Water Industry Embraces Wastewater Treatment Optimisation

As various Directives drive tighter discharge consents across Europe, the water industry is making further investments in wastewater treatment and this will increase costs and carbon dioxide emissions from operational energy use and the emissions associated with the additional processes required. One of the main tools with which the industry can offset this effect is process optimisation, and in the following article Andy Thornton, a wastewater treatment specialist at HACH LANGE, will reveal the outstanding levels of success that have been achieved to-date.

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In England and Wales, more than 10 billion litres of sewage are produced every day (Ofwat, 2006), requiring around 2,800 GWh of energy for treatment - equating to 1.7 million tonnes of greenhouse gas emissions (Water UK, 2007) and these figures are expected to increase as populations grow and discharge consents tighten.

Wastewater treatment optimisation represents one of the main opportunities to meet this challenge, whilst also reducing costs and complying with the regulatory requirements of the CRC Energy Efficiency Scheme. However, in order to optimise a process, greater levels of monitoring and control are often required and the remainder of this article will provide feedback from sites which have already implemented HACH LANGE's Wastewater Treatment Optimisation Solutions (W.T.O.S).

Real-Time Control (RTC) in industrial processes is commonplace; however, wastewater monitoring represents a greater challenge because of its physical and chemical variability. Historically, wastewater monitoring technology has been prone to drift (especially dissolved oxygen monitors) and required a high level of maintenance and for this reason RTC was not possible.

The latest sensing technologies offer much higher levels of reliability than has been possible in the past, with substantially lower levels of maintenance and recalibration, and this has been a major factor in enabling the development of RTC in wastewater treatment. In addition, many of the latest sensors provide a 'health status' output in addition to the readings. As a result, control systems can ignore data from sensors that are not performing to their target specification.

W.T.O.S technology

Treatment methods vary greatly from company to company and from site to site, so under the W.T.O.S umbrella, HACH LANGE has developed a range of RTC modules that can be applied to many of the most common techniques. The range of RTC modules is constantly expanding, but at the time of writing, the list is as follows:

- N-RTC Nitrification control in activated sludge
- DN-RTC DeNitrification Control
- BAFF-RTC BAFF Process Control and Cell Management
- SRT-RTC Sludge Age Control
- P-RTC Chemical Dosing Control for Phosphate Removal
- ST-RTC Sludge Thickening/Polymer Dosing Control
- DW-RTC Dewatering Control

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There are three main components to a W.T.O.S:

(1) the RTC modules (Nitrification, Denitrification, Phosphate Removal, Sludge Retention and Sludge Dewatering)

(2) the process analysers

(3) the PROGNOSYS system, which constantly checks the 'health' status of the analysers.

The capital outlay for the addition of W.T.O.S to a treatment plant is relatively small; the most significant extra cost is simply a requirement for extra sensors. W.T.O.S overlays and compliments existing infrastructure, so it is possible (although very unlikely!) to simply turn W.T.O.S off and revert to the former regime.

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Nitrification

Aeration to achieve the biological oxidation of ammoniacal compounds to nitrite and nitrate is the most expensive process at activated sludge plants; blower power consumption often represents over 50% of total plant costs. The main purpose of the Nitrification RTC module (N-RTC) is to minimise power usage, whilst maintaining or improving the nitrification process. This is achieved by the generation of variable DO set points that 'modulate' according to the load.

To enable this, the N-RTC receives information from inline instruments about the actual

- NH_4-N inflow concentration and flow
- MLSS concentration
- Water temperature

A simulation model is integrated within the controller for open loop control to calculate the DO concentrations necessary to achieve the desired ammonium nitrogen (NH_4-N) outlet concentration. The algorithms for this are mainly based on the Activated Sludge Models of the International Water Association.

The N-RTC also constantly reads the NH_4-N concentration at the outlet of the aeration lane. This value provides a feed back control loop and ensures that the DO concentration is increased/decreased if the ammonium concentration is above/below the desired NH_4-N set point. In this way, the N-RTC control module combines the advantages of feed forward and feed back control, which are (1) rapid response, (2) set point accuracy and (3) robust compliance.

De-nitrification

Following nitrification, a carbon source is sometimes required to facilitate the microbial conversion of nitrate to nitrogen gas which is safely dispersed to the atmosphere. Methanol is commonly employed for this purpose and can represent a significant operational cost.

A de-nitrification RTC (DN-RTC) module calculates the methanol dose to deliver the stoichiometric requirement for the de-nitrification process. It is a closed loop system utilising data from a nitrate probe situated in the anoxic zone, flow monitoring data and the required nitrate concentration (the nitrate setpoint) in the activated sludge plant effluent . The methanol dosing control assumes that there is complete mixing of the MLSS in the anoxic zone.

Phosphate elimination

Phosphate in WwTW discharge is a growing concern because of its environmental effects; algal blooms, eutrophication etc. High phosphate concentrations are derived from domestic soaps and detergents, however, trade effluent can also contribute extremely high levels, and so many plants now have to take extra steps to remove phosphate in order to maintain compliance with discharge consents.

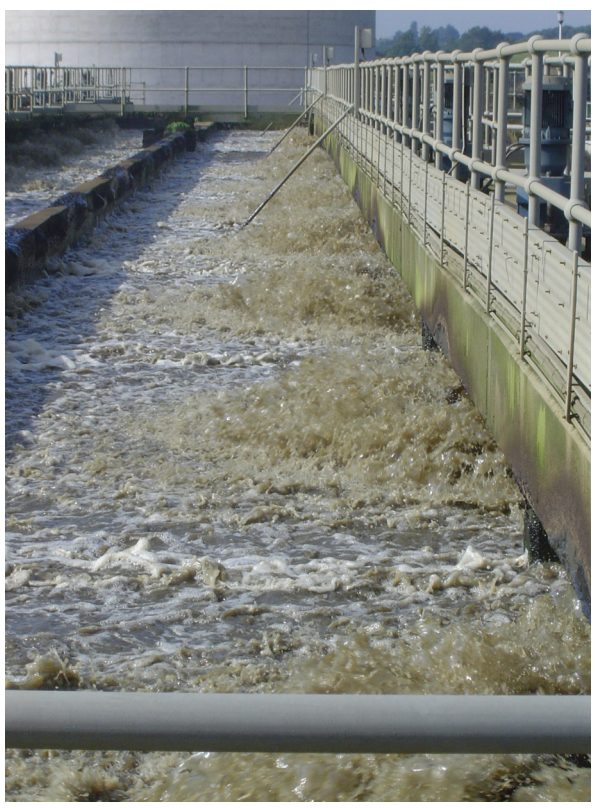
Electric blowers provide aeration for sewage treatment

Bacteria generally remove about 3 mg/l of phosphorus during aerobic digestion, however, significantly higher levels of removal are often necessary, so chemical treatment with lime or the salts of aluminium or iron are necessary. Of these, iron is generally preferred because aluminium salts can be toxic to fish and lime produces high sludge levels. Ferric salts are preferable to ferrous because they have a lower oxygen demand. The stoichiometric dose of iron is approximately 1g Fe: 1g P, but in practice the dose varies from 1:1 to 4:1 because of competitive reactions with organics etc.

The reaction of ferric sulphate with phosphate produces insoluble iron phosphate which precipitates and is removed as sludge in addition to sulphuric acid which is buffered by additional dosing with caustic soda, which ensures that the bacteria within the biological stages are not stressed as a result of a low pH.

The phosphate removal RTC (P-RTC) module utilises influent monitoring data to determine the phosphate load and thereby to calculate the dose rate to achieve the required removal percentage. It is also possible to monitor phosphate after dosing in order to establish feedback control in a closed loop system. However, the development of a sampling technology that was able to deliver a continuously representative sample of the influent was key to the success of this system.

The P-RTC ensures that chemical dosing is as efficient as possible, and that the plant is able to respond quickly to influent phosphate spikes, whilst maintaining consent compliance.



Aeration can be responsible for up two thirds of a treatment plant's total costs

Sludge management

RTC can also bring new levels of efficiency to the management of sludge. A Sludge Retention Time Module (SRT-RTC) module controls waste activated sludge mass by monitoring water temperature and the concentration of solids in the aeration lanes and in the return activated sludge. The system then calculates the optimum SRT and determines the sludge wasting rate accordingly. This helps to ensure stable nitrification and also helps top lower aeration energy costs.

An RTC is also available for Sludge Dewatering (SD-RTC). This module monitors suspended solids and sludge flow to control polymer dosing and produce a stable sludge discharge quality whilst lowering polymer costs.

Feedback from existing users

Individual RTC modules and full W.T.O.S systems have been in operation all over the UK and in Europe. All users are reporting very strong performance; improving efficiency and lowering costs, and the following case studies highlight some of the benefits that can be gained.

Southern Water

As Principal Process Scientist, Cheryl Noble is focused on wastewater treatment efficiency, consent compliance and energy efficiency. She says "A higher level of control is now required in the treatment process because of tighter discharge consents and a need to lower costs, energy consumption and the carbon footprint of the process.

"We now have tight Total-N consents and with nitrification and de-nitrification taking place at the same time, we need a higher level of process control. Historically, most wastewater treatment processes were set to deal with the worst-case scenario, but as influent fluctuates it is necessary for the treatment process to react immediately, so with W.T.O.S we are able to vary the set-points and this has enabled us to make substantial savings in energy and methanol consumption."

In common with all water companies, Southern Water is looking at ways to reduce carbon footprint, and reductions in energy usage and chemical consumption are both making a significant contribution. However, Cheryl says "Whilst the instrumentation cost of W.T.O.S is relatively small, it cannot immediately be applied to all plants because many do not yet have the necessary equipment with which to implement the higher level of control that becomes possible."

The first treatment plant at Southern Water to benefit from W.T.O.S was Peel Common near Fareham in Hampshire which serves a population of around 240,000. Operating a 4-stage Bardenpho activated sludge system, the plant consists of eight lanes (in four pairs) with methanol addition as an extra carbon source in the secondary anoxic zone.

The W.T.O.S system at Peel Common continuously manages the

nitrification, de-nitrification and sludge control, and Process Scientist Duncan Clarke believes that greater control is delivering substantial benefits. "In comparison with a fixed DO system, W.T.O.S reacts quickly and automatically to any changes and optimises blower power consumption. This is particularly valuable at night times when low flows result in less aeration," he says. "In order to achieve this level of control, more monitoring points are necessary, but the cost of these sensors and analysers is far outweighed by the savings. We have four 315 KW blowers, with one or two of them usually running at any moment in time, and methanol also represents a significant cost."

A W.T.O.S system has recently been installed at Chichester WwTW in response to a lower Total-N discharge consent. The new system will ensure compliance with the consent and improve the efficiency of the treatment process. Methanol dosing is not necessary at this plant, so the main cost savings will be from energy efficiency. However, at around £150,000, the cost of installing W.T.O.S at Chichester was a fraction of the capital cost (estimated £6million) that would have been incurred by investing in extra treatment capability.

Following the success of the early installations, Southern Water will install further RTC systems at a number of other plants

Wessex Water

In May 2010, a W.T.O.S system was installed at Holdenhurst sewage treatment works in Bournemouth (175,000 PE) which mainly treats domestic wastewater. The system has reduced power demand by 25% and Wessex Water's Matt Crowhurst says "This represents a substantial reduction in carbon footprint and saves around one sixth of the plant's operational costs."

Matt Crowhurst with the W.T.O.S at Bournemouth WwTW

Matt has measured a 120 KW reduction in power demand since the W.T.O.S was installed and says "Our staff have noticed that the blowers are working less, especially during low load periods – often only one blower is in operation. We have also seen lower final effluent ammonia during storm events and have been able to see the DO set points changing as influent ammonia levels rise or fall."

Data from the plant influent flow monitor are also fed into the W.T.O.S, which helps the plant to respond faster to heavy rainfall events. In addition, a Sludge Retention Time Controller helps to ensure that MLSS is maintained at an optimal level, which prevents unnecessary aeration, reduces pumping and thereby lowers energy consumption.

Following the success of the Holdenhurst W.T.O.S, Matt is looking to install the system at other plants. For example, an RTC system is being installed in the BAFF stream at Chilton Trinity sewage treatment works, in Bridgwater, and a further system will form part of a new activated sludge lane that will be added to the Taunton plant in 2013.

United Utilities

W.T.O.S RTC systems have been installed at a number of United Utilities sites and Alison Summersfield, Asset Optimisation Implementation Manager, says: "We developed the BAFF-RTC at Leigh wastewater treatment works (85,000 P.E.) in conjunction with HACH LANGE and the result has produced power savings of around 30% when the RTC is in operation. At Stockport we have installed the RTC system for aeration control, which to date has demonstrated power savings of up to 25%. Additional instrumentation has also been employed as part of the RTC systems, which gives a better picture of how the plant is performing at all times.

"The RTC work has been undertaken as part of our Asset Optimisation Programme, which is targeting operational efficiency savings at 30 wastewater sites across our region. There are also other benefits to the RTC approach which include a reduction in our carbon footprint. At Leigh, this higher level of control also enables us to manage the cells within the BAFF plant more effectively."

United Utilities has also employed RTC for phosphate reduction at its plant in Colne (17,000 P.E.) near Burnley. The site treats both domestic and commercial wastewater and has a 2.0 mg/l phosphate discharge consent. Historically, phosphate removal by chemical precipitation has been achieved by constant dosing with ferric sulphate at 30 l/h. However, a phosphate analyser (PHOSPHAX) has been installed to monitor the influent and a P-RTC system has been fitted to control the ferric dose rate. The dose now varies continuously and is determined by the controller, based on the inlet phosphate load, the P-percentage removal required and the biological P-removal rate.

Danny Norris, Technical Officer for Burnley, Hyndburn and the Ribble Valley area, is very pleased with the new system. He says: "By dosing at a fixed high rate, it was inevitable that a significant proportion of the ferric was wasted. However, since the installation of the P-RTC system, the level of dosing has been varied to meet the load. As a result, we are constantly in compliance and by monitoring phosphate in the influent we have also been able to identify illegal trade discharges."

The phosphate monitor at Colne has been fitted with a new type of inlet sample preparation system that has been developed to meet the specific challenges of monitoring screened sewage, with occasional storm overflow, in a Zone 2 area. HACH LANGE's Glynn James says "The new filter is a major breakthrough because it provides a representative sample without the need for capital works. It achieves this with a novel filter design that is automatically cleaned by backflushing and air scouring."

The P-RTC system at Colne has been in place for over six months and has resulted in a 38% reduction in chemical usage, thereby ensuring a fast payback on the investment in the monitoring and control system.

In addition to the plants mentioned above, further RTC systems are currently being installed at other plants and in other water companies, and it is anticipated that it will be possible to report further successes in energy reduction at these plants in the future.

Overseas experience with W.T.O.S

RTC is also becoming popular outside of the UK – HACH LANGE has installed systems in Germany, France, Slovakia, Italy and the Czech Republic.

Summary

In comparison with many industrial processes, wastewater treatment presents its own set of unique challenges. However, in recent years monitoring technology has made considerable progress so that advanced control techniques can be applied to deliver significant efficiency improvements.

To-date, every plant that has implemented a W.T.O.S system has experienced significant energy and/or cost reduction, so it would appear that RTC will play a major role in helping the water industry to meet the challenges of tighter consents, energy efficiency and carbon reduction.