Next Generation Autonomous Chemical Sensors for Environmental Monitoring

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In a world where there is increasing demand for environmental monitoring, driven largely by European legislation, monitoring of remote locations has proven to be a major challenge.

Microfluidic technology has great potential as a solution to this problem as it allows minimization of reagents, standards, power consumption, and enables the development of compact autonomous instruments which can perform in situ monitoring of remote locations over long deployable lifetimes.

The objective of this research is to produce next generation autonomous chemical sensing platforms with a price capability that creates a significant impact on the existing market.

The projects begins with deployments of the existing phosphate platform in order to develop familiarity with all aspects of the analytical platform. Following this, the focus will be on developing a detection platform for ammonium, nitrate and nitrite in water and wastewater. The final task will be to integrate biomimetic actuators on the microfluidic platform.

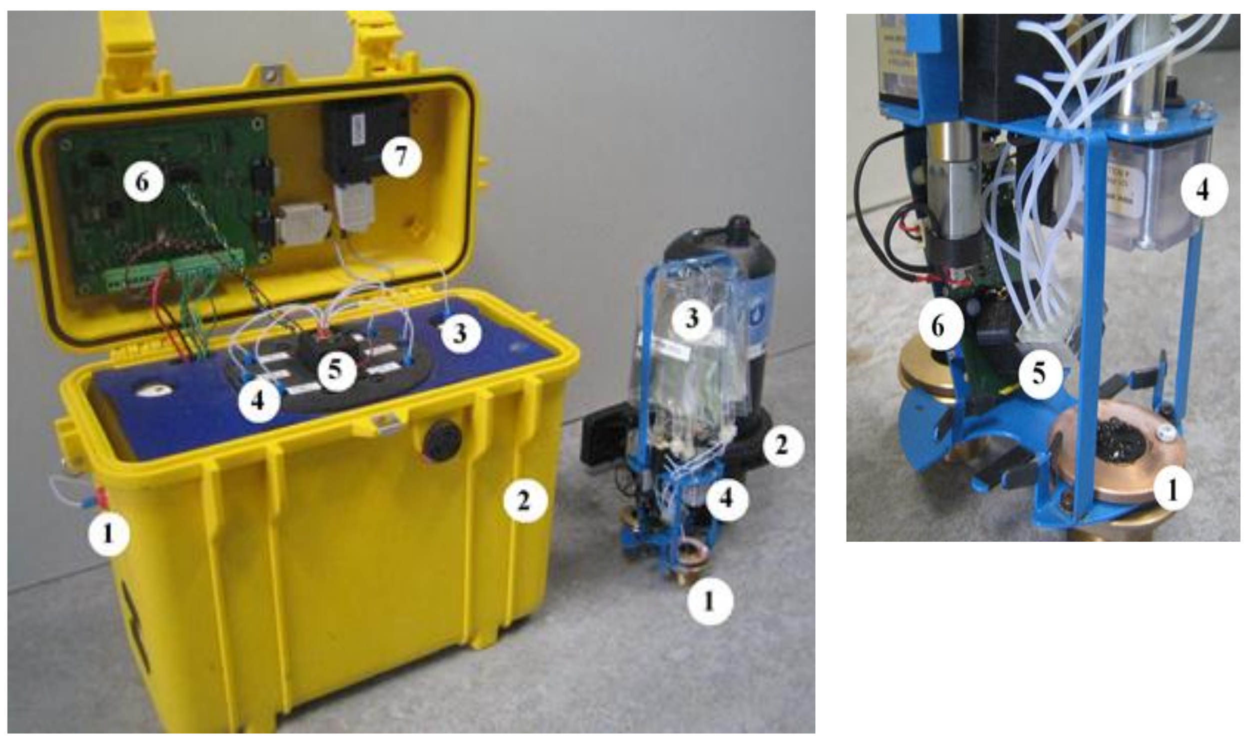

Fig 1: First and second generation phosphate systems. (1) Sample inlet; (2) IP68 Enclosure; (3) Reagent storage; (4) Pumps; (5) Microfluidic detection system; (6) Control board; (7) Communications.

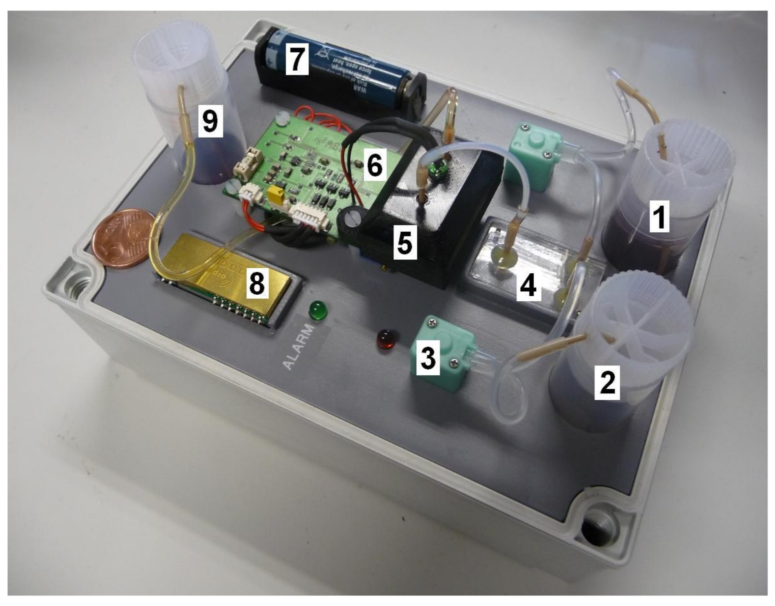

Fig 2: Benchtop nitrite detection system.
(1) Reagent storage (2) Sample storage (3) Micro-pump (4) Mixing chip (5) Detector (6) Control board (7) Battery (8) Easy-Radio (9) Waste storage.

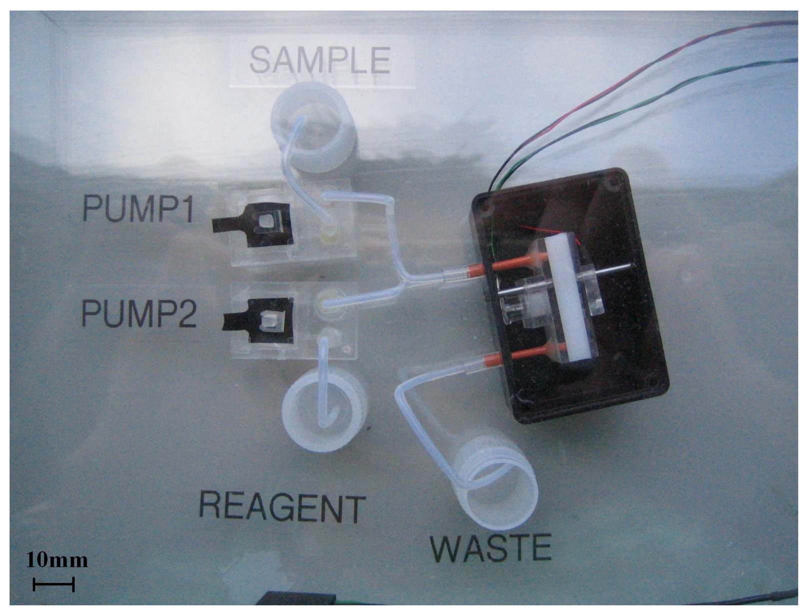

Fig 3: Prototype for next generation micro analyser platform.
Micropumps based on electro-responsive polymer actuators are used to deliver sample and reagent to the LED and photodiode based optical detector.

Nitrite Analyser Based on Griess Reagent

Testing of the nitrite reagent chemistry and detection system has been carried out using the prototype set up shown in Fig. 2. With two micro pumps delivering nitrite sample and Griess reagent through a mixing chip and hence through a detector chip where the LED and photodiode take an absorbance reading after 2 minutes.

The absorbance is proportional to nitrite concentration in the original sample. Using standards of 0.0 – 1.8 mg/L nitrite, the results are shown below in Fig. 5. The reaction time used was 2 minutes. The error bars represent ± one standard deviation with n = 5 at each concentration. Based on this data, the detection limit of the system was determined to be approximately 0.003 mg/L.

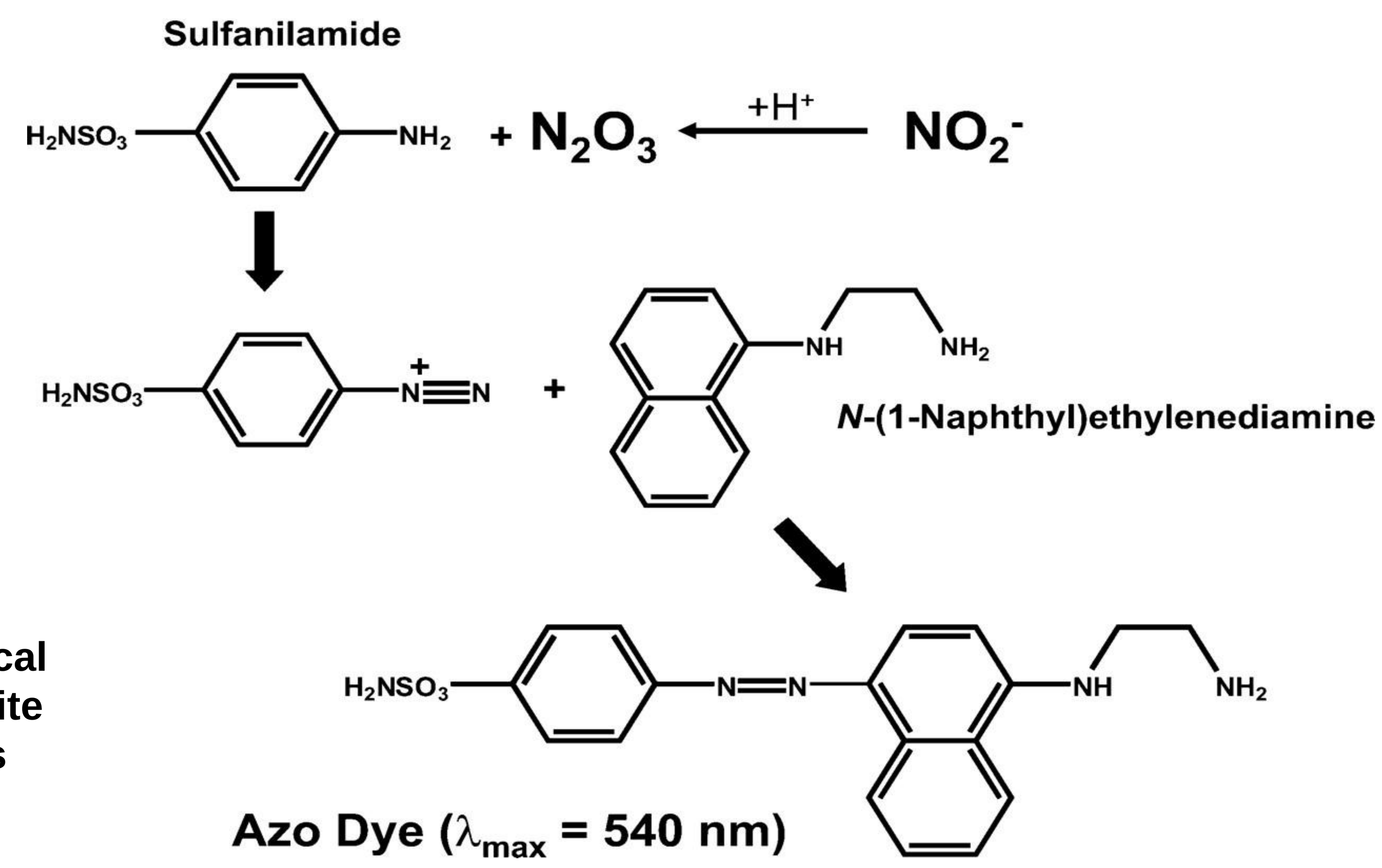

Fig 4: Reaction scheme for optical detection of nitrite using the Griess reaction.

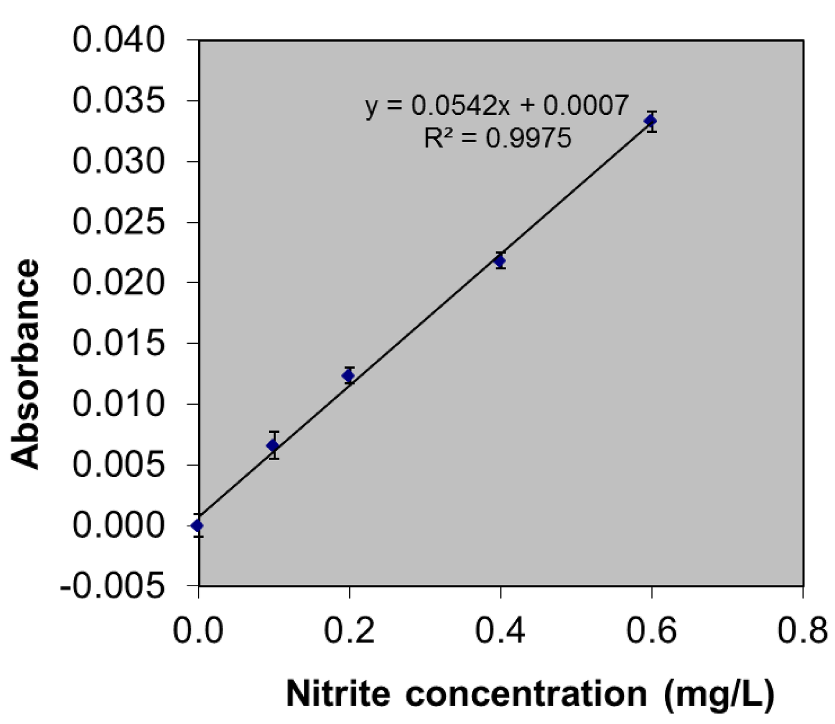

Fig 5: Absorbance of a series of nitrite solutions measured using the nitrite detection system.

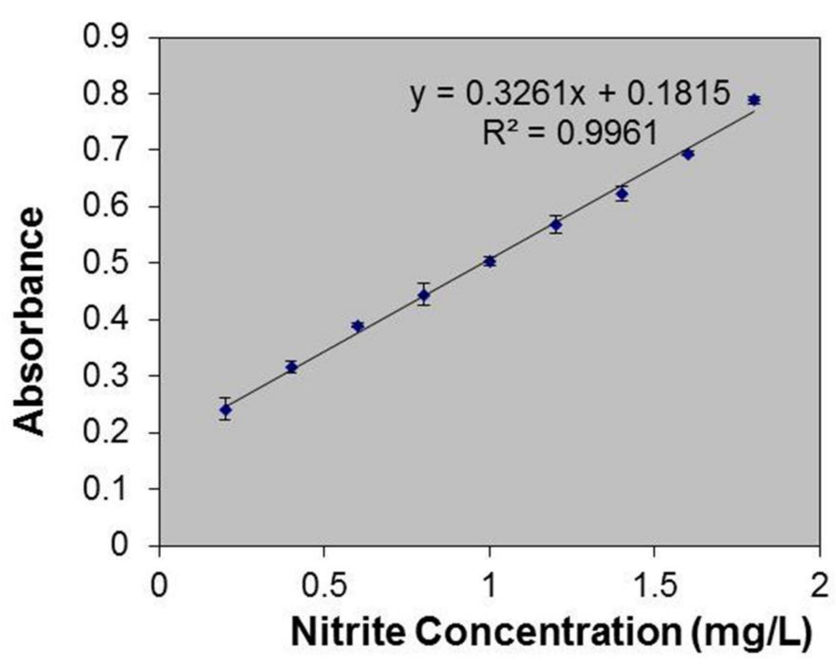

Fig 6: Absorbance of a series of nitrite solutions as measured using UV/Vis spectrometry.

Fig 7: Cuvettes showing the change in colour intensity of 0.2 - 1.8 mg/L nitrite samples with Griess reagent that were measured with UV/Vis spectrometry shown in Fig. 6.

Further Development: Nitrate/Nitrite Reduction

Following on from the excellent promise of the prototype platform, a reduction column can be introduced to enable sample nitrate to be reduced in-line to nitrite. Switching the sample line alternatively from a direct channel to the Griess reagent and detector, to a channel bringing the sample through the reduction column to the reagent and the detector enables sample nitrate to be estimated.

$$NO_3^- + Cd + 2H^+ \rightarrow NO_2^- + Cd^{2+} + H_2O + e^-$$

1. NO_2^- + (Griess) → Azo Colour Dye
2. $NO_3^{-*} \rightarrow NO_2^{-*}$
3. $(NO_2^{-*} + NO_2^-)$ + (Griess)
4. Steps 3-1 → $NO_2^{-*} = NO_3^-$

Fig. 8. Reaction scheme for conversion of nitrate to nitrite using a cadmium column.

The Nitrate (NO_3^-) is first reduced to nitrite (NO_2^-) and then total NO_2^- (converted NO_3^- plus NO_2^-) can be detected via colorimetric Griess reaction as seen in the prototype nitrite analyser.

Acknowledgements

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