OPTIMISATION OF STABILITY AND EFFICIENCY IN WASTEWATER TREATMENT PROCESSES
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Introduction

Increasing levels of instrumentation across wastewater treatment works have produced a wider range of information on process operation. There are also increased incentives for process optimisation, for example due to the rising cost of energy used, and the reduction in the size of the operational staff workforce. This changes the manner in which these works are operated, with a more focussed objective of real-time dynamic control and pushing towards energy, cost and operational expenditure targets. Whilst traditionally, the wastewater industry has operated plants in a conservative manner, minimising risk of consent failure by over-treating, there is now a move towards a more balanced approach to optimisation of the plant with respect to multiple objectives. While the reigning priority is still quality objectives and meeting regulatory consents, the multivariable optimisation approach provides more scope for operational savings, exploiting the wealth of information that is now more readily available and facilitating a more coherent ‘risk based’ approach to final effluent quality.

Keywords
Control, Optimisation, Model Predictive Control, Wastewater, Efficiency

Data Based Strategies

This paper details the application of a robust data-based control and optimisation strategy that has been successfully implemented on a wastewater treatment process. A key consideration when utilising online process data is the reliability of the information available. The level of robustness of the control system depends heavily on the availability of reliable data, or - in the case where the data quality is questionable - the ability to ‘reconstruct’ that information from other correlated process variables. The important objective here is to determine when the process is behaving abnormally, as opposed to an unusual process value being due to an instrumentation problem. For operators to ‘believe’ in closed loop control of their process, they must be satisfied that the new control system is capable of operating safely throughout a range of process conditions, and does not need constant maintenance to perform its function correctly.
Control Approach

By considering the plant as a whole, instead of a series of individual unit processes, the plant as a ‘unit’ in itself can be driven to operate in a ‘sweet spot’, based on current process conditions, meeting energy, quality and operational targets simultaneously. The multi-layer approach described in this paper considers the individual process units which were selected for optimisation (particularly those with significantly differing time scales, such as DO and MLSS), and how these units interact with each other and with the plant as a whole. This integrated scheme for optimisation and control provides a more robust approach to plant operation – especially during ‘abnormal’ operating conditions, such as storm events.

The effect of aeration on DO can be measured on the time scales of seconds to minutes. In the case study presented in this paper, the activated sludge process was jet aerated – this has a relatively high efficiency of oxygen transfer. The effect of load changes (such as dilution during storm events, first flush effects, variations in COD or NH4 load) on aeration requirements typically occurs over a longer timescale of minutes to an hour. This is due to the retention time of the aeration basin, and is dependent on the amount of dissolved oxygen present in the aeration stage. As well as oxygen demand for nutrient
removal, the amount of biomass in the process (indicated by the concentration of MLSS) determines the oxygen demands for endogenous respiration. The concentration of biomass changes slowly in comparison to the dynamics of the aeration process (over the timescale of hours to days), but nevertheless has a strong influence on aeration requirements.

The simplest approach to deal with the large differences in time-scales in this process is to ‘cascade’ the levels of control in a multi-layer scheme. In the case study shown in this paper, manipulation of the dissolved oxygen levels by varying aeration input was modelled, with the load characterised by the flow into the works (due to the lack of instrumentation measuring influent load) as a disturbance variable. In this manner, Layer 1 and 2 above were included within one layer. The final layer (3) of control of biomass concentrations by de-sludging was considered as a separate layer cascaded on top of Layer 1 and 2.

Case Study Application

The case study application discussed in this paper is that of an activated sludge works, within a larger sludge treatment facility, at Teeside, England. This works operated as a primarily municipal treatment plant, with a small volume of industrial wastewater. This works comprises primary and secondary stages independent of other treatment stages at site, but with a common tertiary treatment stage (UV) and a sludge-handling stage (gravity belt thickeners) prior to an Anaerobic Digestion stage. For the purposes of this case study however, which concentrates primarily on the secondary treatment stage, the works could be considered as a ‘standard’ activated sludge process.

![Optimisation of Activated Sludge Process](image)

**Figure 2: Control and Optimisation Modules**

Real-time assessment of data quality was carried out on all critical signals. Critical sensors were supplemented with inferential (software-based) sensors, to provide a real-time reliable measurement in the event of hardware failure. This also provided a real-time alert to operations staff when the existing hardware sensor was becoming unreliable. Furthermore, an integrated approach to data-based optimisation was used by exploiting the information available from off-site pumping stations, to provide a feed-forward of changing conditions, particularly during storm events.

**Results**

The performance of the system has been evaluated according to three objectives: Quality, Cost of Operation, and Ease and Robustness of Operation. Whilst the first two
can be evaluated using performance metrics such as risk of consent failure (risk ratio) or energy/chemical costs, the final performance objective of ‘ease’ and ‘robustness’ is subjective and is based on operator feedback. The first objective of quality is focussed primarily on the COD and solids removal across the works, due to the fact that this works is operated as a carbonaceous removal plant and is not operating to any nitrification targets.

The aim of the model-based control strategy (denoted here by “APC”, Advanced Process Control) was to assist site in avoiding solids-loss issues from their settlement stage. The period of operation under APC control showed a 17% reduction in SSVI (stirred sludge volume index) recorded by daily laboratory tests, in comparison to the previous period of traditional (PLC-based) control. A correlated increase in transmissivity was seen, measured at the final UV stage prior to final effluent, of 25%. This was primarily due to the increased stability in the final settlement stage and, hence, an improvement in fine solids removal.

Risk of consent failure for solids dropped from 35% (under traditional control) to less than 3% (under APC control). This risk reduction was a major factor in the adoption of this system by operators. A 7% reduction in blower current (amperes used), was seen under APC operation. Traditionally, the blowers were operating at minimum during 11% of the time. Under APC control, the blowers have been operating at minimum during 27% of the time. Benchmarking energy consumption showed a reduction of 18% in aeration energy. Prior to the implementation of APC, chemical dosing (hypochlorite) was used to improve settlement during problematic periods. For example, chemical dosing took place for 15 days during 2010, consuming 4500 litres per day of hypochlorite. Under APC, reduced periods of over-aeration (under low incoming load) and under-aeration (under high loads, particularly during first flush events) have resulted in more stable operation of the aeration stage, and avoided conditions that promoted growth of undesirable organisms. As a result, no chemical dosing has been required under the past 12 months of APC operation. Balanced operation of the settlement stage, under varying conditions, has reduced the frequency of high sludge blankets, which had been shown to contribute to solids loss. In addition, maintenance of biomass concentrations was performed using APC, by considering not only the sludge age targets but the settleability in the final stage, as well as the energy use for aeration; balancing all these inter-related objectives resulted in a more stable and efficient process.

Under the previous PLC/SCADA control scheme, adjustments to de-sludging of the final settlers were being made manually 30% of time. This was particularly necessary during storm events, or when settlers were out of service, which resulted in a hydraulic imbalance in the flow split between the settlers. Under the APC system, far less manual input was required, even under abnormal conditions, providing the operator with more robust, more reliable control. Across all FSTs (final settling tanks), periods of high sludge blankets were reduced by more than 50%. The ability of the APC system to deal with different hydraulic loading conditions (for example, when a settler was taken out of service for maintenance) meant that it was capable of providing robust control without operator intervention. The full conference paper will provide further results.