Analysis of key variables controlling phosphorus removal in high rate oxidation ponds provided with clarifiers

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Abstract

This study evaluates the influence of hydraulic retention time (HRT), solar radiation, and water temperature on phosphorus removal from two experimental high rate oxidation ponds (HROP) with clarifiers. Both HROPs were operated for a period of one year with different HRTs (3 to 10 d), but under the same environmental conditions. Phosphorus species, phytoplankton biomass, solar cumulative radiation, water temperature and pH were measured once a week. Average total phosphorus removal (TP) was higher in the HROP operated with a higher HRT (43%) than in that using a lower HRT (32%). TP removal was due to dissolved reactive phosphorus (DRP) removal in the mixed liquor of the HROPs and transformation of DRP into particulate phosphorus (PP), with subsequent sedimentation of PP in the clarifiers. The influence of HRT on TP removal was due mainly to its control over DRP removal, which was observed to be more important in autumn and winter. The lowering of solar radiation and temperature in autumn and winter and their influence on DRP removal can barely be compensated by HRT to obtain a significant TP removal. This work indicates that DRP transformation into PP depends mainly on environmental factors through their mediated influence on pH and chemical precipitation.

Introduction

High rate oxidation pond (HROP) technology was introduced in California in the 1950s, with the aim of reducing the surface area required by conventional oxidation ponds (Oswald and Gotaas, 1957). HROPs are shallow (30 to 40 cm) and operate by means of mechanical mixing. The energy applied to stir the mixed liquor promotes the growth of the phytoplankton and prevents its settling (Oswald, 1988a). HROPs need a lower mean hydraulic retention time (HRT) than oxidation ponds to treat the same wastewater flow (Abeliovich, 1986).

An HROP is an aerobic reactor where organic matter removal is achieved by a mutualistic relationship between bacteria and phytoplankton (Fallowfield and Garret, 1985; Abeliovich, 1986). The oxygen required for aerobic bacterial decomposition of organic matter is provided by photosynthesis, whereas carbon dioxide, ammonia and orthophosphate needed for phytoplankton growth are supplied from bacterial decomposition and from wastewater. The biomass produced in an HROP is due mainly to phytoplankton and should be subsequently separated to complete the wastewater treatment.

HROPs are usually designed for secondary treatment of wastewater; nevertheless, some removal of nutrients occurs (Oswald, 1988b). Nutrient uptake by phytoplankton and subsequent biomass separation causes removal (Nurdogan and Oswald, 1995; Cromar et al., 1996). In addition, phytoplankton photosynthetic activity raises pH in the pond, resulting in ammonia stripping and orthophosphate precipitation (Moutin et al., 1992). Phosphorus removal is concomitant with the biomass separation.

Phosphorus in urban wastewater appears mainly as phosphates, which are classified as orthophosphates, polyphosphates and organically-bound phosphates (*Standard Methods*, 1995). During wastewater treatment in HROPs, complete hydrolysis of polyphosphates and decomposition of organically-bound phosphates results in the formation of orthophosphates (Nurdogan and Oswald, 1995). Most studies on the role of phytoplankton in orthophosphate removal point out that precipitation is more important than algal uptake (Shelef et al., 1982; Picot et al., 1991; Moutin et al., 1992; Nurdogan and Oswald, 1995). The high pH reached in HROPs and the supersaturation of orthophosphates, hydroxides, and carbonates with respect to calcium, magnesium and other metals promote chemical precipitation. In contrast with all of these studies, Mesplé et al. (1995) have estimated that most of the orthophosphate removal occurs by phytoplankton uptake.

In this paper the influence of environmental factors (HRT, solar radiation and water temperature) on phosphorus removal is studied when the HROPs are operated to reach secondary treatment standards. The influence of phytoplankton biomass and pH on phosphorus removal is also evaluated.

Experimental

Two experimental HROPs provided with low surface-loading rate clarifiers for phytoplankton separation were used. The experiments were carried out for a period of one year, from June 1993 to July 1994. The HROPs were constructed in PVC in a raceway form. Figure 1 shows the top and side view of the HROPs, showing size and shape, the location of the inlet and outlet and the six-paddle wheel mixer. Their surface area was 1.54 m^2, the depth 0.3 m and the volume 0.47 m^3. The turning speed of the paddle wheel in both HROPs was maintained at 4 r/min, giving a mid-channel velocity of 9 cm/s. The mixed liquor from the HROPs passed on to the PVC clarifiers. Figure 2 shows a schematic diagram of the side and top

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