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Web app for real-time monitoring of the performance of constructed wetlands treating horticultural leachates

Rafaela Cáceres[a,*], Enric Pol[b], Lola Narváez[a], Anna Puerta[a], Oriol Marfà[a]

[a] IRTA, GIRO Unit, IRTA, Carretera de Cabrils, km 2. 08348, Cabrils, Barcelona, Spain
[b] NADIR Software Solutions. Consell de Cent, 308, 4°. 08007 Barcelona, Spain

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ABSTRACT

Leachates produced in intensive horticulture must be collected, reused and eventually treated in order to prevent environmental pollution of water bodies. Constructed wetlands (CW) try to emulate natural wetlands, where pollutants such as nitrates are removed through the denitrification process. CW are a simple and sustainable technique with a low energy demand that are being used to purify different effluents. No information is currently available on tools used to monitor the performance of such systems in terms of nutrient removal efficiency. Nor is information available on the use of Information and Communication Technologies (ICT) tools to share news on this performance across the Internet. The purposes of the study were: a) to demonstrate the feasibility of using online instruments to measure leachate ions in order to monitor CW performance and to manage it properly and b) to share this real-time data monitoring with the end users through a web App. Under the described experimental conditions, the on-line analyzers are reliable instruments to measure nitrates, nitrite, phosphates and potassium ion. Monitoring of the constructed wetlands through the web is an effective tool that would contribute to show the feasibility of the system to the end users. These two conclusions demonstrated the innovativeness of the whole system to monitor the constructed wetlands through the Internet.

1. Introduction

Water resources available for agriculture in forthcoming decades will be lower in both quantity and quality (Navarro-Hellín et al., 2015). The efficiency in the use of water and fertilizers in horticultural agro systems is low (Grant et al., 2009). Particularly, losses through leaching could be considerable due to the used fertigation and certain irrigation techniques (Cáceres et al., 2007; Narváez et al., 2012, 2013; Cáceres and Marfà, 2013).

The leachates produced in soilless crops are characterized by high levels of nitrates, phosphorous and potassium and very low levels or absence of organic matter or dissolved organic carbon (Narváez et al., 2011). Therefore, leachates produced in intensive horticulture must be collected, reused and eventually treated in order to prevent environmental pollution of water bodies (O.J., 2000; DOGC, 2009). In order to deal with leachates in pot plant nurseries, a new system, named CLEANLEACH® has been introduced through an Eco-innovation project funded by the European Comission. This new system, in line with the circular economy trends (Stahel, 2016), especially circular agriculture, consists of a technological package divided into two techniques (Marfà et al., 2016): a) Horizontal sand bed that acts as slow sand filter, disposed on the base of the permeable areas of cultivation in containers. This system has been evaluated at pilot scale with satisfactory results, minimal maintenance and low cost of implementation (Marfà et al., 2006) and b) Purification using a horizontal subsurface flow constructed wetland (CW). CW try to emulate natural wetlands and are composed with shallow ponds or channels with wetland vegetation, where decontamination processes occur through interaction between water, substrate, plants and microorganisms.

Both systems are on-site technologies that should be monitored, particularly, CWs. Constructed wetlands are simple and sustainable techniques with a low energy demand that are being used to purify different effluents (Wu et al., 2014). It has been demonstrated that horticultural leachates can be treated using CW in which denitrification process under anaerobic conditions are promoted (Narváez et al., 2011; White, 2013; Park et al., 2015).

Previous studies have been carried out to design and setting up the system adapted to nursery leachate characteristics containing high nitrate concentration (Narváez et al., 2011). In such studies, high denitrification rates have been achieved through the use of an appropriate carbon source dosage. Monitoring of nitrate and

* Corresponding author.
E-mail addresses: rafaela.caceres@irta.cat, raficaceres@yahoo.es (R. Cáceres).

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other chemical species is desired during the nitrification or denitrification processes for treating wastewater. Standardized methods are proven to give reliable and comparable results of wastewater quality parameters, but are mainly based on sample collection and retrospective analysis, which makes their application to real-time monitoring and process control very difficult (Drolc and Vrtovšek, 2010).

In recent years, the incorporation of sensors in the context of agriculture production for water management has received an increasing interest for water management purposes, for example (Gutiérrez et al., 2007; Navarro-Hellín et al., 2015; Fernández-Pacheco et al., 2015; Jiménez-Buendía et al., 2015). However, no information is currently available on tools used to monitor the performance of CWs in terms of nutrient removal efficiency. Nor is information available on the use of Information and Communication Technologies (ICT) tools to share news on this performance across the Internet. In order to offer the technology to the sectors concerned it is necessary to demonstrate the reliability of the system, to have tools to manage it properly, and to disseminate its performance. Therefore, the purposes of the study were: a) to demonstrate the feasibility of using online instruments to measure leachate ions in order to monitor CW performance and to manage it properly and b) to share this real-time data monitoring with the end users through a web App.

2. Material and methods

The implementation and development of the whole system were performed in two main stages. First stage was focused on online monitoring dealing with both, correlation between online measures and standardized analysis and to describe the evolution of online measures. The second stage focused on the definition of the architecture of the system and its implementation to achieve a suitable web App.

2.1. Online measurements

2.1.1. Constructed wetland pilot plant

The experiment was carried out in an intermediate-scale pilot plant, comprising six horizontal subsurface flow CW (HSSCW) made of concrete, constructed in a covered outdoor plot at IRTA in Cabrils (Spain) (41° 25′ N, 2° 23′ E). All beds were covered with a geotextile layer and high-density polyethylene (HDPE) to make the CW impermeable. A slope of 1% was required in the plot to maintain the hydraulic gradient of the beds. The inlet zone consisted of a pipe with 2 $L\,h^{-1}$ emitters to regulate the flow (0.24 $m^3\,day^{-1}$) per experimental line (Narváez et al., 2011). Two online instruments to monitor the CW were connected to one of the six available beds of the pilot plant at the inflow and outflow pipes (Figs. 1 and 2).

2.1.2. Online instruments

Nitrates, nitrites, potassium and phosphorus have been assessed by means of pieces of equipments that give real time information on the performance of the system. Technical and specifications could be checked at the website of the supplier (http://www.axflow.com) and main characteristics are:

2.1.2.1. Ionometer analyzer (K). The first instrument was a Potassium (K) analyzer to measure this element in the inflow and outflow of the constructed wetland, doing consecutive measures. This instrument is a PowerMon ionometer (Bran + Luebbe, Norderstedt, Germany). The ionometer is a device for the potentiometric measurements of substances dissolved in water. K^+ concentration is measured using an ion-selective electrode. The ionometer is permanently connected to the process to be analyzed by means of sampling lines; in this application two lines have been connected: line 1 (inflow) and line 2 (outflow).

Fig. 1. Constructed wetland (CW) module and on-line analyzers connected to the inflow and outflow pipes of the CW.

2.1.2.2. Multiparametric instrument (nitrates, nitrites and phosphates). The second instrument was the PowerMon S multiparameter on-line analyzer (Bran + Luebbe, Norderstedt, Germany) which can measure several parameters in one unit. This piece of equipment was designed to measure the following parameters: Nitrates (NO_3^-), nitrites (NO_2^-) and phosphates (PO_4^{3-}). Determination is based on spectrometric measurement in the UV/VIS range (200–710 nm). The instrument is permanently connected to the process to be analyzed by means of sampling lines (inflow and outflow).

Nitrate and nitrite are measured by the described direct spectrometry measures. However, phosphates do not absorb or absorb only weakly in the UV/VIS range and are measured by means of auxiliary chemical reactions, involving a color reaction. Samples and reagents are mixed by peristaltic pumps in an exactly defined ratio with the help of a mixing device and placed in a vessel to react. The reagents are chosen so that they form a colored compound with the component to be measured; the intensity of the color depends on the concentration of the measured phosphates.

The online instruments were calibrated daily at the beginning of the experiment and each three weeks at the end of the monitored period.

2.1.3. Influent (inflow) and sampling

The influent (inlet or inflow) of simulated nursery runoff containing representative concentrations of fertilizers was prepared using an automatic irrigation system MCU Ferti® (Multi Computer Unit; FEMCO, Damazan, France). The effluent (outlet or outflow) was the liquid that has suffered the treatment through the bed of the constructed wetland. The inflow and outflow pipes located in the wetlands were connected to the feeding lines of the two analyzers mentioned in Section 2.1.2.

To check the performance of the system, samples from inlet and outlet were taken at the same time that display readings of the two devices were written down. Sampling was performed during two months (11/05/2015–16/07/2015).

In order to check the response to changes of the measures made by the pieces of equipment, the set point of the electrical conductivity (EC) to manufacture the nutrient solution was downgraded periodically. The change in the EC set point would change the nutrient concentration. This variability in the inflow concentration would provide variability in the readings of the instruments.

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