Thermal Hydrolysis – The Next Generation

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OVERVIEW

The Trinity River Authority (TRA) Central Regional Wastewater System (CRWS) provides wastewater collection and treatment services to all or portions of 21 jurisdictions in the Dallas-Fort Worth (DFW) metroplex, as well as the DFW International Airport. To be proactive at CRWS, TRA embarked on a Solids Management Improvements program in the late 2000s. The key driver for the development of the plan centered around concerns regarding the long-term sustainability of the wastewater treatment plant's (WWTP) solids management program. Another important driver was the need to ensure reliable, low cost solids handling within the plant. After evaluating several alternatives, the master plan recommended changing the stabilization process at the WWTP from lime stabilization to mesophilic digestion, preceded by thermal hydrolysis as a pretreatment step.

As more facilities utilize the thermal hydrolysis process (THP), additional knowledge is gained and facilities are able to become more optimized. Thermal hydrolysis has actually been implemented at more than 30 facilities worldwide, yet at this time there is only one facility in North America using the process, DC Water's Advanced Wastewater Treatment Plant in Washington, DC. DC Water's recent project included the installation of four 3.8 million gallon anaerobic digesters and the world's largest thermal hydrolysis process system. This process results in a Class A biosolids product, as well as biogas utilized for conversion into heat and power for plant operations. The facilities produce Class A biosolids and reduces the volume of biosolids hauled off site by over 50 percent when compared to the previous lime stabilization facilities. DC Water also has the capability of generating 14 megawatts of power from biogas and currently generates approximately 10 megawatts.

The general process used at both DC Water and TRA includes screening, pre-dewatering, thermal hydrolysis, heat dissipation, digestion and post-dewatering. Thermal hydrolysis itself is done in parallel "trains". The thermal hydrolysis process (THP) receives solids from the Pre-Dewatering Cake Bins, thermally hydrolyzes the solids, and then pumps solids through pre-coolers and to the digester facility for further processing. At the digester facility, the sludge is blended with digesting sludge and further cooled to mesophilic temperatures.

Thermal hydrolysis is a process by which sludge is heated under pressure, with the purpose of improving the availability of organic solids to make them more readily biodegradable. While the various THP manufacturers each use slightly different approaches, each Cambi thermal hydrolysis train, whether the current B-6 version or the DC Water B-12 version consists of:

- One pulper vessel
- Reactor vessels
- One flash tank
- Pulper recirculation/reactor feed pumps
- Digester feed pumps
- Process gas cooler
- Process gas compressor skid

The THP feed pumps send the pre-dewatered solids to the pulper vessels in the range of 15–18 percent dry solids (%DS). Once in the pulper, the solids are pre-heated using steam recycled from the downstream flash tank. Solids in the pulper vessels are mixed by pulper circulation pumps. Plant water can be added to the pulper circulation pump loop to reduce the pre-dewatered solids if necessary. The pulper circulation pumps homogenize the temperature and concentration of the solids in the pulper. The reactor feed pumps transfer solids from the pulper vessel to the reactors.

The reactor process utilizes steam to increase temperature and pressure over a period of time to hydrolyze the solids and improve digestibility. The thermal hydrolysis of the solids causes the solids to be partially solubilized and the biological cell walls to break down releasing the water contained in the cells and improving the viscosity (ability to flow). This allows thermal hydrolyzed solids with a 10% DS to 12% DS concentration to have the same flow characteristics as non-hydrolyzed solids at 5% to 6%. As a result, more solids can be added to the digesters—increasing efficiency. High solids feed also increases the pH buffering capacity (alkalinity production) of the digester solids. The final dewatering of the digested solids will also be improved.

Following the reaction, thermally hydrolyzed sludge (THS) is driven into the flash tank by excess pressure. The flash tank reduces the temperature of the solids by recovering steam into the pulper vessel, and also functions as a reservoir for the digester feed pumps, which move solids to the digesters. Upstream of the digester feed pumps, plant water is added to the hydrolyzed solids. This is done to adjust the % DS of the solids feed to the digesters as well as ammonia concentrations. The dilution system also cools the solids, reducing the temperature, which also reduces the wear on the digester feed pumps. Dilution water is set as a ratio or a given flow through a control valve.

The off-gas and steam collected in the pulper vessel is considered foul gas due to malodorous state and water saturation. Process gas is passed through a process gas cooler (heat exchanger) to cool down the gas and condense moisture, with the condensate drained back to the pulper vessel. Cooled foul gas enters foul gas compressor skids to increase gas pressure. The compressed foul gas is fed into the Digester Feed system piping.

Worldwide, there are limited manufacturers of thermal hydrolysis systems, and DC Water is the largest such facility in the world and TRA will be the second largest in North America once

implemented. Based on the risks of the process and the limited number of experienced manufacturers, after competitive pre-selection, TRA determined that Cambi of Norway will be the preferred manufacturer to provide the thermal hydrolysis. Cambi is responsible only for the design and installation of the thermal hydrolysis process and the pre-cooling system; however, it is necessary to integrate the thermal hydrolysis process to the overall design to ensure proper function of the entire plant.

Implementation of the digester pretreatment at both DC Water and TRA required several critical steps to ensure the biosolids meet the criteria necessary for optimal mesophilic digestion. The pretreatment requirements included:

- Biosolids screening
- Predewatering to 15% to 18% dry solids
- Control and transfer of pre-dewatered biosolids
- Thermal hydrolysis for a minimum of 18 minutes at 320°F (160°C)
- Heat dissipation of biosolids from 194°F to 100°F (90°C to 38°C) prior to feeding digesters

The CRWS design is based upon the general process used at DC Water, while incorporating knowledge gained from lessons learned during the design, construction, startup and operation of that facility. The improvements implemented at TRA to the overall process, including pre-dewatering, Cambi thermal hydrolysis, solids cooling and digestion have been designed to optimize the system for reduced capital and operations costs.

PRE-DEWATERING

Pre-dewatering at the DC Water facility includes 10 centrifuges, with space for two additional centrifuges for a maximum of 12 centrifuges total. Three centrifuge locations feed into each cake bin and centrifuges are currently installed 2-3-3-2 by train. Each cake bin is dedicated to redundant THP feed pumps, which pump to a single thermal hydrolysis train. Crossover is not possible between centrifuges and THP trains without the installation of temporary piping and shutdown of the primary feed for the train. As a result, once the sludge enters a centrifuge, it is dedicated to a specific thermal hydrolysis train. The disadvantage of this configuration is that if one centrifuge is out of service on a train with only two centrifuges, the maximum feed to the system drops by approximately 10% since there is no redundant centrifuge on that particular train.

Based upon findings and operating experiences at DC Water, the design at CRWS has seven centrifuges (with space for a maximum of 8 centrifuges) and two cake bins. Each cake bin will be able to send dewatered solids to each of three thermal hydrolysis trains. Three centrifuges feed to one cake bin and four to another. This allows for significantly improved flexibility and a reduction in risk of an outage at the plant. In this way, if a centrifuge is out of service for an extended period, there is no overall change in capacity. Additionally, if a THP feed pump is out of service, there is also no change in capacity. This offers TRA full redundancy of the pre-dewatering process.

Additionally, for pre-dewatering sampling, DC Water has a sampling sink on the centrifuge level. Sampling ports for THP feed are located on the first floor, two levels below centrifuge level. DC Water currently has no provisions for permanent solids testing in the building. During operations at DC Water, it was determined that the quantity of sampling needed for appropriate digester feed concentration and dilution is significant and much greater than the need for sampling at the centrifuges. For this reason, TRA will have sampling provisions for solids testing adjacent to the THP feed with appropriate sampling sinks, solids analyzers and bench areas. TRA determined that the ability to analyze solids in the immediate area will allow for easier operations and for adjustments of dilution water.

THERMAL HYDROLYSIS

The thermal hydrolysis facilities at Blue Plains include Cambi process equipment, and is based upon Cambi's older B-12 model. The B-12 was developed in 1997 and approximately 30 systems have been installed worldwide. The B-12 systems were custom designed for each facility, had long lead times for delivery with extensive on-site installation time. The installation of a B-12 system would take on average 6 months of field installation depending upon the number of trains.

In 2012, Cambi developed their B-6 system and, since that time, has installed approximately 18 facilities with the B-6. The B-6 system is a skid mounted system, which is factory pre-assembled, and factory wired to terminal cabinets. The development of the B-6 system allowed shorter delivery times and installation times of approximately 4 weeks per train, which results in a significant time and cost savings. With the factory assembly of the system, this eliminated all field welding, fit-up issues and other field issues inherent in field construction.

The B-12 system utilized reactors that are approximately 12 cubic meters in volume. During operations, the 12 cubic meters reactor volume is utilized to approximately 55 percent during each batch. The limited use is because of the foam created during the initial de-pressurization to the pulper in the B-12 system. The B-6 system utilizes reactors that are approximately 6 cubic meters in volume. During operations these reactors are filled to more than 80 percent of their capacity. This is possible based on the use of a ceramic nozzle in the flash tank, which eliminated the initial de-pressurization to the pulper from the reactor and significantly reduced foaming in the reactor vessel. This also reduced the overall cycle time for each reactor, allowing a system with a footprint less than half of the B-12 and a capacity of more than 80 percent of the B-12 system.

The B-12 system utilizes a replaceable wear plate in the flash tank to protect the flash tank wall from damage due to high velocities. The wear plate in the B-12 system is required to be inspected annually and replaced as necessary, with typical expected life of approximately 2 to 3 years depending on the quality of the solids feed to the system. The use of the wear plate was discontinued for the B-6 system and the nozzles on the reactor discharge pipe to the flash tank modified to be a ceramic nozzle. The use of ceramic nozzles resulted in lower velocities and a different spray pattern into the flash tank. This eliminated the need for the replaceable wear plate.

In addition to eliminating the wear plate, the new spray pattern into the flash tank eliminated the need for pressure reduction prior to flashing. The B-12 system utilizes a steam release from the reactor to the flash tank, reducing pressure in the reactor from 6 bar (~90 psi) to 3 bar (~45 psi) prior to discharge to the flash tank. The B-12 system then utilizes the remaining pressure to transfer solids from the reactor to the flash tank, further dropping the pressure from 3 bar (~45 psi) to approximately 1.2 bar (~18 psi). The use of the ceramic nozzles allowed a greater pressure drop into the flash tank, resulting in the elimination of the steam flash. This improves the disintegration of the cell walls and produces additional biogas in less time. This new flashing cycle also eliminated foam buildup in the reactors and allowed the higher reactor fill identified above.

The new operating cycle allows higher fill in the reactors, so throughput with smaller vessels is increased. Shorter cycle time allows reduction in number of reactor vessels. Additionally, less precision is needed on reactor fill which allows for the elimination of a precise nuclear level switch. There is one precise nuclear level switch installed on each reactor at DC Water, for a total of 24 switches. Instead, dual flow meters will be installed at TRA for reactor fill. There will be two flow meters per skid, for a total of six flow meters.

As indicated above, the B-6 system operates using only four cycles which allows for higher capacities in smaller reactors. The four cycles within the reactors include: solids fill; steam addition to raise temperature and pressure; 20-minute hold time for Class A pathogen reduction; and flashing to atmospheric pressure to a flash tank providing pressure drop disintegration of the biomass. The cycle time at DC Water is approximately 90 minutes with 30 minute hold time while the TRA cycle time is 50 minutes with 20 minute hold time. This significant reduction in the cycle time has decreased the maximum reactors necessary for full rated throughput from six reactors to four reactors. The B-6 cycles are shown in more detail in Figure 1.

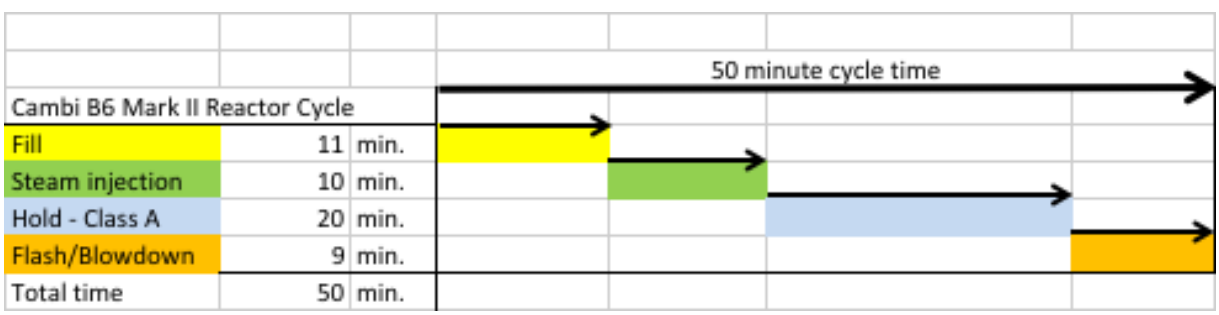

Figure 1. Cambi B-6 Reactor Cycles

Maximum design throughput on the DC Water B-12 system, with six reactors per train, is approximately 120 dtpd (dry tons per day) per train, with 112.5 dtpd guaranteed required by the contract. The maximum design throughput on the TRA system, with four reactors per train, is approximately 95 dtpd per train, with 90 dtpd required by the contract. The footprint of each train at DC Water is approximately 100’ long and 15’ wide (1,500 square feet) with a height of

approximately 28’ to the top of the railings. The footprint of each train at TRA is approximately 33’ long and 26’ wide (858 square feet) with a height of approximately 24’ to the top of the railing, or approximately 55% of the footprint.

Figure 2. Thermal Hydrolysis Train at DC Water

Costs per dry ton are expected to be lower at CRWS. The installed cost at DC Water was approximately $85,000 per dry ton per day capacity while the installed cost at TRA is anticipated to be approximately $70,000 per dry ton per day.

COOLING

The cooling system at DC Water utilizes two cooling heat exchangers and one tuning heat exchanger for each digester. The sludge is cooled from the THP maximum discharge temperature of 194°F (90°C) to mesophilic temperatures in a single pass through one of the

cooling heat exchangers. The heat removal requirements of the thermally hydrolyzed solids led to the requirements for two heat exchangers for each digester. The tuning heat exchangers are provided for the purposes of mixing and providing fine tuning control of temperatures in the digester.

During the past year of operation at DC Water, tuning heat exchanger did not appear to offer significant benefits in stabilizing digester temperatures. Digester temperatures did not change quickly, with or without tuning HEX. During the winter months, the use of tuning heat exchanger resulted in a significant loss of heat such that cooling heat exchangers would have to operate at a higher temperature.

Figure 3. Heat Exchanger Distribution System at DC Water

In an effort to reduce the size and cost of the cooling system at CRWS, a “flash tank cooler” or pre-cooler has been incorporated into the system for TRA. The pre-cooler is intended to reduce the temperature of the hydrolyzed sludge from approximately 194°F (90°C) to a minimum temperature of 158°F (70°C). The use of this pre-cooler system is intended to take advantage of the higher difference between the hot side and cold side temperatures prior to blending with recirculating sludge. The heat removed in this stage allows the digester coolers to be much smaller than necessary at DC Water since the amount of heat removed per ton of sludge is much lower. This reduces the cost of the digester coolers while also providing additional feed temperature control. The tuning heat exchangers have been eliminated as the value seen during the operations at DC Water has been minimal relative to the cost of the cooler and ancillary equipment. Due to the knowledge gained, as described above, TRA will install one pre-cooling heat exchanger per THP train and one primary cooling heat exchanger per digester.

In addition to the cooling system themselves, the feed of thermally hydrolyzed sludge to the cooling system has been improved. Both DC Water and TRA utilize a system that blends the digesting sludge with THP sludge prior to the digester heat exchangers. This is done to ensure minimum velocities are met, solids viscosities are reduced, and plugging of the heat exchangers is eliminated. The DC Water system includes feed points both upstream and downstream of heat exchanger solids feed pumps. Experience to date at DC Water indicates that the inlet side of the pumps provides lower feed pressures than needed. The use of feed downstream of the pump at DC Water has not been used, and would be more difficult to control due to the lower pressure difference. The redundant feed points increase complexity of the system, maintenance requirements, requires two sets of control valves and provides no tangible benefit. The use of a single feed point simplifies the control, which has been implemented at TRA.

COOLING WATER

DC Water uses plant effluent (prior to final filtration) as cooling water for the heat exchangers at the Blue Plains Advanced Wastewater Treatment Plant. This is done in a single pass where water is pumped from the channel and returns downstream of the withdrawal. After start-up, DC Water experienced fouling of the heat exchangers with an iron and manganese coating on the water tubes. While the cause of this fouling is currently unknown, it may be potentially caused by the use of the final effluent. The use of potable water will eliminate this concern.

TRA has decided to use a cooling tower in its design with potable water recirculated. Additionally, there will be a chemical addition for corrosion inhibition and control of fouling.

DIGESTERS

Operations of the system at DC Water has demonstrated the need for fast and accurate total solids analysis on multiple streams ranging in concentration between 3% and 22% total solids. As such, the facilities for these analyses have been incorporated into the design for the TRA improvements.

Digester design at CRWS has been improved to account for various issues seen during commissioning at DC Water. The DC Water digesters utilize draft tube mixers; however, these mixers cannot operate below full levels in the digester. By implementing pumped mixing at CRWS, it will allow earlier feed of thermally hydrolyzed sludge and a shorter ramp-up period. Additionally, the CRWS system will include field capability for rapid analysis to allow increased process controls and reliability.

In respect to digester rapid rise control, the experience at DC Water indicates that an extreme rapid rise event is not likely even when the mixers stop and are restarted. DC Water has approximately 5 percent capacity above the normal overflow level to contain any overflow solids inside the tank. A backup overflow and an emergency overflow were provided in addition to the normal overflow. The double u-tube backup overflow will transfer rapid rise solids into a wetwell located between each pair of digesters. The single u-tube emergency overflow will spill

solids to grade through methane dispersion devices. Each u-tube is filled with glycol-water mixture to eliminate freezing.

Figure 4 – DC Water Digester

Based on the DC Water experience, an alternate configuration of digesters and digested sludge holding tanks will be implemented. The ability to have a large capacity digested solids storage tank strategically located in the middle of the digester complex allows conveyance of overflowed solids without any need for u-tube traps, simplifying operations and maintenance and eliminates concern of overflow to the ground. Based on the DC Water experience, TRA will have approximately 7 percent capacity above the normal overflow level to contain any overflow inside the digester. Additionally, one backup overflow will be provided per tank that will convey rapid rise solids to the digested solids storage tank directly. There will be no need for a u-tube trap since both the digester headspace and digested solids storage tank headspace are connected. The digested solids storage tank will be operated at minimum levels in order to have enough storage to contain rapid rise solids from all three digesters if needed.

For digester mixing, DC Water has five 25HP draft tube mixers per digester that operate in reverse rotation for deragging on a regular basis. Draft tube mixers require any maintenance activities to be completed on the tank cover. If a mixer is stopped for any reason, 20 percent of the mixing capacity will be lost; however, the design accounts for this and has adequate turnover with one mixer out of service although there may be dead spots in the digester. Construction and operating experience of the digester mixing system indicated that programming five mixers to allow reverse operation of only one mixer at a time was challenging and restarting all five mixers slowly in a sequence takes a significant amount of time. This is critical to minimize any rapid rise event when all mixing is stopped.

TRA selected 125 HP pumped mixing systems per digester using knowledge gained from DC Water's experience. There will be a nozzle system installed inside the tanks to distribute solids and provide complete mixing. The pumps will be located at grade for easy access and

maintenance. There will be a redundant pump for each digester so the mixing capacity will not be sacrificed if the duty pump is stopped.

At DC Water, distribution of solids from each heat exchanger is done through alternating valves. There are two pairs of valves on each digester, one for each cooling heat exchanger. The valves are located 90 degrees from each other and only one of each pair is used at a time. During operation at DC Water, it was found that initial distribution of the THP feed solids to the digester is extremely important. The alternating valve sequence works well; however, if one valve fails, there is a localized area of feed which can result in poor digester performance. At TRA, the solids from the heat exchangers will be discharged into the mixing piping. This will allow for significantly improved distribution of the THP solids in the digester and eliminate the risk of a single valve failure. At DC Water, this is accomplished by alternating two cooling HEX discharge locations to each digester on a timed basis.

START UP AND COMMISSIONING

The seeding process at DC Water utilized biosolids from the AlexRenew facility, which is a Class A biosolids process which pasteurizes the feed solids to mesophilic digesters. During the ramp up phase of commissioning the DC Water digesters, the dewatered biosolids demonstrated fecal coliform above 1,000 MPN/gram thus the solids did not meet Class A requirements. After approximately six months of digester operation, the fecal coliform in the dewatered biosolids were less than 200 MPN/gram and now consistently measure at less than 10 MPN/gram. The exact cause of the initial increase in fecal coliforms between the time of seeding and during the ramp up is unknown; however, in executing the startup and commissioning at TRA this will be considered.

At TRA, the need for Class A biosolids is not immediate; however, it is necessary to produce the highest quality biosolids and obtain Class A EQ status during long term operations. There are several methodologies currently under consideration, including seeding with reconstituted biosolids from DC Water which is already acclimated to thermal hydrolysis; utilizing Class B biosolids from a nearby facility and expecting three or more solids retention time (SRT) turnovers prior to obtaining Class A biosolids; and bringing seed solids up to thermophilic temperatures for 24 hours, cooling to mesophilic temperatures then introducing the thermally hydrolyzed biosolids. While the specific methodology is not currently known, this issue is significant for any utility considering thermal hydrolysis solids pretreatment.

SUMMARY

While Cambi thermal hydrolysis has been implemented at more than 45 facilities worldwide, the only facility using THP in North America at this time is DC Water's Advanced Wastewater Treatment Plant in Washington, DC. As more facilities utilize the thermal hydrolysis process, facilities optimization will increase as new knowledges is gained with this process.

The Trinity River Authority is planning to implement THP as a part of its Solids Management Program at the Central Regional Wastewater System in the Dallas, Texas area. The CRWS design

is based upon the general process used at DC Water, while incorporating knowledge gained from lessons learned during the design, construction and operation of that facility.

The improvements implemented at TRA to the overall process, including pre-dewatering, Cambi thermal hydrolysis, solids cooling and digestion, have been designed to optimize the new system for reduced capital and operations costs. These improvements can be considered by other Owners planning to implement thermal hydrolysis systems at their facilities.