DEVELOPMENT OF A LOW-COST SMARTPHONE-INTEGRATED PORTABLE IMAGING DEVICE FOR THE DETERMINATION OF NITRATE AND PHOSPHATE IN SOIL AND WATER

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ABSTRACT

This research presents a smartphone-integrated imaging device to detect phosphate (PO_4^{3-}) and nitrate (NO_3^-) in soil and water samples for agricultural input management and environmental pollution monitoring. This low-cost and field-deployable device uses a smartphone with a camera to take a color photograph of the solution under test. The sensing principle is based on the standard colorimetric phenoldisulfonic acid, Chromotropic acid, and ascorbic acid methods for NO_3^- and PO_4^{3-} in soil and water samples, respectively. A 3D printed device that houses the optical components is coupled to the phone's built-in rear camera and turned into a compact handheld system. An android application, 'SMART NP,' is also developed to quantify the concentrations of NO_3^- and PO_4^{3-} in soil and water samples using the Value (V) component of the HSV color space model. The results obtained with the proposed device were comparable to laboratory-grade spectrophotometer data. The limit of detection of the device for NO_3^- in soil, NO_3^- in water, PO_4^{3-} in soil, and PO_4^{3-} in water were calculated as 0.1 mg L^{-1}, 0.07 mg L^{-1}, 0.001 mg L^{-1}, and 0.02 mg L^{-1}, respectively, with good accuracy (≤1% bias) and precision (~2% residual standard deviation). The device exhibited a sensitivity of 0.17 mg L^{-1}, 0.12 mg L^{-1}, 0.026 mg L^{-1}, and 0.49 mg L^{-1} for NO_3^- in soil, NO_3^- in water, PO_4^{3-} in soil, and PO_4^{3-} in water, respectively. Using the Chromotropic acid method, the limit of detection was calculated as 0.1 mg L^{-1} with a sensitivity of 0.26 mg L^{-1}. The device showed a bias of 0.9% and a precision of 1.95%, indicating its reliability. Additionally, the device-predicted soil NO_3^- data, combined with kriging interpolation, showcased spatial variability in soil NO_3^- levels at the regional level, and the device was also used for estimating soil available P and applying DSM techniques to create high-resolution soil available P maps. Overall, this sensing device has the potential to assist farmers or scientists in easily measuring NO_3^- and PO_4^{3-} concentrations in soil and water media, without the need for laboratory equipment.

Keywords: soil; water; nitrate; phosphate; smartphone, imaging device; HSV; kriging; DSM