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Chemical sensor for haemodialysis application

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Abstract

The water used to supply a haemodialysis center requires particular mode of treatment in order to achieve the best technical, economic and therapeutic distribution. Dialysis patients come in contact weekly with a large amount of water through the dialysis apparatus. It is therefore essential that this solution has a high quality and purity in terms of proper electrolyte composition, low concentration or absence of organic and inorganic chemical pollutants, low concentration or absence of bacteria, yeasts, fungi and endotoxins. The chemical and microbiological quality of water intended for medical and biomedical treatments, such as haemodialysis, is generally defined on the basis of a plurality of international reference standards (ASTM International standards D1193 and D5196; International Pharmacopoeia and European Pharmacopoeia CAP / NCCLS 1988). In this work the authors have designed an electrochemical device used to characterize pure and ultrapure water for biomedical applications (Patent: TO2014A000765). The results obtained show a good ability of the device in the discrimination of different bacteria and of their concentration (CFU); Pseudomonas and E-coli have been here tested.

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Keywords: haemodialysis; fingerprinting; ultra-pure water; e-coli; pseudomonas

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1. Introduction

Standard methodologies for bacterial microorganisms detection are currently based on the possibility of growing the bacteria on suitable substrates and in a proper culture conditions. When applied for the analysis of water sample collected by plants or instruments, this technique needs the water samples to be added to a culture media. The bacterial colonies growing on the medium allow the tracing of the microorganism's number present in a known volume of the sample. This method is obviously time-consuming and somewhat complex, thus it is not suitable for online analysis and fast response. Besides, several works has shown the possibility to use electrochemical sensors to monitor specific bacteria [1-4]. They are mainly based on functionalized screen-printed electrodes, in which there is often a trade-off between selectivity and resolution. Here a fast, low-cost, and high resolution techniques based on not functionalized screen printed electrodes is presented.

2. Experimental

In this work the authors have applied a specific device to detect low concentrations of Escherichia coli e Pseudomonas in ultra-pure water. The device consists of Screen Printed Electrodes (SPEs) inserted in haemodialysis apparatus (Fig.1). The device is controlled by an electronic interface devoted to input supply and output acquisition which is designed to obtain a S/N ratio > 1. Signal input consists of a triangular waveform between -1V and 1V with a frequency of 10 mHz. The registered output is a sequence of 100 current values. The final pattern is a multidimensional array composed of 100 virtual sensors, each referred to the current output response to a specific voltage input. The measurement procedure can be completed in 3 minutes. These patterns, stored on board in a flash memory (SD card), can be analyzed with multivariate data analysis techniques to provide classification, characterization and identification of complex chemical mixtures and/or solutions. Here Principal Component Analysis (PCA) and Partial Least Square (PLS) have been used with the Leave-one-out as cross-validation criterion.

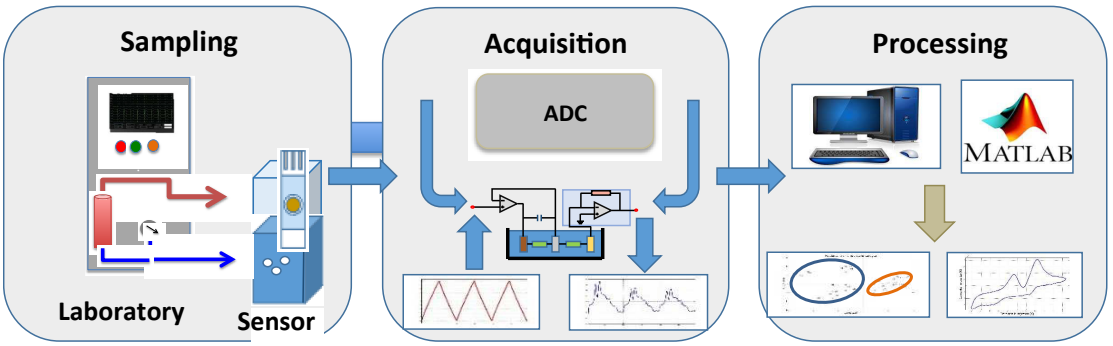

Fig. 1. Experimental set-up. The sensor has been calibrated using certified samples provided by a qualified laboratory.

3. Results

The results (Fig. 2) show a good discriminative power between contaminated water with different bacteria (Escherichia coli and Pseudomonas) obtained via a PCA model in a range of concentration of 20-300 Colony Forming Units (CFU).
In Fig. 3 the predicted models are shown: (A) E.coli bacteria, (B) Pseudomonas bacteria. Root Mean Square Errors in Cross validation (RMSECV) of 17.41 CFU and of 76.56 CFU have been calculated for E.coli and Pseudomonas, respectively.

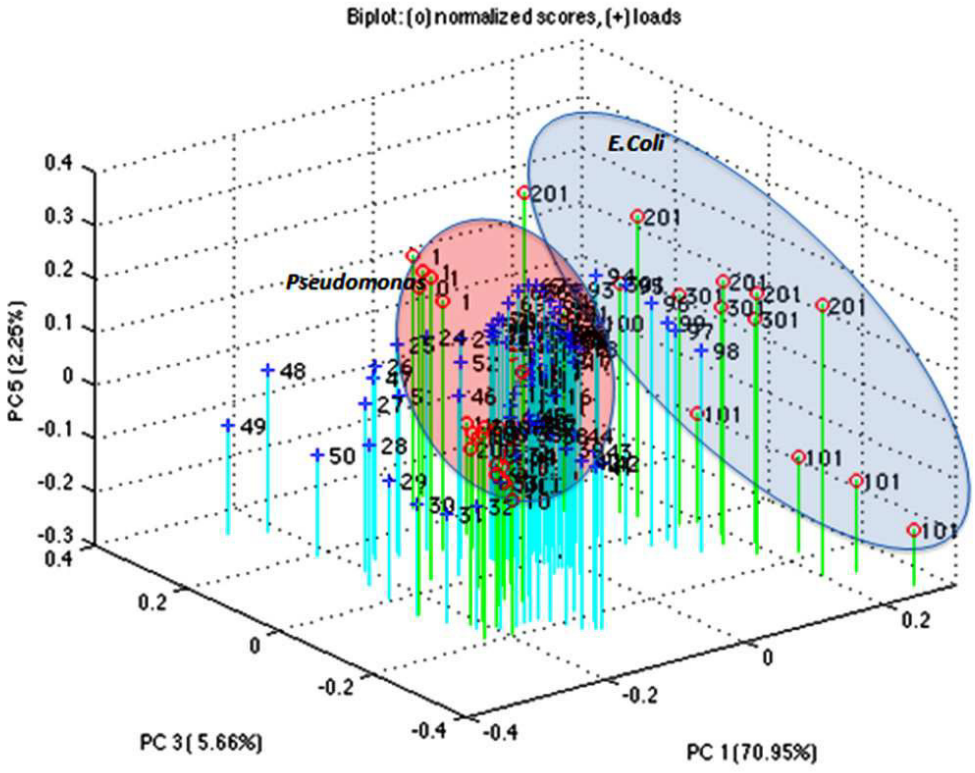

Fig. 2. Scores plot obtained by a Principal Component Analysis. The samples are reported at different concentrations.

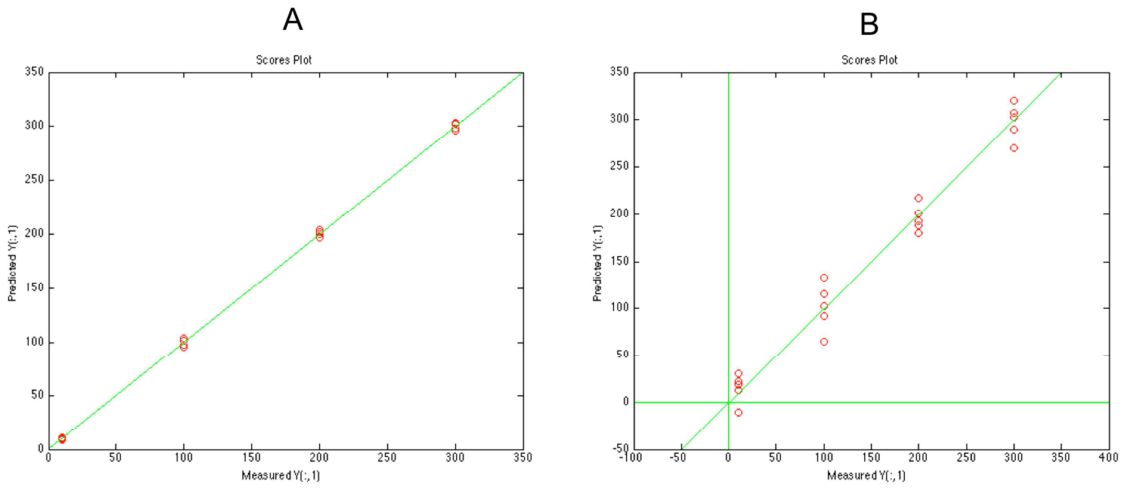

Fig. 3. Predicted model obtained by a PLS-DA model. The device has been calibrated to E.Coli bacteria (A) and to Pseudomonas bacteria (B) at different CFU.

4. Conclusion

The innovative system here proposed for bacteria identification is able to identify two bacteria species in ultra-pure water samples: E.coli and Pseudomonas under a threshold of 50 CFU and 100 CFU respectively. It is fast, low-cost and it does not need any functionalization, which addresses this method to a broad variety of other bacteria. It can be applied online and it is suitable for haemodialisys applications.

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