Optimization of Thermal Dryer Operations

Hari Santha, Neil S. Massart, Gary W. Neun, and Robert W. Bates

The Morris Forman Alternative Solids Project

The Morris Forman Wastewater Treatment Plant is owned and operated by the Louisville and Jefferson County Metropolitan Sewer District. It currently processes a mixture of primary and waste activated sludge from the facility itself and additional solids pumped or trucked from other Metropolitan Sewer District plants to the facility.

The treatment plant is located on the Ohio River in the western part of Louisville, Kentucky. It has a wastewater treatment capacity of 105 million gallons per day (MGD), and design year (2015 to 2020) average and maximum month solids production are 170 to 205 dry tonnes per day (186 and 225 dry tons per day), respectively.

Biosolids produced at the facility formerly were processed by a thermal conditioning system, dewatered in centrifuges, and then trucked for disposal in a landfill. The thermal conditioning system was effective in reducing solids and improving the dewaterability of the sludge, but odors associated with the process had become a source of public complaints and the equipment had deteriorated with age and required increasing maintenance. As a result, the Metropolitan Sewer District opted to implement an Alternative Solids Project to enable the existing thermal conditioning system to be decommissioned and to produce biosolids suitable for beneficial use.

The project consisted of 1) converting existing sludge storage tanks to anaerobic digesters to reduce solids and stabilize the sludge, 2) replacing existing centrifuges with new high-solids centrifuges to improve dewatering, and 3) installing four drying trains to produce a Class A granulated product, which can be marketed as a fertilizer or soil amendment.

The drying system consists of four rotary drum dryers, as manufactured by Andritz-Ruthner, each dryer sized with a nominal capacity of 71 dry tonnes per day (78 dtpd) with feed solids of 26 percent. To minimize energy use, methane produced by the digesters is used as a fuel source for the dryers and heat from the drying system's scrubber/condensers is recovered to heat the digesters.

Drum Drying System

Each drum drying system includes a triple-pass rotary drum dryer with direct gas heating and recycle feed system. A process flow diagram for the drum drying system is shown in Figure 1.

Dried recycle product is coated with dewatered cake in a mixer to make pellets, before entering the front of the rotary drum dryer. As the drum rotates, cascading the material, heated process gas flows through the drum, heating the pellets and removing the moisture that is evaporated from them.

The pellets make three passes through concentric cylinder sections of the drum dryer. At

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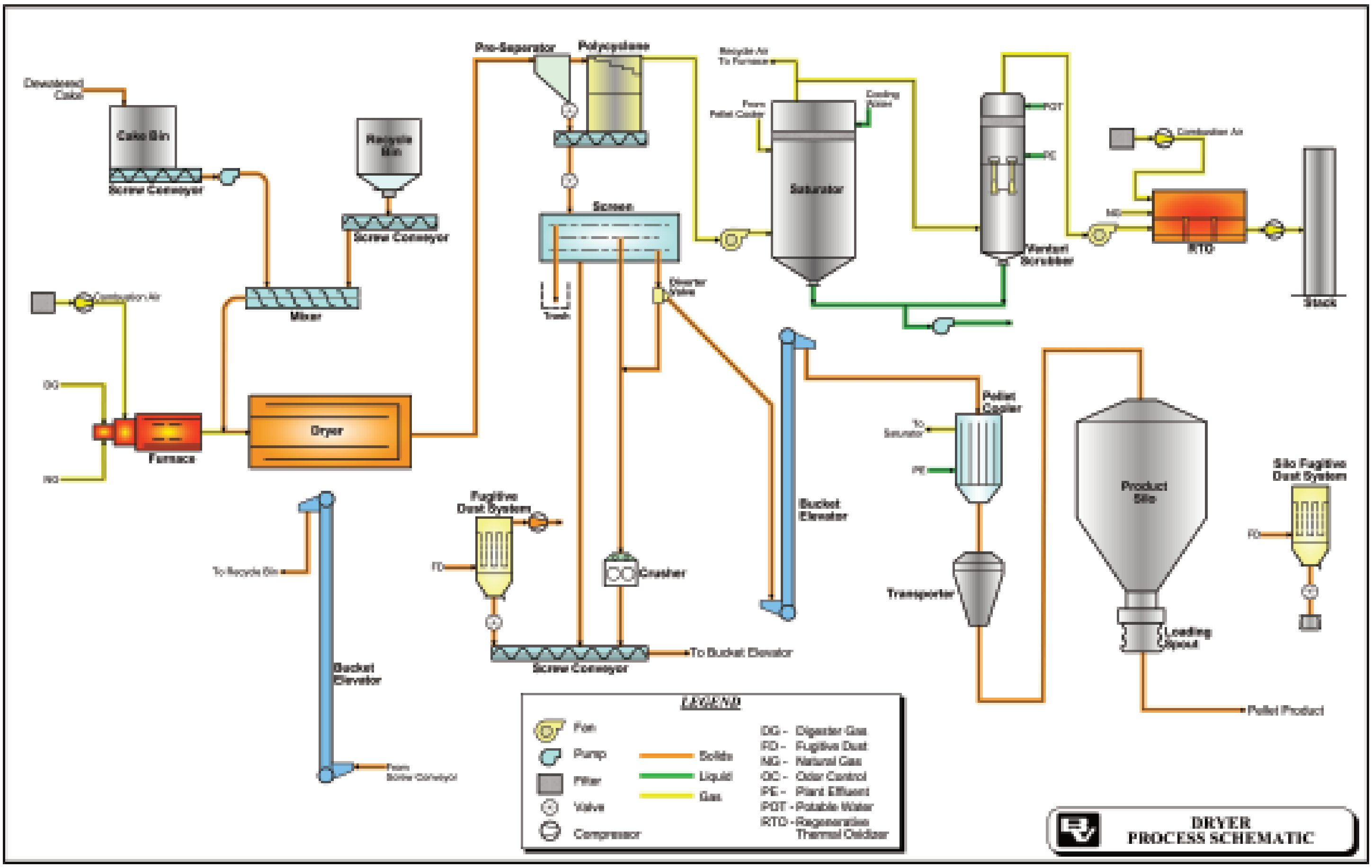
Hari Santha is a Process Engineer in the Kansas City, Missouri, office of the engineering firm Black & Veatch. Neil S. Massart is a Process Engineer in the Kansas City, Missouri, office of Black & Veatch. Gary W. Neun is a Director of Operations Technology Group in the Kansas City, Missouri, office of Black & Veatch. Robert W. Bates is a Biosolids Manager with the Louisville and Jefferson County Metropolitan Sewer District in Louisville, Kentucky.



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the end of the drum, the dried product is light enough that it becomes entrained in the process gas flow. The process gas conveys the dried pellets to a preseparator and cyclone, where the pellets are separated and conveyed to a screen.

The dried product is then screened, and oversized material is crushed and returned to the mixer, along with fines and a portion of properly sized pellets. This dried material is then recoated with dewatered cake and sent back through the dryer. A portion of the properly sized pellets downstream of the screen is not recycled, but is cooled in a product cooler and then conveyed to storage as finished product.

The drying system has a recirculated process gas system with direct heating. Recycled gas is introduced into a furnace, where a burner raises the process gas temperature. The heated gas is then drawn through the rotary drum, where it heats the pellets, removes evaporated moisture, and entrains dried pellets in the gas stream. The process gas then passes through a cyclone where the entrained sludge pellets are separated.

Downstream of the cyclone, the process gas flows through a wet scrubber condenser, where particulate and moisture are removed. Then the gas returns to the furnace to repeat the cycle. A portion of the process gas stream is removed and directed to a high-efficiency wet venturi scrubber to remove fine particulate. This blow-down gas is then directed to a regenerative thermal oxidizer (RTO) for thermal odor control before release to atmosphere.

Initial Difficulties of Start-up

Material Characteristics

Poor material characteristics, whether percent solids outside of acceptable ranges or too much fiber, can cause dryer malfunction. There are several locations within the drying system where solids concentrations must be controlled to avoid malfunctions.

- ***Dewatered Cake Feed to the Mixer***—At the mixer, if the solids concentration of wet cake is too high, the cake will not adhere to and properly coat the dry recycle material. As a result, a pellet with a dry core and an outer layer of wet material will not be produced. Wet material not bound to the pellets can adhere to dryer walls and plug process equipment, requiring cleaning. If the water content of the cake is extremely high, a "slop" material will be produced, creating significant safety hazards. Large clumps of wet material may form, which then tend to smolder.
- ***Mixed Material sent to the Dryer***—If the mixed material sent to the dryer is too wet, it can overload the drum dryer drive and plug dryer components. Mixed material, which is too dry, can produce dust in the drying system, requiring frequent cleaning of the recycle bin and other components.
- ***Dried Material***—If the solids concentration of the pellets is too high at the discharge of the dryer, "dusting" will occur, requiring cleaning of the drying system. A more serious problem occurs if too much water, typically more than 8 percent, is left in the dried material, which can reactivate microbial elements left in the product and cause biological activity that results in heat of reactivation, which can ultimately lead to smoldering and fires in the final product.

Also, too much fiber in the sludge sent to the dryers can cause poor pellet formation and create dust and packed fibers within the drying system, which in turn can plug equipment. As described in the following paragraphs, start-up conditions made it difficult to maintain acceptable material characteristics and resulted in operational difficulties.

Temporary Upstream Facilities

The Alternative Solids Project's solids processing systems included anaerobic digestion, dewatering, and drying systems. The original project approach was to start up the new digestion and dewatering facilities before operation of the drying system.

There were several reasons to start up the processes in this sequence: First, the anaerobic digestion process would break down fiber in the sludge, which can collect and clog components of the drying system. In addition, several of the sludge storage tanks that would be used temporarily to feed the centrifuges had no mixing, resulting in stratified solids and a wide variation in feed solids percentages sent to the centrifuges. Changed feed solids to the centrifuges make it difficult to produce consistent solids in the dewatered cake, making it difficult to control the percent solids of material throughout the drying system.

The original sequence was altered to address increasing maintenance issues with the thermal conditioning system, which had experienced a serious equipment failure during construction of the new Alternative Solids Project facilities. Because of the increased safety concerns with the equipment and the desire to demonstrate progress regarding odor issues at the plant, the Metropolitan Sewer District decided to decommission the system.

Without the solids reduction and improved dewaterability associated with the thermal conditioning system, the amount of dewatered cake sent to the local landfill nearly doubled. The district requested that the drying systems be started up before activation of the digestion systems so that the amount of material sent to the landfill could be greatly reduced.

The drying system had been installed before the conversion of all the storage tanks into digesters, since the storage tanks could be taken off line only one at a time, in order to have sufficient tanks available to keep the solids processing facilities in service. Although shutting down the thermal conditioning system allowed the district to address its most pressing priorities, using temporary facilities to supply sludge to the drying system did create some dryer start-up problems because of the use of undigested sludge and the variability in its feed solids.

Undigested Solids—Undigested primary raw sludge contains fibrous organic material that is normally broken down in an anaerobic digestion process. Examples of fiber include hair, grass clippings, plant material, and paper. Without digestion, this material was included in the sludge sent to the drying systems for processing.

This fibrous material was detrimental to good pellet formation because the pellets tend to break apart at the location of the fibers. Broken pellets result in poor product quality and the creation of dust in the system.

The dust and fibers caused significant operational and maintenance problems, with the main problem being that the drying equipment would become plugged. Operations and maintenance personnel spent many hours cleaning "fuzz" from the pellet cooler, pneumatic transporter, transport lines, bucket elevators, fugitive dust collectors, and silo offloading chute.

To perform the cleaning, often the equipment had to be disassembled to remove the packed material. This fuzz was analyzed and found to consist of cellulose material which had not broken down by upstream processing. Other operational problems associated with the dust and fiber included difficulty in controlling the recycle bin level and increased loading of the fugitive dust collection system.

Inconsistent Feed Solids—Using unmixed sludge storage tanks resulted in inconsistent feed solids being sent to the centrifuges for dewatering, with reported variations as great as 4-percent solids content within a 30-minute period. With such variations in feed solids to the centrifuges, controlling the solids content of the dewatered cake sent to the dryers was difficult. In the worst case, a centrifuge would lose seal, sending sloppy, too-wet material to the drying system wet cake bin.

The difficulty in controlling solids content of the dewatered cake made it difficult to maintain the mixed material and dried material solids content within acceptable ranges. Operating the drying system with solids contents outside of acceptable ranges led to drying system malfunction.

Because of the importance of maintaining consistent feed to the centrifuges, after the startup issues were discovered, the Metropolitan Sewer District established operating protocols for

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the processes upstream of dewatering (primary raw sludge pumping and thickened waste-activated sludge) to provide as much uniformity as possible to compensate for the lack of mixing.

Inconsistent feed to the drying process forced the dryer operators to expend more effort monitoring the dryer feed mix. Changes in dewatered cake affect the mixed material sent to the dryer. They require changes to the recycle rate and/or the dewatered cake feed rate to the dryer in order to maintain mixed material characteristics and account for changed moisture loading to the dryer. If dryer operating parameters are not adjusted to account for changed feed characteristics, many aspects of the dryer operation are impacted, including drum dryer drive load, heating requirements, cooling water needs, and performance of the condenser and scrubber.

Lack of Experience with Dryer Operations

Drying presented a new level of operation complexity operation for the Morris Forman Treatment Plant personnel. The level of monitoring and control needed to operate the new drying facility efficiently was unlike most processes in place at the plant, except the oxygen-generating system used by the waste-activated sludge process. Mastering the new process was made more difficult by the different types of equipment, the amount of equipment, and the large operating area of the drying system.

In addition to learning how the different components of the drying system interacted with each other, staff members had to learn how the new digestion and dewatering system components affected the drying system. Not only did the drying system operation have to be mastered during start-up, but new polymer, dewatering, digester heating, mixing and gas control, and pumping systems were brought on line during this period.

Coupled with learning the operating procedures for all the Alternative Solids Project processes, the Metropolitan Sewer District had experienced a recent staff reduction, leaving a relatively inexperienced staff to be trained and assume responsibility for operating these systems. To address some of these difficulties, the district created a start-up team charged with operating the new drying facility to develop a core group of experts. This approach was successful when those operators were on site, but was less successful when they were not.

Training was provided prior to start-up, but nothing can take the place of actual operation. An example of the importance of experience is illustrated in the ability to confirm that the solids concentrations of the dewatered cake and mixed material were within acceptable ranges. An experienced dryer operator can check by sight and touch the cake and mixed material solids content and make appropriate adjustments to ensure proper operation. An inexperienced operator can not, which could result in material being too wet or too dry. As a result, it was important that the optimization program establish standard procedures and quantifiable measuring techniques to ensure that solids content stayed within acceptable ranges.

Impacts of Drying System Malfunction

Drying system malfunctions had a significant impact on plant operations and solids processing costs. Two of the major cost impacts came from cleaning the dryers, when material was built up in the drying system, and from additional landfill costs, when inoperable drying systems forced dewatered cake to be sent to the landfill.

Drying System Cleaning—Cleaning a dryer system that has operated with material that is too wet or too dry is expensive, although the difficulty of cleaning will be affected by which of these two conditions has occurred.

Typically a system that has been operated with material that is too dry creates a recycle bin level that can not be controlled and continues to climb until high-level alarms shut the process down. The drying system can not be started with a completely full bin, so material must be removed using a vacuum. Typically, an outside service came to the plant and removed enough solids to restart the system. Vacuum services on an emergency basis can run as high as $300 an hour.

A drying system that has been operated with material that is too wet is more difficult to clean. If the situation is not addressed in time, wet material can accumulate in many components of the system, including the drum, outlet duct, pre-separator, shaker screen, mixer, conveyors, and recycle bin. Cleaning the system requires significant effort; removal of hatches or partial disassembly is needed to effectively clean the equipment.

Additional Landfill Costs—Sending dewatered cake to the landfill is more expensive than sending dried material because the additional water with the dewatered cake greatly increases the volume and weight of the material being removed. Before the thermal conditioning system was decommissioned, it was not uncommon for the Metropolitan Sewer District to send 20 trucks a day to the landfill. After decommissioning, when there was no more solids reduction from the thermal conditioning process and before the drying system came on line, the district would typically send 30 to 35 trucks a day to the landfill.

This contrasts with approximately five trucks per day required when the drying system is operating. Based on the amount of material sent to the landfill, operating costs were impacted greatly by whether the drying system was operating.

When the drying system was not operating, the amount of cake sent to the landfill increased and was not easily absorbed. The additional material and the messy conditions fouled garbage trucks from the city of Louisville. As a result, city officials decided to send their garbage to other landfills. The lack of city garbage meant an insufficient ratio of garbage to sludge, so the landfill decided not

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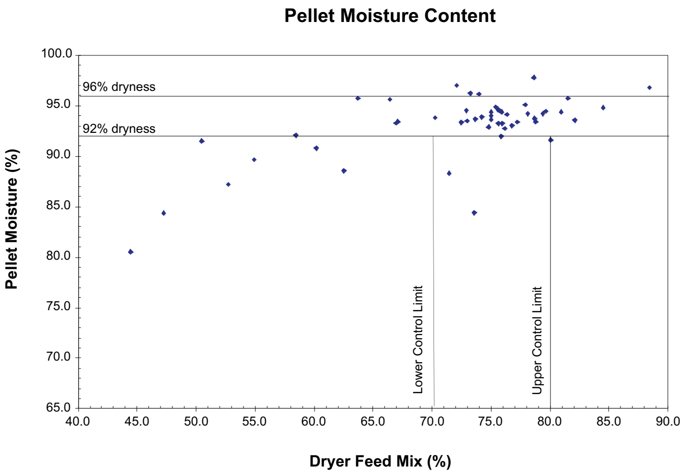

Figure 2: Relation of Dryer Feed Mix Solids to Pellet Solids

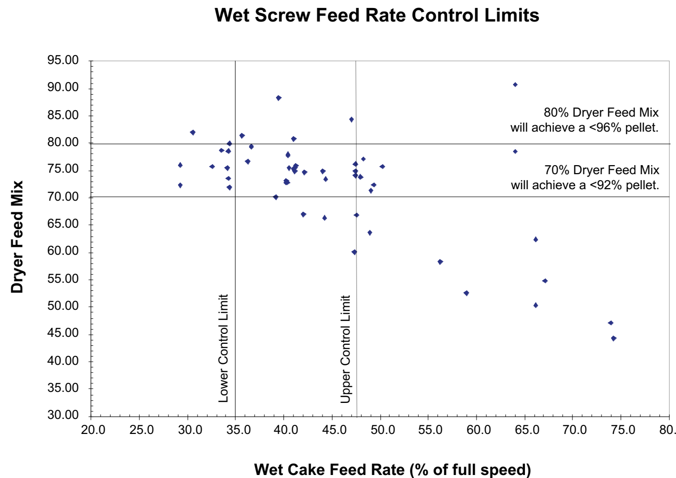

Figure 3: Limits for Wet Cake Screw Feed Rate

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to accept any more cake. The Metropolitan Sewer District then had to locate alternative sites for the dewatered solids that were farther away and more expensive.

Optimization Procedures

A set of optimization procedures were established to monitor the solids concentrations of the dewatered cake, mixed material (dryer feed mix), and dried (pellet) material in order to establish the following:

- The solids content ranges for each material with which the drying system produced an acceptable product.
- A systematic measurement procedure to ensure that the material stayed within the acceptable ranges.

The parameters to be monitored included the percent solids of the dewatered cake, dryer feed mix, pellet material, dewatered cake feed rate, and dried (recycle) material feed rate. The feed rates for dewatered cake and recycle material were monitored because the speed of the feed devices had a direct impact on the solids content of the dryer feed mix.

Samples to determine solids content were obtained from the locations indicated in Figure 1. Moisture content was determined by the use of a microwave analyzer to provide fast, accurate measurements in the operating area. Use of instrumentation to provide quantified readings removed possible error that can result from subjective estimations of moisture content based on sight and touch.

Feed rates were recorded from the drying system monitoring screen. Sampling and data collection were obtained hourly. It is important to take measurements at least hourly to ensure that there is sufficient time to respond to changing solids conditions.

Results of the monitoring were tabulated for data analysis. The optimization procedures also established the statistical methods for correlating the solids concentrations data with successful drying system operation, defined as production of an acceptable pellet material, to establish acceptable operating ranges.

Solids concentration data, which was taken during successful drying system operation, were used to calculate average values. Standard deviations determined from this same data were then used to establish the upper and lower limits of acceptable operating ranges. The procedures and results of this data analysis are reviewed in more detail in the following section.

Implementing the Optimization Program

During the process optimization period, data was gathered and analyzed to determine acceptable operating ranges for the various parameters. Subsequently, monitoring and control procedures were established to ensure that operating conditions fell within the acceptable ranges.

Data Analysis

Successful drying system operation was defined as production of an acceptable pellet material at the end of the drying process, which was determined by whether the pellet dryness fell between 92 and 96 percent solids. Experience at the Morris Forman Plant had established that if pellet dryness exceeded 96 percent solids, the pellets became brittle and broke apart, which created unacceptable amounts of dust within the drying system. Experience also had established that if the pellet dryness was less than 92 percent solids, the pellets were too wet, adhering to the sidewalls or components inside the drying system.

Once the acceptable range for dried material moisture content had been set, then the data was analyzed to determine the acceptable operating ranges for upstream processes which directly impacted downstream processes. As a result, acceptable ranges for mix feed dryness were determined in order to produce dried material of acceptable moisture content, since mix feed dryness directly impacted the dryness of dried product.

Then, acceptable ranges for the moisture of dewatered cake, the dewatered cake feed rate, and the recycle feed rate were established, since these factors all had a direct impact on whether the feed mix dryness fell within the acceptable range.

The optimal dryer feed mix dry solids content was determined to be 75 percent and the upper and lower control limits were established at 80 and 70 percent, respectively, based on the following analysis procedures. Readings of acceptable pellet dryness were correlated to corresponding readings of feed mix dryness. The average and standard deviation of the dryer feed mix percent solids samples were then calculated. The average was established for the optimal control point. Adding or subtracting one standard deviation from the average established the upper and lower control limits, since this would encompass the majority of the set points where optimal pellet dryness was achieved.

Figure 2 shows the relationship between moisture content of the pellet and dryer feed mix material, for data collected during two weeks of March 2003.

With the range of dryer feed mix dryness that typically produced acceptable pellets established, additional data was analyzed to determine acceptable operating ranges for the two parameters—the wet cake feed rate and the recycle material feed rate—which the operators could use to control dryer feed mix dryness. These rates are monitored and controlled through the drying system control system, Human Machine Interface (HMI), and

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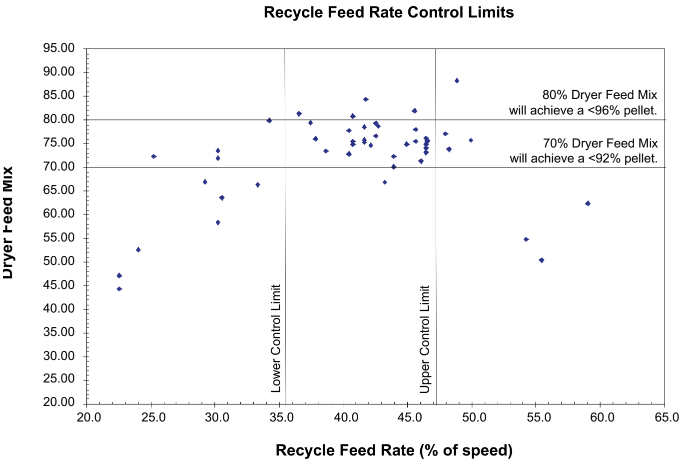

Figure 4: Limits for Recycle Screw Feed Rate

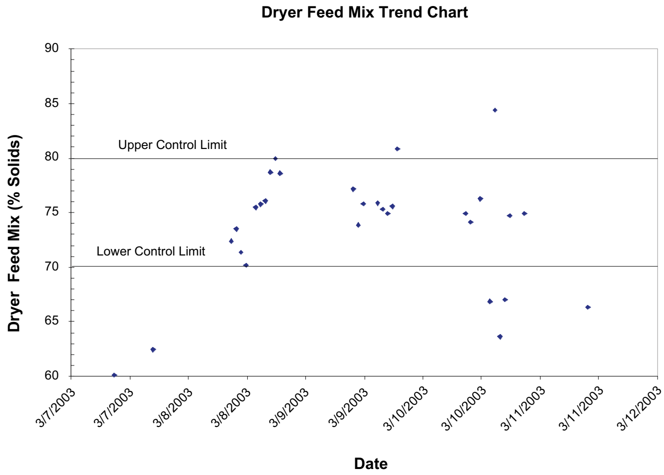

Figure 5: Typical Dryer Feed Mix Trend Chart

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are expressed as a percentage of full speed of the respective screw conveyors. The wet cake feed screw conveyor had a maximum capacity of 600 cubic feet per hour (ft^3/hr), and the recycle feed screw conveyor had a maximum capacity of 1,860 ft^3/hr.

Figures 3 and 4 illustrate the data collected for each of the operator-controlled parameters, the wet cake screw feed rate and the recycle screw feed rate, with respect to dryer feed mix dryness.

Using the statistical analysis outlined previously for establishing an acceptable dryer feed mix range, a wet cake screw feed rate range of 37 and 47 percent of full speed was established to maintain a dryer feed mix of 70 to 80 percent dry solids, which in turn will produce a pellet of 92 to 96 percent dry solids. The recycle feed rate as a percentage of full speed ranged from 35 to 47 percent to maintain an acceptable pellet dryness and dryer feed mix.

Once the parameters were determined, trend charts were established to monitor dryer system operation. Process upsets are averted by adjusting the parameters to within established control limits and maintaining control of the recycle bin levels and wet cake bin levels. Figure 5 shows an example of the trend charts for dryer feed mix.

Control limits varied, based on the type of sludge dried. The control limits for the dryer feed mix solids were higher for a mixture of digested sludge and thickened activated sludge than the control limits for all digested sludge. It was concluded from this fact that the digested sludge dries more easily.

Other sludge characteristics will affect the control limits. As optimization procedures were implemented, a 50/50 mixture, by weight, of thickened waste-activated sludge and anaerobic digested sludge was sent to the dryer system. This mixture resulted in control limits of 70 percent and 80 percent solids of the dryer feed mix to maintain acceptable pellet dryness.

Since implementation of optimization, the Metropolitan Sewer District has begun adding ferric chloride to the thickened waste-activated sludge for odor control. Ferric chloride changed the characteristic of the dewatered cake, and control limits of 62 and 65 percent solids of the dryer feed mix were established to maintain acceptable pellet dryness.

Not only have control limits been modified as a result of changed conditions, but control parameters have also been modified. Since the procedures were implemented, the district has determined that it is more effective to monitor the ratio of dewatered cake to recycle material than to separately monitor the dewatered cake and recycle feed rates. Although conditions or measured parameters may change, the optimization procedures provide a systematic method to determine and monitor acceptable operating ranges.

Implementation Results

Implementing optimization procedures significantly reduced the number of dryer process malfunctions. With acceptable operating ranges established and regular monitoring of solids concentrations, operators were able to identify conditions that would lead to problems and take corrective action. As a result of the optimization plan, operational issues and costs have been greatly reduced.

Reduction of Dewatered Cake to Landfill—Implementing the optimization plan significantly reduced the amount of dewatered cake sent to landfill because of the increased availability of the dryers to process solids. From January to March 2003, before executing the optimization procedures on a continuous basis, the percent of solids processed by the drying system was 88.0 percent. From July to September 2003, after optimization procedures were fully implemented, the percent of solid processed by the drying system increased to 97.4 percent. Based on 2003 averages of 25.7 percent dewatered cake solids, 94.1 percent pellet solids, and 2,095 tons per month of dry solids production, the increase in the amount of solids which were dried, reduced the amount of material sent to the landfill by 549 tons per month.

Reduction of Cleaning Costs—Optimized operation of the drying system has virtually eliminated the need to "clean" the dryers. Maintaining the dryer feed mix moisture content within an acceptable range means there are few problems with wet material overloading a dryer or excessive fines causing recycle bin or fugitive dust collection system issues. Currently, except for the routine cleaning and inspection program the Metropolitan Sewer District has implemented on dryers that are out of service, the need for major cleanups has been eliminated. Only major dewatering or drying equipment malfunctions, or significant process changes such as the production of a smaller pellet for market reasons, require anything other than routine cleaning.

Conclusions

Optimization procedures have provided the Metropolitan Sewer District with a systematic method to maintain material characteristics within acceptable operating ranges. This method has resulted in fewer process malfunctions, significantly reducing operational issues and costs.

While acceptable operating ranges determined by optimization procedures will be site specific, based on the biosolids characteristics of a particular wastewater treatment plant, the procedures themselves are applicable to any drying facility. The procedures outlined in this article have also been implemented successfully at the Buckman Wastewater Treatment Plant, owned and operated by JEA in Jacksonville, Florida.