A LOW COST PORTABLE MICROFLUIDIC ELECTROCHEMICAL SENSOR FOR DETECTION OF ARSENIC IN DRINKING WATER
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ABSTRACT
Cheap and portable means of analyzing drinking water is of increasing importance for low-resource settings but also for infield testing in the developed world. The most important compounds tested for include bacterial contaminations, heavy metal ions and hazardous chemicals such as, e.g., biocides. Numerous methods have been described for cheap and fast in-field tests making use of microfluidic technology. In this paper we demonstrate a very cheap, portable and highly sensitive sensor platform based on electrochemical based on differential pulse voltammetry. The sensor is capable of monitoring heavy metal ions in relevant concentration regimes set by the World Health Organization.

KEYWORDS: Electrochemical Sensor, Microfluidics, Drinking Water Analysis

INTRODUCTION
Arsenic is one of the most widely known toxic substances for humans and animals. Even short term exposure to arsenic causes in severe body response and acute symptoms of poisoning [1]. Most incidents of arsenic poisoning have been reported from Southeast Asia, India, Bangladesh, China and South America [2]. However, high concentrations of arsenic in drinking water are also known to occur in the developed world due to high local concentration of soil arsenic that leak into drinking water.

The aim of this study is to develop a low-cost, sensitive and portable sensor system for detection of arsenic in drinking water in low-resource settings. For this we have custom-developed an electrochemical sensor system based on differential pulse voltammetry (DPV). In many cases, DPV is a more sensitive technique compared to, e.g., cyclic voltammetry (CV) which we found not sufficient for detection of arsenics at low concentrations in small sample volumes. In general two relevant species of arsenic must be detected (and preferable discriminated): As(III) and As(V). The World Health Organization (WHO) sets the maximum allowed concentration of total arsenic in drinking water to 0.01 mg/l (10 ppb).

Figure 1: Developed sensor system. a) Different electrode layouts tested. b) Microfluidic flow cell. c) Assembled sensor system (without electronics). d) Custom-developed 4-channel electronics. Data transfer and power supply is provided via USB-interface.
EXPERIMENTAL

The sensor setup is shown in Figure 1. It consists of a microfluidic flow cell made from polydimethylsiloxane (PDMS) and electrodes made of gold on a ceramic substrate ($\text{Al}_2\text{O}_3$) using a maskless projection lithography developed in-house [3]. The system allows multiplexing of up to 4 channels at a time and can be used in conjunction with an external fluidic system (if operated in a lab) or probed simply using a pipette (if operated in-field). For sampling, the sample liquid is blended with sulfuric acid, mixed thoroughly and then probed into the microfluidic channel network. Measurement is performed in an automated fashion using the developed electronic circuit.

[Graphs showing measurement results on As(III) and As(V) obtained with the sensor system using differential pulse voltammetry (DPV).]

RESULTS AND DISCUSSION

The system was found to be sensitive for detection of threshold values of arsenic for both species As(III) and As(V) (see Fig. 2). The most prominent response is found at a potential of about 0.25 V. For As(V) a second peak potential at -0.5 V was found. This peak is not present for As(III) which effectively allows distinguishing both species. A first application of the developed system was performed on a set of commercially available mineral waters. To our own surprise, several of these waters showed significant arsenic concentrations with two waters exceeding the threshold limit stated by the WHO (see Fig. 3). We believe that this setup is a simple and convenient system for in-field testing of drinking water.
Figure 3: Measurement of arsenic concentration on two commercial mineral waters. Baselines were obtained in electrolyte solution, which was then added with about 50 µl of mineral water observing the signal increase. Another 50 µl of a 10 ppb As(III) solution was added in order to allow referencing the signal increase. Concentrations beyond the threshold value set by the WHO were found on both samples.

CONCLUSION

DPV is a suitable method for the cheap in-field detection of heavy metal ions and similar complexes in drinking water. Current research focusses on the development of a fully integrated sample-to-answer system which can be operated and powered via USB and may also be interrogated using a smart phone. We believe that this system will provide easy, flexible and sensitive analysis of drinking water for low-resource settings but also for in-field testing.

REFERENCES


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