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Low-Cost, Portable Optical Sensor with Regression Algorithm Models for Accurate Monitoring of Nitrites in Environments

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Abstract : Nitrites enter waterways as runoff from croplands and are discharged from many industrial sites. Excessive nitrite inputs to water bodies lead to eutrophication. On-site rapid detection of nitrite is of increasing interest for managing fertilizer application and monitoring water source quality. Existing methods for detecting nitrites use spectrophotometry, ion chromatography, electrochemical sensors, ion-selective electrodes, chemiluminescence, and colorimetric methods. However, these methods either suffer from high cost or provide low measurement accuracy due to their poor selectivity to nitrites. Therefore, it is desired to develop an accurate and economical method to monitor nitrites in environments. We report a low-cost optical sensor, in conjunction with a machine learning (ML) approach to enable high-accuracy detection of nitrites in water sources. The sensor works under the principle of measuring molecular absorptions of nitrites at three narrowband wavelengths (295 nm, 310 nm, and 357 nm) in the ultraviolet (UV) region. These wavelengths are chosen because they have relatively high sensitivity to nitrites; low-cost light-emitting devices (LEDs) and photodetectors are also available at these wavelengths. A regression model is built, trained, and utilized to minimize cross-sensitivities of these wavelengths to the same analyte, thus achieving precise and reliable measurements with various interference ions. The measured absorbance data is input to the trained model that can provide nitrite concentration prediction for the sample. The sensor is built with i) a miniature quartz cuvette as the test cell that contains a liquid sample under test, ii) three low-cost UV LEDs placed on one side of the cell as light sources, with each LED providing a narrowband light, and iii) a photodetector with a built-in amplifier and an analog-to-digital converter placed on the other side of the test cell to measure the power of transmitted light. This simple optical design allows measuring the absorbance data of the sample at the three wavelengths. To train the regression model, absorbances of nitrite ions and their combination with various interference ions are first obtained at the three UV wavelengths using a conventional spectrophotometer. Then, the spectrophotometric data are inputs to different regression algorithm models for training and evaluating high-accuracy nitrite concentration prediction. Our experimental results show that the proposed approach enables instantaneous nitrite detection within several seconds. The sensor hardware costs about one hundred dollars, which is much cheaper than a commercial spectrophotometer. The ML algorithm helps to reduce the average relative errors to below 3.5% over a concentration range from 0.1 ppm to 100 ppm of nitrites. The sensor has been validated to measure nitrites at three sites in Ames, Iowa, USA. This work demonstrates an economical and effective approach to the rapid, reagent-free determination of nitrites with high accuracy. The integration of the low-cost optical sensor and ML data processing can find a wide range of applications in environmental monitoring and management.

Keywords : optical sensor, regression model, nitrites, water quality
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