Oxford STW Sludge Stream Upgrade

working with Thames Water to meet their sludge management targets and regulatory drivers

by Ashley Back & David Tankard

In 2008, Thames Water produced its Strategic Proposals for Sludge Management to address the current and future requirements in the Thames Water operational area. The preferred options in the sludge strategy are based on processes that reduce sludge volumes and maximise gas production potential to increase power generation. Advanced sludge digestion is one such process, and Oxford STW was identified as a preferred location for an advanced sludge treatment centre. The sludge stream upgrade at Oxford increases treatment capacity from 17.4tds/d to 67tds/d. This was an AMP5 regulatory requirement and facilitates the import of sludge cake from a number of smaller neighbouring sites. In addition, the Oxford upgrade will contribute to the regulatory requirement to generate an additional 12.6GWH of power by the end of AMP5 across the whole of the Thames region.

The heart of the thermal hydrolysis process, Veolia's Biothelys THP plant - Courtesy of AECOM Kier Joint Venture

Contract

The proposed development integrates and builds on the existing sludge treatment processes on site. The sludge will be subjected to advanced digestion within a new thermal hydrolysis process (THP) plant.

The THP involves the sludge being subjected to high temperatures and pressure through the injection of pressurised steam, prior to being pumped into the existing digestion tanks where it undergoes anaerobic digestion. Biogas from the digesters is harnessed and converted to electricity using the existing combined heat and power (CHP) engines. The electricity produced will be used to power the Oxford STW with additional electricity exported to the national grid. Steam generation for the THP will be augmented by using waste energy from the CHP engines.

The existing works

The works which is located to the south of Oxford caters for the waste from a population equivalent of approximately 214,000. The wastewater is treated using the activated sludge process and the sludge is treated by anaerobic digestion. Treated sewage sludge is pressed into a dry cake on site before being removed offsite for disposal to agricultural land. The biogas produced from the digestion process is used in the digester boilers and CHP engines.

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Raw sludge handling and thickening: Surplus activated sludge from the final settlement tanks is thickened and blended with thickened raw sludge and scum from the primary settlement tanks and imported liquid sludge before being treated by anaerobic digestion. Sludge imported by road tanker is screened on site before blending.

Sludge digestion: There are currently 4 (No.) primary digesters at Oxford STW. The primary digesters are arranged in two pairs of two, and are mixed and heated by recirculation of the sludge from bottom to top. The digested sludge gravitates to one of 4 (No.) rectangular secondary digesters where it is stored for a set period, before it is pumped to Klampress belt dewaterers.

Biogas produced by the digesters is stored in a gas bell which feeds three CHP engines to produce power for site use and export. The waste heat from the CHPs is used to heat the hot water for the digester's heat exchangers. The biogas can also be used in the 6 (No.) existing hot water boilers to heat the digesters.

Digested sludge dewatering: Two circular buffer tanks store sludge from the secondary digesters and feed 3 (No.) Klampress belt dewaterers, housed in the press house building, which dewater the digested sludge. The dewatered cake is then deposited onto the cake pad via conveyors. The cake is removed by mobile plant from the 'drop zone' and placed in bays located either side of the pad. Filtrate from the belt dewaterers gravitates to a filtrate return tank outside the press house, before being returned to the works inlet.

The new works

The project was awarded following a competitive tendering process under the IChemE Burgundy Book (GMP) to a Kier Enpure JV (KE Water). Following the subsequent administration of Enpure, Kier appointed AECOM as their new process partner and formed the AECOM Kier Joint Venture, through which the works are currently being delivered.

Sludge cake import reception facility: A new cake reception facility, designed to receive up to ten vehicle movements a day, will receive sludge cake ranging between 25 to 32%ds from satellite sites in the Oxfordshire region.

The vehicles deposit the sludge cake into a cake bin. Screws in the base of the bin will discharge the cake into the 2 (No.) duty/standby cake transfer pumps sited below the bin. The cake will be blended to between 21 and 23%ds with indigenous screened sludge mixed in the auger section of the pumps. The pumps will then transfer the cake into the duty pre-THP sludge buffer silo.

Indigenous raw sludge screening: The indigenous raw sludge is currently unscreened. Primary sludge is thickened in 2 (No.) picket fence thickeners. Replacement thickened sludge pumps will pump to new duty/standby Strainpress sludge screens and the screened sludge will then gravitate into the existing sludge blending tanks.

Indigenous SAS & liquid sludge imports: SAS is thickened using belt thickeners and is also currently transferred into the existing sludge blending tank. The thickened SAS will be diverted to the existing liquid sludge import tank, and then transferred along with imported sludges through the existing Strainpress sludge screen.

All indigenous sludges and liquid sludge imports will consequently be screened prior to transfer to the THP Plant.

Pre-THP sludge dewatering: The blended sludge will be pumped across the site from the blended sludge tank(s) to the dewatering feed tank. Liquid sludges from this tank are fed to the three belt dewaterers, and also used for re-wetting the imported cake as necessary. Cake from the dewaterers is transferred to the THP feed silos by a dedicated cake discharge pump at each dewaterer.

Optimised layout of the cake import facility, polymer plant, fired boilers, sludge cake storage and THP plant - Courtesy of AECOM Kier JV

One of the 300m^3 sludge buffer silos, which enable constant processing, 24 hours a day 7 days a week - Courtesy of AECOM Kier Joint Venture

The existing cake slab, now covered and with push walls Courtesy of AECOM Kier Joint Venture

The filtrate discharges into a common sump under gravity and then transferred to a liquors balance tank.

Pre-THP polymer make-up & dosing: Powdered polymer is stored in a bulk silo prior to make-up with clean water and then diluted to dosing strength by final effluent into a common duty tank; individual polymer dosing pumps deliver to the dewaterers.

Pre-THP cake storage: 2 (No.) pre-THP sludge buffer silos each of 300m^3 capacity receive cake at 21% to 23%ds from the belt dewaterers & the sludge cake import facility. These silos provide buffering to allow the THP plant to operate 7 days per week, whilst only receiving cake imports 4 days per week. However indigenous sludges are processed continuously.

Screws in the base of the silos allow sludge to discharge into the auger section of the THP feed pumps. The sludge cake entering the feed pumps is further conditioned with hot water from the THP plant and reduced to 16% to 18%ds for onward feed to the THP plant reactors.

Thermal hydrolysis process (THP) plant: Thermal hydrolysis of dewatered sludge takes place prior to the digesters as a pre-treatment.

The objective of the hydrolysis process is to hydrolyse organic solids, to solubilise them, and by so doing make them more readily biodegradable. In addition, the greater biodegradability of hydrolysed sludge improves removal of volatile suspended solids, which increases the biogas yield and reduces the quantity of sludge for final disposal. The THP also destroys pathogens, which means that the plant does not require secondary digestion.

The THP process plant is supplied by Veolia Water Services and has 6 (No.) Biothelys reactors, configured as three process lines, each comprising a pair of reactor units, nominally rated to process 33% of the plant capacity. There are 2 (No.) buffer tanks each rated for 50% plant capacity during normal operation. These tanks are configured to receive hydrolysed sludge from three reactors. The reactors operate according to a recurring 150 minute cycle to give continuous treatment.

Thermal hydrolysis is carried out at temperatures in the range of 140-170ºC. At a pressure of 7 barg the Biothelys system consists of batch hydrolysis reactors working in parallel, out of phase with each other. Each reactor, in turn, goes through a multi-step cycle.

First, the reactor is filled with raw sludge and this is preheated with recycled flash steam from its reactor pair. Heating to hydrolysis temperature is completed by injecting live steam, produced by a heat recovery boiler and fired steam boilers, into the sludge.

Once the required temperature for hydrolysis has been reached, it is maintained for a preset time before the steam is released as flash steam. The flash steam is recovered for preheating another reactor.

Finally, the reactor is emptied using the residual pressure inside it to aid discharge to a buffer tank. Here the hydrolysed sludge is stored, before being cooled by a heat exchanger prior to being transferred to the anaerobic digestion stage. Hydrolysed sludge from the THP plant is fed into the digester recirculation loops by 4 (No.) feed pumps operating as 2 (No.) duty/standby pairs; the flow split is 2/3 to 1/3 to Digesters 1 and 2, and Digesters 3 and 4 respectively.

Anaerobic digesters: Each pair of the 4 (No.) digesters has 2 (No.) duty/standby recirculation pumps. These pumps operate continuously, whilst automatically actuated valves are used to alternate the recirculation between the digesters in each pair on an adjustable timed basis. The recirculation pipework runs from each pair of digesters to a point adjacent to the THP plant, where the

Dewatering feed tank and 2 (No.) of the belt dewaterers, all shrouded and odour controlled to minimise odour impact to the surrounding area
Courtesy of AECOM Kier Joint Venture

hydrolysed sludge is added to the recirculation lines. The flow and temperature of the hydrolysed sludge into the recirculation loop is calculated to match the daily feed requirements of the individual digesters.

After the timed period, the recirculation alternates from Digester No.1 to Digester No. 2. The recirculation valves on Digester No. 2 are opened and when they are open, the recirculation valves on digester No. 1 are closed and all feed and recirculation is switched to digester No.2. The same principle applies to Digesters 3 and 4.

Heating of the digester will rely solely on the THP as the existing hot water heating systems will be decommissioned.

Biogas storage: An additional double membrane gas holder has been provided to increase the site biogas storage capacity by 1,000m^3. This provides six hours gas storage for the largest single gas user - in this case the largest CHP unit.

A new ground flare has also been installed to enable the site to flare off biogas based on the expected peak production rate of 1,600m^3/hour, should no or limited gas users be available.

THP plant steam boilers: The boiler system provides sufficient steam to the thermal hydrolysis process to treat the 67tds/day of feed sludge. The maximum steam demand provided to the THP Plant is 4.3t/h. with the average design demand at 2.4t/h. The steam condition requirement at the THP plant is 190ºC and around 12 bar.

This steam demand is provided by a waste heat steam generating boiler linked to two existing cogeneration reciprocating gas engines. This provides the base load of steam to the THP. The remaining steam demand for the THP is provided by two containerised dual fuel (biogas and natural gas) steam boilers operating in a duty/assist configuration.

Digested sludge dewatering: The existing secondary digesters become redundant under the sludge stream upgrade, and the sludge from the digesters gravitates into the existing digested sludge transfer pumping station. Sludge is transferred to the existing dewatering buffer tanks and then onto final dewatering.

The scheme included the replacement of the three existing dewatering belts with similar units. A subsequent trial and variation has resulted in the provision of 4 (No.) high dry solids presses supplied by Bucher Unipektin.

Digested sludge is pumped to each press by a feed pump. Polymer is dosed to an in-line mixing point in each feed line by a polymer dosing pump. Each press has three parallel cross screws conveying pressed cake to a dedicated inclined screw conveyor discharging the product to the cake storage area.

Filtrate from the pressing sequence gravitates to a liquor balancing tank, prior to discharge into a liquor treatment plant.

Similar to the pre-THP dewaterers, powdered polymer is stored in a bulk silo prior to make-up with clean water and then diluted to dosing strength by final effluent into a common duty tank. Individual polymer dosing pumps deliver polymer solution to the presses.

Cake storage: The existing open cake storage area has been covered with a Dutch barn type structure along with increased height perimeter push walls. This allows cake storage to a depth of 3m, providing a storage capacity in excess of 60 days.

Liquor treatment plant: All liquors from the pre-THP dewaterers and digested sludge presses are balanced in the existing liquor balancing tank and pumped to the liquor treatment plant (LTP) by duty/standby feed pumps.

Liquor treatment is provided by an AECOM patented, Cyclic Activated Sludge System (CASS) sequencing batch reactor (SBR). The flow will be fed in batches to the reactors and each reactor will treat four batches per day.

The liquor treatment plant comprises 2 (No.) CASS SBR tanks with fine bubble diffused aeration, effluent decanters, sludge recycle pumps, surplus sludge pumps and treated effluent pumps. Air is supplied by 3 (No.) blowers. There is one dedicated duty blower per SBR tank and a common standby blower. The air supply is controlled to maintain a set-point dissolved oxygen concentration to enhance process efficiency and minimise power usage. Level instrumentation is provided in each tank for continuous monitoring and control of the water level.

In normal operation there will be 2 (No.) basins available to accept liquor flows and no balancing is required. However, the existing liquors balancing is retained to allow treatment to continue should it be necessary to take a CASS SBR stream out of operation for any reason. Balancing also limits the peak liquor loads sent to treatment and the aeration blower capacity required.

Each CASS reactor basin is divided by baffle walls into three sections (Zone 1: Selector, Zone 2: Secondary Aeration, and Zone 3: Main Aeration) in the approximate proportions of 5%, 10% and 85%.

Sludge biomass is continuously recycled from Zone 3 to the Zone 1 selector to remove the readily degradable soluble substrate and favour the growth of the floc-forming micro-organisms. System design is such that the sludge return rate causes an approximate daily cycling of biomass in the main aeration zone through the selector zone.

Surplus sludge is removed from the CASS basins by dedicated pumps. It is discharged to the SAS balance tank via an existing SAS pipeline serving the existing works ASP No. 1 and 3. Decanted treated effluent is held in a decant tank for return pumping to the head of the main works.

An alkalinity dosing plant has been installed to provide the correct environmental conditions for the LTP, by ensuring optimal pH is maintained. This is achieved by dosing sodium hydroxide to provide alkalinity to balance the natural acidification of the LTP process.

The pH of the activated sludge will be maintained within a suitable range for nitrification. The target is to maintain pH in the range of 7.0 +/- 1. A dosing cabinet with proprietary dosing equipment along with a bulk chemical storage tank is used to dose 47% sodium hydroxide. The dosing pumps operate on a duty/duty/common standby arrangement and are controlled by a feedback loop based on pH measurement in each CASS basin.

Conclusion

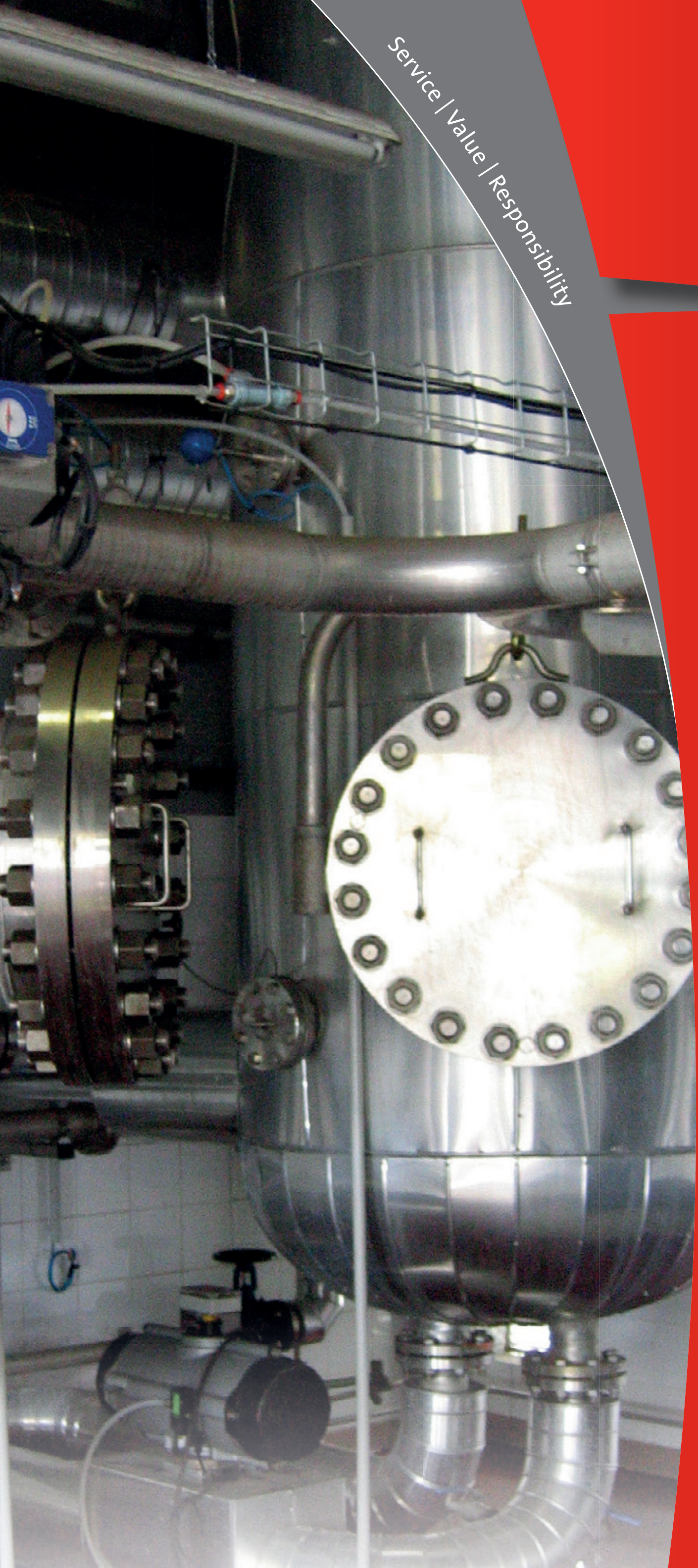
The £22.5m project commenced on site in April 2013 following a 6 month design period. The plant is currently in its commissioning phase and is expected to achieve takeover in September 2014. The process design has been undertaken by AECOM's in house team, with the civils design elements carried out by Pell Frischman.

Veolia Water Technologies was engaged to supply and install their Biothelys thermal hydrolysis process plant, with the following key sub-contractors:

Damar *(mechanical installation)*, Interface Contracts *(electrical installation)*, STAM Construction *(formwork and reinforced concrete)*, Bucher Unipetkin *(digested sludge dewatering presses)*.

The Editor and Publishers would like to thank Ashley Back, Project Manager, and David Tankard, Project Engineer, both with AECOM Kier Joint Venture for providing the above article for publication.

The third, of four Bucher presses being jacked up into position in the existing press building - Courtesy of AECOM Kier Joint Venture



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