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Long term diurnal variations in contaminant removal in high rate ponds treating urban wastewater

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Abstract

In this investigation, diurnal variations in contaminant removal in high rate ponds (HRP) treating urban wastewater were evaluated. Two experimental HRPs (surface area 1.54 m^2 and depth 0.3 m), each with a clarifier in series (surface area 0.025 m^2), were operated in parallel with different hydraulic retention times (3–10 days) but with the same environmental conditions over a period of one year. The operating strategies adopted only yielded a significant overall difference in removal between the two HRPs for nutrients. Effluent total suspended solids and chemical oxygen demand were slightly higher at midday than at dawn, while for total nitrogen and total phosphorous the concentrations were slightly higher at dawn. All these differences were related to the diurnal changes of DO and pH. The main conclusion of this work is that the diurnal variations of the contaminant concentrations in HRPs do not seriously affect their reliability in treating wastewater.

Keywords: Wastewater; High rate ponds; High rate algal ponds; Diurnal variations; Nutrient removal; Algal biomass

1. Introduction

High rate pond (HRP) technology for urban wastewater treatment was developed in California 40 years ago and essentially consists of a shallow raceway reactor 0.3–0.4 m in depth with mechanical mixing to promote algal growth (Oswald and Gotaas, 1957). Full scale applications exist all over the world, but the technology is especially suitable for arid and semiarid areas, such as the Mediterranean (Bontoux and Picot, 1994). HRPs are very appropriate for the sanitation of small rural communities because of their simplicity of operation in comparison to conventional technologies such as activated sludge facilities. In HRPs the photosynthesis reaction provides oxygen for the decomposition of the organic matter through the metabolic activity of aerobic heterotrophic bacteria. Wastewater treatment in HRPs allows a significant reduction not only of the influent organic matter, but also of nitrogen and phosphorus (Picot et al., 1991; Nurdogan and Oswald, 1995; García et al., 2000a). HRPs should not be viewed as a complete wastewater treatment. They are usually combined with other ponds such as facultative and sedimentation ponds to meet

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effluent requirements prior to effluent discharge (Oswald, 1991; Green et al., 1995).

The diurnal rhythm of the algal photosynthetic activity in the mixed liquor of the HRP causes variations of dissolved oxygen (DO) and pH during the day. Both DO and pH peak at midday and attain the lowest values at night. In fact, systematic anoxic periods have been reported at night, whereas DO concentration at midday can easily exceed 20 mg/L (Picot et al., 1993; El Ouarghi et al., 2000). Diurnal variations of these parameters affect the removal efficiency throughout the day. Thus, if at night the surface re-aeration rate of the HRP is not enough to reach the oxygen demand of the aerobic respiration, the pond could have temporary overloading conditions giving rise to a poor treatment level in terms of organic matter removal. Moreover, the lowering of the pH during the night reduces nitrogen and phosphorus removal by the pH-dependent processes of volatilisation and precipitation (Cromar et al., 1996). This is the reason why Picot et al. (1993) observed that the variations in ammonia and orthophosphate removal efficiency were highly dependent on the daily cycle. The removal efficiency over time and the mechanisms of contaminant removal in HRPs have been intensely studied in recent years; nevertheless, the diurnal variations in contaminant removal over a long time scale have not had much attention. To the authors' knowledge, only in the work of Picot et al. (1993) were diurnal variations in contaminant removal studied in depth for two days. The present investigation evaluates the diurnal variations in contaminant removal in two experimental HRPs operated with different hydraulic retention times (HRT) but with the same environmental conditions over a period of one year.

2. Methods

The HRPs were installed in parallel on the roof of the Department of Hydraulics, Coastal and Environmental Engineering building, in Barcelona, Spain. The experiments were conducted from July 1993 until July 1994. Raw wastewater was taken daily from the nearest street sewer and pumped to a tank acting as a primary clarifier. This wastewater was a typical urban wastewater from a residential area of the city of Barcelona. Two peristaltic pumps continuously fed the two HRPs, named A and B. Each HRP was equipped with a low-loading clarifier in series to allow algal removal. Experimental HRPs were typical raceway reactors, each with a surface area of 1.54 m^2 and a depth of 0.3 m (Fig. 1). The turning speed of the paddle wheel mixer in both HRPs was adjusted to produce a mid-channel velocity of 9 cm/s. The clarifiers had a surface area of 0.0255 m^2. A detailed description of the experimental system can be found elsewhere (García et al., 2000b, 2002). The mean hydraulic retention time

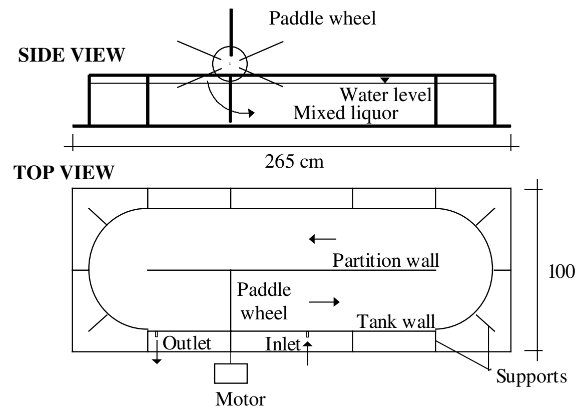

Fig. 1. Diagram of the top and side view of the experimental HRPs.

(HRT) was controlled through the wastewater flow rate according to the recommendations of Oswald (1986). During the study, two different operational criteria were adopted: HRP A was usually operated with higher HRT than B. During spring and summer, HRP A was operated with a HRT of 7 days, while HRT in HRP B was 4–5 days. During autumn and winter, HRP A was operated with a HRT of 10 days, while in HRP B it was 8 days. The loads applied ranged between 8.2–28 g COD/m^2 day, 1.6–5.2 g N/m^2 day and 0.3–0.9 g P/m^2 day, and fell within the ranges usually used in these types of ponds. The surface-loading rate of the clarifiers was also controlled through the wastewater flow rate and ranged approximately between 2 and 6 m^3/m^2 day.

Grab samples of the HRPs influent settled wastewater, mixed liquor and effluent of the clarifiers were taken twice a week, one at midday and the other the next day at dawn to evaluate diurnal variations. This sampling strategy was selected after the findings of Picot et al. (1993), who observed the lowest removal efficiencies at the end of the night. TSS (total suspended solids), COD (chemical oxygen demand), Kjeldahl nitrogen, ammonia nitrogen, nitrite, nitrate, total phosphorous (TP) and orthophosphate were analysed using conventional methods (APHA-AWWA-WPCF, 1992). Total nitrogen (TN) was calculated by adding Kjeldahl nitrogen, ammonia nitrogen, nitrite, and nitrate. Particulate forms of COD, organic nitrogen and organic phosphorus were estimated by analysing raw and filtered samples. What is described as organic phosphorus actually corresponds to the sum of particulate and dissolved organically bound phosphates and hydrolysable phosphorus. Chlorophyll *a* was estimated by spectrophotometric quantification after extraction with 90% acetone (Jeffrey and Humphrey, 1975). All these analyses were carried out immediately after sampling. pH was measured in situ with a Crison Portable 506 pH-meter. Water temperature and DO were also measured in situ with an YSI 58 oxymeter. Solar radiation measurements were provided by a nearby meteorological station. Data analysis and statis-