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Chemical engineering modelling of a vegetated submerged reedbed for winery effluent treatment

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Summary

Environmental concerns for wineries in South Africa cover not only the conversion of effluent into more benign forms, but the reclaiming of water, a resource that is scarce and precious in a drought-prone country. However, not all waste treatment options are available to small wineries, because many are too sophisticated and expensive to be commercially viable. Accordingly, this study investigated the use of constructed wetlands in the form of Vegetated Submerged Reedbeds (VSR) as a practicable alternative for small-scale wine producers. Winery effluent is known to have a high chemical oxygen demand (COD) and low pH. In this study, effluent was extensively analysed from two cellars, including the temporal changes over the duration of a harvest and the duration of a year. It was found that for raw winery effluent, ethanol contributes approximately 85% to 90% of the COD, with acetic acid being the next significant contributor. The pH showed some dependence on the concentration of acetic acid. The concentration of sodium in the effluent is strongly dependent on the cleaning regime in place at the cellar, and the concentration of potassium has been shown to be linked to the spillage of juice, wine or lees.

It was also found that the hydraulic processes occurring within the VSR display significantly non-ideal behaviour. If the feed to the VSR was located on the surface the dead volume accounted for approximately 25% of the non-ideal behaviour of the system and bypass accounted for a further 6% of non-ideal behaviour. In the system studied, there was a preferential flow pattern within with the greatest flow occurring closest the surface and in the centre, and the least at the sidewalls. It was proposed that the flow profile can be conceptualised as being hull-shaped. We believe this hypothesis is correct and as far as we are aware this flow pattern has not been described previously. It was found that this profile was the same for irregularly shaped gravel and for spherically shaped gelatinous beads and it is therefore believed it is not dependent on the geometry of the VSR or the packing medium.

This study also investigated the use of three different methods for determining the rate constants for the degradation of winery effluent within a sub-surface flow constructed wetland (CW). These methods comprised using a dispersed plug flow (the Peclet) equation; a tanks-in-series (TIS) equation; and analysing the residence time distribution (RTD) directly.

The last of these was called the Convolution Integral (CI) method. Within the CW studied, the principal constituent of the chemical oxygen demand (COD), ethanol, was always fully degraded by the time the flow reached the outlet. It was therefore possible to calculate the rate constant of degradation from the initial eight metres of the CW. Self similarity of the RTDs was also demonstrated, which meant that in general the system's hydraulics were similar throughout the CW. This meant we could extrapolate the data so as to develop a more complete understanding of the hydraulic properties of the CW and examine how they affected the kinetics of degradation. It was found that whilst both the Peclet and the TIS equation were able to predict concentration within the CW accurately, this required multivariate optimisation. This rendered a result that was more of a modelling exercise than a useful design tool. The CI method, however, could be applied to predict system parameters effectively. This study used the CI to measure the rate constants of removal for both ethanol and potassium, which were found to be the key species that responded to the degradation/treatment of the effluent. The rate constant found for the biodegradation of COD was found to have significantly more uncertainty associated with it than the measurement of the rate of degradation individual components and it was therefore posited that it is better to describe the processes of degradation by tracking individual components rather than lumped parameters. In each chapter, a short abstract is provided in which results are given.