the trade-off of higher energy consumption and noisy operation. In the case of the OCU, the combination of high throughput and dewatered cake solids have made centrifuges the biosolids dewatering technology of choice.

The innovative new linear electro-dewatering technology increases the solids content of biosolids cake produced via mechanical dewatering. At the present time, limited throughput and the increased materials handling associated with batch operation are challenges to the implementation of this equipment. However, as the technology develops, linear electro-dewatering has the potential to pair well with heat drying of biosolids to reduce overall energy costs.