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A voltammetric electronic tongue as tool for water quality monitoring in wastewater treatment plants

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ABSTRACT

The use of a voltammetric electronic tongue as tool for the prediction of concentration levels of certain water quality parameters from influent and effluent wastewater from a Submerged Anaerobic Membrane Bioreactor pilot plant applied to domestic wastewater treatment is proposed here. The electronic tongue consists of a set of noble (Au, Pt, Rh, Ir, and Ag) and non-noble (Ni, Co and Cu) electrodes that were housed inside a stainless steel cylinder which was used as the body of the electronic tongue system. As a previous step an electrochemical study of the response of the ions sulphate, orthophosphate, acetate, bicarbonate and ammonium was carried out in water using the electrodes contained in the electronic tongue. The second part of the work was devoted to the application of the electronic tongue to the characterization of the influent and effluent waters from the wastewater treatment plant. Partial Least Squares analysis was used to obtain a correlation between the data from the tongue and the pollution parameters measured in the laboratory such as soluble chemical oxygen demand (CODs), soluble biological oxygen demand (BODs), ammonia (NH_4–N), orthophosphate (PO_4–P), Sulphate (SO_4–S), acetic acid (HAC) and alkalinity (Alk). A total of 28 and 11 samples were used in the training and the validation steps, respectively, for both influent and effluent water samples. The electronic tongue showed relatively good predictive power for the determination of BOD, COD, NH_4–N, PO_4–P, SO_4–S, and Alk.

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1. Introduction

The growing concern of the society about the environmental protection has led to the establishment of stringent discharge requirements for wastewater treatment plants (WWTP) with the aim of reducing the impact on the receiving aquatic ecosystems. These new requirements have put pressure on the water and wastewater treatment processes. The use of sensors for monitoring and control the biological processes that take place in WWTP make it possible to increase their pollutant removal capacity and to achieve a consistent and stable operation, meeting the effluent requirements at minimum cost (Olsson et al., 2005). Traditionally, the quality of treated wastewater is defined by the measurement of parameters such as chemical oxygen demand (COD), biological oxygen demand (BOD), ammonium, orthophosphate, nitrate, sulphate, etc. These parameters provide vital information on the quality of the influent, effluent wastewater and process performance, which is useful for process control and to demonstrate that the effluent meets the discharge requirements. All these parameters are determined through traditional laboratory analytical techniques, which are off-line and some of them, such as BOD, require 5-day or 20-day to obtain the measurement making these tests inadequate for automated monitoring and control. The past two decades have seen increasingly rapid advances in the field of innovative equipment for on-line monitoring (see for instance Table 1) (Yoom et al., 2003). However, not all parameters can be measured on-line and some researches (Ruano et al., 2009; Olsson, 1992) have pointed out that the maintenance and operation of some of the analyzers are both tedious and time consuming to manage and most of them required considerable economic resources. In fact, the investment and operational costs can somehow limit the applicability of these analyzers, especially in medium-sized and small-sized WWTPs.

Electronic tongues have emerged as a rapid, low-cost and simple tool for liquid analysis. The strategy of electronic tongues relies on the use of semi-specific sensors that produces a signal pattern when subjected to a sample that can be related to either a specific compound or a quality aspect, which is done by treating the signal pattern with multivariate data analysis (Winquist et al., 2011). When the electronic tongue is subjected to a sample containing different compounds, it generates an output pattern that represents a synthesis of all the components in the sample. The basis of the technique is that although the specificity of each sensor unit is low, the combination of several specificity classes entails a very large information potential. For the design of electronic tongue devices two main approaches employing electrochemistry techniques have been followed based on the use of potentiometric or voltammetric sensor arrays. The main difference between both approaches is that in potentiometry the potential between two electrodes is monitored without current flow while in voltammetry a potential is applied and the resulting current is measured (Winquist, 2008). Although potentiometric measurements are more simple, voltammetric methods are more versatile and robust since are usually less influenced by electrical disturbances additionally having a favourable signal to noise ratio (Holmin et al., 2001).

Due to the simplicity and versatility of electronic tongues, much research efforts have been dedicated to their development and their use in a wide range of applications, such as in food industry (fish, milk, meat, wine, etc.) (Campos et al., 2010; Gil et al., 2008; Paixão and Bertotti, 2009; Parra et al., 2006a,b; Francioso et al., 2007; Winquist et al., 2005; Collier et al., 2003), environmental analysis, water quality monitoring, etc. (Campos et al., 2010; Mimendia et al., 2010). However, very few studies have been carried out regarding to the application of electronic tongues in characterizing wastewaters. A recent example has been devoted to the characterization of waters coming from the paper mill industry (Gutés et al., 2006). However, we believe that electronic tongues can have a wide range of applications in water quality monitoring in wastewater effluents due to their facile use, their simple on-line implementation and their low-cost.

Following our interest in the design of sensing system (Martínez-Máñez et al., 2005a,b; Masot et al., 2010; Labrador et al., 2007; Moragues et al., 2011; Martínez-Máñez and Sancenón, 2003) we report herein a simple electronic voltammetric tongue that has been used to characterize influent and effluent waters of a WWTP treating domestic wastewater. The proposed system consists of an array of eight metallic electrodes: Au, Pt, Ir, Rh, Ag, Cu, Ni, and Co and their combined use as working electrodes in voltammetric experiments. With this system a prediction of typical pollution parameters measured in wastewater treatment plants such as soluble chemical oxygen demand (COD_S), soluble biological oxygen demand (BOD_S), ammonia (NH_4–N), orthophosphate (PO_4–P), sulphate (SO_4–S), acetic acid (HAC) and alkalinity (Alk) have been performed using Partial Least Squares (PLS) analysis.

Table 1 – Commonly used measurements performed by on-line instrumentation on WWTP [4].

Flow rate	pH	Turbidity	Nitrate
Liquid level	Redox	Sludge concentration	Orthophosphate
Pressure	Conductivity	Sludge blanket level	Organic Matter
Temperature	Dissolved Oxygen	Ammonium	Biogas production

2. Material and methods

2.1. Pilot plant description

The pilot plant used in this study is a Submerged Anaerobic Membrane Bioreactor (SAMBR) applied to domestic wastewater treatment. The SAMBR pilot plant (see Fig. 1) consists of 1.3 m^3 anaerobic reactor (1 m^3 working volume) connected to two 0.8 m^3 separation tanks, each one with one ultrafiltration membrane commercial system (PURON®, Koch Membrane Systems, 0.05 μm pore size). A rotofilter (0.5 mm screen size),