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Diurnal changes in two algae ponds for wastewater treatment

J. M. González, E. Bécares, F. Soto, M. García, G. López, G. Ansola and E. Luis

Introduction

Wastewater treatment viability is a pressing problem, especially for small communities in regions characterised as "sensible". It is, therefore, necessary to develop new low cost installation and operation technologies. These must efficiently remove organic and nutrient loads, allowing water reuse and biomass utilisation in order to reduce operating costs. Stabilisation ponds are among these efficient low cost technologies, nevertheless, their dependency on climate conditions calls for further studies on their applicability in extreme climatic gradients. Treatment systems based on microalgal cultures are particularly suitable because of their photosynthetic capacity, which allows in situ oxygen generation for biodegradation of organic matter and its transformation to utilisable biomass (SHELEF 1980, RICHMOND 1986). Besides mixotrophic and autotrophic assimilation of nutrients, photosynthetic activity-related physico–chemical processes (mainly phosphate precipitation and ammonia removal) contribute to a reduction of pathogens in the receiving waters (BOROWITZA 1988).

Conventional – anaerobic and facultative deep ponds – are, nowadays, the main technologies associated with these processes, with variable results. Problems related to stabilisation ponds include the need for a large available land area, and the presence of great amounts of algae in the final effluent, which prevents its reuse. High rate algae ponds (HRAPs), designed by W. J. Oswald of Berkeley University in the latter part of the 1960s (OSWALD 1963, 1988), form an optimal treatment system for wastewater following their initial conception as algae production reactors. The main advantage of such a system is the great reduction in land requirement, keeping a high efficiency and low operation cost due to minimal energy requirements. HRAPs are a combination of conventional ponds (photosynthetic activity) and plug-flow algae reactors (continuously mixed). Species selection ensures the maximum nutrient removal rate and sedimentability characteristics in order to allow algae removal using simple decantation. These systems are basically thin channels or basins (30–50 cm depth) through which water flow is driven by means of small propellers or blowers

Systems description and methodology

The two pilot systems are located in the Experimental Low Cost Wastewater Treatment Champ of Mansilla de las Mulas, León, NW Spain. Close-by is a rural area (agriculturally based, 1,637 inhabitants) of the same name. The area has a Mediterranean climate (PAPADAKIS 1961) with an average annual rainfall of about 500 mm and an average annual temperature of 11 °C (minimum average temperature of –1.1 °C).

The waste stabilisation ponds (WSPs) have a total volume of 11,015 L, with an effective depth of 73 cm and a surface area of 15.09 m^2, while the HRAPs have a volume of 462 L, a depth of 30 cm and a surface area of 1.54 m^2. Water in the HRAP system is impelled by small paddle wheels operating at 3 rev. min^{-1} (rotational velocity) obtaining a water flow of 15 cm s^{-1} which gives optimal mixed results.

Raw water is taken from the municipal sewer and pumped to a settlement tank and then fed to each system by metering pumps. Hydraulic detention time is 20 days in the WSP and 6 days in the HRAP in the two periods of this study – summer and winter. Final effluent is carried out to the Esla River.

Samples were taken over 1 day every 2 h at depth intervals and were repeated in both seasons – summer and winter. Direct measurement of water temperature, pH, solar radiation, electrical conductivity and dissolved oxygen were taken at depth intervals of 10 cm. Other parameters such as alkalinity, nitrate, ammonia, total phosphorous, particulate organic phosphorous, orthophosphate, total organic carbon, chlorophyll *a*, faecal coliforms, faecal streptococci, clostridium, staphylococci, and total heterotrophic bacteria were analysed in the laboratory from samples taken at two depths (10 and 60 cm) from the WSP and at one depth (20 cm) from the HRAP, due to its completely mixed characteristic. APHA (1989) recommendations for analytical determination practices were followed. Phytoplankton were determined in both systems by counting cells using optical

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microscopy in samples taken from the settlement tanks.

Water influent was characterised by the measurement and determination of several parameters, most importantly: temperature, pH, electrical conductivity, dissolved oxygen, total suspended and volatile solids, chemical, oxygen demand, biological oxygen demand, alkalinity, nitrate, ammonia, total nitrogen, orthophosphate, total phosphorus, faecal coliforms and faecal streptococci (Table 1).

Results

Wastewater influent has a low concentration or charge which, following the considerations outlined by METCALF & EDDY (1991), is a characteristic of domestic municipal sewage .

Water temperature had no depth variations, except in the WSPs in summer, the same is true of electrical conductivity and this is also higher in the WSPs in summer.

High pH values (up to 10) were detected in the WSPs and between 8 and 9.2 in the HRAPs as a consequence of photosynthetic activity. We found higher concentrations of chlorophyll *a* in the WSPs than in the HRAPs, and it was highest at the 60-cm depth at 12:00 h. This explains why dissolved oxygen (D.O.) follows the same pattern, and also in accordance with the temperature dynamics, causes high levels of oxygen in the WSPs (up to the HRAP levels). Both systems had maximum concentrations of D.O. in winter. Solar radiation was at a maximum at 12:00 h and presents a typical gausian distribution. Radiation was highest at the 30-cm depth in the WSPs.

Alkalinity had maximum concentration values in WSPs, highest at the surface and showed no seasonal variation in the two systems.

Nitrate was maximum at 12:00 h in winter at the 10-cm depth in the WSPs. Ammonia removal was best in summer, with a clear difference between the two seasons in the HRAPs.

Phosphorus was assimilated better in summer than winter in both systems and presented higher levels at the 60-cm depth in the WSPs

Seasonal differences in total organic carbon (TOC) did not occur in the WSP, but in the

Table 1. Characteristic parameters of raw water influent to the pilot WSP and HRAP systems.

Parameter		Summer	Winter
Temperature (ambient)	°C	16	8.5
Temperature (water)	°C	22.2	11.8
pH		7.9	7.9
Conductivity	$\mu S\ cm^{-1}$	410	415
D.O.	$mg\ O_2\ L^{-1}$	0.6	1.4
Total suspended solids	$mg\ L^{-1}$	17.2	20
Volatile suspended solids	$mg\ L^{-1}$	17.2	20
COD	$mg\ O_2\ L^{-1}$	91.28	111.6
BOD_5	$mg\ O_2\ L^{-1}$	21	14.07
Alkalinity	$mg\ CO_3Ca\ L^{-1}$	172.41	182.31
Nitrate	$mg\ L^{-1}$	0.543	7.71
Ammonia	$mg\ L^{-1}$	8.15	6.19
T.K.N.	$mg\ L^{-1}$	11.35	3.6357
Ortophosphate	$mg\ L^{-1}$	4.188	10.244
Total phosphorus	$mg\ L^{-1}$	5.756	7.751
P.O.P.	$mg\ L^{-1}$	0.566	3.534
Faecal coliform	$col\ 100\ mL^{-1}$	619333	449500
Faecal streptococci	$col\ 100\ mL^{-1}$	134100	24600

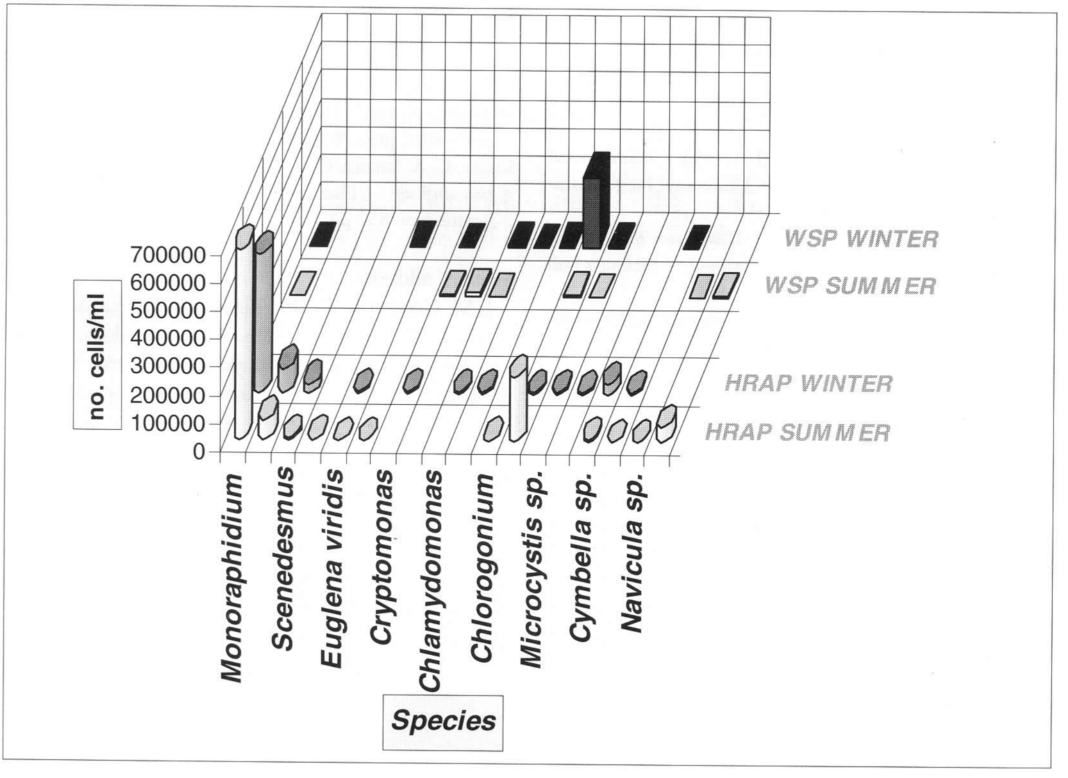

Fig. 1. Phytoplankton seasonal population dynamics in waste stabilisation ponds (WSP) and high rate algae ponds (HRAP) (cells mL^{-1}).

HRAP it was higher in summer. There were depth differences in the WSP – at 12:00 h, the TOC concentration was highest at the 60-cm depth and lowest at the 10-cm depth.

Pathogenic bacteria and faecal indicators were best removed from the WSP, where we found minimum concentration values at the 10-cm depth at 12:00 h.

There was a greater abundance of phytoplankton in the HRAP than in the WSP. In the HRAP, monospecific blooms of *Monoraphidium contortum* occurred and they were higher in summer. We represent the phytoplankton population dynamics in Fig. 1.

Conclusions

- Stratification is observed in the WSP system in summer as reflected in temperature, conductivity, dissolved oxygen and pH distribution. This system was permanently mixed in winter.
- HRAP systems are completely mixed all of the time, and reflect diurnal and seasonal effects.
- Daily changes are reflected by the WSP dynamics.
- Photosynthetic activity determines pH increases and ammonia evolution.
- There is a greater abundance of phytoplankton in HRAP than WSP systems. High values of cells mL^{-1} of monospecific blooms were observed in HRAP systems. These values are higher in summer than winter.
- The results obtained in this study show differences in the properties of the final effluent produced by these two systems.

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Authors' address:

J. M. González, E. Bécares, F. Soto, M. García, G. López, G. Ansola, E. Luis, Area of Ecology, Faculty of Biology, University of León, 24071 León. Spain.
E-mail: degjgm@unileon.es