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Short communication

A vertical flow constructed wetland for the treatment of winery process water and domestic sewage in Ontario, Canada: Six years of performance data

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ABSTRACT

Wine production is a growing industry in the Canadian province of Ontario. Due to the high organic loads and large amount of suspended solids found in winery process water it is important for wineries to adopt sustainable water management practices. Constructed wetlands (CW) have been shown to be a viable option in the warmer climates of the Mediterranean and the western USA but little research has examined their feasibility in the cold climate of Ontario. The purpose of this paper was to assess six years of performance data from a vertical flow CW treating winery process water and domestic sewage at a winery in the Niagara region of Ontario with an average hydraulic loading rate (HLR) of 22.3 mm d^{-1} and an average chemical oxygen demand (COD) surface loading rate (SLR) of 34.0 g m^2 d^{-1}. The CW has four cells, each 101 m^2, and was designed to treat 16,620 L day^{-1} of wastewater consisting of winery process water and domestic sewage. The performance data were separated by season to determine the effect of temperature on treatment performance during the colder months. There was little variation in seasonal performance and the average treatment efficiencies over the six-year period were: 99% for COD, 99% for carbonaceous COD, 98% for total suspended solids, 83% for total phosphorous, 94% for total Kjeldahl nitrogen, and 85% ammonium. Effluent nitrate, total coliforms, and *Escherichia coli* concentrations were also monitored and consistently met the regulatory standards for discharge to a subsurface leaching bed. The CW system proved to be an option for treating winery wastewater.

1. Introduction

Wine production in Ontario, Canada is an expanding industry with an estimated 6600 ha dedicated to grape production in 2013 (OMAFRA, 2014). There are over 100 wineries in operation in southern Ontario (Dawson et al., 2011) and each one produces high strength wastewater. Winery process water has low nutrient content but is high in soluble organic matter with chemical oxygen demands (COD) ranging from 500 to 45,000 mg L^{-1} (Shepherd et al., 2001; Serrano et al., 2011; de la Varga et al., 2013; Masi et al., 2015). The organic load is made up of sugars, alcohols, phenols, acids, tannins and ligands all of which have variable degradation rates (Masi et al., 2015). Winery process water can also have low pH and contain large amounts of suspended solids (TSS) with concentrations reaching up to 7300 mg L^{-1} (Serrano et al., 2011; de la Varga et al., 2013). Many wineries in Ontario are open to the public for wine tastings and other events and as a result the wastewater produced by wineries also contains domestic sewage. Conventional options are ineffective for the treatment of winery wastewater because of the large organic load, as well as the fluctuating quantity and quality of the wastewater, which depends on the season and production schedule of the winery (Strong and Burgess, 2008; Serrano et al., 2011).

Constructed wetlands (CW) are engineered treatment systems designed to facilitate the biological, chemical, and physical processes that occur in natural wetlands; and they have been proven to be a viable option for the treatment of winery wastewater in certain regions (Strong and Burgess, 2008; Serrano et al., 2011; de la Varga et al., 2013). The majority of the literature reports on CWs at wineries in areas with temperate or arid climates, for example, California (Shepherd et al., 2001; Grismer et al., 2001, 2003), Italy (Masi et al., 2002), Spain (Mena et al., 2009; Serrano et al., 2011; de la Varga et al., 2013) and South Africa (Mulidzi, 2007, 2010). However, the use of CWs at wineries in cooler, continental climates

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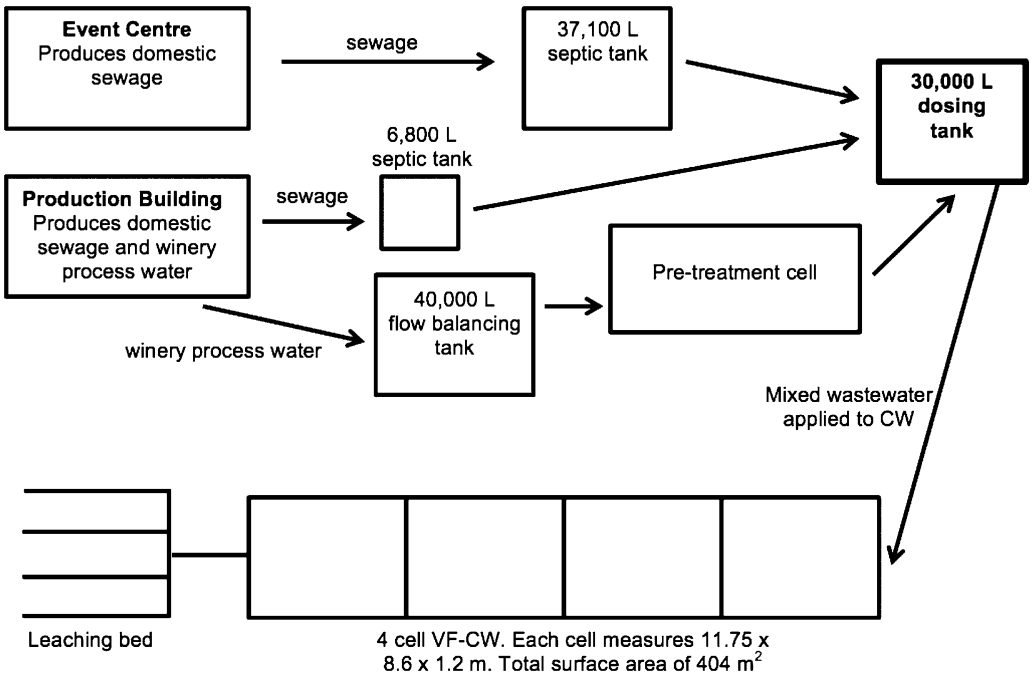

Fig. 1. Schematic diagram of the winery operations and the vertical flow constructed wetland treatment system.

in active viticulture regions such as southern Ontario, Canada, has received little attention, even though there are ~20 to 30 in use in this area. Therefore, the objectives of this study were to assess the year-round performance of a vertical flow (VF) CW at a winery in southern Ontario treating winery process water and domestic sewage.

Six years of performance data were collected from June 2008 to December 2013. The data were separated by growing season (GS; the six warmest months of the year) and non-growing season (NGS; the six coolest months) to assess the effect of temperature on treatment performance. Influent and effluent water samples were analyzed for COD, carbonaceous biochemical oxygen demand (CBOD), TSS, total phosphorous (TP), total Kjeldahl nitrogen (TKN), ammonium, nitrate, total coliforms, and *Escherichia coli*.

2. Materials and methods

2.1. Site description

The VF CW was located at a winery in Niagara-on-the-Lake, ON, Canada, an area with over 25 wineries that serve as a major tourist attraction for the region. The average annual temperature is 9 °C and the average temperatures for the GS and NGS are 17.1 °C and 1.4 °C, respectively. The average monthly precipitation is 39.6 mm and is 55.5 mm and 23.8 mm for the GS and NGS, respectively (Environment Canada, 2014). The climate is classified as humid continental (Dfb) according to the Köppen–Geiger classification system (Peel et al., 2007).

The CW was designed and installed by Aqua Treatment Technologies (Ontario, Canada) in 2008. The CW was designed to treat a maximum of 4250 L day^{-1} of winery process water and 12,435 L day^{-1} of domestic sewage for a total flow of 16,620 L day^{-1}. The CW system has four identically sized cells, 11.75 m × 8.6 m × 1.2 m and a separate 18 m × 8 m × 1.2 m pre-treatment cell (Fig. 1). The total surface area of the CW (not including pre-treatment cell) was 404 m^2 and the volume is 485 m^3. The cells were lined with a PVC liner and filled with a 5–10 mm gravel and sand mix. The top 30 cm of the cells were covered with a peat moss and sand mix and planted with *Typha latifolia* L. (broadleaf cattail) and *Schoenoplectus tabernaemontani* (C.C. Gmel.) Palla (softstem bulrush). To facilitate denitrification cell 3 contained wood chips and the water level was higher than the other cells to reduce the presence of oxygen because denitrifying bacteria require an anoxic environment as well as a carbon source. The water levels of cells 1, 2, and 4 were kept at ~0.4 m and cell 3 was kept at ~0.8 m.

The wastewater was pumped to the CW from a 30,000 L concrete storage tank, referred to as the 'dosing tank'. The dosing tank contains water from three different sources: winery process water from the production building, a small amount of domestic sewage from the production building (no more than 250 L day^{-1}), and domestic sewage from the winery event building housing a kitchen and a public wine tasting venue (Fig. 1). The ratio of domestic sewage to winery process water fluctuated due to the nature of wine production and it was affected by the season. For example, during the summer months more people visit the winery for tastings and special events leading to an increased amount of domestic sewage but less process water is produced. In the fall after harvest wine productions begins and the processes of crushing, pressing and washing produces large volumes of wastewater. In general there were larger volumes of less concentrated wastewater produced in the NGS.

The winery process water was stored in a 40,000 L concrete flow-balancing tank before entering a pre-treatment wetland cell. A timer controlled pump in the tank limited the flow into the pre-treatment cell to a maximum of 4250 L day^{-1}. The pre-treatment cell has a similar design and plumbing system as the CW cells, it was filled with gravel and can be easily cleaned out if it becomes clogged. It acted to reduce the organic load and TSS of the wastewater before it flowed via gravity to a pumping station that pumped to the dosing tank. The sewage from the production building entered a 6800 L septic tank and a gravity overflow sent the water to the same pump station as the winery process water, from there it was eventually pumped to the dosing tank. The sewage from the event building was stored in a 37,100 L septic tank and entered the dosing tank via a gravity overflow (Fig. 1). The wastewater in the dosing tank was then applied to the cell 1 of the CW by a timer controlled pump which dictates the volume added to the CW.