Winery and distillery wastewater treatment by constructed wetland with shorter retention time

A. R. Mulidzi

ABSTRACT

The rationale for using constructed wetlands for treating wastewater is that wetlands are naturally among the most biological active ecosystem on earth. The aim of the study was to determine the impact of shorter retention time on the performance of constructed wetland in terms of Chemical Oxygen Demand (COD) and other elements removal. The application of wastewater with retention time of seven days as well as the evaluation of water quality after treatment at Goudini experimental wetland was carried out throughout the year. The results had shown an overall average COD removal of 60% throughout the year. Results also showed reasonable removal of other elements namely; potassium, pH, nitrogen, electrical conductivity, calcium, sodium, magnesium and boron from the wastewater by constructed wetlands.

The results showed low COD removal during July until September after which it improved tremendously. The reason for low COD removal during first three months could be attributed to the fact that there was no gradual increase of wastewater application to the wetlands i.e. from 4,050 litres per day to 8,100 litres per day. The results had showed that constructed wetland as a secondary treatment system is effective in terms of COD and other elements removal from winery and distillery wastewater. COD removal throughout the year was 60% with seven days retention time. When compared with previous studies that showed 80% COD removal within 14 days retention time, therefore the 60% removal is very critical to wine industries as more wastewater will be applied to the system.

Key words | COD, constructed wetlands, plants, retention time, wastewater

INTRODUCTION

The wine industry produces large quantities of wastewater associated with washing operations during grape harvesting, pressing and first fermentation phases of wine processing (Mulidzi 2007). Traditionally wastewaters from wineries and distilleries have been disposed off in evaporation ponds and in some cases in natural water courses (Shepherd 2002). In South Africa more than 60% of wineries still dispose their effluent by means of land application (Mulidzi 2008). Constructed wetlands have been investigated extensively in the last twenty years for municipal wastewater treatments. The rationale for using constructed wetlands for treating wastewater is that wetlands are naturally among the most biological active ecosystem on earth (Cooper 1999). Wetlands are efficient at removing excess nutrients and pollutants by physical settling and filtration, chemical precipitation and adsorption (Day et al. 2004). Because high biological activity enhances the potential for efficient wastewater treatment, natural wetlands may be thought of as natural bioreactors.

Constructed wetlands are created for specific purposes, in this case distillery and winery wastewater treatment (Van Schoor 2002). Furthermore, wetlands are among the least expensive treatment systems as compared to other wastewater treatment systems. For the past 10 years,
research trials on the use of constructed wetland to treat winery and distillery wastewater were conducted in Goudini near Worcester in Western Cape. The results had shown that constructed wetlands with retention time of 14 days were effective in treating Chemical Oxygen Demand (COD mg/l) and other elements from the wastewater. The aim of the study is to investigate the impact of shorter retention time (7 days) on the performance of constructed wetlands in terms of COD and other elements removal from winery and distillery wastewater. The study was conducted at the same wetland that was used for previous studies (14 days retention time). The reason was to enable the research team to compare the previous results of 14 days retention time with the new results of 7 days retention time.

### MATERIAL AND METHODS

The wetland is 45 metres long, 4 metres wide and 1.2 metres deep. The wetland was lined with a 1 mm thick dam liner. After the lining, the wetland was filled up to 0.9 meters with dolomitic gravel having a particle size range of 20 to 30 mm. The porosity of the gravel bed was 35%, giving a total wetland volume of 162 cubic metres and a pore volume (accessible to roots and wastewater) of 56.7 cubic metres.

#### Wetland plants

Three plant species namely: *Typha*, bulrush and cattails were planted at a spacing rate of 10 plants per square metre. During plants establishment, only clean water was used. Plants were fertilized with nitrogen, phosphorus and potassium on a weekly basis. When selecting plants for constructed wetlands; pH and temperature tolerances for the plants need to be considered. Mulidzi (2005) presented a partial list to assist in plant selection (Table 1). The capacity of the wastewater treatment system to work depends on how long the water stays in the system.

### Table 1

<table>
<thead>
<tr>
<th>Common name</th>
<th>Scientific name</th>
<th>Temperature range (°C)</th>
<th>pH range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulrush</td>
<td><em>Typha</em> spp.</td>
<td>10–30</td>
<td>4–10</td>
</tr>
<tr>
<td>Cattail</td>
<td><em>Scirpus</em> spp.</td>
<td>16–27</td>
<td>4–9</td>
</tr>
<tr>
<td>Common reed</td>
<td><em>Phragmites</em> spp.</td>
<td>12–23</td>
<td>2–8</td>
</tr>
</tbody>
</table>

Figure 1 | COD results for Goudini constructed wetland with 7 days retention time (8,100 litres per day) indicating an average overall performance COD removal 60%.
The retention time of the constructed wetland was seven days (8,100 litres/day). When the plants were fully established, wastewater was applied to the system via manifold through step feeding pipes. Wastewater was sampled prior to wetland and after the wetland on a weekly basis in order to determine the performance of the system. The wastewater samples at the inlet were collected by putting a 500 ml bottle through the step feeding pipe. At the outlet, wastewater was collected at the outlet pipe and placed into a 500 ml bottle. After sampling, the bottles were put in a cooler bag and sent to the laboratory for analysis. The wastewater samples were analyzed for chemical oxygen demand (COD), pH, potassium (K), nitrogen (N), electrical conductivity (EC), calcium (Ca), sodium (Na), magnesium (Mg) and boron (B).

RESULTS AND DISCUSSION

Evaluation of water quality after treatment

The application of wastewater with a retention time of seven days (8,100 litres/day) as well as the evaluation of water quality after treatment was carried out the whole year. The results had shown an overall average COD removal of 60% throughout the year. The results showed low COD removal during July until September after which it improved tremendously (Figure 1). The reason for low COD removal during the first three months could be attributed to the fact that there was no gradual application of wastewater to the wetlands i.e. from 4,050 litres per day to 8,100 litres per day. This sharp increase of volume could have an adverse effect on the composition and performance of micro organisms in the system. Under normal circumstances, there should be a gradual increase of volume but this done deliberately in order to find out how the system would react an abrupt change of flow and volume.

Electrical conductivity (EC), sodium (Na) and chlorine (Cl) removal by wetland

The analysis of the above mentioned elements had showed that constructed wetlands were able to reduce the concentrations from winery and distillery wastewater (Table 2).

This is mainly done by plants that use the nutrients from the wastewater to feed themselves (Shepherd & Grismer 1997). In constructed wetlands, vegetation provides a substrate (roots, stems and leaves) upon which microorganisms can grow as they break down organic materials. The microorganisms and natural chemical processes are responsible for approximately 90% of pollutant removal and waste breakdown.

According to Mulidzi (2005), plants remove about seven to ten percent of pollutants and they also act as a carbon source for the microbes when they decay. In addition to the removal nutrient elements, macrophytes contribute to water purification by providing substrates and habitats where organic compounds may be broken down (Zingelwa & Wooldridge 2009). Selection of plant species is very important as diversity of plant species could provide...
protection from and resilience to perturbations such as disease, insects or herbivores (Reed 1990). Aquatic plants are essential component of a wetland and contribute to the nutrient transformation by abetting in the physical, chemical and microbial processes besides removing nutrients for their own growth (Martin et al. 1999).

Monitoring and maintenance of constructed wetlands

When the wetland plants were more than 1 metre tall, they were harvested in strips of 2 metres starting from the inlet according to procedures developed from previous seasons (Mulidzi 2007). The idea behind harvesting plants in strips was that when you finish harvesting the whole wetland, plants at the beginning will be ready for harvest again. These stimulate plant growth even during winter periods, thereby improving wetland performance. Due to vigorous growth of wetland plants, routine removal of excess plants as well as dead materials in the wetland system is recommended to avoid clogging of the system.

A wetland is a biological filter and like all filters, requires some occasional cleaning and maintenance (Kadlec 1997). A big advantage of wetland system is that less maintenance is needed as compared to other treatment systems. Routine removal of excess plant material and captured sediments will allow the wetland to continue to function. Regular harvesting of the crop can prevent the system from becoming clogged.

CONCLUSIONS

Wetlands were efficient at removing excess nutrients and pollutants by physical settling and filtration, chemical precipitation and adsorption, and biological metabolic processes. The results had showed that constructed wetland as a secondary treatment system is effective in terms of COD and other elements removal from winery and distillery wastewater. COD removal throughout the year was 60% with seven days retention time. When compared with previous studies of 80% COD removal with 14 days retention time (see Figure 2), the 60% is very critical to wine industries as more wastewater is applied to the system. Although the retention time of seven days did not get the same water quality as compared to 14 days, it is very important to know the level of performance by wetlands at a shorter retention time. This is of utmost importance, as it will serve as guideline for future consultations and as a basis for designing and maintaining wetlands.
for future research. The retention time plays an important role in terms of the size of wetland to be constructed. Shorter retention time will result in small space needed for the construction of wetlands as more water will be treated in a short space of time.

**RECOMMENDATIONS**

When constructed wetlands are considered for the treatment of winery wastewater, the following recommendations should be considered during designing stages.

- A compulsory pre-treatment system for solids removal, as solids contain more than 40% of the COD load. The solids will also cause clogging of the system if not removed.
- Rainwater should be included during the design phase. The system should be designed so that its capacity is bigger than required as rainwater will decrease the retention period by pushing untreated effluent out of the system.
- A 10% safety factor should be incorporated into a design. This will allow for unknowns such as fluctuations in effluent composition. It also allows for the removal of plants from parts of the wetland without affecting overall performance.
- A combination of more than one type of plant is essential as various types of plants tolerate wastewater differently and their ability to remove nutrients from effluent also differs.

**REFERENCES**


