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# **An Electrochemical Impedance Spectroscopy Based Nitrate Sensor for Practical Application**

A Project Report Submitted in Partial

Fulfillment of the Requirements

For the Degree of

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By

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## Abstract

Water contamination not only affects human health, but can also damage the ecological system and the natural environment. Agriculture is the backbone of New Zealand's economy, however the sector has been identified as a primary source of nitrate contamination in many waterways. Therefore, monitoring of water quality in agricultural areas is paramount. The contemporary measurement methodologies applied for contaminant quantification are expensive, laboratory-based and time-consuming so the development of a low-cost, convenient sensing system is required. An electrochemical impedance spectroscopy based nitrate sensing system has been developed for nitrate detection. The system is designed to measure the nitrate concentration in water is stand-alone, robust, real-time and low-cost. The microcontroller in the designed system was used to generate the excitation signal applied to the sensor; for data processing and controlling time interval for the switch on/off the automatic sample-intake pump. The data in the microcontroller is transmitted to a computer for data storage and calculation via wireless communication. As the sensor geometry used in the project is the interdigital type which is very sensitive to the temperature, therefore, the sensor was initially tested in the deionized water at variable temperatures. From the result of testing in various temperature ranges, the temperature correction factor was obtained for nitrate measurement. The calibration samples were prepared by the serial dilution of a nitrate stock solution using sodium nitrate ( $\text{NaNO}_3$ ) and ammonium nitrate ( $\text{NH}_4\text{NO}_3$ ) with different concentrations. The sensor was immersed in the solution to observe the impedance change at various nitrate concentrations. The experimental result showed a good linear relationship between the concentration and real part of the measured impedance and the computational model for nitrate concentration was predicted based on the experimental results achieved. The sensor was also tested in the water samples collected from different local agricultural streams, and the results were validated with the applied laboratory testing results using contemporary techniques. The experimental results showed that the sensing system is more sensitive to the lower nitrate concentrations in the surface water. The system was prototyped and applied in the field. The real-time low-cost testing system displayed its potential for the in-situ continuous nitrate monitoring in the paddocks.

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## Research Output

### Conference Proceedings

1. **L. Xie**, Zia A., Mukhopadhyay S.C, Burkitt L, “Electrochemical Impedimetric Sensing of Nitrate Contamination in Water”, Proceedings of the 9th International Conference on Sensing Technology, December 8-10, 2015, Auckland, New Zealand, pp. 257-262.
2. Zia A., Afsarimanesh N., **L. Xie**, Nag A., Al-Bahadly I.H, P.L. Yu, “ Improved Detection Limits for Phthalates by Selective Solid-phase Micro-extraction”, Proceedings of the 9th International Conference on Sensing Technology, December 8-10, 2015, Auckland, New Zealand, pp. 733-738
3. **L. Xie**, Zia A., Alahi M.E.E, Mukhopadhyay S.C, Burkitt L, “Practical Nitrate Sensor Based on Electrochemical Impedance Measurement”, Proceedings of 2016 IEEE International Instrumentation and Measurement Technology Conference, May 23-26, 2016, Taipei, Taiwan.

### Journal Publications:

1. S. Mukhopadhyay, A. Nag, A. Zia, **X. Li**, and J. Kosel, "Novel sensing approach for LPG leakage detection: Part I: Operating Mechanism and Preliminary Results", **IEEE Sensor Journal. (Accepted)**.
2. S. Mukhopadhyay, A. Nag, A. Zia, **X. Li**, and J. Kosel, "Novel sensing approach for LPG leakage detection: Part II: Effects of particle size, composition and coating layer thickness", **IEEE Sensor Journal. (Accepted)**.

### Conference Attendance:

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### Conference Presentation

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