WATER RESEARCH COMMISSION

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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

A WRC-funded study has investigated the feasibility and practicality of using constructed wetlands to treat effluent from the wine industry.

Constructed Wetlands for Treatment of Winery Effluent

Background

The South African wine industry disposes of about a billion litres of wastewater every year. This winery effluent is seasonal in nature, and can be highly concentrated in terms of levels of chemical oxygen demand (COD) and of sodium and potassium ions.

With conventional treatment (anaerobic or aerobic digesters) not being cost-effective for this industry, effluent treatment is the exception rather than the rule. Winery effluent is normally irrigated on pastures or, in some cases, dumped directly into the nearest river.

Since most wine cellars are small, the individual effect of effluent disposal practices on the environment is negligible. Collectively, however, the industry does contribute to environmental degradation in drainage basins where wineries operate.

As a low-cost alternative treatment method, use of **constructed wetlands** may prove acceptable for winery effluents. Additional benefits may add to their attractiveness. These include minimal labour requirements, no chemical usage, very little maintenance, potential recreational use and provision of habitat for wildlife species (especially birds and indigenous flora) through the creation of an environment suited to them.

Issues to be addressed

Wetlands are among the most biologically active of all living systems, but are susceptible to high-strength effluents. In order to establish the limits of effluent strength that constructed wetlands can treat safely, characterisation of the wastewater entering the wetland is necessary.

Other issues to be addressed in assessing and enhancing the suitability of wetlands as a treatment option are the sensitivity of potential wetland plants to high COD levels, an inadequate understanding of the contribution of wetland microorganisms and plants to the process of effluent biodegradation, an inadequate understanding of the hydraulics of constructed and natural wetlands, and a lack of suitable mathematical design models with which to design constructed wetlands.

Studying wetland performance

Wetland microbiology has great significance with respect to the performance of constructed wetlands. Of particular interest is the functioning of plant and microbial communities. The linkage between biological activity and chemical changes is also clearly relevant and important.

Thus, as a first step, WRC funded research has sought to correlate biochemical, microbial and chemical variation over the seasonal course of wetland operation. Based on information relating to microbial and enzyme activities with organic pollutant removal, the next step has been to investigate the feasibility of using a molecular/biochemical approach in developing a preliminary model of a constructed wetland. Finally, the study has sought to build new understanding of the contributions and complex interactions of microorganisms and complex interactions of microorganisms and plants in wetland bioremediation systems into a novel predictive model of a wetland, customised for winery effluent treatment.

To support the study, data has been collected from wetlands of three different types: firstly, an establish wetland operating as an effluent disposal facility at a winery in Stellenbosch area; secondly, a wetland situated at a research station; and thirdly, small-scale laboratory-bench artificial wetlands.

Research findings

Chemical characterisation and wetland modelling

Findings confirmed that effective characterisation of the biodegradation of the main constituents of winery effluents in the wetland is possible and that this characterisation can be used as the basis for developing a model of wetlands biodegradation.

Initial characterisation of winery wastewater showed that ethanol was the major constituent for winery effluent and contributed up to 91% of the COD. Acetic acid was the second organic component that contributed significantly to the COD of the effluent.

The quantity of potassium in the effluent was strongly dependent on the time of year and the intensity of the harvest season, while sodium was less dependent on the harvest season than potassium.

While other constituents, such as carboxylic acids, other organic acids and phenolic components were present in winery effluent, they were found to be not significant as modelling parameters. However, they did contribute significantly to the organic loading supplying carbon nutrient for microbial growth.

The mathematical model of a constructed wetland, subsequently developed to predict removal of wastewater components in the wetland, also has the purpose of providing engineers with information about both the required size of a constructed wetland intended for use as a treatment system, and the expected final effluent specification. Variables included in the model are ethanol, acetic acid, sodium, potassium and COD.

By incorporating, into the mathematical model, the data generated through chemical characterisation of winery effluent, the following trends could be demonstrated:

- The pH rises rapidly as wastewater enters a wetland, and then stabilises at about 7.5 to 8.
- Propanol, propionic acid and butyric acid, minor organic constituents of the effluent, are removed well before ethanol and acetic acid, and can thus be ignored.
- The model is accurate in determining the rate of removal of the critical parameter, ethanol. If anything, ethanol conversion in the wetland is under-predicted, implying that the model is conservative and that wetlands designed on the basis of the model will be safely oversized.
- Acetic acid is a significant but non-critical parameter, being fully consumed further down the wetland.

Botanical survey

Based on findings of the botanical survey component of the study, different regions of a wetland would be best planted to a mix of one or more of the following species: *Carex* (common sedge); *Zantedeschia aethiopica* (arum lily); *Typha capensis* (bullrush) and *Persicaria decipiens*.

Microbiological and biochemical analysis

The study demonstrated that the microbial community present in the wetlands, and its seasonal variation, can be effectively characterised using phylogenetic techniques. Standard enzyme assays can be manipulated to allow for the detection of specific enzyme activities in soil samples; key enzymes that may be involved in wine wastewater degradation can be detected using these modified assays.

Conclusions

An approach to the monitoring of wetlands for use in reducing the pollutant load of winery wastewaters has been developed and demonstrated.

Chemical and biochemical analyses and molecular phylogenetics have been used successfully in preliminary characterisation of the active microbial population and in the development of a predictive model of degradation rates in a wetland exposed to winery wastewater.

The impact of pollutant addition on natural microbial populations can be demonstrated by molecular methods. These methods allow the survival, and more importantly, the health of the microbial population responsible for the biodegradation of the impacting pollutant to be monitored. However, because natural microbial communities are complex and contain hundreds, or thousands, of individual species of which relatively few may be directly involved in the primary degradation process, definitive correlation of chemical composition with microbial and/or enzymatic activity remains extremely challenging.

Constructed wetlands have been demonstrated to be both feasible and practical in treating winery effluent. A conservative semi-empirical model that predicts the effluent treatment efficiency of the constructed wetlands can be used in conjunction with botanical data for the design of new constructed wetlands for the wine industry.

Despite the usefulness of the newly-developed approaches and methodologies, designing wetlands for optimal microbial activity will require further study. Priorities in this regard are:

- Developing a better understanding of the effect of pollutants on wetland microbial population distributions and the metabolism of microbial populations; and
- Acquiring knowledge regarding the adaptation of constructed wetlands to effectively remediate pollutants impacting on surface and groundwater.

Further reading:

Integrated Research for Use in Constructed Wetlands for Treatment of Winery Wastewater (**Report No: 1544/01/07**). To order this report contact Publications at Tel: (012) 330-0340; Fax: (012) 331-2565; E-mail: orders@wrc.org.za