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Design Aspects for Developing a Microfluidics Diagnostics Device Used for Low-Cost Water Quality Monitoring

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Abstract : Many devices for real-time monitoring of surface water have been developed in the past few years to provide early warning of pollutions and so to decrease the risk of environmental pollution efficiently. One of the most common methodologies used in the detection system is a colorimetric process, in which a container with fixed volume is filled with target ions and reagents to combine a colorimetric dye. The colorimetric ions can sensitively absorb a specific-wavelength radiation beam, and its absorbance rate is proportional to the concentration of the fully developed product, indicating the concentration of target nutrients in the pre-mixed water samples. In order to achieve precise and rapid detection effect, channels with dimensions in the order of micrometers, i.e., microfluidic systems have been developed and introduced into these diagnostics studies. Microfluidics technology largely reduces the surface to volume ratios and decrease the samples/reagents consumption significantly. However, species transport in such miniaturized channels is limited by the low Reynolds numbers in the regimes. Thus, the flow is extremely laminar state, and diffusion is the dominant mass transport process all over the regimes of the microfluidic channels. The objective of this present work has been to analyse the mixing effect and chemistry kinetics in a stop-flow microfluidic device measuring Nitride concentrations in fresh water samples. In order to improve the temporal resolution of the Nitride microfluidic sensor, we have used computational fluid dynamics to investigate the influence that the effectiveness of the mixing process between the sample and reagent within a microfluidic device exerts on the time to completion of the resulting chemical reaction. This computational approach has been complemented by physical experiments. The kinetics of the Griess reaction involving the conversion of sulphanilic acid to a diazonium salt by reaction with nitrite in acidic solution is set in the Laminar Finite-rate chemical reaction in the model. Initially, a methodology was developed to assess the degree of mixing of the sample and reagent within the device. This enabled different designs of the mixing channel to be compared, such as straight, square wave and serpentine geometries. Thereafter, the time to completion of the Griess reaction within a straight mixing channel device was modeled and the reaction time validated with experimental data. Further simulations have been done to compare the reaction time to effective mixing within straight, square wave and serpentine geometries. Results show that square wave channels can significantly improve the mixing effect and provides a low standard deviations of the concentrations of nitride and reagent, while for straight channel microfluidic patterns the corresponding values are 2-3 orders of magnitude greater, and consequently are less efficiently mixed. This has allowed us to design novel channel patterns of micro-mixers with more effective mixing that can be used to detect and monitor levels of nutrients present in water samples, in particular, Nitride. Future generations of water quality monitoring and diagnostic devices will easily exploit this technology.

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