PORTABLE AUTOMATED OSMOLALITY AND pH ADJUSTING APPARATUS FOR PRETREATMENT OF ENVIRONMENTAL WATER SAMPLES DELIVERED INTO A CELL-BASED BIOSENSOR

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ABSTRACT

Using our portable in-line fluidic pretreatment apparatus we have adjusted the osmolality and pH of Swiss river samples automatically without any dilution or degradation of the samples. The samples will be tested by means of a cell-based water quality biosensor for detection of toxins. For cell-based biosensors, the osmolality and pH of the sample are critical parameters that must be precisely controlled to prevent cell lysis. Using forward osmosis (FO), we developed a device for a low-cost adjustment of these parameters to the standard values of a cell-culture medium (pH: 8.5, Osmolality: 330 ±10 mmol/kg).

KEYWORDS

Sample preparation, Osmolality, pH, Environmental water, Cell-based biosensor

INTRODUCTION

Conventional methods for pre-adjustment of sample osmolality and pH require complex procedures and expensive devices [1]. These methods mostly affect sample components or cause unwanted sample dilution upon adding dissolved substances like buffers, cell nutrients, etc. To avoid these drawbacks, we developed a fully automated apparatus that works in two steps: firstly, the river sample is mixed with a concentrated cell-culture medium to add all the necessary ions and molecules to the sample; and secondly, the excess water added in the first step is selectively removed using FO with a high osmolality draw solution.

EXPERIMENTAL

The apparatus prototype and its schematic design are shown in Figure 1.a and 1.b respectively. The sample is mixed with a concentrated standard cell-culture medium, and accumulated in the feed reservoir. The heart of the apparatus is the osmotic chamber where the FO takes place (Figure 1.c). We presented an earlier version of this chamber suitable for submicroliter samples fabricated by rapid prototyping elsewhere [2]. The chamber contains two identical fluidic channels separated by an osmotic membrane. The membrane was provided by Hydration Technology Innovations, and it is shown in Figure 1.d. The mixture is the feed solution which is pumped into the osmotic chamber. It flows along one side of the membrane, and is redirected back into the reservoir. On the other side of the membrane, the draw solution ($MgCl_2$, 1 molar) is replenished continuously. A microprocessor regulates the pumps and the valves precisely according to the data received from the capacitive liquid level sensor (CLS) attached to the reservoir. Due to the osmotic pressure water diffuses through the membrane towards the draw solution. When the feed solution volume equals the initial sample volume, the excess water is completely transferred to the draw solution, and the pretreatment is finished.

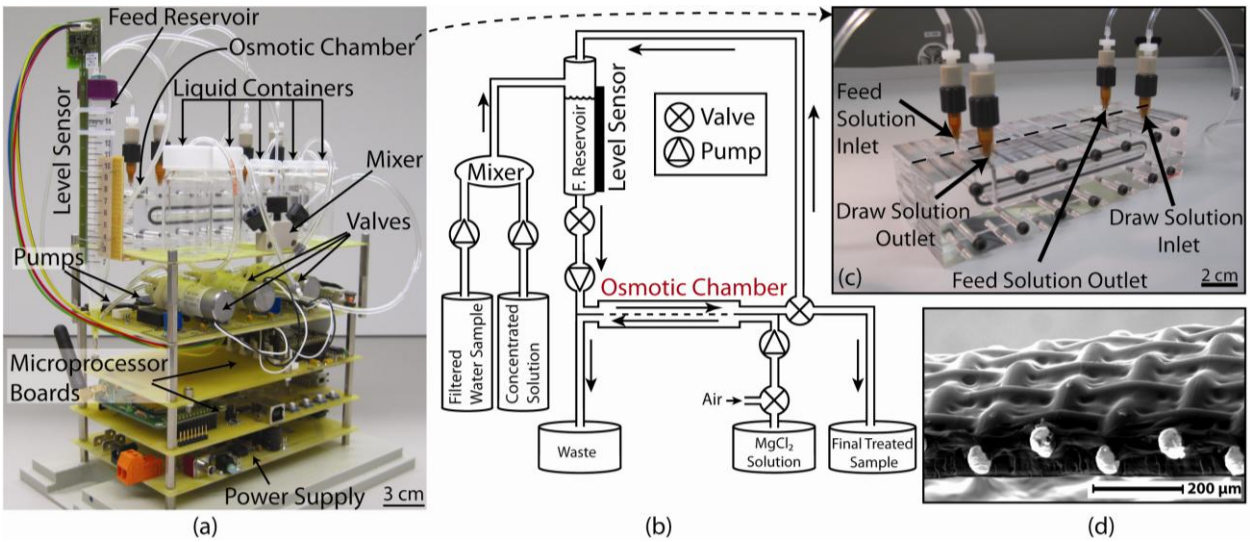

Figure 1. a. Photo of the apparatus prototype with an integrated microprocessor controlling 4 pumps, 2 valves and a CLS. b. Schematic design shows the connections between different parts of the apparatus. c. Osmotic chamber fabricated in PMMA. d. SEM image of the osmotic membrane

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RESULTS AND DISCUSSIONS

Flow-rate and temperature are two of the most important factors influencing the water flux in FO [3]. In the presented osmotic chamber, over time, the solutes can accumulate at the feed side of the membrane while a thin diluted layer of the draw solution can be formed at the draw side of the membrane due to the water transport. This phenomenon that reduces the osmotic pressure across the membrane is called concentration polarization, and it reduces the flux [4]. Increasing the flow-rate of the feed and the draw solutions can minimize this effect and also the membrane fouling [3]. In order to investigate the minimum flow-rate for the highest water flux in this system, both feed and draw solutions were pumped at equal but successively increasing flow-rates. The feed solution was a glucose solution (230 mmol/kg), and the draw solution was an $MgCl_2$ solution (3600 mmol/kg). According to the results shown in Figure 2.a. the highest water flux was at 400 µl/min.

Increasing the temperature can also increase the water flux [5]. The impact of temperature on the water flux is shown in Figure 2.b. In this experiment the feed solution was a standard cell-culture medium with osmolality of 330 mmol/kg and the draw solution was an $MgCl_2$ solution with an osmolality of 3500 mmol/kg. It was observed that by increasing the temperature from 25 °C to 37 °C, the water flux was increased by 2.9% per degree Celsius.

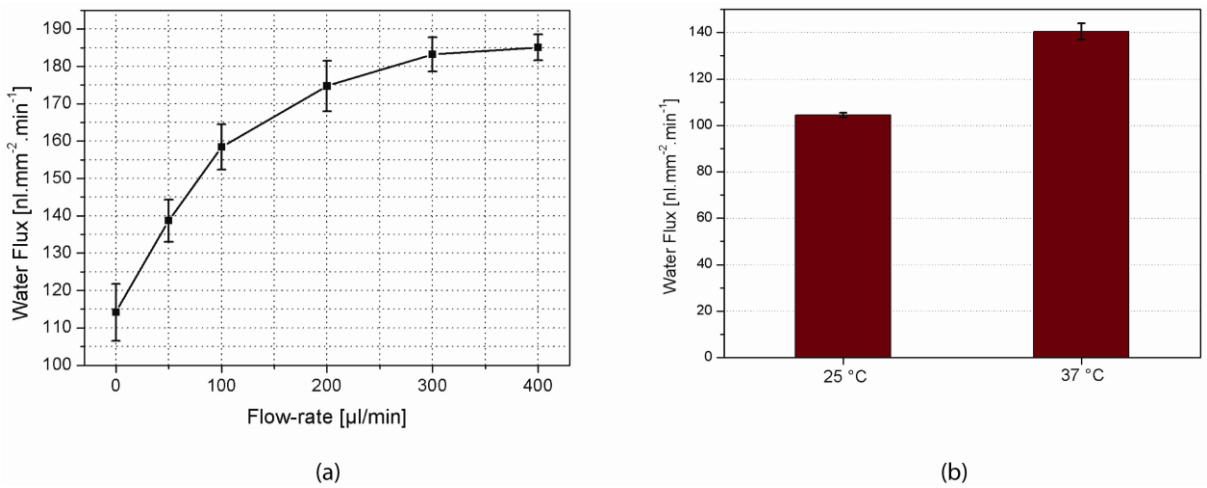

Figure 2. Effect of flow-rate and temperature on the water flux. a. By increasing the flow-rate of the feed and draw solutions, the water flux was increased gradually. b. Increasing the temperature from 25 °C to 37 °C raised the water flux by 2.9% per °C.

Figure 3 demonstrates the osmolality and pH fluctuations of samples monitored over time. The experiment was performed at room temperature (25 °C), and both feed and draw solutions were applied at the flow-rate of 400 µl/min. The feed solution was a 4 ml water sample mixed with 2 ml of a double concentrated cell-culture medium, and the draw solution was a 1 molar $MgCl_2$ solution. Due to the buffering substances in the concentrated cell-culture medium mixed with the sample, the pH remained steady. However, the osmolality of the feed solution was elevated by gradual transfer of water from the feed solution towards the draw solution. After almost 30 minutes, the osmolality of the sample was increased from 220 mmol/kg to the standard value of 330 mmol/kg.

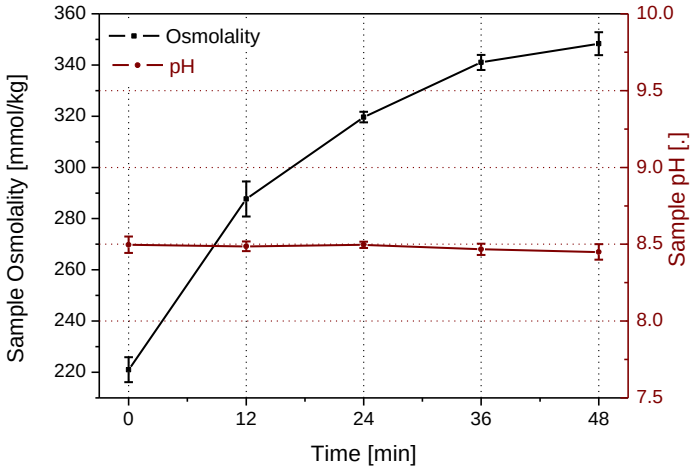

Figure 3. Changes in the osmolality and pH of the samples over time as they flow through the osmotic chamber of the presented apparatus.

Finally, we studied the pretreatment of 4 ml water samples at two different temperatures (Figure 4). As it is shown in Figure 4.a, the final osmolality of the treated samples (twin bars on the right) at both 25 °C and 37 °C was equal to the standard values (the twin bars on the left). The twin bars in the middle correspond to the osmolality of the water samples after being mixed with the double concentrated standard cell-culture medium (660 mmol/kg) in the ratio 2:1. The mixture had an osmolality of almost 220 mmol/kg. Figure 4.b demonstrates that the pH of the final treated samples was almost equal to the pH value of the standard cell-culture medium at the both temperatures.

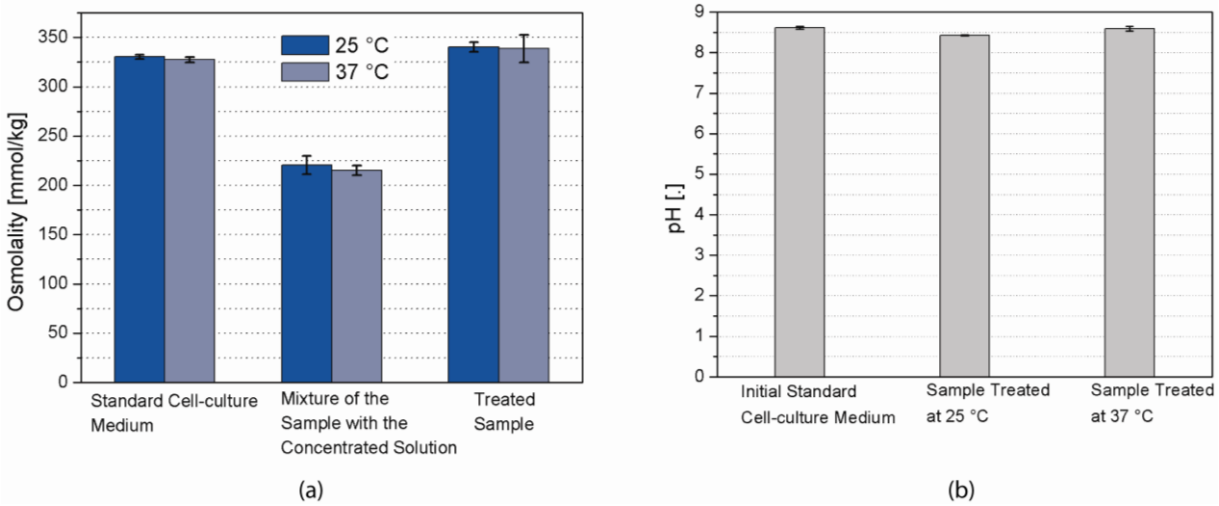

Figure 4. Osmolality and pH adjustment at 25 °C and 37 °C. The flow-rate of both feed and draw solutions was 400 µl/min. a. The final osmolality of the treated samples is equal to the standard value. b. The pH of the treated samples at both temperatures was equal to the pH of the standard cell-culture medium.

CONCLUSION

Using our in-line osmolality and pH adjusting apparatus, we could adjust the osmolality and pH of the river water samples to the standard values of a cell-culture medium. The time required for the pretreatment of a 1 ml sample using an unused membrane at 25 °C and 37 °C was 7.5 min and 5.5 min respectively. This pretreatment process neither dilutes the sample components not affects their chemical structures. By adapting some parameters of the process, the apparatus can be used for pre-concentration of the samples as well. Moreover, the apparatus is fully automated, and can be fabricated at very low price.

ACKNOWLEDGEMENTS

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REFERENCES

[1] N. J. Mourlas, K. H. Gilchrist, L. Giovangrandi, N. I. Maluf, G. T. A. Kovacs, *An In-line Osmometer for Application to a Cell-based Biosensor System*, Journal of Sensors and Actuators B, 83, pp. 41-47, (2002).

[2] S. Talaei, P. D. van der Wal, N. F. de Rooij, *Sample Preparation Microfluidic Cartridge for On-line Adjustment of Osmolarity in Miniaturized Cell-based Analysis Systems*, Proc. Pittcon 2011, Atlanta, USA.

[3] B. Jiao, A. Cassano, E. Drioli, *Recent advances on membrane processes for the concentration of fruit juices : a review*, Journal of Food Engineering 63, pp. 303-324, (2004).

[4] T. Y. Cath, A. E. Childress, M. Elimelech, *Forward osmosis: Principles, applications, and recent developments*, Journal of Membrane Science 281, pp. 70-78, (2006).

[5] K. B. Petrotos, P. Quantick, H. Petropakis, *A study of the direct osmosis concentration of tomato juice in tubular membrane – module configuration. I. The effect of certain basic process parameters on the process performance*, Journal of Membrane Science 150, pp. 99-110, (1998).

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