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Monitoring System of Water Quality on Hydroponic Planting Media using Total Dissolved Solid (TDS) Sensor Based Arduino Uno R3

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ABSTRACT

A water quality monitoring system in hydroponics with a Total Dissolved Solid Sensor (TDS) equipped with the Arduino UNO microcontroller has been developed. The TDS SEN0244 sensor read the water sensitivity, which will display the value of the reading on the LCD. Furthermore, if the output is less than 2.30 Volts or 1000 ppm, the buzzer will sound once, and the dosing pump will rotate to automatically add nutrients A and B. The buzzer will sound twice if the output is more than 2.40 Volts or 1200 ppm. When reading the sensitivity of water (well water) with a water value of 400 ppm, the relevant results were obtained, namely, 1000 - 1200 ppm when 4 - 5 mL of the nutrient solution was added to water with a capacity of fewer than 6 liters. The appropriate value was obtained when testing the TDS sensor on several water samples. However, in the salt and soapy water samples, the voltage value reading was unstable or experienced an error. Implementing this system is expected to make it easier for the community, especially farmers, to cultivate hydroponic plants.

1. INTRODUCTION

The increasingly narrow agricultural land is the biggest challenge that farmers in Indonesia must face today; based on data from the Central Statistics Agency (BPS), the agricultural land cover, including rice fields, in 2014 was 13,230.6 Ha. Meanwhile, in 2020 land cover has increased to 75,131.8 Ha. Because of this, there is a need for development in the agricultural sector. This development is expected to assist the implementation of regional development in the agricultural sector. It aims to increase agricultural production to keep pace with the increasing population growth in Indonesia. In 2014 the population of Indonesia was 237.6 million, while in 2020, it increased to 270.2 million, according to BPS data. Many things can be developed in agriculture in Indonesia, especially in the agricultural economy. In line with Indonesian Law No. 22 of 2019 concerning sustainable agricultural cultivation systems to better meet human needs. One of the sustainable agricultural cultivation systems is the development of hydroponic planting media.

Hydroponics is a method of cultivating plants that uses water as a growing medium while still paying attention to the fulfillment of nutrients for the plants. The use of hydroponics as a method of cultivating plants has several advantages, such as being environmentally friendly, requiring less water in hydroponics, a relatively easy maintenance system, and being cleaner because the planting medium uses water and does not use soil (Cifuentes - Torres et al., 2021; Swain et al., 2021).

Water is used for the body's metabolic processes for humans, animals, and other living things. In addition, water is also the primary medium used in hydroponic plant cultivation. Water can be classified into two, clean water and dirty water, with different characteristics. Clean water is the water of good quality and is usually used to meet daily human needs with an appropriate pH and total dissolved solids (TDS). The liquid contains dissolved particles that are not directly visible. These particles are usually solid particles such as metal particles (iron, aluminum, copper) and then non-solid particles such as microorganisms (Pratama, 2017).

In the process of hydroponic cultivation, water quality must be considered so that plants remain healthy and well maintained. One form of hydroponic plant care is to ensure the nutritional needs of plants are appropriate. The nutrient solution is one of the essential determinants in determining crop yield and quality (Nugraha & Susila, 2015; Fatiha et al., 2022). For optimal nutrition efficiency, the nutrients must be in sufficient quantities to meet the plant's needs. The TDS sensor works based on Arduino microcontroller commands with open source modules and programming languages with sensor output data in analog data (Lokananto et al., 2020). The nature of the electrolyte or the content of ionic particles in a liquid will affect the results of the electrical conductivity measurement on the TDS sensor (Wirman et al., 2019; Warlina et al., 2022). The TDS sensor has a reading unit called Parts Per Million (PPM). If water sensitivity is too high, plants will grow slowly, and the farming production costs will be high. On the other hand, a low ppm value reduces plant productivity. So that by monitoring the sensitivity of water in hydroponics with the control of Arduino UNO R3, it is expected to get the appropriate ppm value to meet the nutritional needs of this hydroponic system plant.

2. METHODS

The research flow chart can be seen in Figure 1. After reviewing the reference, the next step is to design the tool. Several primary and supporting components are needed in designing the system, including Arduino UNO R3, TDS Sensor, Jumper Cable, Media Interface (Laptop), LCD, Relay, and Power Supply. At the tool design stages, the first process is creating a block diagram as a basic description of the tool and sensor system to be designed.

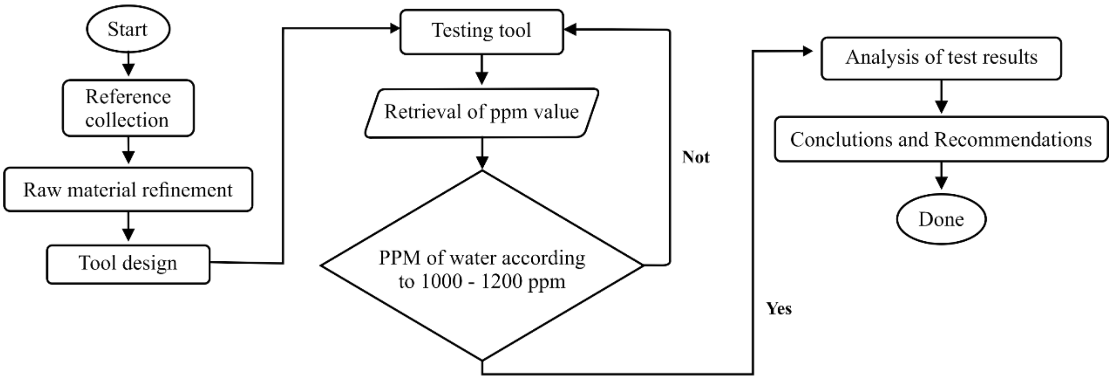


Figure 1. Flowchart of research.

The next stage is to design the tool according to the block diagram (Figure 2) made in a series of water quality monitoring system tools using a T.D.S. sensor, as shown in Figure 3. The T.D.S. sensor functions to measure dissolved solids or the sensitivity of solutions in water (Sunarya et al., 2020; Irawan et al., 2021; Megantoro et al., 2021). First, the T.D.S. sensor is connected to the 5V, GND, and A1 pins (sensor output) on the Arduino U.N.O. R3. Then the LCD is connected to the 5V pin, GND, and the A4 and A5 pins are connected to S.D.A. and S.C.L. on the I2C LCD. Furthermore, the buzzer, used as an indicator (sound), is connected to the relay as the ON-OFF regulator and the power supply as the input voltage. The power supply is connected to Vin on the Arduino U.N.O. R3 so that the tools and systems can run on their own after the Arduino IDE program has been uploaded without having to continue to be connected to the computer. The Arduino IDE program used to operate the system is shown in Figure 4 and Figure 5.

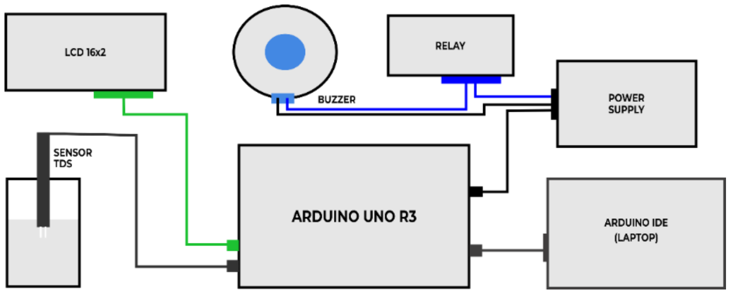


Figure 2. Tool design block diagram.

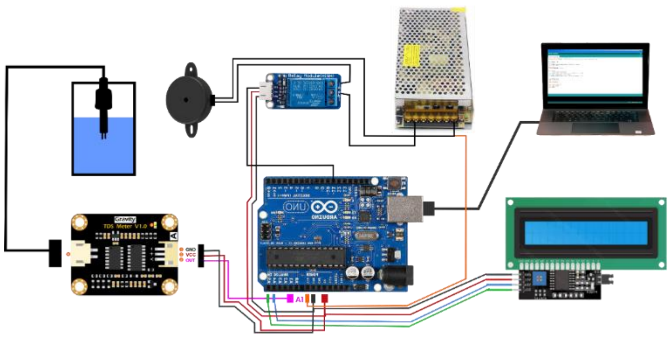


Figure 3. Design of water quality monitoring tools and systems.

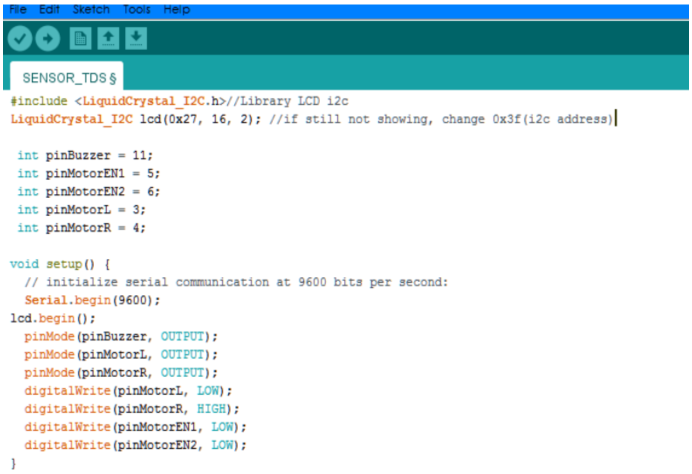
After the tools and systems have been successfully designed, make a program design using the Arduino IDE software and a monitoring system that will be used using the C programming language (Pratama et al., 2019). Arduino UNO has the advantage of having Digital and Analog PINs because there is already an analog-to-digital converter (ADC) (Calibra et al., 2021; Fanani & Hariono, 2021). The commands used in the program design for this system are as shown in Figure 4: buzzer (indicator) and dosing pump (nutrient addition). At the same time, the commands for the void loop are sensor input readings, and the logic for operating the buzzer and dosing pump displays the value on the LCD. The test's success parameter is to compare the water quality sensors and calculate the percent error (Yunior & Kusrini, 2021). The equation to calculate the percentage error is given by.

$$\text{Relative error} = \left[\frac{\text{Exact value} - \text{Relative value}}{\text{Exact value}} \right] \text{x } 100\% \tag{1}$$

$$\text{Relative error} = \left[\frac{\text{TDS Meter} - \text{TDS Sensor}}{\text{TDS Meter}} \right] \text{x } 100\% \tag{2}$$

3. RESULTS AND DISCUSSION

Figure 6 shows all the systems in this study. The TDS sensor (red) in this system is placed under the Arduino, which is connected to pins A1 (output), GND, and 5V on Arduino UNO R3. The LCD is connected to the GND, 5V, SDA, and SCL pins which will later display the output of the TDS sensor. The buzzer, whose function is as a TDS sensor indicator in detecting the ppm value in water, is connected to a relay and inputs the voltage directly from the 12V power supply. The USB port on the Arduino Uno R3 is connected to the laptop, then sends the program from the Arduino IDE software to the Arduino UNO R3 hardware using the USB port.




```
#include <LiquidCrystal_I2C.h>//Library LCD i2c
LiquidCrystal_I2C lcd(0x27, 16, 2); //if still not showing, change 0x3f(i2c address)

 int pinBuzzer = 11;
 int pinMotorEN1 = 5;
 int pinMotorEN2 = 6;
 int pinMotorL = 3;
 int pinMotorR = 4;

void setup() {
  // initialize serial communication at 9600 bits per second:
  Serial.begin(9600);
lcd.begin();
  pinMode(pinBuzzer, OUTPUT);
  pinMode(pinMotorL, OUTPUT);
  pinMode(pinMotorR, OUTPUT);
  digitalWrite(pinMotorL, LOW);
  digitalWrite(pinMotorR, HIGH);
  digitalWrite(pinMotorEN1, LOW);
  digitalWrite(pinMotorEN2, LOW);
}
```

Figure 4. Void setup program listing on arduino IDE.


```
void loop() {
    //  read analog input pin 0:
  int sensorValue2 = analogRead(A1);//this is for PPM or TDS sensor
  float PPM = sensorValue2 * (5.0 / 1023.0);

  // Convert the analog reading (which goes from 0 - 1023) to a voltage (0 - 5V):
 if (PPM< 2.29){
   digitalWrite (pinBuzzer, HIGH);
   delay(100);
   digitalWrite (pinBuzzer, HIGH);
   delay(1000);
 }
  else if (PPM> 2.41){
   digitalWrite (pinBuzzer, HIGH);
   delay(100);
   digitalWrite (pinBuzzer, HIGH);
   delay(100);
   digitalWrite (pinBuzzer, LOW);
   delay(100);
   digitalWrite (pinBuzzer, HIGH);
   delay(1000);
 }
  if (PPM < 2.30 ){
    analogWrite(pinMotorEN1,255);// Micro Pump
    analogWrite(pinMotorEN2,255);// Macro Pump
 }
  else if ((PPM >= 2.30) && (PPM <= 2.40 )){
    analogWrite(pinMotorEN1,0);
    analogWrite(pinMotorEN2,0);
 }
  // Tampilan nilai
```

Figure 5. Void loop program listing on arduino IDE.

After the tool's design is complete, the tool's testing is carried out. This test is to confirm the function of the TDS sensor based on the sensor's command and response to changes in nutrients in the water. Table 1 and Table 2 show the results of the TDS sensor testing on several samples of water (no nutrient) and nutrient solutions.

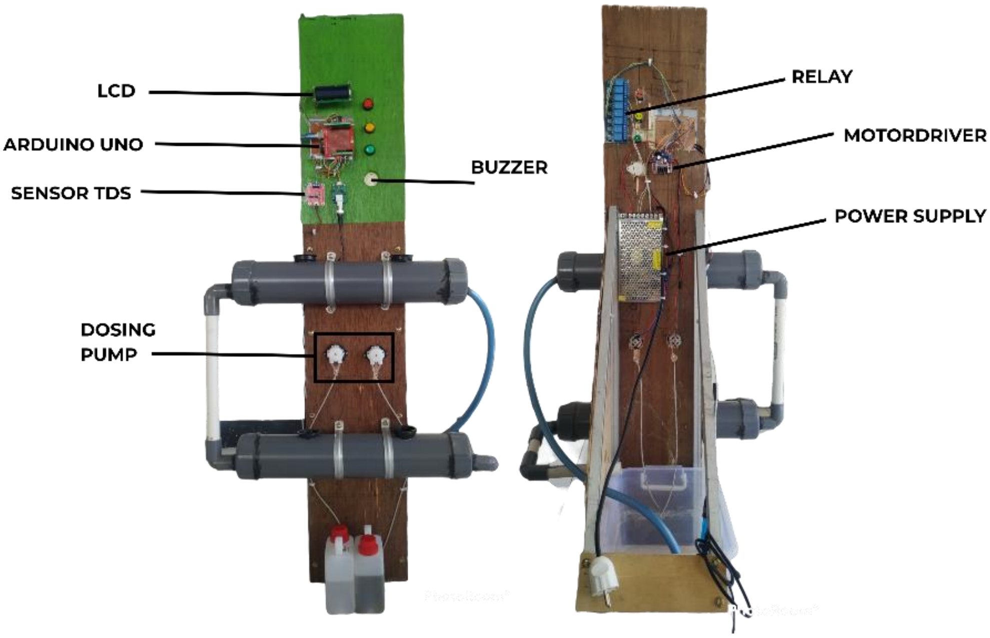


Figure 6. Overall system physical appearance

Table 1. TDS sensor testing using water samples instead of nutrients.

No.	Water Sample	TDS Sensor (Voltage)	TDS Meter (ppm)
1	Well water	1 Volt	396
2	Lake water	0.47 Volt	186
3	Brine	2.49 Volt	6740
4	AC water	0.08 Volt	30
5	Soap water	2.49 Volt	4430
6	Mineral Water	0.18 Volt	71

Table 2. TDS sensor testing using nutrient water samples.

No	Nutrient Addition (mL)		TDS Sensor (Voltage)	TDS Meter (ppm)
	A (Micro)	B (Macro)		
1	Initial Value		1 Volt	396
2	1 mL	1 mL	1.44 Volt	576
3	2 mL	2 mL	2.23 Volt	891
4	3 mL	3 mL	2.54 Volt	1040
5	4 mL	4 mL	2.54 Volt	1170
6	5 mL	5 mL	2.55 Volt	1530

Testing samples of well water, lake water, drinking water, and AC water obtained the appropriate ppm value from the TDS sensor, as evidenced by a TDS meter (Table 1). Meanwhile, in testing Brine and soap mixture, the TDS sensor could not read the ppm value accurately because there were too many dissolved particles in the water (Hong et al., 2021). Furthermore, the TDS sensor works well in testing the nutrient solution and produces ppm values, as shown in Table 2. The TDS sensor is designed using specific components. The working principle of the TDS sensor uses a probe with two separate electrodes to measure the electrical conductivity of a water sample. From the research data of several water samples, the voltage values obtained are consistent with the comparison of the TDS meter, namely samples of well water, lake water, AC water, and drinking water. Thus, the data obtained from the analysis and observations were used for comparison of the voltage value of the TDS Sensor with the TDS meter.

This TDS sensor test uses Arduino UNO R3, which has not been connected to a power supply. From the TDS sensor test on non-nutrient solutions and nutrient solutions, the sensor can read a maximum voltage of 2.55V, resulting in a significant difference between the TDS sensor and the TDS meter.

Figure 7 shows that when the program from Arduino IDE is uploaded, the TDS sensor is inserted into the water sample (Figure 7a), then the power supply is connected to a voltage source so that the system will turn on (Figure 7b). Furthermore, in Figure 7c, the system starts from the TDS sensor reading the water ppm value, then the LCD will display the voltage value (0 - 5V), and the buzzer will sound as an indicator. The buzzer will not sound when the voltage value meets or matches.

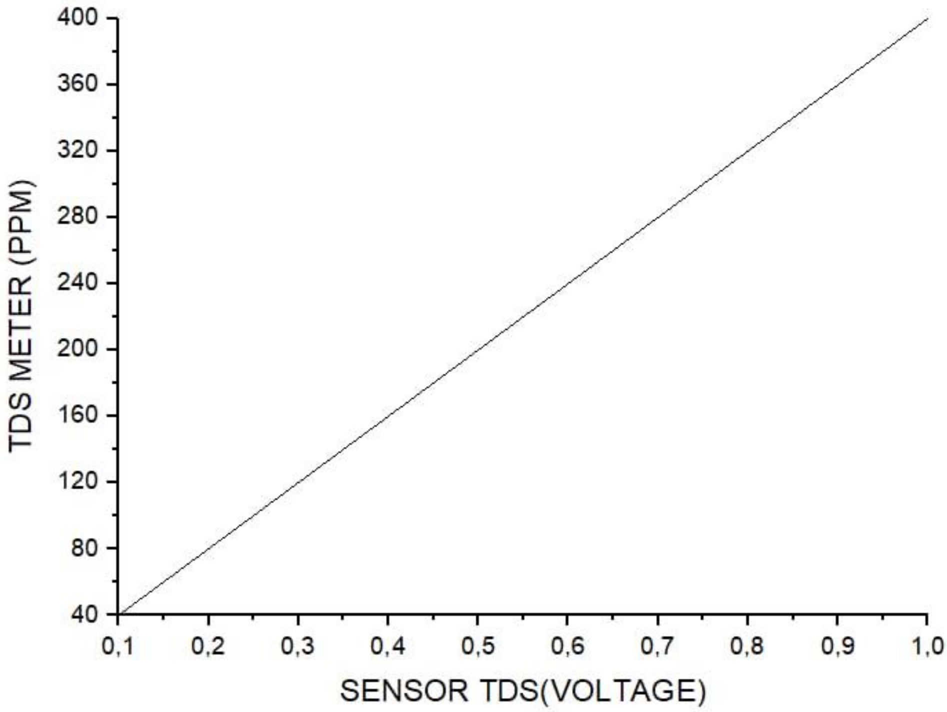
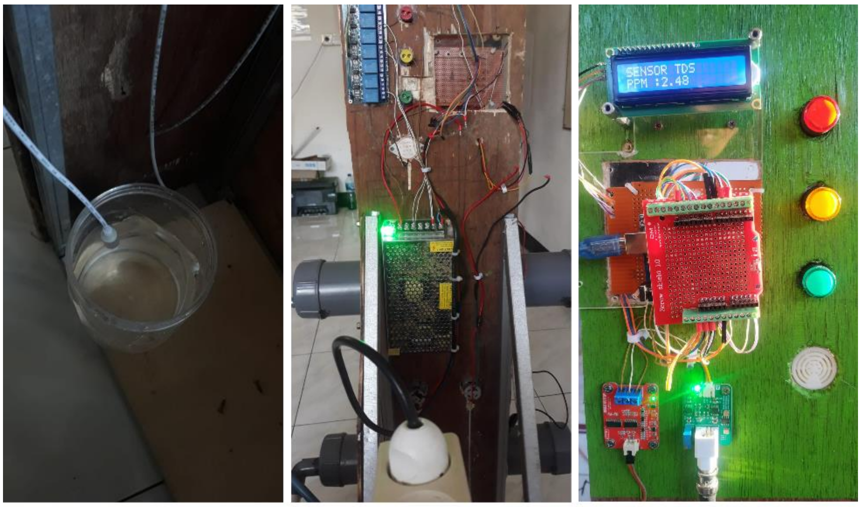


Figure 7. Test result data and voltage value conversion to ppm.

Figure 8 shows all tools and systems when running. In general, the instrument works well, consistent with previous research (Pratama, 2017; Wirman et al., 2019; Irawan et al., 2021). However, In collecting data, there is a constraint factor for tool limitations, namely the reading by the TDS sensor, which is only a maximum of 2.41V when the entire system is run with a direct voltage source from PLN electricity. This affects the conversion data of the voltage value to the ppm value. So that in its implementation, the system is connected to a Direct Current (DC) voltage source. The appropriate ppm value was obtained in the data collection process, namely (1000 - 1200) ppm with a voltage value of 2.3 to 2.4 Volts. In this study, the TDS sensor can only read a maximum voltage value of 2.41 volts because the TDS SEN0244 sensor can only read an output voltage of 0 - 2.3 volts, so it cannot read a voltage value of up to 5 volts. This causes a significant error between the TDS sensor and the TDS Meter.



(a) (b) (c)

Figure 8. View of all tools and systems when running.

Table 3. The data of analysis result.

No	Voltage value (Volt)	TDS Sensor (ppm)	TDS Meter (ppm)	Difference	Error (%)
1	2.3	920	1000	80	8,00%
2	2.31	924	1023	99	9,68%
3	2.32	928	1044	116	11,11%
4	2.33	932	1059	127	11,99%
5	2.34	936	1082	146	13,49%
6	2.35	940	1100	160	14,55%
7	2.36	944	1125	181	16,09%
8	2.37	948	1142	194	16,99%
9	2.38	952	1156	204	17,65%
10	2.39	956	1178	222	18,85%
11	2.4	960	1200	240	20,00%
12	2.41	964	1235	271	21,94%
13	2.41	964	1256	292	23,25%
14	2.41	964	1272	308	24,21%
15	2.41	964	1300	336	25,85%

4. CONCLUSION

Monitoring water quality with Total Dissolved Solid Sensor that works using Arduino UNO R3 microcontroller with open source module and programming language with sensor output data in the form of analog data (volts), has been successfully developed. After the entire system run, the TDS SEN0244 sensor will read the water sensitivity, which will display the value of the reading on the LCD. Furthermore, if the output value is less than 2.30 Volts or 1000 ppm, the buzzer will sound once, and the dosing pump will rotate to add nutrients A and B automatically. The buzzer will sound twice if the output value is more than 2.40 Volts or 1200 ppm. The working principle of the TDS sensor uses two separate electrodes on the probe to measure the electrical conductivity of a water sample. The appropriate value was obtained when testing the TDS sensor on several water samples. However, in the brine and soapy water samples, the voltage value reading did not match or experienced an error. So it is known that the nature of the electrolyte or the particle content of a liquid will affect the results of electrical conductivity measurements on the TDS sensor. The test results and data analysis show that the TDS sensor accurately reads the nutrient solution and some water samples containing little particles. However, the sensor reading system cannot work properly when reading samples of salt water and soapy water.

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