

Instant Detection of Macronutrients Nitrogen, Phosphorous and Potassium using Analog pH Sensor

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Abstract - The customised sensor-based analysis may provide the precise data quickly rather than mundane and traditional methods, which are generalized and not to the targeted area or specific area. Quickly and accurately soil data can be analysed by the precise agriculture practice through electronic systems rather than traditional geochemical analysis. Also, unsystematic use of fertilizers may lead to ground water pollution, hence nutrients management, balanced plant nutrition, which are ecological alternatives for fertilizers. This research work facilitates the exploration of major macronutrients – Nitrogen (N), Phosphorous (P) and Potassium (K) by the measured value of pH from pH sensor with suitable conversion, signal conditioning and embedded programming. The macronutrients present in soil are displayed on LCD module interfaced with Microchip PIC16F877A microcontroller. Hence, by this method it is possible to measure the concentration of NPK and also this method prevents the overfeeding of nutrients through fertilizers.

keywords - Macronutrients, Detection, Exploration, NPK, pH Sensor

I. INTRODUCTION

Traditional exploration techniques usually rely on extensive geographical field work by ground surveying. However, this approach can be limited by field accessibility, financial status, area size and climate. The smarter agriculture practice can be made by the measurement of major macronutrients such as Nitrogen (N), Phosphorous (P) and Potassium (K) through electronic sensors, and hence the prediction of soil fertility and selection of suitable crop. The macronutrients N, P, K in oxidized forms are present in the ratio of 18:22:26 respectively, where Nitrogen promotes the growth of leaves and regidation, Phosphorous promotes growth of roots and Kalium (Potassium) provides flowing, fruiting and general hardiness [1]. And other minority nutrients are present like Aluminum (Al), Iron (Fe), Copper (Cu), called as micronutrients. Primary nutrient contents of soil are necessary to decide how much additional contents of appropriate nutrients are to be added to improve the quality of soil fertility that is the macronutrients N, P, K present in compost. The various traditional chemical methods can be replaced by the electronic sensors to grow the quality of compost.

Soil is most important medium for plant growth. The nutrients in soil improve the fertility and hence the growth of seeds and crops. In agriculture as well as electronics, several research have been sustaining to improve the practice in agricultural field. But, due to increase in population in India, a major disadvantage requires new methods which will grow the crop plantation management methods in dominant ways without expense [2].

II. OTHER METHODS OF DETECTION

The rise of use of magnetic techniques to characterize iron oxide mineral / nutrient in soil. In this detection has been carried out by the observations of granular soil particles relationally together by sensing the ferromagnetic property of welsh soil granular by Secondary Ferromagnetic Mineral (SFM) method with dependent pre-matured mechanism to explain the observed link between soil magnetism and climate. Since, there is evidence that some soils contain significant number of ultrafine grains that are not detected not detected by low temperature below 20 Kelvin. Hence, the effect of depressing values of low field susceptibility percentage [3].

The portable Raman sensor for soil nutrient detection was provided to obtain significant phosphorous absorption band in soils and thus determines the phosphorous concentration with the use of bulky components – Laser source, Spectrometer, Computer and File storage [4].

Discussion on remote sensing estimation of soil nutrient contents by Hongyan Chen et.al was analyzed the macronutrients N, P & K by the ground method spectrum data in the laboratory by exploration on spectral measurements, interior diameters and surface treatment of soil roughness and Signal to Noise Ratio (SNR) / Spectra these compared with standard spectrum. But there was no image data in this method. The second is multispectral remote sensing allows capture of hyper spectral images, not possible in first method. But, poor resolution of images prone to difficulties in extraction of soil information and spectral reflectance relation, so not suitable for quantitative estimation of nutrients in soil. Also, a lot of statistical data logging is required [5].

For robust, accurate and self-calibrating soil moisture and nutrient sensor with in-built transmission and reception capability is presented on the principle of impedance spectroscopy. The amplitude and phase signals reflected from soil by proximity sensor will analyze the soil with distributed line transmission module on board, which minimizes the errors in measurements. The on-board solution of sensors which can measure local soil conditions like moisture and iron content as well through Medium Access Control (MAC) protocol [6].

Testing the nutrient contents by the sensors, we can help to select the fertilizers to improvise crop growth without going into soil test laboratories, it would take lot of time to analyze instead electronic analysis [7][8].

Mineral identification and mapping using airborne data collection in Alaska, USA and Khandahar, Afghanistan research was proposed by calibration of spectrometer and its data including sensor characterization, channel wavelength position, bandpass, radiometric accuracy and atmospheric collection. But because of design of minerals and their discriminations and separations, spectrometer readings can have variable wavelengths bandpass in across track direction. This hyMap Data is difficult to investigate on steep terrains and high latitudes. Also, it's difficult to get image data from spectrometer atmospherically from surface reflected [9].

Then electrochemical sensors for soil nutrients detection. A system was consisting ion selective membrane and a transducer, which transforms chemical reaction into detectable electrical signals. Two types of sensors – Ion Selective Electrode (ISE) in which the voltage of second electrode is compared with / measured with the reference (first) electrode. Ion Selective Field Effect Transistor (ISFET) chemically modulates the threshold voltage and measured with the related concentration of a targeted ion. But due to ion selective membrane, measurement of one target ion by electrochemical measurement is possible. However, electrochemical sensors may be integrated onto chip to provide feasible approach of multi target simultaneous detection of nutrients in soil [10].

Electrophoresis based microfluidic ion nutrients sensor for detection of anions in soil solution samples, in which the sensor was capable to analyze various anions in extracted soil nutrition with high sensitivity as well as high specificity. The soil nutrient sensor is important for optimizing nutrient management, since the changes in nutrient ion concentrations are vital for providing nutrient-sufficient conditions for maximum plant growth & yield. The principal aim is to design economic affordable sensors for site-specific real-time measurement [11].

Real time monitoring of macronutrients N, P, K by the use of Wireless Sensor Network (WSN) and android phone facilitates the user can view soil fertility at the convenience on his phone through mobile application. Overall system helps farmer to get real time information. The data from sensors is sent to IBM Bluemix Cloud. These values are stored in cloud database which helps to access from anywhere, anytime [12].

Soil macronutrients were detected by using optical sensors containing transmitter and receiver. The soil sample was taken on flat glass plate and transmitters, receivers are placed at opposite ends. The photodiodes at receiver system with signal conditioner responses to remaining light passed through glass plate. Hence detection of nutrients in terms of individual potential differences for N, P, K. This system requires more space as transmitter and receiver are bulky hence will not a portable. Also, the readings / detections may be improved by optical fiber instead Light Emitting Diode (LED) and photodiode [13].

Internet of Things (IoT) can help transforming the agriculture to modern real time cloud-based data helps to optimize resource usage and improved yield size rather than mundane or traditional approximate methods. The sensor subsystem sends the data analytics to information subsystem (cloud) and send further to action subsystem to control the fertility [14].

With the application of Information Technology (IT) and WSN, the term comes named as Precision Agriculture (PA). This system strategy can be adopted to solve precision agricultural problems with different types of crops and agriculture regions as farmers can access valuable information to utilize land efficiently and long-term sustainable farming. Here an artificial neural network and cloud console with the mentioned above is used to analyze the measured data and estimates the levels of Phosphorous (P) in soil [15].

Estimation of Tin and Zinc, micronutrients by using multiple sensors approach in mineral mapping and targeting followed by extensive field work and possible airborne surveying and high-resolution aerial remote sensing data is essential. Hence multiscale remote sensing is particularly beneficial especially in inaccessible and remote areas with little infrastructure. The huge cost, difficult to analyze and characterization at local level and limitations in identifying critical minerals via remote sensing solely by spectral information will restrict the use of this system [16].

Hence, there are various sensors in agriculture such as electrical, electromagnetic, optical, radiometric, mechanical, acoustic, pneumatic and electrochemical. Meanwhile electric and electromagnetic sensors are widely used today, but other types may be suitable to improve the soil relevant information in coming days. Following sensors in Table 1 are preferred in Precision Agriculture (PA) to improve soil fertility [17] –

Table 1 Sensors used for precision agriculture practice

Sr. No.	Sensor Type	Measurement Principle
1	Electrical / Electromagnetic	Resistivity, conductivity, capacitance, inductance
2	Optical and Radiometric	Level of energy absorbed / reflected from particles
3	Mechanical	Resulting force from object
4	Acoustic	Sound produced / reflected from object
5	Pneumatic	Ability to inject air into object
6	Electrochemical	Ion-selective membrane that produce voltage output with chemical reaction

The food yield in global is based on the presence of nutrients. The Phosphorous (P) is an important nutrient due to its low recovery and finite availability. To obtain the good and healthy growth of crop, the average sum of macronutrients N+P+K=2 (N=0.5, P=1.0, K=0.5), however ideal ratio of concentration of NPK is 4:2:1 [18-19].

III. NPK DETECTION USING pH SENSOR METHOD

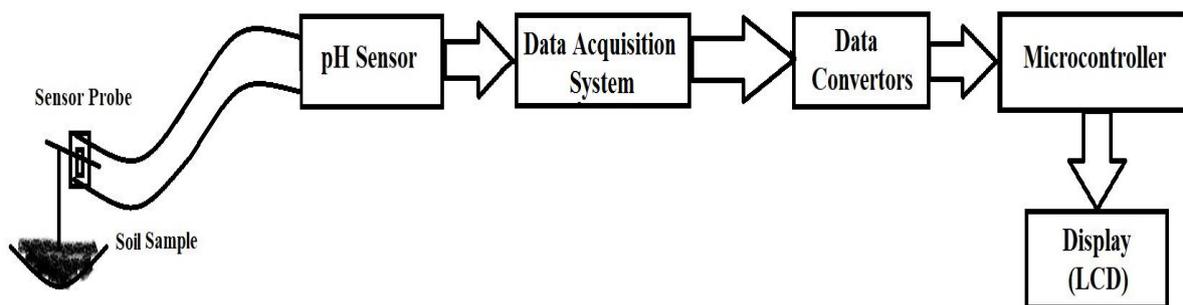
Need of pH sensor

With reference to other methods reviewed above, there are different methods to find the nutrients and their analysis through chemical and electronic cordially. In the developing countries like India, it's quite difficult to carry the soil analysis by the farmers themselves through the web, wireless medium or WSN. Because, still farmers in India are not aware of advanced techniques like networking, cloud, web. It would be good practice to do the instant spot analysis of soil nutrients and deficiencies together in presence of the Kisan (farmer), because a lot of different soil sample testing and their chemical analysis take a lot of time, perhaps number of days to estimate the finalized results in Agricultural Laboratories. Hence, waste of time. In addition to this, unless soil does not absorb the necessary nutrients for growth of plants even if 70 % of fertilizers have no effect on soil, wastage of money. Though geochemical analysis in agricultural laboratories although gives accurate results, but might not be a real time. By use of electronic sensor-based method like the pH sensor, which identifies the pH value of soil nutrients and the corresponding seed solution with the necessary fertilizers to improvise the agro-practice. pH sensor is a type of electrochemical sensor and able to measure the power of Hydrogen in soil probably provides accurate and real time results.

Essential components

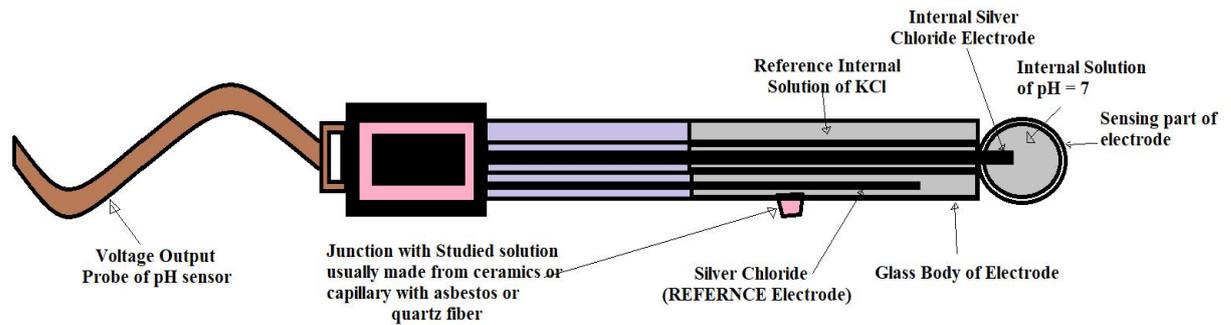
Following components are required at prior to explore NPK concentrations and cascaded in terms of blocks as shown in Figure 1.

Figure 1 System block diagram to explore NPK contents



- **Laboratory analog pH sensor** – Basically used to analyse pH from water, solutions that is alkalinity and basicity.

Figure 2 Laboratory analog pH sensor with sensing probe

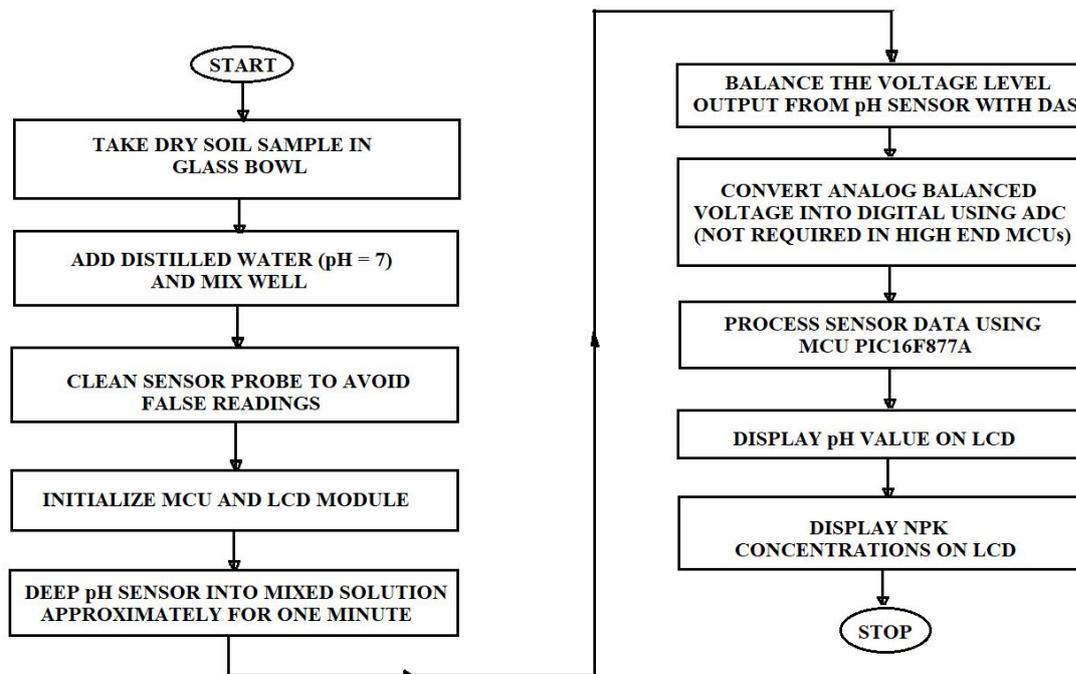


Laboratory analog pH sensor is contribution of glass and reference electrodes in single package as shown in Figure 2. The internal electrode is usually made by Silver Chloride (AgCl) or Calomel. The internal solution (usually pH = 7, neutral) called as buffer solution is of 0.1 mol/L of KCl and also the reference internal solution is the same [20]. The important is body of electrode made by non-conductive material like plastic or glass (most cases). The ion exchange take place at sensing electrode and hence generation of small amount of voltage, this is due to electrochemical process.

- **Data Acquisition System (DAS)** – Used for augmentation of data or conversion of same type of data into the required for future or further processing. DAS are generally Current to Current converters, Voltage to Voltage converters, Current to Voltage converters (trans-impedance amplifiers), Voltage to Current Convertors (trans-conductance amplifier), like successive stages of amplifiers usually designed using Operational Amplifiers (OpAmps).
- **Data convertors** – Typically of two types: Analog to Digital Converter (ADC) and Digital to Analog Converter (DAC). Since the core part is microcontroller who process and controls the system can't be operated unless data is digital. Sensor data levelled by DAS is of course analog, hence might be converted into digital with the help of data convertors (here, an ADC).
- **Microcontroller Unit (MCU)** – Controls the system. Here Microchip PIC16F877A MCU (PIC – Peripheral Interfacing Controller) has been chosen because it has all important features those modern embedded system deserves [21]. The important function of MCU in this research work is to get the signal from DAS since, PIC16F877A has on chip ADC (8- channels, 10-bits resolution), so part (3) explained is optional for other low end MCUs not having data convertors on board, for example INTEL 8051. With the correction factors applied, MCU simply processes the sensor's voltage data to readout of an equivalent pH value and hence finally converted to view the Nitrogen (N), Phosphorous (P) and Potassium (K) concentrations on LCD module interfaced. MikoC PRO advanced embedded compiler, emulator and debugger used to program PIC16F877A is very powerful tool and code compatible with basic PIC as well as other advanced PIC microcontrollers.
- **Liquid Crystal Display (LCD) module** – LCD, the output peripheral device is most important part of various MCUs to display the results, outputs. LCDs are replaced by LED displays now a days because of performance, power domains. Still, several types of LCDs are preferred due to availability, low cost and need not require additional co-processor to drive hence easy to interface. The typical types include alphanumeric LCDs (16X2, 16X4, 20X4) controlled by Hitachi HD44780, mono-coloured LCDs controlled and driven by Nokia [22]. Now touch LCD panels can be easily interfaced with Raspberry Pi, Arduino and Node MCUs.

Algorithm

Figure 3 Algorithm to carry out NPK exploration using analog pH sensor



IV. RESULTS AND FINDINGS

The following analysis is carried out by the well-established procedure according to the algorithm illustrated in Figure 3.

Conversion of voltage to pH value

Table 2 shows that pH sensor probe gives 0 mV represents neutral solution, till +1500 mV, solution might be acidic that is low pH and vice and negative voltage data beyond the pH value 7. It is noticed that acidity increases the salinity (that is salt contents) as well as conductivity in soil representing the over use of fertilizers.

Table 2 pH values and Equivalent voltages of Analog pH Sensor Probe

pH Value	Equivalent Voltage Value	Nature
0	+ 1412 mV that is greater than some 0 mV	Very Strongly Acidic
1	+1342.86 mV	Strongly Acidic
2	+285.71 mV	
3	+228.57 mV	Weakly Acidic
4	+171.43 mV	
5	+114.29 mV	
6	+57.14 mV	Neutral
7	0 mV	
8	-57.14 mV	Weakly Alkaline
9	-114.29 mV	
10	-171.43 mV	
11	-228.57 mV	Strongly Alkaline
12	-285.71 mV	
13	-342.86 mV	Very Strongly Alkaline
14	-400 mV	

Conversion of pH value into NPK concentrations

The following coefficients are used to describe pH value dependencies of soil organic major macronutrients or important minerals as –

- Function of Nitrogen $fN = 0.25(pH - 3)$
- Function of Phosphorous $fP = (pH - 6)^2$
- Function of Potassium (Kalium) $fK = 0.625(3.4 - 0.4pH)$

Exploration of NPK within different soil samples

Soil macronutrients detection have been carried out by taking four different soil samples (Targets – Refer Table 3). The food yield in global is based on the presence of nutrients. Phosphorous is an important macronutrient due to its low recovery and so finite availability. To obtain good and healthy growth of crops, the sum of macronutrients is 2 (N = 0.5, P = 1.0 and K = 0.5). Also, the ideal ratio of NPK is 4:2:1.

Table 3 Results Obtained by Exploration of NPK using Analog pH Sensor

Soil Sample	Voltage Observed at pH Sensor Probe	pH Value (From MCU)	Concentration of Nitrogen (N)	Concentration of Phosphorous (P)	Concentration of Potassium (K)
Target 1	122.1 mV	5.20	0.550	0.640	0.825
Target 2	-185 mV	10.51	1.877	20.34	- 0.4275
Target 3	45.2 mV	6.12	0.780	0.014	0.595
Target 4	-155.6 mV	9.66	1.66	13.39	- 0.290

From Table 3, it is better to conclude that,

- Target 1 having pH 5.20 (weakly acidic) has a stable and healthy soil since sum of NPK is approximate to 2. Almost no need of fertility treatments.
- Alkaline Target 2 shows that high amount of phosphorous (phosphate in oxidised forms) while no net amount of Potassium content.
- Target 3 is quite stable showing the balance of NPK.
- Again Target 4 showing the instability due high use of phosphate containing fertilizers, hence need to balance.
- Hence from above discussion, it is clear that the soil samples having pH values closer to neutral and having weakly acidic are stable.

V. SUMMERY AND CONCLUSION

The analog pH sensor based NPK macronutrients detection is quite simpler than other methods explained in this paper. The laboratory probe type analog pH sensor is easily available and fair in cost. Also, the results with the same sensor from different targets are relevant and comparable with the standard exploration results. The electronic system using this type of pH sensor is stable and the Farmer (Kisan) himself can carry the detection of NPK without going into agricultural laboratories that consumes much more time, a number of days sometimes. In future it is also possible to integrate this exploration technique with self-containing or on board IoT, Cloud and Wireless Sensor Network (WSN) with replacement of Microchip PIC16F877A to high end other MCUs like PIC18FXX, PIC32x, Raspberry Pie or Node MCUs.

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