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Seasonal variation of nutrient removal in a full-scale horizontal constructed wetland

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Abstract

The main objective of the present study was to evaluate the difference in removal efficiency (RE) of nitrogen and phosphorus compounds based on the seasonal changes in a full-scale gravel-based horizontal subsurface flow constructed wetland located in Interior Central Region of Portugal. The RE of nitrogen and phosphorus compounds were relatively poor, but the results allow us to conclude that season had a significant ($p<0.05$) effect on the RE of TN, NH4+-N, NOx-N, TP and DP, with higher values in spring-summer period (10.4%, 10.4%, 3.4%, 27.5% and 26.1%, respectively) than in autumn-winter (0%, -7.7%, -9.8%, 12.9% and 0%, respectively).

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*Keywords:*Constructed wetlands; horizontal subsurface flow; domestic wastewater; nutrinet removal; seasonal variation

1. Introduction

The presence of nitrogen (N) and phosphorus (P) compounds in domestic wastewater has contributed to enrichment of water bodies which is generally associated with water eutrophication process, a relevant environmental issue. So, Nutrient removal during wastewater treatment in sewage-treatment plants is vital to minimize the impact of nitrogen

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and phosphorus pollution on Europe's water bodies and to achieve the environmental objectives of the Water Framework Directive (WFD; Directive 2000/60 / EU) in Europe [1].

Horizontal subsurface flow Constructed Wetlands (HSSF-CWs) are biological treatment systems that seek to mimic the biogeochemical processes occurring in the natural wetlands in order to remove the contaminants present in the wastewater. When compared to conventional wastewater treatment systems, HSSF-CWs are shown to be a sustainable technology that is simple to build and easy to operate and maintain. They are also characterized by being low energy and chemical reagents demanding systems, as a consequence, they have become an alternative to conventional systems for the sanitation of small scale treatment plants.

These systems seem to be appropriate to remove many types of pollutants, including nutrient compounds. Among all nitrogen removal mechanisms, ammonification followed by nitrification-denitrification is usually accepted to be the most important in constructed wetlands [2]. However, HSSF-CWs often exhibit inconsistent and highly variable nitrogen removal efficiency and has been reported in long term studies between 20 % and 70 % [3]. Regarding to P removal it was reported values ranging from 30% to 60%, depending on the wastewater and the media used [4]. In fact, HSSF-CWs phosphorus removal, must be limited because the material used in substrate (usually gravel) are poor in iron and aluminum hydrous oxides minerals as well as in calcium and magnesium concentrations, elements essentials for adsorption and precipitation of insoluble forms in wetlands, the most important mechanisms for removal P in those systems.

Although a considerable numbers of studies have contributed for understanding the mechanisms associated to removal process in CWs, inconsistence in the results suggest the importance of further studies for contributing for the optimization of this technology and thus ensuring that they comply with the increasingly strict requirements discharge standards for treated effluents and for its reuse. In Portugal, the used of HSSF-CWs is recent in comparison with others European countries and although, in recent years, have been conducted some studies on the treatment performance of HSSF-CWs systems [5, 6], it appears that there is still a lack of data in sufficient detail, both temporally and spatially, on full-scale CWs for wastewater treatment. On the other hand, although the effects of climate and seasonality are considered relevant for the performance of the treatment of CWs, its role remains unclear [7]. Therefore, further investigations are needed to clarify the influence of climatic and season on the removal of pollutants in Mediterranean climatic conditions.

The aim of this study was to evaluate the effect of seasonal conditions on N and P removal for temperate Mediterranean climate conditions with strong continental influence in a full-scale HSSF-CW located in a Centre Interior region of Portugal.

2. Materials and methods

The study was carried out in a full-scale wastewater treatment plant (WWTP) located in Sarnadas Rodão, a small village of 637 inhabitants [8] in the Centre Interior region of Portugal (39° 45' 32" N 7° 38' 35" W). The region is in the warm temperate zone and according to the Classification System of Köppen-Geiger the climate is Csa, corresponding to a Mediterranean climate, clearly influenced by continentality climate [9]. The climate is characterized by cold winters alternating with hot and dry summers. There are episodic heavy rains, contrasting with a total rainfall moderate. The WWTP is operating since 2006 and t was sized for treating domestic wastewater produced by a population of 550 equivalent inhabitants, with an average flow rate from 60 m^3 day^{-1} (2006) to 73 m^3 day^{-1} (2020).

The treatment system consists of pre-treatment trough physical separation, primary treatment in a three compartmentalized septic tank, and secondary treatment through one HSSF-CW with as 40 m x 28 m (length and width), and a total surface area of 1120 m^2. The bed was planted with common reed plants (*Phragmites australis*), which were well-established covering the entire surface of the wetland.

A monthly sampling was carried out from August 2012 to June 2013for evaluating the CW performance under different climatic conditions, at inlet (after septic tank) and at the outlet of the wetland bed. At the same time, it was also collected samples from the raw influent (after screen bars). Samples were analyzed in duplicate for total nitrogen (TN), ammonium nitrogen (NH_4^+-N), Organic nitrogen (Org-N), oxidized nitrogen (NO_2^--N+NO_3^--N: NO_x-N), total phosphorous (TP) and total dissolved phosphorus (DP) according to the Standard Methods for the Examination of Water and Wastewater [10]. To acquire information about the possible influence of seasonality on the performance of