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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.

TECHNICAL BRIEF

Industrial effluent

Water reuse using a dual-stage membrane bioreactor for industrial effluent treatment

A WRC-funded project assessed the performance of membrane bioreactors (MBRs) for the treatment of textile and paper mill effluent.

Background

Previous WRC-funded research focused on the development of a unique operations strategy employing laboratory-scale MBRs for the treatment of wastewaters of industrial origin. The process design facilitated a continuous development and acclimation strategy for generation consortia of microorganisms capable of degrading specific industrial wastewaters.

These adapted consortia were then 'harvested' to be used in the continuous operation of 'hydrolysis' reactors. The reactors were operated under similar conditions to conventional wastewater treatment facilities. However, the continuous addition of adapted microbial populations developed within the seeding reactor configuration facilitated, firstly, significantly decreased adaptation periods associated with conventional treatment strategies and secondly, an inherent robustness facilitated by obviating the requirement for adaptation within the hydrolysis reactor configuration.

In comparison with activated sludge systems, the long-term operation of this MBR process treating high-strength effluents was characterised by more stable microbial populations that are significantly less susceptible to deleterious shifts in the community dynamics resulting in enhanced process efficiency due to less process variability.

Due to the associated robustness of the dual-stage MBR system, it is ideally suited to the treatment of a variety of industrial process wastewaters generated by diverse industries. However, variations in wastewater streams make it imperative to assess the performance of the system on-site and at the pilot scale in order to accurately gauge the impact of real wastewater challenges on the robustness of the process technology.

This pilot project therefore aimed to address several challenges currently experienced by the water and wastewater sector in the Western Cape. First, to develop on-site wastewater treatment solutions for industries monitored and tariffed by local municipalities as increases in monitoring and legislative framework capacity are realised.

This technology aimed to address these increasingly prevalent needs by providing a mobile, adaptable solution.

Treating textile effluent

A textile manufacturer was selected as one of the industrial partners for the on-site evaluation of the pilot plant. A 5-10 m^3/day MBR pilot was designed and operated on site from March to December 2010.

The design of the dual-stage MBR process was geared towards optimal microbial community enrichment, and was based on a pre-denitrification configuration coupled with enhanced biological phosphate removal (EBPR). The anaerobic-anoxic-aerobic process was designed to incorporate two primary functionalities: influent azo dye cleavage in a reducing environment followed by oxidation of the resultant aromatic amines; and biological nutrient removal through enrichment of associated microbial consortia using nitrification, denitrification, and phosphate removal process control.

In terms of the overall results, chemical oxygen demand (COD) removal fluctuated considerably during the three-month start-up stage. The effluent stream was characterised by a COD range of between 45 and 2 820 mg/ℓ and an average biological oxygen demand (BOD) of 192.5 mg/ℓ.

The dual-stage MBR achieved an average COD reduction of 75% with a maximum 97% over the next 9-month test period. The COD concentration obtained after dual-stage MBR treatment averaged at 190 mg/ℓ, which was well within the discharge standard.

The average reduction in turbidity and total suspended solids (TSS) was 94% and 19.6% respectively during the ultrafiltration (UF)-MBR stage of the system. Subsequent treatment of the UF-permeate with nanofiltration (NF) and reverse osmosis (RO) removed both the residual colour and remaining salt.

A consistent reduction in the colour of the incoming effluent was evident. The American dye manufacturing index (ADMI) was reduced from an average of 659 to below 20, a lower ADMI and colour compared to their potable water. An average conductivity rejection of 91% was also achieved.

Implementing a dual-stage MBR system coupled with NF successfully removed colour from industrial textile effluent, bringing all the parameters measured during the study to within the City of Cape Town wastewater discharge standards, thereby reducing their discharge costs financially. However, coupling the MBR system with RO not only successfully removed the residual colour from the effluent; RO also had the ability to reduce the salts present in the dual-stage MBR product to within potable water standards.

By treating the effluent to within potable water standards the treated water can be reused on site within the textile dyeing processes, thereby reducing the wastewater load sent to the municipal treatment works, reducing the volume of water used by the textile company, thus decreasing their water dependence on the municipality, and assisting in reducing their impact on the environment.

However, a dual-stage MBR system would not be ideal for this particular textile company since the industry does not operate continuously, and has periods of downtime over weekends and public holidays. Biological systems require continuous effluent feed in order to supply the activated sludge with nutrients and thus operate efficiently.

Treating paper and pulp effluent

A paper and pulp industry was also selected as an industrial partner for the evaluation of a pilot-scale MBR plant for the treatment of paper mill effluent. A 45-65 ℓ/day MBR pilot plant, incorporating ceramic membranes in an external modular configuration, was designed and operated in a laboratory from June to November 2010.

The design of the dual-stage MBR process was geared towards optimal microbial community enrichment, and was based on a pre-treatment high rate anaerobic system coupled with a post-treatment denitrification/nitrification configuration. The high rate anaerobic process was designed to reduce influent COD to reduce the need for high-volume dosing.

In addition to the COD reduction, the potential for extracting methane as a potential energy source was also considered. The anoxic-aerobic processes were designed to incorporate two primary functionalities: further reduction of COD concentration; and biological nutrient removal through enrichment of associated microbial consortia using nitrification and denitrification process control.

The paper mill effluent stream was characterised by a COD range of between 1 600 and 4 400 mg/ℓ and an average BOD of 2 400 mg/ℓ. In terms of effluent COD reduction efficiency, the anaerobic pre-treatment stage facilitated an average of 70% COD removal, thus lowering the MBR COD feed concentration to consistently below 750 mg/ℓ.

The subsequent anaerobic product stream was the feed stream for the modified Ludzack-Ettinger (MLE)-MBR which facilitated an average of 97% COD removal over the piloting trial period. Combining a high-rate anaerobic pre-treatment EGSB with a modified MLE-MBR process configuration produced a high-quality permeate. Preliminary NF and RO results indicated an overall COD removal of around 97% and 98% respectively.

Challenges and conclusions

Based on the above case studies the project team recommends that the following initiatives be considered when making decisions to implement full-scale interventions:

- On-site piloting trials must be conducted to provide long-term optimisation and scalability data
- Cleaner production and waste minimisation audits should be conducted in parallel to capitalise on increased long-term savings potential
- Stream segregation analysis should be implemented during the latter phases of pilot trials if a decision to implement a treatment strategy at full scale is considered
- Full-scale implementation should be done using a modular approach to match expansion requirements when necessary.

Process designs for full-scale treatment should be conducted using a modular approach to accommodate potential production capacity increases in the short to medium term – in terms of footprint requirements, the modular design is based on incremental capacity expansion.

Based on the calculated OPEX savings potential, overall savings taking into account full-scale CAPEX and OPEX should translate into a ROC period of about 5 to 7 years, with an overall savings potential of 25-50% calculated on a cost-per-kℓ basis calculated over the 10-year operating period.

Further reading:
To order the report, *Water reuse using a dual-stage membrane bioreactor for industrial effluent treatment* (**Report No. TT 556/13**) contact Publications at Tel: (012) 330-0340, Email: orders@wrc.org.za, or Visit: www.wrc.org.za to download a free copy.