THE EFFECT OF ORGANIC LOADING RATE ON THE PERFORMANCE OF FULL-SCALE WASTE STABILIZATION PONDS IN TEMPERATE CLIMATE: A STUDY IN THE ARGENTINE PATAGONIA

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Abstract

This work focuses on the performance of a primary facultative pond, in a full-scale waste stabilization pond (WSP) system, located in a temperate climate region in the Argentine Patagonia (42° 45´S; 65° 05´W). Seven sampling points were selected to monitor water quality and removal efficiencies regarding organic matter and inorganic forms of nitrogen. Samples were collected fortnightly for 38 months and processed for temperature, dissolved oxygen, pH, total and filtered BOD_5, Nitrite, Nitrate, Ammonium, Chlorophyll *a* and Suspended Solids. Weather conditions clearly determined three water temperature intervals with average figures of 7.7°C in winter, 14.0°C in spring and autumn, and 20.0°C in summer. During the experimental timeframe, the influent flow rate increased from 12,051 m^3/day to 14,846 m^3/day; consequently, the surface organic loading supported for the primary facultative pond ranged from 55 kg BOD/ha to 68 kg BOD/ ha day, and the theoretical retention time decreased from 31 to 24 days. Generally speaking, a better pond performance was reported when surface organic loading was lower than 60 kg/ha day (i.e., soluble BOD_5 removal > 70%); while ammonium removal was clearly seasonal, with higher ammonium concentrations in the pond effluent during the colder months. Nitrification was reported during the warmer months of the year and partially responsible for ammonium removal as nitrate concentrations up to 14 mg $N\text{-}NO_3^-$/L were found in the pond effluent; however, nitrification was restrained to few months a year when organic loading was higher than 60 kg/ha day.

Keywords: natural wastewater treatment, nutrient recovery, wastewater irrigation

Introduction

Waste Stabilization Pond (WSP) technology is worldwide used for domestic and industrial wastewater treatment. The reasons behind that popularity are based on its economic advantages over highly electro-mechanized systems and its high efficiency regarding organic matter and pathogen removal, despite variations in the quality of the influent (Ellis and Rodrigues, 1995; Athayde Júnior *et al.*, 2000; Madera *et al.*, 2002). WSPs in operation have also shown relatively steady removal efficiencies throughout the year, particularly in tropical countries where environmental conditions are more favourable. However, their performance in temperate and cold regions is deeply affected by variations in weather conditions, mostly during colder months. Such pattern is attributed to well-defined changes in the metabolism of the biological communities that WSPs support, which includes variations in the

dynamics of nutrients, organic matter and phytoplanktonic activity (Santos and Oliveira, 1987; Heaven *et al.*, 2003; and Abis and Mara, 2003, 2005; among others).

The use of WSP technology in Argentina has been widespread for similar reasons in conjunction with the availability of large areas of land near urban centres. Full-scale WSP systems are in operation both in important cities like Mendoza (≈1m inhabitants) and in small communities like Sierra Grande, Patagonia, (≈8,000 inhabitants); nevertheless, there is little information about their performance and further research is needed to adjust design criteria to local conditions (Esteves *et al.*, 1996; Anzorena, 2001). Along the Patagonian coast there are ten WSP systems in operation, including two in Puerto Madryn (Esteves and González, 2008). Puerto Madryn is located in a semi-arid zone with a temperate-cold climate and an important water deficit; in fact, the local government has included the final effluent from the WSP system within a comprehensive water management programme which is aimed to achieve zero discharge of treated wastewater to the Nuevo Gulf (site chosen by the Southern Right Whale to procreate and to give birth). Therefore, nearly a half of the final effluent flow would be pumped back to the city for irrigation (i.e., parks, street gardens) and the other 50% of treated effluent will be used to fight forest fires in the Valdes Peninsula Nature Reserve – listed as a World Heritage Site by UNESCO in 1999 and for productive irrigation areas distant from the city..

The aim of this work is to study the effect of organic loading variations on the performance of a facultative WSP, in order to help us to understand the dynamics of organic matter, inorganic nitrogen and chlorophyll *a*, in a full-scale WSP system currently in operation in a temperate climate region. That would contribute to determine the more suitable surface loading rates to maintain a good quality effluent throughout the year, under the very variable weather conditions in the Argentine Patagonia.

Methods

The present study was conducted at the sewage treatment works in Puerto Madryn, Argentina (≈90,000 inhabitants). It is a natural wastewater treatment system based on WSP technology and it is located at 10km Norwest from the City (42° 45´ S; 65° 05´ W). The WSP system has been in operation since 2001 and comprises a screening unit (3-mm bar screen) followed by a primary facultative pond in U-shape (surface area: 25ha; depth: 1.5m) and two maturation ponds connected in series (35ha surface area and 1m depth, each). For this work seven sampling points were selected as follows: (a) S1: inlet channel after screening; (b) S2: inside facultative pond at 200m from S1; (c) S3: at 400m from S1; (d) S4: at 600m from S1; (e) S5: at 800m from S1; (f) S6: at 1000m from S1; and (g) S7: outlet channel. Water samples were collected fortnightly for 38 months in selected sampling points from the inlet (S1), an intermediate point inside the pond (S4) and the outlet (S7). Composite samples were collected from S1, whereas single samples were collected from S4 and S7. In total, 62 sampling sessions were conducted over the experimental timeframe. Additionally, one sampling session was conducted per season (8 in total) for the five stations inside the facultative pond (sampling points S2, S3, S4, S5 and S6), in order to collect representative samples through the cross-section and along the pond length. Each sample was processed *in situ* for temperature, dissolved oxygen and pH; in the laboratory, water samples were

processed following standard analytical methods (APHA, 1980) for total and filtered BOD_5, Nitrite, Nitrate, Ammonium, Chlorophyll *a* and Suspended Solids.

Results and discussion

During the experimental timeframe, Puerto Madryn had an important increment in sewer coverage and for that reason, both inlet flow and organic loading rates raised about 23% (i.e., inlet flow varied from 12,051 m^3/day to 14,846 m^3/day, and organic loading increased from 55 kg BOD/ha to 68 kg BOD/ ha day). Raw wastewater entering the primary facultative pond was classified as weak type (i.e., average total BOD_5 was 114.6mg/L), due to dilution associated to high water consumption (i.e., 370 litres pppd).

Results from the primary facultative pond under study showed that total BOD removal was independent to the variation of surface organic loading; however, total BOD concentrations in the pond effluent increased in the warm season, coinciding with higher chlorophyll *a* concentrations. Filter BOD removal was consistently higher than 70% when surface organic loading was less than 60 kg/ha day, regardless weather conditions. The dynamics of suspended organic matter was found clearly dependant on phytoplankton production, which at the end responds to weather conditions. The behaviour of inorganic nitrogen was clearly seasonal, with high ammonium concentrations during the colder months; in fact, a significant correlation was observed between ammonium concentration and temperature during summer and winter months ($r = -0.84$; $p < 0.001$). Nitrification was reported during the warmer months of the year and partially responsible for ammonium removal under such conditions; however, the increment of organic loading produced longer ammonium supremacy over nitrate as nitrification process was restrained to few months a year when organic loading was over 60 kg BOD/ha day. The effect of organic loading over ammonium removal was very evident during spring and summer, and even more critical when organic loading was over 60 kg BOD/ha day. In fact, ammonium concentration in the pond effluent rose up to 40 mg $N\text{-}NH_3$/L in summer, when the primary facultative pond was loaded at 66 kg BDO/ha day; low concentrations of dissolved oxygen and nitrate were also reported.

Conclusions

In order to keep predominant facultative conditions and acceptable soluble BOD removals, primary facultative ponds in temperate climates should be loaded with up to 60 kg BOD_5/ha day. Considering the evident dependency of nitrogen removal and transformation processes on weather conditions, nitrogen control in facultative pond effluents should be conducted by polishing units aimed to deal with high concentrations of organic nitrogen in warm periods, and high ammonium concentrations in cold periods. Even though total BOD removal was independent from changes in surface organic loading, there are other signs that may be considered as clear symptoms of poor treatment conditions, such as the prevalence of ammonium in the final effluent and low chlorophyll *a* and dissolved oxygen concentrations.

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