TECHNICAL BRIEF

October 2016
The WRC operates in terms of the Water Research Act (Act 34 of 1971) and its mandate is to support water research and development as well as the building of a sustainable water research capacity in South Africa.

Reducing energy use in wastewater treatment plants

A Water Research Commission (WRC) study has tested ways to improving energy use in the wastewater treatment sector.

Background

Similar to the global industry, the South African wastewater sector has historically focused on achieving the primary objective of wastewater treatment of protecting the environment and compliance with the Department of Water and Sanitation (DWS) regulatory standards. Energy costs have been viewed as simply part of the cost of doing business, and no significant focus has been placed on mitigating cost increases.

However, with the sharp increases in Eskom electricity rates, which are predicted to continue increasing in the foreseeable future, energy will continue to be a significant operating cost which requires additional funding. In order to remain sustainable, it is therefore prudent for South African municipalities to follow global trends and consider energy management as an intrinsic part of wastewater operations and a de-facto secondary treatment objective of wastewater treatment.

The need for energy efficiency in the South African water sector has already been identified by previous WRC research. The latest study identified that wastewater treatment uses about 55% of the energy consumed in the South African water sector.

The bulk of this energy is used for aeration at biologically nutrient removal activated sludge plants which are widely employed for municipal wastewater treatment in order to meet the DWS final effluent discharge regulations. Focusing on aeration energy use reduction therefore yields the most savings in energy cost.

Current study

This project was focused on aeration energy conservation in wastewater treatment. The project investigated feasible practical aeration energy conservation measures that can be implemented at biological nutrient removal activated sludge plants that not only result in energy use reduction, but also ensure final effluent compliance with discharge regulations; thus satisfying both the primary objective of wastewater treatment as well as energy conservation.

Two biological nutrient removal activated sludge plants were selected as case studies:

- Zeekoegat wastewater treatment works (WWTW) owned and operated by the City of Cape Town with a design capacity of 85 ML/day average dry weather flow and utilising fine bubble diffused aeration and
- JP Marais WWTW operated by ERWAT, with a design capacity of 15 ML/day and utilising surface aeration.

The scope of work for both plants covered collection and analysis of plant data, determination of 2014 baseline energy use and benchmarking, identification of feasible aeration energy conservation measures, application of advanced process modelling and simulation to determine optimal process and aeration control strategies and economic evaluation of feasible measures.

Feasible aeration conservation measures were classified into three categories:

- Simple measures that only require changes to process operation and control to optimal levels, with little to no additional capital investment apart from operator training.
- Low to medium capital measures that involve upgrading

aeration and control strategies requiring investment in new monitoring equipment and control systems
- Complex measures that involve redesigning and replacing less efficient aeration systems with more efficient technology as well as introducing influence flow balancing.

Main results

Zeekoegat is a fairly new plant with the second module and aeration upgrades commissioned in 2013. The plant was designed to minimise aeration energy use with highly efficient fine bubble diffused aeration systems.

Influent flow is balanced after primary clarification and the plant aeration control system is also optimised to minimise energy wastage. Final effluent complied with all parameter limits except for nitrate/nitrite.

For the 2014 baseline year:
- Total annual power consumption was 11 240 MW at a cost of R9.8 million. Aeration accounted for around 42% of the total 4 750 MWh and a cost of R2.9 million.
- The baseline aeration energy use intensity, which serves as a benchmark for this plant was 22 kWh/peCOD$_{100}$/year (0.7 kWh/kgCOD treated)

A number of feasible energy conservation measures were identified:

- Simple measures using existing process and aeration equipment: Optimal process and aeration control resulting in potential cost savings of 9%.
- Low to medium capital investment: Upgrading the current aeration control strategy from traditional dissolved oxygen based control to ammonia based control with potential cost saving of 17%. Preliminary financial analysis indicates a payback period of 1.7 year.
- Complex high capital investment: Replacing the existing Module 1 stage centrifugal blowers with more efficient turbo blowers similar to Module 2. Potential savings of 19-23% can be achieved with payback periods of around 5 years.

JP Marais is an old plant constructed in 1990. The design of the activated sludge process is typical of most activated sludge processes of this era that were not designed for energy efficiency. In addition, the aeration design is not tapered and aeration control was designed to be semi-automated but was manually controlled in 2014 due to equipment breakdowns.

Total annual power consumption at the plant was 3 340 MWh at a cost of R3.1 million. Aeration accounted for 74% of the total energy usage at 2 465 MWh/year and a cost of R2.3 million.

Aeration energy use intensity, which serves as a benchmark for the plant was 31 kWh/pe COD$_{100}$/year (0.9 kWh/kgCOD treated). The value is 41% higher than that for Zeekoegat.

Feasible aeration energy conservation measures were as follows:
- Simple measures using existing process and aeration equipment: Optimal process and aeration resulting in potential cost savings of about 14%.
- Low to medium capital investment measures utilising the existing aeration equipment: Fully automating aeration control and implementing advanced process control with ammonia based aeration control. Potential cost savings of 21% and a payback period of 1.1 years.
- High capital investment – replacing existing surface aerators. This measure requires a complete redesign of the aeration system similar to the one at Zeekoegat plant will yield maximum energy savings greater than 40%. Flow balancing also results in simplified, more efficient process and aeration control systems.

For both plants implementing advanced process control strategies resulted in optimal process and aeration control which improved both denitrification and enhanced biological phosphorous removal. Model predicted final effluent nitrate/nitrite and Ortho Phosphate values were significantly lower than the baseline measured values as well as licence discharge limits.

Two workshops were held in Pretoria and Durban to discuss the findings of the project. Input was received from participants on the experience and challenges faced by South African municipalities in implementing energy management programmes at their wastewater treatment plants. Some of the challenges identified which are also similar to challenges experienced globally were:
- Unreliable technology
- Poor designs
- Limited funding, technical expertise and top management commitment
- Restrictive/poor supply chain management practices
- Lack of or misleading incentives to stakeholders.

Conclusions and recommendations

The approach of applying advanced process modelling to evaluate aeration energy conservation measures yields other benefits, the most significant of which is to ensure that final effluent compliance with regulatory requirements is met satisfying the primary wastewater treatment objective of protecting the environment.

Model predicted energy and cost savings might not be realised in practice due to both technological and human challenges that have been identified as hindering the implementation of efficient process and aeration control systems in practice.

Before practically implementing aeration energy conservation measures identified from desktop studies of this nature, the following is recommended:

- A more detailed investigation of market available options for aeration technologies as well as process and aeration control technologies. The quality and costs, including maintenance requirements, are of critical importance to the success of the aeration energy conservation measures.
- Application of a superior economic evaluation technique such as lifecycle cost analysis, which takes into account all the costs incurred during the project life, so that the most cost-effective measures can be selected for implementation.
- Detailed engineering design support for medium to high capital measures that require significant modifications to existing infrastructure as well as new treatment units and equipment.

The South African water sector could benefit from an aeration energy use benchmarking exercise for activated sludge plants to guide municipalities in planning for energy management initiatives.

Further reading:

To obtain the report, *Energy use reduction in biological nutrient removal wastewater treatment plants: A South African case study* (**Report No. TT 654/15**) contact Publications at Tel: (012) 761-9300; Email: orders@wrc.org.za or Visit: www.wrc.org.za to download a free copy.