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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 wastewater management

Assessing industrial effluents for permitting of discharge

The Water Research Commission (WRC) has completed an investigation into methods for the development of a protocol for quantitative assessment of industrial effluents for permitting of discharge to sewer with eThekwini metro as a case study.

Background

The major elements that the local authority has for managing industrial wastewater are its wastewater treatment plants for remediation, discharge permits for placing limits on what may be discharged, and a discharge tariff for financing the treatment and for providing a set of incentives and penalties to influence users of the system.

An optimal management strategy will use all these elements in proper relation to one another. However, the relationships are complex and poorly understood because of the complex and variable nature of both the multitude of effluents discharged from industries, and the response of the biological processes to them.

An effluent discharge permit consequently is a crucial interface between the local authority and an industry, and the permit system has to carefully balance protection of the general public and the environment against the rights of those working in industry and the promotion of economic activity.

The principle of administrative justice implies that the process of issuing a permit requires reasons for decisions taken. The White Paper on Integrated Pollution Control and Waste Management, 2000, requires all activities to control pollution to relate source control strategies and regulation directly to the resource it serves.

The activated sludge process is the most common form of treatment for municipal wastewater in South Africa. Industrial effluent can often be accommodated up to a point without compromising the quality of the treated water.

WRC project objectives

The broad objective of this project was to develop a methodology for predicting this point with sufficient reliability to be useful in setting discharge limits for industrial effluents.

The conceptual basis of this project was to develop a protocol, involving a combination of laboratory testing and process modelling, which would be able to predict the effect of a range of loads of factory effluent on the operation of the treatment plant receiving its effluent, and to inform the process of granting a discharge permit. Because of the sustained high impact of textile effluents on several wastewater treatment plants in eThekwini, textile effluents were chosen as the subject of all the investigations.

South African industrial effluent permit systems

A comparison of the permitting systems administered by South African municipalities was undertaken in 2007. A questionnaire was sent to 37 municipalities requesting some basic information about their industrial effluent permit systems. Replies were received from 12 (32% excluding eThekwini). Those that had sent replies include all the larger industrial centres.

The replies to the questionnaire were analysed in terms of the experience of dealing with industrial effluents that existed in each municipality, and the sophistication of the permit system which had been developed in response. According to these scores, eThekwini appeared to have the most sophisticated system, based on the most experience

of dealing with industrial effluents, followed by Ekurhuleni, then Nelson Mandela, Buffalo and uThukela.

There were some surprises in the ranking of municipalities according to these scores, with some larger municipalities ranking lower than one might have guessed (for instance Johannesburg and Tshwane). However, these municipalities indicated that their wastewater treatment works experience few problems associated with industrial effluents, which suggests that the more sophisticated permit systems have evolved in response to more problematic effluents.

Baseline wastewater treatment models

Most wastewater treatment plants were originally designed for the treatment of domestic wastewater. The presence of industrial wastewater introduces various difficulties in the treatment process due to the complex and varying nature of the industrial wastewater.

Baseline models were developed for two wastewater treatment plants in the eThekwini Municipality: Mariannridge and Verulam, which receive a significant volume of industrial effluent.

For Mariannrdige, characterisation of the incoming wastewater was accomplished largely through the use of respirometry (oxygen utilisation rate) measurements to fractionate the incoming COD into the categories required for modelling. However, in the case of Verulam it was found that substances present in the wastewater (presumably of industrial origin) interfered with the functioning of the respirometer, and invalidated the measurements. Consequently, a method was developed to estimate the wastewater characteristics based on the flow balance on the wastewater treatment plant's catchment, using data on the major industrial sources drawn from records kept as part of the municipality's permit system.

Laboratory methods for WWTP feed characterisation

The objective of influent wastewater characterisation is to determine the volumes and concentration of the carbon, nitrogen, phosphorous and other constituents present in the wastewater entering the wastewater treatment plant. Characterisation of the effluent leaving the wastewater treatment plant provides a way to assess the extent to which transformations of the wastewater constituents occur, in relation to achieving the required effluent standards. The measurements required to support wastewater treatment plant modelling are much more intensive than those generally used to monitor their operation.

The combination of respirometry and COD measurements was the main focus of the laboratory work in this project. For most of the other measurements results from the municipal analytical service were used. The respirometry apparatus that was used did not give reliable results due to interference encountered.

Laboratory testing for textile effluents

Effluent from textile wet finishing operations typically has BOD and COD values that are above generally accepted levels for discharge to sewer, with significant contributions from detergents and softeners. Textile wastewater composition varies frequently and markedly. It has been observed that a change in the surfactant content of such wastewater can affect the COD removal efficiency.

SAlkyl-phenol oxylates (non-ionic surfactants commonly used in textile processing) have intermediate degradation products with an aromatic group that is more difficult to biodegrade. Consequently, textile effluent COD may be slightly more difficult to treat than normal sewage, no necessarily in terms of ultimate biodegradability, but in terms of the rate at which degradation takes place.

Several series of tests were carried out to establish a methodology for assessing the biodegradability of surfactants using the apparatus available to the team, but these failed to provide consistent and reliable results. It appeared that the surfactants interfered with the response of the dissolved oxygen electrode, causing it to give incorrect oxygen utilisation rate results.

The interference by surfactants in textile effluents in the oxygen utilisation rate measurement also prevented the team from obtaining reliable indicators of whether textile effluents inhibit the activated sludge process. However, no indications have been found in the literature of such inhibition.

Textile effluents contain a variety of highly coloured components, depending on the combination of processes that give rise to them. From a wastewater treatment point of view, these can be divided into two broad classes, particulate and soluble.

Two laboratory studies on the removal of representative particulate and soluble dyes by activated sludge were carried out in order to provide a basis for a model of colour removal in a wastewater treatment plant.

The activated sludge process removes azo dyes from wastewater to a small extent. The mechanism for this appears to be physical adsorption onto the sludge, with the adsorptive capacity of actively growing sludge a little higher than for inactive sludge.

The adsorption rates are such that equilibrium is attained within approximately 1 hour, which is substantially faster than other processes in the activated sludge process. Consequently, an accurate kinetic model of the adsorption process is not necessary.

The integrated effluent evaluation protocol

The project plan envisaged that the entire protocol would be tested in a case study which would be undertaken as part of the process of granting an actual effluent discharge permit to a textile factory. However, for reasons that were not all within the control of the research project, the case study could not be completed.

The factory that was originally chose closed down. JMV Textiles in Verulamn was then chosen as a substitute, but because the pollution officer assigned to the permit investigation left the employ of the municipality, the permit was granted hurriedly, without involving the proposed protocol. So this report is only able to present the preliminary investigations that were part of the envisaged protocol.

A spreadsheet model of the process was developed which could be used to predict the quantity and composition of textile effluent from the factory's production schedule, based on dyeing 'recipes' provided by the factory. The model predictions have been partially validated by comparing the predicted and measured cumulative frequency distributions of conductivity in the factory effluent.

Discussion

Despite the challenges experienced, there were some positive developments achieved during the project:

- A much deeper understanding of the complex issues surrounding the treatment of industrial wastewater in conventional municipal wastewater treatment plants.
- A body of experience in the modelling of wastewater treatment plants, although not complete, particular in relation to treating industrial effluents.
- A body of experience, similarly incomplete, in respirometry and other laboratory techniques for characterising industrial wastewater for modelling purposes
- A production-based model of effluent generation in a textile factory
- A promising, material balance approach to characterising wastewater in an industrial catchment, which appears to provide a much more effective alternative to the laboratory based approach which was pursued for most of the project.
- A greater appreciation on the part of the municipality on the potential, the limitations and the resource requirements of wastewater treatment plant modelling.

Conclusions

The potential advantages of modelling for design, optimisation and control of wastewater treatment plants are well documented. However, to realise these requires a critical mass of expertise, in both the computational and analytical aspects. It is clear that these requirements were seriously underestimated, firstly in the matter of the research project, but perhaps more critically in terms of what municipalities are able to devote to the technology.

Their ability to attract and retain sufficient staff with the requisite skills is severely limited, and those they have are needed for more immediate urgent responsibilities. On the other hand, there is a perception within the municipality that they need to develop in-house modelling competency to meet their future needs. This project has turned out to be too ambitious, with too many aspects that needed to be developed simultaneously.

Although the project was motivated by a perceived need of the municipality to develop a more scientifically defensible basis for setting permit limits, there seems little chance that they would be able to implement such a complex protocol in-house in the near future. The obvious alternative would be to set up a specialist consultant service, with integrated laboratory and computational capabilities. This possibility has been discussed with the municipality, and there is a proposal to establish a laboratory service along these lines.

A follow-up project has started in the meantime, which will provide a vehicle for continuing the development of wastewater treatment works modelling. How it is concluded will be informed by the experiences gained in this project. The proposed methodology and deliverables are formulated in sufficiently broad terms that they do not need to be reformulated, but the following issues should be emphasised:

- Investigation of more robust and reliable laboratory methods for wastewater characterisation;
- The further development of influent wastewater characterisation using a combination of catchment balance and laboratory measurements;

- Training of municipal staff in setting up and using wastewater treatment works models;
- Establishing a sustainable system for providing modelling services to municipalities;
- Establishing a sustainable system for providing the supporting laboratory investigations.

Further reading:
To order the report, *Investigation into methods for the development of a protocol for quantitative assessment of industrial effluents for permitting of discharge to sewer: An eThekwini case study* (**Report No. 1734/1/13**) contact Publications at Tel: (012) 330-0340, Email: orders@wrc.org.za or Visit: www.wrc.org.za to download a free copy.