Loughborough Sewage Treatment Works

activated sludge plant conversion & capital maintenance

by Dale Collison CEng, MIMechE

Loughborough Sewage Treatment Works serves the university town of Loughborough and the neighbouring village of Hathern. The current population equivalent of the catchment varies from a base line of 55,000 to 68,000 during term time, with industrial effluents accounting for between 10% and 20% of the load. The site, built circa 1974, is a five lane Activated Sludge Plant (ASP) operated in a conventional anoxic/aerobic configuration, with the anoxic fraction comprising 7% of the total volume. The works currently has a 20:30:5-10 (BOD/SS/AMM) consent. In order to comply with requirements of the Urban Wastewater Treatment Directive (UWWTD) the works is required to meet an additional total phosphorous (P) limit of 2 mg/l and a total iron concentration of 3.5 mg/l in the final effluent.

Converted lane prior to process commissioning *courtesy Severn Trent Water*

There are two main options for achieving the new P consent; modifications to the biological process and/or chemical dosing.

In terms of modifying the process, Biological Nutrient Removal (BNR) offers potentially significant revenue savings over 'conventional' chemical P removal, while also providing a more environmentally sustainable option. The BNR process works on the principle of creating the right conditions to promote the growth of Phosphate Accumulating Organisms (PAOs) within the mixed liquor. These bacteria release phosphate under anaerobic conditions and then preferentially take-up phosphate under aerobic conditions. However, a successful BNR operation is strongly influenced by the waste water characteristics and can require supplemental chemical dosing to achieve the P consent. Provisional screening tests indicated that the wastewater at Loughborough was of typical strength for a domestic wastewater, but may not contain enough carbon to facilitate adequate biological phosphorous uptake to meet the new P limit through BNR alone.

Pilot plant

To establish to what extent BNR could be achieved at Loughborough, a scale model pilot plant was installed on site to simulate the new process. The unit was built by WRc and was operated for a period of 200 days in order to fully assess performance of the various configurations.

The pilot plant was equipped with baffle plates that allowed the tank to be split into discrete segments of five per cent of the total volume. Each segment could be aerated and/or stirred, and this allowed the plant to be configured as a series of separate aerated and un-aerated zones. The plant was fed with a source of settled sewage which was taken from the wet well of the settled sewage pumping station. The feed pump followed a set diurnal flow profile to mimic the incoming load to the works. The plant was also equipped with a return activated sludge (RAS) pump, and two internal mixed liquor recycle pumps. Sludge was wasted continually from the system directly from the reactor by means of a peristaltic pump set to deliver a specified sludge age.

Chemineer mixer suspended under walkway *courtesy Severn Trent Water*

Ideal configuration
Following completion of the tests, analysis of the data showed that a 15/15/70 anoxic/anaerobic/aerobic split of the 68m long ASP lanes would be the most effective arrangements to promote BNR.

In addition, the pilot plant was able to demonstrate that it is only possible to achieve approximately 60% P removal solely through biological means, thus indicating that a supplementary chemical dose of Ferric Sulphate was required.

RAS Fermentation
The pilot plant also revealed that BNR would only achieve 60% P removal if an additional side process was provided. This additional stage holds and ferments 6% (15 l/s) of the RAS for 48 hours. The fermentation stage greatly improves the plant's ability to support PAOs, and thus reduced the overall Ferric Sulphate dose required to achieve the new P consent.

To achieve the required 48 hour residence time a new 2,000m/3 concrete tank had to be constructed. Due to land restrictions, service locations, ground conditions and process requirements, a 57m (L) x 8m (W) x 6m (D) tank was built within a piled cofferdam between two of the existing ASP lanes. The tank is split into four equal under/over baffled sections, each being mixed with a variable speed 4kU Chemineer GUT paddle mixer keeping the liquors in suspension.

Future process modifications built in
Should the fermentation process not perform as expected, it will be possible to strip out nitrate from the RAS by simply sending all of the RAS to the new tank. By removing the nitrate from the RAS, the un-aerated portion of the modified ASP will become anaerobic, those promoting biological phosphorus removal.

The volume of the tank at the current RAS rate of 220 l/s will equate to a retention time of 2.5hrs, giving sufficient time for endogenous

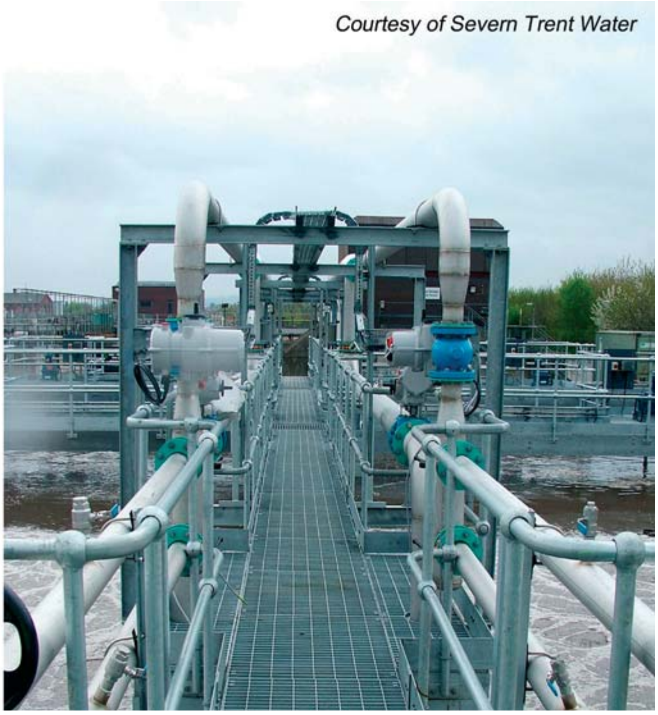

Photo showing the 3D model (left) & actual installation (right)

Model (left) courtesy Hope Drafting photo of installation (right) courtesy Severn Trent Water

de-nitrification to occur. By designing the tank to take all of the RAS flow, it minimises the risk associated with scaling-up from the pilot plant.

To provide the additional anoxic/anaerobic zones in the ASP, two new baffles measuring 12m (W) x 3m (D) were installed in each of the five lanes. The post and fence arrangement allows for future process modifications should the characteristics of the incoming sewage dictate the change in the optimum anoxic/anaerobic/aerated zone split.

Reducing operating costs
Various mixing methods were studied for the un-aerated zones within the ASP to keep the mixed liquors in suspension, with Chemineer GUT paddle mixer proving to offer the lowest whole life cost. All 14 mixers installed (2 in each ASP lane and 4 in the RAS Fermented) are fitted with field mounted Lenze variable speed drives. During process commissioning, tracer mixing tests at various motor speeds will allow energy costs to be minimised whilst achieving the minimum mixing requirements.

The existing blowers, diffusers and air pipework associated with the ASP will be renewed by ITT/Sanitaire. Within the aerated section of the ASP a total of 4,650 membrane diffusers have been installed in two dissolved oxygen (DO) control zones to replace the old inefficient ceramic diffusers. The BNR will require an average air flow of $8648m^3$/hr achieved by three new 150kW ABS HST blowers (Duty/Assist/Standby) housed within the existing blower house. The new blowers are to replace three (D/A/S) 280kW Bryan Donkin positive displacement blowers, completed in stages to keep the treatment process running. The more efficient HST blowers, associated pipework and diffuser design will provide a substantial energy saving. The plant is designed to offer a wire to water efficiency of $4kgO_2$/kWhr, reducing the site energy costs by over £100,000 per annum.

As well as normal DO control, the BNR process will have an ammonia control loop. This loop measures the ammonia concentration in the ASP lane, which gives an indication of the plant's ability to treat the incoming ammonia load. The controller has an ammonia setpoint, below which the 'normal' DO set-point is over-written by a lower value. By operating the ASP at the lower DO set-point the reduced DO demand can result in a 30% reduction in blower energy costs without the risk of breaching consent limits, thus further improving the estimated £100,000 energy savings.

3D modelling
The new blowers feed a common 450mm stainless steel manifold, which splits to feed the five ASP lanes via new 300mm stainless steel headers, run at a high level. All new access walkways, valve locations and pipework runs have been designed using a 3D model provided by *Hope Draughting.* The 3D model helped the engineering team, manage the interfaces with existing plant and also obtain full buy in from the site operational staff prior to installation, minimising rework once installed.

Intelligent control
The new BNR control system will be based on the use of the Rockwell Control Logix programmable logic controller's intelligent functionality. The main MCC supplied by Saftronics, will communicate with the field devices (drives and instrumentation) using the Process Field Bus (Profibus) communications protocol. The intelligent control panel will use all of the information available over the Profibus network to optimise the new process, and provide trending information to optimise the process and to allow for predictive maintenance to be carried out. The field mounted variable speed drives on the mixers have their parameters stored within the intelligent MCC, allowing device replacement to be carried out simply and reliably. The system is also supported by the Endress & Hauser "Field Care" package which is used to configure and store instrument and Profibus parameters.

Summary
Although full chemical dosing could be used to meet the P consent without these process modifications, it is predicted that BNR plus RAS Fermentation will reduce the required chemical dose by 50% (ferric sulphate dose reduced to 5 mg/l). Based on an assessment over 20 years, incorporating both the initial capital costs and ongoing operational costs of the various options, BNR plus RAS Fermentation has the lowest whole life cost and has the least impact on the environment.

The RAS Fermentation stage constructed at Loughborough is the first full scale plant in operation in the UK.

Progress

As of April 2008, 4 out of the 5 ASP lanes, the RAS Fermented and the P removal dosing rig have been completed. The process is due to be fully commissioned in BNR mode during May 2008 with full handover at the end of June 2008.

Project Details

Project Name: Loughborough Sewage Treatment Works Activated Sludge Plant Conversion & Capital Maintenance

Client: Severn Trent Water
Capital value: £3.5m
Construction Start Date: July 07
Completion Date June 08
Project Manager: Dale Collison, Severn Trent Water Ltd

Process data
Design Population Equivalent = 95,000

REFERENCES:

"Loughborough EBPR Pilot Plant, RAS Fermentation Trial Summary Report" January 2007: Pete Vale, Severn Trent Water Technology & Development, Process Engineering & Development Group.

"Loughborough BPR Conversion Design Report": February 2007: David Thomas, Severn Trent Water Technology & Development, Process Engineering & Development Group.

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RAS Fermenter Coffer dam piling rig *courtesy Severn Trent Water*

Pilot Plant *courtesy Severn Trent Water*