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Winery wastewater treatment using the land filter technique

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ABSTRACT

This study outlines a new approach to the treatment of winery wastewater by application to a land FILTER (Filtration and Irrigated cropping for Land Treatment and Effluent Reuse) system. The land FILTER system was tested at a medium size rural winery crushing ~20,000 tonnes of grapes. The approach consisted of a preliminary treatment through a coarse screening and settling in treatment ponds, followed by application to the land FILTER planted to pasture. The land FILTER system efficiently dealt with variable volumes and nutrient loads in the wastewater. It was operated to minimize pollutant loads in the treated water (subsurface drainage) and provide adequate leaching to manage salt in the soil profile. The land FILTER system was effective in neutralizing the pH of the wastewater and removing nutrient pollutants to meet EPA discharge limits. However, suspended solids (SS) and biological oxygen demand (BOD) levels in the subsurface drainage waters slightly exceeded EPA limits for discharge. The high organic content in the wastewater initially caused some soil blockage and impeded drainage in the land FILTER site. This was addressed by reducing the hydraulic loading rate to allow increased soil drying between wastewater irrigations. The analysis of soil characteristics after the application of wastewater found that there was some potassium accumulation in the profile but sodium and nutrients decreased after wastewater application. Thus, the wastewater application and provision of subsurface drainage ensured adequate leaching, and so was adequate to avoid the risk of soil salinisation.

1. Introduction

Environmental Protection Agencies (EPA) in many countries have promoted land treatment and reuse of sewage effluent and other wastewater to reduce pollution of natural water bodies (Greenway, 2005).

Simplified treatment systems with low energy consumption, lagoons, wetlands, land spreading/irrigation, are important techniques for effluent treatment and disposal. This form of treatment and disposal needs integration with the general landscape capacity to receive the wastewater and obviously requires that land be available (Bustamante et al., 2005). When soil conditions are suitable, land treatment of wastewater for irrigated cropping or forestry systems can be successfully practiced, especially with low salinity wastewater. However, there are two difficulties with land application of wastewater for cropping in the southeastern wine growing areas in Australia: 1) poorly drained soils leading to water logging and salinisation, hence reducing crop yields and nutrient removal, and so affecting the long-term sustainability of such sites; 2) storage requirement for wet weather and winter periods when the evapotranspiration needs for irrigated cropping falls, leading to escalated costs. The benefits and risks of using land based systems for the disposal of wastewater have been reviewed (Cameron et al., 1997; Bond, 1998; Magesan and Wang, 2003). The management of winery wastewater differs from some other effluents such as sewage in that it has high salinity, a very variable composition and its generation rate varies significantly over a daily, monthly and annual cycle.

In Australia, most of the current low cost treatments are based on evaporation ponds that can generate foul odors, insect proliferation and groundwater contamination (Quayle et al., 2006).

On-site land based wastewater disposal systems in Australia can be an attractive approach to the treatment of wastewater for medium to small scale wineries, which are often located in rural areas and represent about 75% of the total number of wineries in the industry. In the past, in Australia, winery wastewater was disposed of directly into ponds where the wastewaters were held to

Abbreviations: FILTER, Filtration and Irrigated cropping for Land Treatment and Effluent Reuse; COD, chemical oxygen demand; BOD, biological oxygen demand; EC, electrical conductivity; TSS, total suspended solids.

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allow solids to settle and then either the water allowed to evaporate or applied onto soil or into watercourses. However, current environmental controls prohibit the return of such waters to watercourses. The most prevalent form of winery wastewater treatment in Australia is biological treatment through aerobic and anaerobic methods (Quayle et al., 2006). The disadvantages of these systems are the high costs and the need to dispose of sludge or other by products derived from the process.

Most wineries in Australia have land available for treatment and disposal of wastewater, making land based treatment and disposal attractive. The treated effluent can then be used for irrigation of gardens, trees and landscapes, vineyards, other crops or recycled back to the winery (with further treatment). As such this research implemented a land based wastewater treatment technique named FILTER (Jayawardane et al., 1997, 1999), in combination with an existing pond system. The innovation of the land FILTER disposal system designed by our team with respect to other land disposal systems is based on the collection of the filtered wastewater though an intensive network of subsurface drains. As such this system both disposes of water and also provides treated water for later reuse. Since the technique had been trialled with success for the treatment of sewage water (Jayawardane et al., 1997, 1999, 2001a,b) we deemed it worthwhile to test the approach for the treatment of more saline wastewater such as that from wineries. The FILTER design is based on an intensive network of subsurface drains operated to minimize pollutant loads in the treated water and provide adequate leaching to manage salt in the soil profile.

The FILTER relies on the soil to act as both a physical filter and as a medium for chemical exchange and degradation processes. The technique has been trialled with success for the treatment of sewage water (Jayawardane et al., 1997, 1999, 2001a) and combines using the nutrients in wastewaters to grow crops, with filtration through the soil to a subsurface drainage system during periods of low cropping activity and heavy rainfall and thus provides wastewater treatment throughout the year without the need for storage ponds. This filtration phase can be combined or followed, if and when necessary, by a cropping phase to remove nutrients stored in the soil, thereby maintaining a sustainable system and eliminating the need for a separate cropping phase (Jayawardane et al., 2001a). The treated subsurface drainage water can then either be disposed of or reused.

The FILTER design and management at a given site depends on factors such as the land area available, the pollutants present in the wastewater and the daily wastewater discharge rate. A prototype system was installed at a medium size rural winery in southeastern Australia. This paper describes the principal design specifications of the pilot scale system and the analysis of the influent and effluent characteristics, pH, electrical conductivity (EC), total suspended solids (TSS), chemical oxygen demand (COD), etc. and hence quantifies the removal of pollutants by the FILTER. The study also identifies potential long-term problems at the land application site and potential improvements in routine field operation to assist the development of a sustainable system.

2. Materials and methods

2.1. Site selection and performance of the existing pond system

The trial of the experimental treatment system was undertaken at a medium size winery crushing about 20,000 tonnes of grapes per year in southern New South Wales, Australia. The region is semi-arid with ~1800 mm reference evapotranspiration and ~400 mm rain per year. Before implementing the experimental pilot system the wastewater treatment consisted of a coarse solid screening combined with evaporation ponds filled directly from a small solids settling pond. This treatment system was not working effectively and could not handle the increasing volumes of wastewater with winery expansion. The ponds were producing odour problems due to anoxic conditions and did not allow for reuse of the wastewater. The excess wastewater from the treatment ponds cannot be discharged into the surface drainage system of the area, as the pollutant levels exceed limits for discharge. Comparing the Australian Environmental Protection Agency (Melbourne, Australia) regulatory limits for surface water (ANZECC, 1998; Chapman et al., 2001) with the general characteristics of the winery treatment pond water, it was found that pond treated winery wastewater had chemical oxygen demand (COD) and TSS concentrations 200 and 10 times higher than the EPA trigger values, 15 and 50 mg L^{-1}, respectively. Total phosphorus levels, 1.4–8.7 mg L^{-1}, were also above the regulatory limit of 1 mg L^{-1}. Also nitrogen concentrations were too high and the pH sometimes too low for discharge. Thus discharge of the wastewater is inappropriate and a land based treatment system on the land adjacent to the winery was proposed.

2.2. FILTER design

The FILTER area drainage design and control was designed using concepts of maintaining an appropriate nutrient and water balance and leaching fraction to control salinity (Fouss et al., 2008). Fig. 1 shows a conceptual diagram of the FILTER system. This is a controlled drainage system enabling the manipulation of the watertable, and hence controls the depth of the aerated and anoxic soil layers. A network of subsurface drains is installed to allow for the regulation of leaching rates through the soil.

2.3. Field site and wastewater application

The land application site located next to the winery was a 1.8 ha area divided into 7 irrigation bays, with a 0.35% lengthwise slope. The bays were planted with a mixed pasture. Each bay had two 1.2 m deep subsurface drains at 10 m spacing. The application of the winery wastewater was by surface flooding of the bays. This took around 12–24 h. The drainage was controlled by turning off the pump for the day of the wastewater irrigation event and then commencing pumping the following day. During the field trial each of the bays was treated as a separate FILTER plot. Applied wastewater and treated drainage water samples from the bays were collected periodically through each application event to monitor the changes in the pollutant concentration as the water flowed through the soil to the subsurface drainage system. In operating the system, the wastewater was applied to FILTER plots on a 10–14 day rotation. A water balance approach was used to design the water management component of the system, using monthly wastewater discharges from the winery and the climatic factors affecting the net evaporation from the bays. Wastewater flow was applied to the FILTER bays based on the irrigation requirements for pasture plus a further 30% wastewater as a leaching fractions and so that the system produced treated water for further reuse.

To operate the FILTER system, the seven bays were rotated through the sequence described above. The results reported here are for the vintage and post vintage period of late autumn and winter, a total period of about 7 months.

2.4. Wastewater quality analysis

Irrigation and treated drainage water was sampled and analyzed during each irrigation event, as follows. Water samples were tested on-site for pH, salinity (EC) and total dissolved solids (TDS). Na, K, Ca, Mg and biological oxygen demand (BOD_5) were all analyzed