Removal of emerging contaminants in wastewater treatment: comparison of photosynthetic systems and activated sludge

POSTER
Ph.D. Student: Y
Journal: NONE

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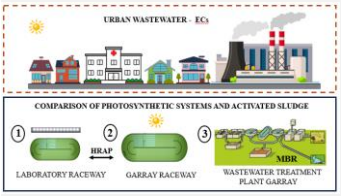

Contaminants of emerging concern (CECs) are chemical substances that are commonly detected in the environment and can cause ecological or human health effects. In this scenario, algal-bacterial processes have recently emerged as an economically viable and environmentally friendly option for eliminating chemical and biological contamination from different types of wastewaters: domestic, industrial and agricultural. Utilizing solar energy, wastewater treatment with microalgae converts carbon and nutrients into algal and bacterial biomass and showed similar high removal efficiencies with membrane bioreactor of activated sludge systems.

Introduction

There is a growing alarm about the presence of contaminants of emerging concern in the aquatic environment, due to the potential problems they pose to human health and the environment. There is also not much information available regarding the issues that CECs may cause to aquatic ecosystems' fauna and flora, possibly leading to diseases and population decline. Additionally, CECs when discharged into rivers, can re-enter the food chain, causing problems for humans depending on the specific compound.

Eliminating CECs with conventional physical and chemical treatments does not seem a sustainable solution, due to the poor removal efficiency of Wastewater Treatment Plants (WWTPs). This is why an alternative treatment such as microalgae has been studied. It is a promising and sustainable microalgae biotechnology solution. Additionally, the microalgae-based process offers several advantages, as these microorganisms can capture carbon dioxide and produce oxygen in the presence of light through photosynthesis, mitigating greenhouse gases and climate change. It is environmentally friendly technology due to the use of solar energy as a power source for organisms to perform photosynthesis, and its ability to adapt to different types of wastewaters makes it a low-maintenance and low-energy cost technology.

Material and Methods

The work was carried out in three sets of experiments. In the first one, the study used a raceway in laboratory composed volume of 30 L, Fig.1. The surface of the raceway was illuminated with a day simulator program depend on of two LED module PHILIPS 94V covering a total surface of 0.16 m2 (length= 40 cm; width= 23 cm; 140 LEDS for module). LED modules were operated by means of a programmable electronic driver (Philips LED Xitanium 8173345).

The second experiment was performed in the municipal WWTP of Garray, and consisted of a raceway of 130 L volume, Fig.1. The system treated real-world pretreated wastewater from this municipality, which is placed in the province of Soria (Castilla y León, Spain), and has a population of 736 inhabitants. The raceway was fed with a pump at an inlet flowrate of 26 L d-1 from a 1.000 L homogenization tank resulting in hydraulic retention times of 5 days.

The last study was performed in the WWTP treating the discharges generated by the municipality of Garray and the City of the Environment in compliance with the most demanding regulations and with an effluent of the highest quality, Fig.1. The technologies used in this plant are fully automated, allowing remote control, which is designed in three stages: Pre-treatment, consisting of a course well, spillway and coarse grate, raw water pumping well and screening of raw water, where solids larger than three millimetres are removed and a sedimentation chamber and grease separator. Biological treatment consisting of two parts, the aerobic part of prolonged aeration and nitrification and the anoxic part of denitrification. The settling tank consisting of

a membrane bioreactor (MBR).

Fig. 1. Raceway laboratory, raceway pilot plant and MBR of WWTP Garray.

Two operational conditions were applied to evaluate domestic wastewater treatment efficiency for emerging contaminants: summer and winter. The raceways and MBR were operated for 180 days. Liquid samples were collected every two days to monitor photobioreactors and MBR performance. Each operational conditions were maintained for 90 d to achieve representative steady states, which were kept for at least 15 days (thus allowing 4 replicate measurements for photobioreactor).

The quantitative determination of 39 target pharmaceuticals was performed by liquid chromatography coupled to tandem mass spectrometry (LC-MS/MS) with triple quadrupole (Waters Acquity H-Class UPLC, equipped with a binary pump system, interfaced to a triple quadrupole Xevo TQS mass spectrometer, with ESI source (Waters Corp)) **[1].**

Results and Discussion

The removal efficiencies met the most restrictive urban wastewater discharge regulations and achieved the disinfection levels required for water reuse in agriculture, Fig.2. High removal efficiencies were obtained for emerging contaminants, particularly for antibiotics, antimicrobials, and non-steroidal anti-inflammatory drugs, which achieved removal rates exceeding 90%, with total removal in the pilot microalgae system. The removal efficiencies in the MBR system were significantly higher than in conventional activated sludge systems. In the case of the microalgae systems, the removals were notably superior to conventional activated sludge systems. The high solar exposure, relatively long residence times, and the conditions of microalgae cultivation—high pH and oxygen concentration—favoured the disruption of molecules, resulting in an effluent with a low load of these contaminants.

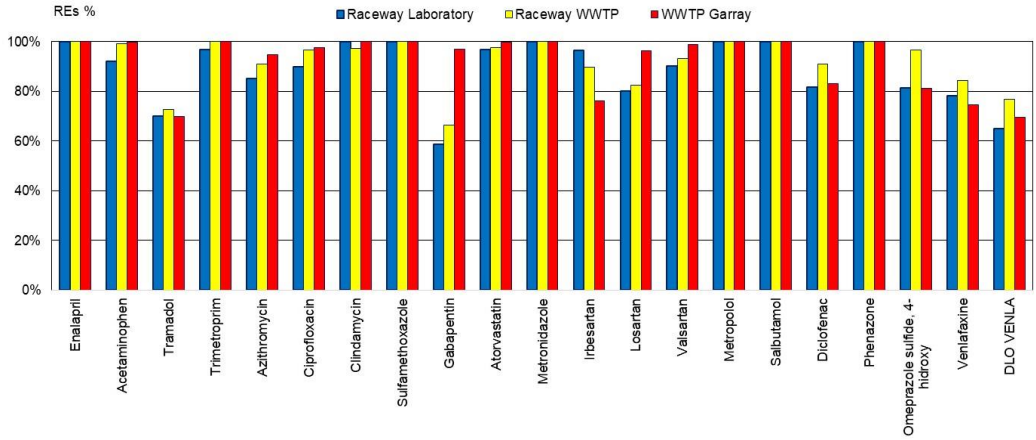

Fig. 2. Removal efficiencies (REs) for contaminants of emerging concern.

Conclusions

This work has studied the use of microalgae for the removal of CECs in high rate algal pond for the wastewater treatment, under different climatic conditions, with and without ultraviolet light. The removal efficiencies in the MBR system were significantly higher than in conventional activated sludge and similar to the microalgae system.

References

[1] M.A. Prada-Vásquez, M. Mestriner Pituco, M.P. Caixeta, S.A. Cardona Gallo, A.M. Botero-Coy, F. Hernandez, Ricardo A. Torres-Palma, Vítor J.P. Vilar (2024) **"**Ozonation using a stainless-steel membrane contactor: gas-liquid mass transfer and pharmaceuticals removal from secondary-treated municipal wastewater" *Chemosphere 349*