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Study on Microfluidic Paper-based Analytical Device layouts for simultaneous analysis purposes applying colorimetric reactions

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Abstract
In this project, the adequacy of different layouts for Paper-based Analytical Device (µPAD) for simultaneous analysis in mixtures was evaluated through the use of colorimetric reactions in their reactional zones. Hence, the following parameters of the µPAD were varied: width of the hydrophobic barrier, width and length of the hydrophylic channel, shape and dimensions of the reactional zones, and geometry of the device. The analytical system used in this research was based in comercial tests for domestic quality control of pool water with pH measure through Phenol Red deprotonation, and free chlorine determination through o-Toluidine oxidation.

Key words:
microfluidic, simultaneous analysis, colorimetric measures

Introduction

Microfluidics refers to the manipulation of fluids in the scale of micro to nano liters with analytical applications in a series of fields like clinical diagnostics[1] and environmental monitoring[2]. Several types of reactions can be applied in this kind of system to generate an analytical signal that can be correlated to an analyte concentration. A large range of reactional supports may also be utilized in this context, being the paper-based ones called µPAD (Microfluidic Paper-based Analytical Device). In this project, the variation of some parameters in µPADs (width of the hydrophobic barrier, width and length of the hydrophilic channel, shape and dimensions of the reactional zones, and geometry of the device) was studied in order to provide adequacy and better performance in simultaneous analysis through the use of colorimetric reactions commonly present in domestic quality control of pool water and visual comparisons with commercial kit results.

Results and Discussion

The three layout geometries for the µPAD that were used in this study were elaborated using the software CorelDraw CorelDRAW X6®, (Image 1). The µPAD were produced according to the procedures established by Favero (2016)[3] e Ferreira (2016)[4], staying in the oven for an adjusted time of 180 s.

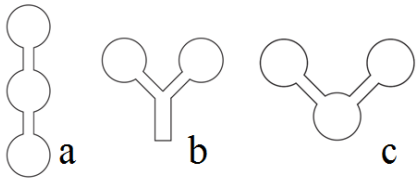

Image 1. µPAD layouts with a) linear; b) Y-shaped and c) V-shaped geometry

The colorimetric reactions applied in this research were: the deprotonation of Phenol Red for pH determination (yellow to pink transition with increasing pH), and the oxidation o-Toluidine due to free chlorine (forming a yellow product).
The best geometry found for the simultaneous determination of the two selected analytes was the linear one, which generated a more homogeneous colored spot using a smaller sample volume and with the least risk of cross contamination due to having the biggest distance between the reactional zones. The smallest width for the hydrophobic barrier found was of 0.2 mm; being a circle of 8.25 mm diameter was the best shape for the reactional zones, with hydrophilic channels of 2.0 x (4.12 to 8.25) mm giving the best results (Image 2). The dynamic range of the analytes detection was established through visual comparisons between the color observed in the paper-based device and the ones present in the commercial kit that correlated to the concentration of each analyte.

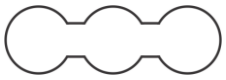

Image 2. Most adequate µPAD layout found for simultaneous analysis with linear geometry 8.25 mm diameter circular reactional zones and 2.0 x 4.12 mm hydrophilic channels

Conclusions

It was determined that the most adequate geometry for the µPAD layout for simultaneous analysis was the linear one. The tested concentration ranges for pH and free chlorine were chosen according to the acceptable values to be present in pool water: for pH the ideal value was of 7, and the tested range was from 3 to 10; for free chlorine the ideal range was from 1 to 4 ppm, and the tested range was from 1 to 10 ppm. An alternative reagent for free chlorine determination was also tested, N-N-diethyl-1 4-phenylenediamine (DPD), which formed a red product when oxidized but its color scale did not match the lowest concentration intended: 10 ppm and thus was not fit for this study.

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