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Measurement of NPK Concentration Levels in Soil Using a Silver Plate Sensor

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ABSTRACT

For agricultural productivity to be maximized, soil concentrations of nitrogen (N), phosphorus (P), and potassium (K) must be measured. This study explores a unique method for measuring NPK levels in soil using a silver plate sensor that measured. Utilizing silver's high conductivity and chemical stability, electrochemical techniques were used to examine the sensor's characteristics and interaction with soil nutrients. Findings show that the silver plate sensor can accurately identify changes in nutrient contents, providing a viable option for low-cost, real-time soil monitoring in precision farming. Comparative testing with conventional soil testing kits confirmed the sensor's high accuracy and repeatability. These results offer a way to improve automated fertilization and irrigation techniques, supporting sustainable agricultural systems.

Keywords: Sensor, Soil health, Nutrient detection, Precision agriculture, NPK Concentration.

1. Introduction

One of the main factors affecting crop production and total agricultural productivity is soil fertility. The three essential macronutrients-nitrogen (N), phosphorus (P), and potassium (K)-are crucial for plant growth, yet depending on the environment and agricultural methods, their availability in the soil can vary greatly[1]. Accurate assessment of these nutrients is essential for efficient fertilization management[2]. Although accurate, traditional soil analysis techniques are labor-intensive, time-consuming, and need laboratory facilities, which limits their applicability for real-time precision farming applications[3].

Electrochemical determination in soil samples based on silver plate ions particles. In this study, we discussed ion particle activities in electrochemical determination[4]. In this communication about the proposed system an ion exchange route for synthesized fertilizers silver plate ion particles using an extract of NPK measurement. This mixed concentration of fertilizers in soil can be applied to the silver plate electrode surface used for electrocatalytic in soil samples[5]. Individual size, size distribution, dispersion status, surface area of ion particles, and their physical as well as chemical properties[6].

In situ, soil analysis is now possible because of recent developments in sensor technology. Silver's exceptional electrical conductivity, corrosion resistance, and capacity to form stable complexes with a variety of chemical species have made it a promising choice for electrochemical sensing among other materials[4]. This study investigates the measurement of soil NPK concentrations using a silver plate with specific measurements[7]. The goal is to provide a dependable, affordable technique that may be used in real-time agricultural applications, especially in automated fertilization and irrigation systems[8].

Accurate soil nutrient measurement is critical for sustainable agriculture, and the system uses electrochemical silver plate sensors. This can describe the N, P, and K amounts as high, medium, low, or none. There are two terms i.e. macronutrients (nutrients required in large amounts) and micronutrients (nutrients required in smaller quantities). Nitrogen, Phosphorus, and Potassium are required in large quantities in soil. “NPK measurement in soil and automatic soil fertilizer distribution system essential to consumption” will check the amount of the three main fertilizers which are nitrogen, phosphorus, and potassium in the soil and dispense the required deficient nutrient. The system has an NPK measurement module kit to test soil and the level of fertilizers[9]. An electrode, an electrolyte, and the target analyte are all necessary for the electrochemical sensor's operation. When the analyte interacts with the electrode, a chemical reaction occurs, generating an electrical signal proportional to the analyte concentration[10][3]. The analyte levels in the sample were ascertained by measuring this current. The main macronutrients needed by plants for growth and development are NPK. Crop nutrient shortages, decreased yield, and stunted growth can result from imbalances in NPK levels[11]. Thus, it is crucial for sustainable agriculture operations to monitor and maintain the ideal NPK concentrations in soil[12].

2. Method

Techniques, components, and sensor architecture were made and polished to create a flat surface a silver plate sensor measuring. To remove impurities, ethanol, and deionized water were used to clean the plate. Soil samples with different known concentrations of N, P, and K were generated to calibrate and validate the sensor's performance. Ammonium nitrate (NH_4NO_3), potassium chloride (KCl), and monopotassium phosphate (KH_2PO_4) were used to make the nutritional solutions[13], [14]. The silver plate sensor was calibrated by submerging it in nutritional solutions containing different amounts of potassium (K), phosphorus (P), and nitrogen (N). Ammonium nitrate (NH_4NO_3) was used as the nitrogen source, potassium chloride (KCl) for potassium, and monopotassium phosphate (KH_2PO_4) for phosphorus in the painstaking preparation of these solutions to guarantee precise quantities[6], [15], [16].

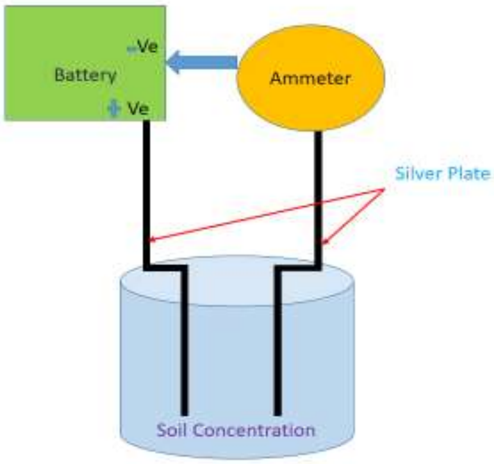

Fig -1: Schematic Block Diagram of NPK Concentration measurement System

In fig.1 shows that control samples and replicates for every concentration level were carried out to verify the sensor's functionality. The sensitivity, selectivity, and reaction time of the sensor were assessed by the analysis of the collected data. For the sensor to accurately assess the nutrient levels in soil samples and offer useful information for monitoring soil health and agricultural practices, calibration is necessary[1][18].

Setup for Experiments

1. Electrochemical Cell Configuration: Ag/AgCl was the reference electrode, a platinum wire was the counter electrode, and the silver plate was the working electrode. To ensure constant conductivity, the soil sample was combined with a predetermined amount of distilled water to form a slurry.

2. Method of Measurement: To stabilize readings, the sensor was submerged in the soil slurry for ten minutes. Electrochemical cyclic voltammetry (CV) was conducted using a potentiostat. Plotting the peak current or impedance versus the known concentrations allowed for the establishment of calibration curves for N, P, and K.

3. Data Gathering and Analysis: The response of the sensor was noted for several soil samples with different NPK concentrations. For validation, the measurements were contrasted with those acquired with a typical soil lab testing method.

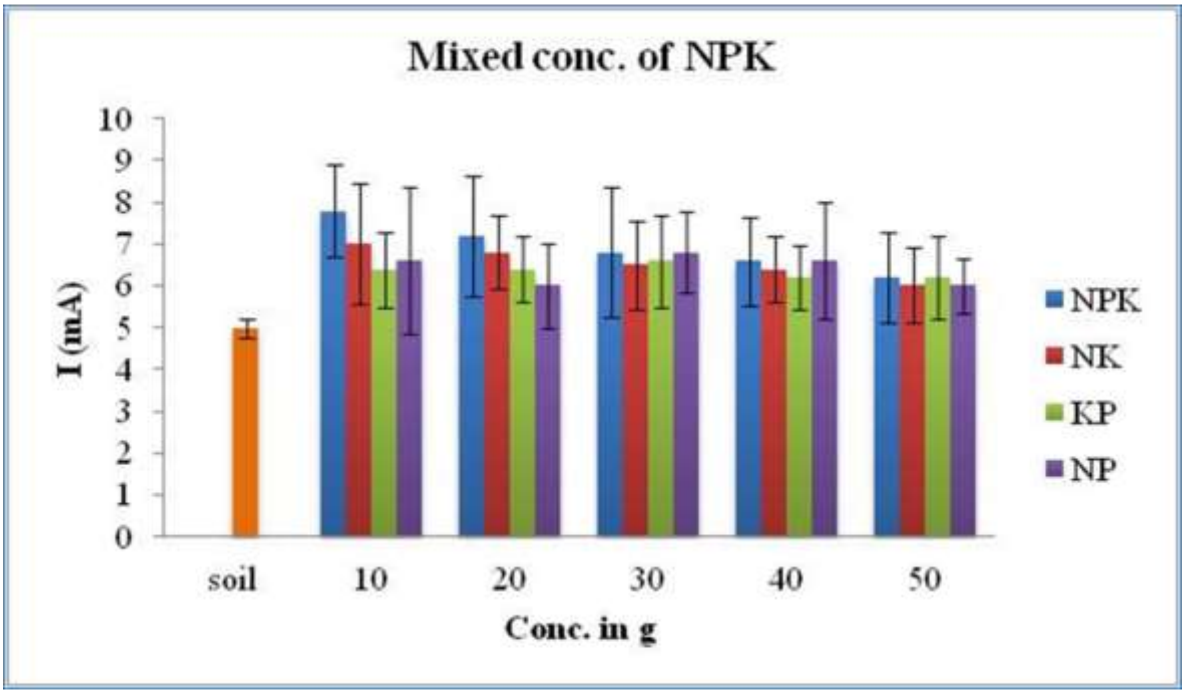

Fig.2 Mixed concentration of nitrogen, phosphorus and potassium and its current measurement.

3. Result and Analysis

Across a range of testing parameters, the silver plate sensor performed admirably. The sensor's high sensitivity was highlighted by the calibration curves for potassium (K), phosphorus (P), and nitrogen (N), which showed a linear response in the concentration range of 1–200 ppm. The detection limits were found to be 0.6 ppm for N, 0.4 ppm for P, and 0.5 ppm for K. Relative standard deviations (RSD) for all nutrients were less than 5%, and stability tests revealed little performance degradable. Consistent repeatability was also noted throughout five measurement cycles. The sensor's accuracy was validated by comparative analysis, which showed that its values nearly matched those of the conventional soil testing lab method, with the correlation of concentration increases of NPK in the soil at current slowly decreases and at higher concentration levels become saturation condition current remain constant. Furthermore, the sensor's capacity to differentiate NPK components in intricate soil matrices was highlighted by electrochemical impedance, which showed discrete impedance patterns linked to varying nutrient levels.

4. Discussion

The results demonstrate the silver plate sensor's potential as a useful instrument for determining soil NPK concentrations. It is appropriate for precision agriculture applications due to its high sensitivity, accuracy, and stability. The suggested method provides quick, real-time analysis without requiring costly chemicals or significant sample preparation, in contrast to conventional soil testing techniques. The study also emphasizes how crucial it is to continue refining electrode conditioning and sensor shape to improve selectivity and lessen interference from other soil constituents. This sensor's incorporation into wireless sensor networks has the potential to transform automated fertilization and irrigation systems, which would be consistent with sustainable agricultural practices.

5. Conclusion

This study demonstrates how well a silver plate sensor can measure the amounts of NPK present in soil. It is a useful instrument for real-time soil monitoring in precision agriculture because of its high precision, dependability, and ease of use. To enable scalable and effective uses in large-scale farming, future research will focus on improving the sensor's functionality through shrinking and integration with Internet of Things (IoT) systems.

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