Starting From Scratch: Commissioning the First Thermal Hydrolysis Fed Digesters in North America

Peter Loomis

The 370-mil-gal-per-day (mgd) average daily flow Blue Plains Advanced Wastewater Treatment Plant is operated by the District of Columbia Water and Sewer Authority and serves the metropolitan Washington, D.C., area. The facility has been undergoing a solids processing modification since 2011 that includes three primary projects: main process train (MPT), combined heat and power (CHP), and final dewatering facilities (FDF). The upgrades have reduced the volume of biosolids and provide a Class A product.

The new $216 million biosolids MPT includes 5-millimeter (mm) sludge screening, centrifuge predewatering, the first Cambi™ thermal hydrolysis installation in North America, and mesophilic anaerobic digestion in four 3.8-mil-gal (MG) digesters, which are some of the largest in the world. The MPT is followed by belt filter press dewatering with beneficial use of the Class A biosolids product. The digester gas is used to fire three 4.6-megawatt gas turbines in the new CHP facility, which generates up to 10 megawatts of power to the plant and steam for the thermal hydrolysis process. The new MPT and ancillary facilities are capable of processing solids up to 450 dry tons per day (dtpd).

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Start-Up Methodology

The goal of the start-up process was to ramp up the digesters to capacity in the most reasonable amount of time without risking souring. One of the difficulties with implementing a novel facility of this type and magnitude is that no seed sludge produced from thermally hydrolyzed sludge was available in North America at the time of commissioning. In addition, the size of the digesters results in a very high volume of biosolids required to seed even one digester, so shipping seed solids from Europe would have been very difficult and expensive. The seed sludge for the new digesters was provided from Alexandria Renew Enterprises (AlexRenew), since thermally hydrolyzed digested seed sludge was unavailable. AlexRenew uses a pasteurization process, followed by mesophilic anaerobic digestion to produce Class A biosolids.

The seeding process was initiated in late September 2014 and was started by filling each of the four digesters approximately 60 percent full with water. The water was heated to 38°C (100°F) using steam in preparation for feeding of seed biosolids. Filling to this level allowed recirculation pumps to be started, which began mixing of the digesters; however, complete mixing was not available from the draft tube mixers until the digester was nearly full. The head space of the digesters and the gas piping were purged of air using nitrogen. Approximately 3 MG of digested biosolids were transported from the AlexRenew facility to Blue Plains and were added to the heated water in two of the digesters. This seed volume provided approximately 40 percent of the volume of these two digesters. Once a digester was full, thermally hydrolyzed sludge was introduced.

The introduction of thermally hydrolyzed sludge to the digesters presented several chal-

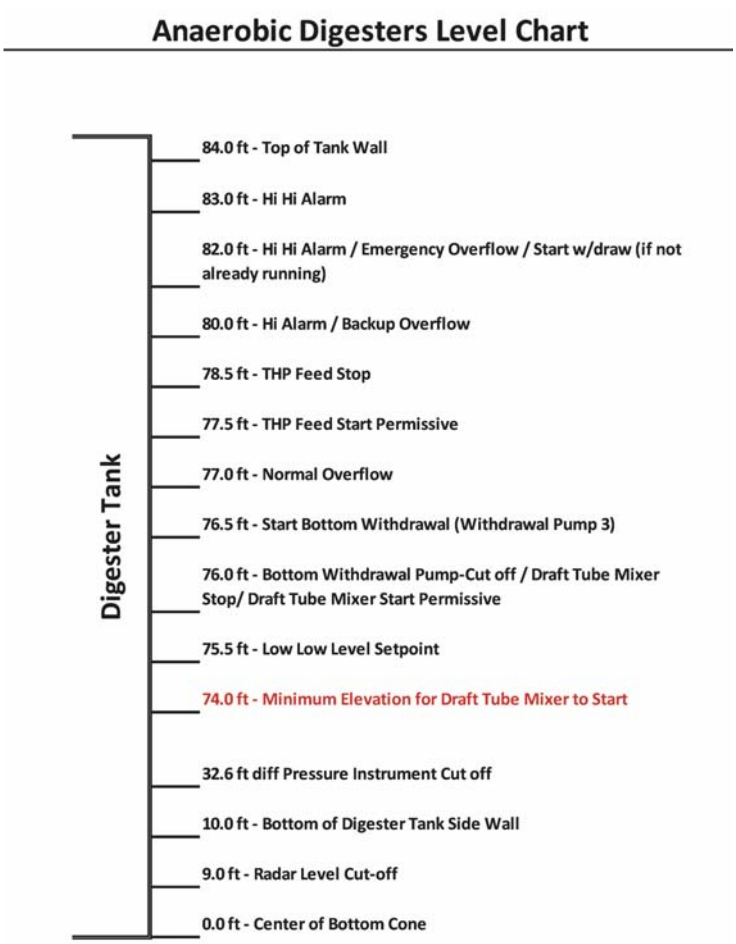

Figure 1. Anaerobic Digesters Level Chart

lenges. The digesters could not be mixed until the digester was close to or at the normal operating level due to utilization of draft tube mixers; Figure 1 shows various liquid levels within the digesters and the corresponding operations. It was imperative that thermally hydrolyzed sludge be added to a digester with the mixing system in operation; otherwise, the sludge would settle to the bottom of the digester and become very difficult to remove.

Based on preparatory testing, it was determined that there would be significant reduction in time in the ramp-up gained by adding alkalinity to the digesters. Tests indicated that by adding alkalinity, the pH of the digester and acid/alkalinity ratio would allow increasing feed by as much as 5 percent solids per day. Without alkalinity, the increase of solids needed to be closely controlled as pH tended to drop below 7 standard units in the first two weeks, resulting in steady feed for a period of time, instead of ramping up.

Thermally hydrolyzed sludge was added to the digester slowly based upon volatile solids (VS) in the digester, starting at a rate of approximately 20,000 lb VS per day (7 percent of the VS in the digester) to each of the first two digesters, and increasing approximately 3 to 5 percent per day. The feed rate was adjusted based on the digester performance. The pH, solids inventory, relative gas production compared to feed, and other parameters were monitored on a regular basis in order to determine if the feed should be increased, lowered, or suspended.

The volume fed to the two full digesters was displaced to the remaining pair of digesters to provide the seed sludge for them. In this way, the system was brought online with all four digesters at full capacity approximately 140 days after the start of the seeding process. Figure 2 presents the forecasted solids loading in each digester.

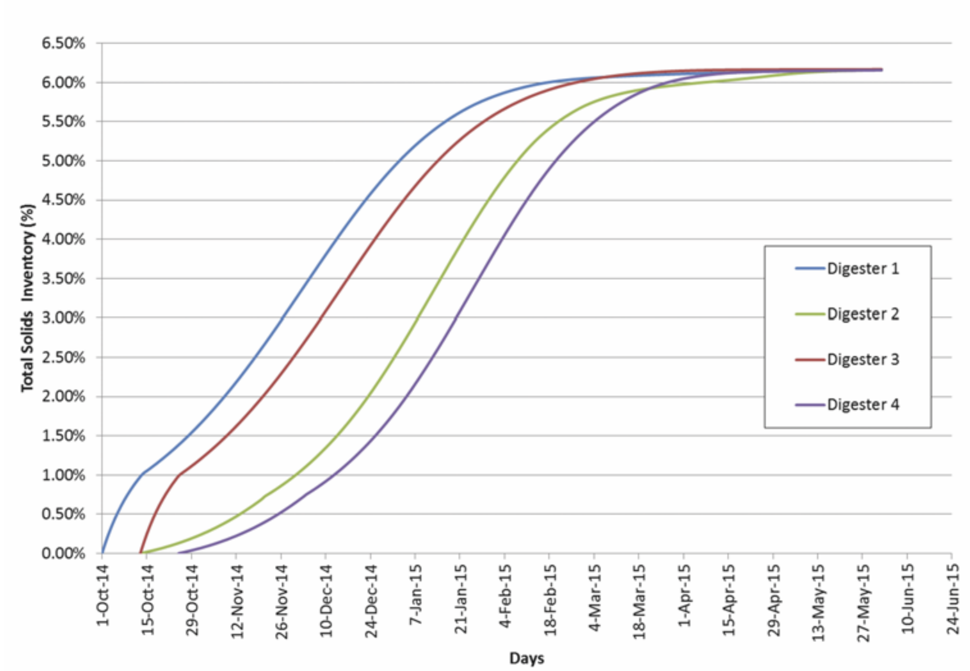

Figure 2. Forecasted Total Solids Concentration in Each During Ramp-Up

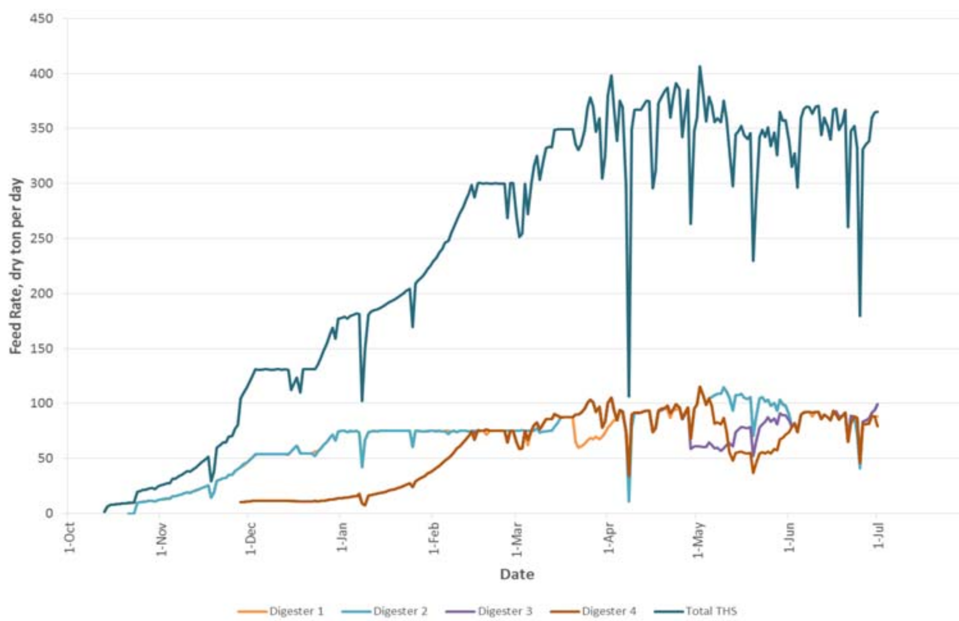

Figure 3. Thermally Hydrolyzed Sludge Feed Rate to Digesters

Seeding Results

As with any start-up, there were events that impacted the initial plan, such as lack of steam, digester performance, lack of sludge predewatering, and extreme cold weather, which resulted in reducing feed to certain digesters. While the original anticipation was that each digester would be on an individual track for the start-up, variations in the seed sludge feed resulted in each pair of digesters being fed similarly during start-up. Upon the seeding of digester 1, it was found that significant steam was necessary to maintain digester temperature during the seeding process, resulting in a more diluted sludge concentration than expected. This was compensated for in the seeding of digester 2 by lowering the water level by approximately 100,000 gal to compensate for the steam necessary during the initial seeding.

Solids concentration in digester 1 was found to be approximately 0.8 percent solids at the conclusion of solids transfer, which was below the anticipated 1 percent solids. The feed rate to this digester of thermally hydrolyzed solids was therefore initially below original expectations and was started at approximately 12,000 lb on the first day of seeding and ramped up at between a 2 and 3 percent increase each day during the first week. In this period, pH and alkalinity were observed to be dropping in the digester, which was predicted by earlier pilot-scale testing.

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The pilot-scale testing had also indicated that the addition of alkalinity could allow a faster and smoother ramp-up, so magnesium hydroxide was added to the digester approximately nine days after the first thermally hydrolyzed sludge was introduced. The addition of magnesium hydroxide immediately increased the pH and alkalinity, improving digester health and preventing any need to suspend ramp-up of solids feed. During the ramp-up of this digester, it was found that digester stability could be maintained at daily solids feed increases exceeding 5 percent, and following the addition of alkalinity until completing the ramp-up to average capacity, the digester feed was only reduced or suspended due to outside factors such as the loss of steam, unavailability of predewatered sludge, or loss of power.

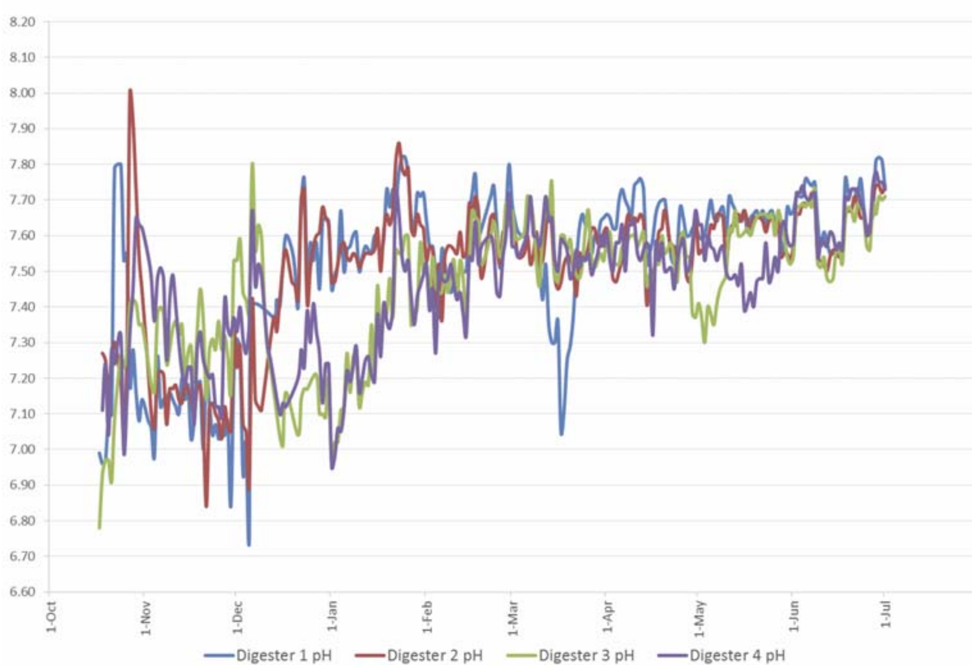

Figure 4. Digester pH During Commissioning

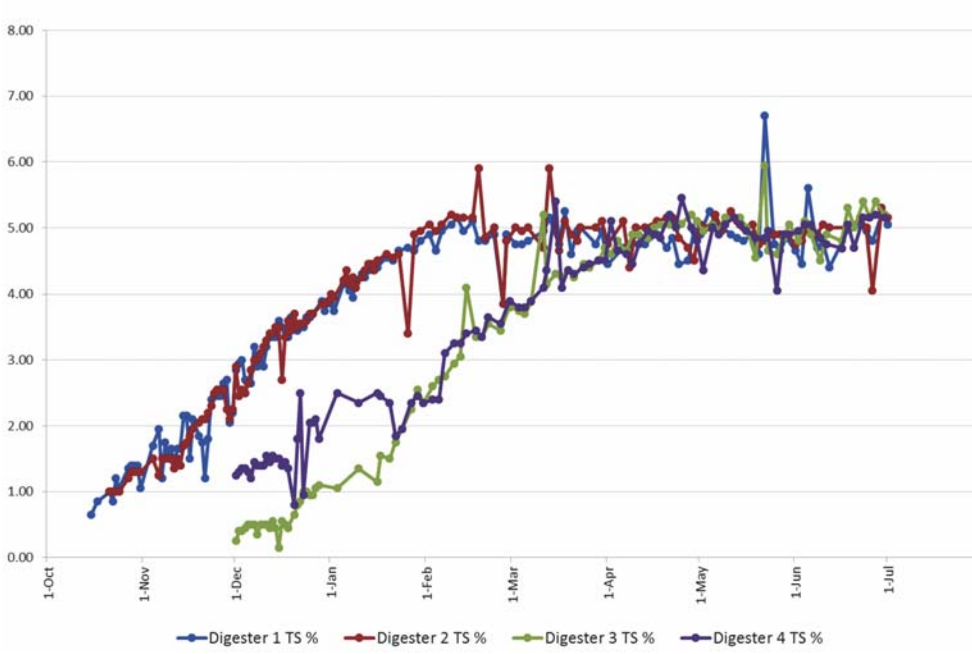

Figure 5. Actual Total Solids Concentrations in Each Digester During Start-Up

Digesters 1 and 2 were generally fed at the same rate throughout the start-up and digesters 3 and 4 were generally fed at the same rate during start-up. Once all digesters were operating at the expected normal capacity of 75 dtpd feed, the feed to each digester was the same, except during brief periods of concern for digester 1 and digester 3. The actual feed rates to each digester are presented in Figure 3. Note that feed to digesters 1 and 2 were equal, and feed to digesters 3 and 4 were equal through February 2015. At that time, feed to digesters 2, 3, and 4 were equal for the entire month, while feed to digester 1 was reduced due to concern related to the digester being in distress.

Digester 1 distress appeared to be related to a single point of feed for the digester. The digester design includes two heat exchangers for each digester and each heat exchanger alternates between two digester feed points. During operations, one digester solids pump failed on digester 1, and one automatic valve on the opposite heat exchanger also failed. For a period of approximately 10 days, the digester was fed through only one location instead of the expected four and fed at the full throughput (75 dtpd) at this single location. While the temperature in the digester was controlled and did not vary from the expected +/-0.5°C from 38°C on any day, the digester began to have reduced gas production, reduced methane concentration, and a lower pH than the other equally fed digesters. While digester mixing testing demonstrated a well-mixed digester, with nearly 100 percent of the volume active, it is hypothesized that the feed to a single location resulted in pockets of poorly mixed or nonhomogeneous sludge. This occurrence leads to recommendations that digesters should be fed as consistently as possible and in as many locations as possible to allow the sludge to be fully homogeneous in the digesters.

Figure 4 presents the digester pH tracked throughout the seeding process. As can be seen from this information, digesters 1 and 2 greatly benefited from the injection of alkalinity. The direct provision of alkalinity rapidly increased the pH and provided a source of alkalinity for the methanogens to develop rapidly. This figure also demonstrates that each period of concern for digesters corresponds to a period of pH lower than 7.5 standard units after seeding has been completed. While pH is often a lagging indicator of digester health, in the case of thermal hydrolysis process (THP)-fed digesters, the higher operating pH of near 7.8 allows a greater warning of digester health before complete souring of a digester.

Figure 5 presents the actual total solids seen in each digester. The total solids concentrations forecasted prior to the start-up have not yet been achieved in the digesters. It is believed that this is a reflection of the greater-than-expected volatile solids removal achieved in the digesters.

The apparent volatile solids reduction (VSR) on a 22-day moving average is between 60 and 65 percent for each digester, which is in the range of other facilities utilizing THP. This VSR far exceeds the minimum 48 percent set as a process guarantee for the project and represents a significant reduction in the volume of solids for land application.

As previously indicated, the seed sludge was provided from a pasteurization plant, and while the material is a Class A biosolid, this sludge does not have the same biological colonies as a fully hydrolyzed sludge. While both the pasteurized sludge and hydrolyzed sludge can be Class A, being different requires acclimatization of the digesters to meet Class A requirements for fecal coliforms.

After the initial seeding and introduction of thermally hydrolyzed biosolids into the digester, the fecal coliforms were measured at nearly 2,000 most probable number (MPN)/dry gram, or nearly double the Class A standard. Figure 6 presents the fecal coliform results starting in February 2015 after all digesters are operating on hydrolyzed sludge. After approximately 150 days of processing from the start of seeding, the fecal coliforms were below 1,000 MPN/dry gram (U.S. Environmental Protection Agency Class A standard) and continued to decline. Current levels are well below 100 MPN/dry gram and are continuing to decline.

Sidestream Impacts

As part of the solids treatment upgrade program, a new belt filter press facility was constructed for dewatering of digested solids. This facility consists of 16 belt filter presses, polymer day tanks and secondary dilution equipment, polymer dosing pumps, and solids feed pumps. In anticipation of high ammonia concentrations in the digested solids stream and the corresponding increase in ammonia load to the main plant, a new belt press filtrate treatment facility was designed and is currently under construction. This filtrate treatment facility will use the DEMON® process for deammonification of ammonia, and is scheduled for commissioning this year. The belt press filtrate, which is mostly comprised of digester liquor and is high in ammonia content but has relatively low suspended solids, is captured separately from the belt wash water to minimize the solids content of the filtrate that will be sent to the DEMON process.

During commissioning of the digesters, and throughout the interim period of operation until the filtrate treatment facility is commissioned, the belt press filtrate is returned to the secondary treatment process. The additional ammonia passes through secondary treatment to the separate stage nitrification and denitrification system where it is nitrified and then denitrified using methanol as the carbon source.

The digesters were initially commissioned at low solids concentrations and the ramp-up occurred over a period of six months. The filtrate ammonia load was relatively low at the time the dewatering facility was commissioned in late November 2014, and the impact on the main plant was minimal. As the solids loading to the anaerobic digesters increased, the solids and ammonia concentrations inside the digesters also increased, and then stabilized at just over 5 percent total solids and 2,500 to 2,600 mg/L ammonia-N.

Digesters 1 and 2 reached these conditions in February 2015, while digesters 3 and 4 did not reach these conditions until April of that year. Thus, the ammonia load returned to the liquid stream process increased slowly, and reached a total loading of about 15,000 lb/day in April. This increases the plant influent Total Kjeldahl Nitrogen (TKN) load by 15 to 20 percent and additional aeration cells were placed in service in the nitrification/denitrification reactors. The corresponding increase in methanol consumption has been about 6,000 gal/day); however, methanol dosing is expected to return to prior levels once the filtrate treatment facility is commissioned. It is noted that the digested solids are currently diluted with reclaimed plant effluent water from 5 to approximately 3.5 percent prior to feeding the belt filter presses. This dilution water, along with the polymer flow, increases the total filtrate flow, but decreases the observed ammonia-N concentration from 2,500 mg/L (in the digesters) to about 1,500 mg/L (in the filtrate).

Findings

Overall, the performance of the thermal hydrolysis and digestion has been exceptional through the start-up and ongoing operations. Methane concentration in the digester gas have ranged between 60 and 65 percent methane, gas production has been approximately 0.28 m^3 per kilogram of chemical oxygen demand (COD) fed (4.5 cu ft per lb of COD fed), and COD reduction has been approximately 48 percent. The digesters required approximately 140 days to become fully acclimated to the thermally hydrolyzed sludge, and since that time, all sludge has met Class A requirements for pathogen reduction.

Once acclimatized, the digesters have been found to be extremely resilient to extreme changes in digester feed. While the digesters must be closely monitored during these periods, increases of as much as 10 percent feed per day for four consecutive days have been successfully digested by maintaining the approximate methane, gas production, and COD reduction that was noted.

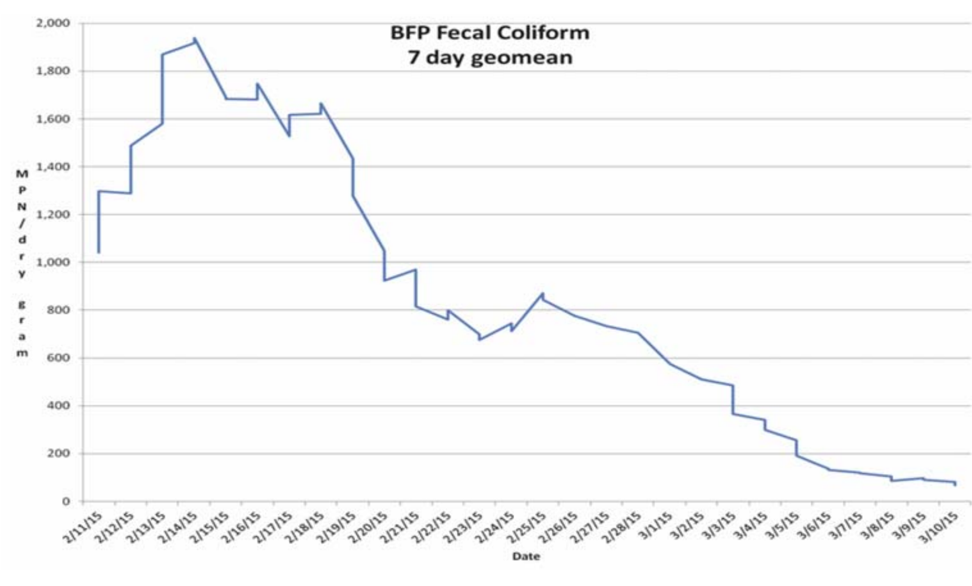

Figure 6. Fecal Coliforms in Digested and Dewatered Biosolids