

ABSTRACT

Nitrate efflux from agricultural lands in the Midwestern United States mixes with surface streams and creates hypoxic conditions in the Gulf of Mexico, which lead to destruction of aquatic ecosystems. Besides, excess nitrate in drinking water poses a serious threat to human health, including blue baby syndrome, birth defects, and cancer. The current nitrate management techniques are inefficient and expensive, and a major reason for this is the lack of low-cost, effective ionic concentration monitoring systems. The dependence of nitrate concentration on local hydrology means that laboratory techniques yield incomplete data, whereas the available real-time monitoring techniques have drawbacks like exorbitant cost, ion selectivity issues, and others. This research aims to bridge the gap between reliable concentration monitoring and economic feasibility by developing a low-cost, effective, real time ion monitoring system which is field deployable and sensitive to changes in ionic concentration at agriculturally-relevant levels.

In this work, a resonant sensor is designed using an open-ended coaxial transmission line which can be evanescently perturbed by a liquid sample and shows a shift in its resonant frequency on change of ionic concentration of the sample. The dimensions of the coaxial resonator are optimized to ensure high sensitivity to changes in the ionic concentration of the sample at relevant concentrations, low manufacturing costs, and small physical dimensions to enable field deployment. The resonant sensor design is followed by the design and optimization of a suitable coupling structure which can take two-port transmission measurements to measure the characteristics of the resonator.

Finite Element Analysis (FEA) simulations are carried out using ANSYS HFSS, using as input data the complex permittivity of aqueous solution samples with varying concentrations

of nitrate, sulfate, and chloride ions. Deionized water is taken as a reference sample, and a clear correlation between shift in resonant frequency and ionic concentration is observed for each of the three resonant modes studied, with the sensor being highly sensitive to concentration changes at agriculturally relevant concentrations. Appropriate fitting functions are implemented to represent the correlations between resonant frequency and ion concentration, and discussion on the feasibility of the designed sensor for field deployment is presented.