Development of Real Time Arsenic Heavy Metal Concentration Monitoring System

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Abstract. This paper focuses on the ongoing development of real-time monitoring system with implementing the Internet of Things (IoT) element for arsenic heavy metal concentration in paddy field using pH sensor for data collection. The pH sensor will detect the hydrogen ion concentration from the prepared soil put in pot contained with various arsenic concentration. The developed system is then compared with the pH sensor in the market to verify its accuracy and sensitivity. The collected data will be transferred wirelessly into data cloud so that it can store the previous and current reading data. Besides, the system’s function is also to ensure the safeness of paddy plant to be planted with knowing the right amount of arsenic concentration can be passed.

1. Introduction

Arsenic is a natural toxic metalloid element that can be found abundantly in water, air and soil. In most South East Asia country, paddy is planted in flooded area. Arsenic is most likely to be deposited there and thus, more paddy is contaminated with arsenic rather than other country [1]. This is because water becomes the source of irrigation. The plant could not distinguish the good or bad mineral to be absorbed because of aerobic process, hence arsenic is absorbed involuntarily from the soil. Rice plant needs the uptake of silicon for their stem, roots and leaves to grow stronger and protection support but the arsenic compound tends to share the same path in absorbing and soak arsenate too without intention [2]. This will affect the production of rice in total.

Nowadays, the amount of food contains with unknown toxicity trace are quiet worrying. People in most country tends to eat whole grain food and protein such as corn and rice as their source of energy [3]. Moreover, a lot of baby’s food are from rice product. This can lead to invade the growth rate and development [4]. To ensure the health of one’s body, a good monitoring system in ensuring the soil for the plant growth have the safe level of arsenic is conducted.

A research found out that exposing with arsenic in a long period of time can lead to a very serious disease such as increasing the risk to have a cancer in skin, lungs, bladder and kidney. It also gives the impact to have hyperkeratosis and pigmentation changes [1,5,6]. Arsenic forms in both organic and inorganic compound, which inorganic compound, the arsenate and arsenite become the most toxic element. When both of this element are combined with dissolve organic matter in environment, it prevents the sorption and co-precipitation with solid phase organics and inorganics [7].
In this project, a monitoring system in paddy field to determine the arsenic concentration is created. The detection of arsenic will be done by using pH sensor and can be monitored remotely with the access of mobile phone. With the development of the system, this can help the industry in measuring the amount of arsenic that can be absorbed by a living organism, which is the paddy. Since arsenic cannot be change its toxicity, it is compulsory to monitor the arsenic amount to which level it can be elevated. Knowing the condition of soil could alarm the farmers and agriculture industry in planting the paddy in that area. With that, the effort to reduce the amount of arsenic in soil could be done with the technology nowadays before proceeding in paddy planting to increase the production and safety.

2. Methodology
Flowchart in Figure 2.1 describes briefly the process flow of this research. This research aims to develop a monitoring system of arsenic concentration in paddy field in a real time manner with the use of a pH sensor. Data will be obtained through develop system through this research and will be compared its validity with the actual system in the market from the prepared paddy soil. This sensor will be placed inside the pot with the prepared soil having different arsenic concentration concentrations such as 0mg, 2mg, 7mg and 12mg. The reason of using the pot as test bed is to control the Arsenic concentration, because it is impossible to control the Arsenic concentration in the real paddy field. The data will be collected for 10 seconds per reading and repeated for five times for each sample. The mean is calculated and undergoes Anderson-Darling test to validate its normality for acceptability of the data set. Later, all the normalise data are being processed to find the matching group using linear regression and Pearson’s correlation coefficient analysis. The percentage error analysis is used to verify and validate the experimental device with the actual device. Plus, all the data will be transferred wirelessly and can be view current and past data reading.

![Figure 2.1. Research flowchart](image-url)
2.1. Experimental Sensing Module

In this paper, pH sensor is used as the detector concentration because it is highly sensitive, have excellence response of time, high repeatability and stable [5]. pH sensor is a type of sensor that are used to detect the acidity and alkalinity in an aqueous solution. The parameter pH will determine the degree of acidic or alkaline. It will define about the validity of the different nutrients in soil, the solubility of the toxic substances, influence the physiological reactions of the roots of the plants and the microbe. The configuration of pH sensor in Figure 2.2 provide the understanding of how arsenic concentration can be captured.

![Figure 2.2. pH sensor configuration](image)

This sensor is linked to pH signal conversion board that are connected to the Arduino controller board. The calibration of PH electrode is done before starting the experiment. Calibration is important to ensure result that will be get is accurate and dependence. The calibration of pH sensor will be done on single-point calibration, two-point calibration and three-point calibration. Single point calibration is done for solution with pH 7, two-point calibration is for solution between pH 7 and the range of pH 0-6 while three-point calibration for the full range of pH. It is a straightforward process that will ensure the accuracy of the device before starting up the experiment. The pH sensor is actually will give the outputs of mV signal that will corresponds to pH value, which indicates that each value of pH has its own range of voltage. The lower the pH value, the higher the voltage level it will be.

2.2. Actual Sensing Module

Experimental setup in getting the actual value for arsenic concentration in soil are completed using pH meter Eutech Instruments from Thermo Scientific in Figure 2.3. This product has a wide range of pH detection starting from -2.00 to 16.00 with resolution 0.01 pH and accuracy of ±0.01 pH. The calibration of the pH can be done up to 6 points calibration. As for the voltage, the range detected is about ±2000 mV with resolution 0.1 mV ±999.9 mV; 1 mV beyond and accuracy of ±0.2 mV +2 LSD or +0.5 % of reading; whichever is greater. The calibration can be done up to ±200 mV. The accuracy of the device is ±0.5 °C and ±0.9 °F for respective unit and calibration is offset in 0.1 increments, ±10 °C and ±18 °F with respective unit. This device undergoes the same protocol as experimental device as to compare the collected data to use as results.
2.3. **IoT platform**

This system uses NodeMCU ESP8266 which has an integrated Wi-Fi module and is capable of transmitting sensed data for storage and display purposes to the database and webpage Graphical User Interface (GUI). Data transfer is carried out wirelessly over an Internet link. The NodeMCU ESP8266 is connected to Arduino Firebase is used as the server side of cloud computing and real-time database in this project.

2.4. **Data Analysis Method**

In this research, there are three types of statistical analysis and that is data normality test, data matching and correlation and data verification and validation as shown in Figure 2.4. Experimental device data will be compared to the actual device data in order to make sure it is reliable and proves the experimental device is ready to use. Data normality is done by using Anderson-Darling test, which it is used to verify the collected data in line with the normal distribution region. It is important to carried out this test to validate the collected data so the further analysis can be carried out. For data matching and correlation analysis, Pearson’s correlation coefficient analysis and linear regression is used in this research. As for validation and verification of the device developed in this research, percentage error is conducted between the experimental and actual device to validate the efficiency and reliability of the experimental device created.

![Figure 2.4. Analysis method](image)

**Figure 2.3. pH meter Eutech Instruments**
3. Expected Results

Based on the selected statistical method, the expected results for each method must meet their own requirement. By using the actual device and experimental device in this research to determine the concentration of arsenic, the regression, correlation and percentage error value for both devices are reviewed equally to prove the functionality and reliability of using pH sensor.

Anderson-Darling normality test is important on the first stage as it will determine the collected data to be distributed normally. In order for null hypothesis to be accepted, the calculated p value must be bigger than 0.05 which indicates that the data are normally distributed [8]. Abnormal data cannot be proceeded with another statistical method; hence it is very important to ensure that the data lies in the normal distribution region.

As for linear regression, the acceptable value must be 70% and above to indicates a strong linear relationship within variables for reliability [9]. Meanwhile for Pearson’s correlation coefficient, the value needs to be more than 0.5 to show a strong correlation between two variables [10]. Thus, the higher the value of regression and correlation, the better relationship between it will be. The percentage error between experimental value and actual device should be less than 10% to be considered as acceptable and valid device [11]. If the percentage is achieved, it shows that the device is reliable.

Table 1. Expected result

| No | Analysis Method                  | Analysis type                      | Expected result |
|----|----------------------------------|------------------------------------|-----------------|
| 1  | Normality test                   | Anderson-Darling                   | p > 0.05        |
| 2  | Data matching and correlation    | Linear regression                  | R² > 70%        |
|    |                                  | Pearson’s correlation and coefficient| r > 0.5         |
| 3  | Data verification and validation | Percentage error                   | %error < 10%    |

4. Discussion

This research is still in development, but every process is well planned and prepared. The motivation with intention to take a good concern of healthy food, especially for kids and infant will help us in developing this system very well and make it reliable.

5. Conclusion

This paper discusses on the development of real time Arsenic heavy metal concentration that will be implemented at paddy field. With the implementation of smart farming agriculture that will be developed through this project, it will benefit the agriculture transformation as it integrates the two main process: To modernize agriculture by increasing the productivity and functioning of paddy field, and to strengthen the linkage between paddy fields and other economic sectors in a mutually beneficial process. The optimization of IoT in this project, will comply with the requirement of Industrial Revolution 4.0 by having a robust model, scalability, affordable and sustainable.
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