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Real-Time Food Quality Assessment: An Integrated Microsystem with Selective Gas Tracking for Early Spoilage Detection

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Abstract— Food spoilage poses a significant threat to human health due to the presence of harmful bacteria and toxins in spoiled food. This paper proposes a novel two-module sensor system for early detection of spoilage in both solid and liquid food items. The first module utilizes an MQ-4 sensor to detect methane gas emissions, a telltale sign of spoilage in solid food. The second module employs a pH sensor to monitor the acidity/alkalinity (pH) of liquid food, detecting deviations from safe consumption ranges indicative of spoilage. This non-invasive system offers several advantages, including early detection before visual or olfactory cues appear, user-friendliness, and hygiene. It is particularly beneficial for individuals with anosmia (loss of smell) who struggle with traditional spoilage detection methods. The system's potential applications range from domestic kitchens and food service industries to food storage facilities, promoting broader food safety practices and contributing to a healthier and more sustainable food consumption cycle.

Keywords— Food Safety Management, Real-Time Monitoring, Smart Gas Sensor component, Food Spoilage, Methane Sensor

ntroduction

Food safety is a critical concern, directly impacting human health. Spoilage not only renders food unappetizing but can also harbor harmful bacteria and toxins, leading to illness. This paper proposes a novel two-module system to address this challenge, enabling early detection of spoilage in both solid and liquid food items.

Food spoilage is a complex process involving various factors. Microorganisms like bacteria and fungi thrive on unprotected food, producing byproducts that alter its properties, including color, taste, aroma, and nutritional value. Enzymes naturally present in food can also contribute to spoilage by accelerating ripening in fruits and vegetables. Additionally, environmental factors like temperature and oxygen exposure play a significant role. While traditional methods rely on visual inspection and smell, these cues may not always be reliable indicators, particularly in the early stages of spoilage.

This proposed system offers an innovative solution by employing sensors to detect subtle changes associated with spoilage. The first module tackles the detection of spoilage in solid food items. The key lies in the fact that decaying solid food releases various gases, with methane being a particularly indicative compound. The system utilizes an MQ-4 sensor, specifically designed to detect methane gas concentrations. By monitoring the levels of methane emitted, the system can identify spoilage at an early stage, even before visual or olfactory cues become apparent. This allows for timely intervention, preventing potential health risks and reducing food waste.

The second module focuses on detecting spoilage in liquid food products. A crucial parameter for liquids is pH, which reflects the degree of acidity or alkalinity. Each liquid food item has a specific pH range considered safe

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for consumption. Spoilage often disrupts the chemical balance within the liquid, causing the pH value to deviate from this safe range. The system incorporates a pH sensor that continuously monitors the pH level of the liquid food. If the measured pH falls outside the established range for a particular food item (e.g., milk with a healthy pH range of 6.5-6.7), it signifies spoilage and triggers an alert. This approach proves particularly valuable when taste or smell remains unchanged during the early stages of spoilage.

The system's benefits extend beyond early detection. Its non-invasive nature eliminates the need for direct contact with the food, ensuring hygiene and user-friendliness. Additionally, the user-centric design simplifies operations, making it accessible to a broader audience. This is especially beneficial for individuals with anosmia, a loss of smell that hinders the traditional method of food spoilage detection. For such individuals, the system provides a reliable and independent tool for ensuring food safety.

In conclusion, this multi-sensor system presents an approach to early food spoilage detection. By leveraging advanced sensor technology, the system provides a comprehensive and reliable solution for safeguarding food safety. With its user-friendliness and non-invasive nature, the system has the potential to revolutionize food safety practices in homes, restaurants, and food storage facilities, ultimately contributing to a healthier and more sustainable food consumption cycle.

Literature Survey

Rajesh Megalingam et al. propose a novel approach to food deterioration detection by integrating artificial intelligence, machine learning, and photo classification [1]. To identify food that is deteriorating, they have used AI, deep CNN networks, computer vision, and machine learning techniques like the k clusters approach for color classifications in images and its HSV values for spoiling detection. This project is completed on the Jupyter Notebook platform using the anaconda prompt. According to this perspective, AI is beneficial in practically every industry today.

The electronic nose (e-nose) developed by Green et al. includes four gas sensors composed of polymer nanocomposites and functionalized single-walled carbon nanotubes (f-SWNTs) to serve as a low-cost means of monitoring microbiological deterioration and contaminants in canned food [5]. The early warning signs of degradation provided by the gas-detecting signals helped to prevent harmful effects on health.

Food spoils due to the fast multiplication of food-spoiling bacteria in warm, moist environments where bacteria are easily created when food is inadvertently reversed, such as in an inadequate temperature [3]. If people take certain degenerative foods, the effects could be even more severe because they could result in bromatoxism. To monitor food deterioration, this study aims to construct and test a wearable RFID patch with smart packaging that can be recognized and used to read temperature data by a device that supports near NFC technology through the use of an attached circular antenna.

One of the main issues facing the food industry right now is food safety [4]. To identify problems with food quality early in the production process, food enterprises need to set up quality monitoring systems. This article provides a smart contract and quality rating algorithm-based intelligent quality monitoring system for fruit juice manufacturing. Both a high degree of automation and dependability are provided by this system. In this system, response surface models are built using preproduction data, and the optimal production condition for each stage is identified. During the real production process, production data is captured on a blockchain using smart contracts.

I. Methodology

There are two modules in the development and setup of this system. Evaluating whether or not the solid food has decayed is the first module's task. Determining whether or not the liquid food has been spoiled is the focus of the second module.

Technique for Detection of Solid Food Spoilage

Methane is one of the many gases released when solid food spoils, and it is extremely dangerous. Since the MQ-4 Gas sensor can sense methane gas at lower concentrations as well, we employed it in this work to detect the concentration of methane gas. Methane gas can be detected by the MQ-4 sensor at 300–10,000 parts per million. The Arduino Uno, MQ-4 gas sensor, LCD, ESP8266 Wi-Fi module, and power supply board are the hardware needed to create the system. The 5V and GND pins of the Arduino are connected to the 5V and GND pins of the power supply board to power the Arduino Uno. The analog output pin of the MQ-4 sensor is linked to the analog pin A0 of the Arduino Uno, and the VCC and GND pins of the sensor are connected to the 5V and GND pins of the power supply board. The digital pins 8, 9, 10, 11, 12, and 13 of the Arduino are connected to the data pins D4, D5, D6, and D7, as well as the LCD enable and reset pins. The GND pin of the Arduino is linked to the Vss, READ/WRITE, and LED Negative pins of the LCD, while the VCC 5V pin of the Arduino is connected to the Vdd and LED Positive pins of the LCD. A potentiometer is attached to the LCD's VE pin. We are using 4-bit output, thus the LCD's data pins D0, D1, D2, and D3 are not in use. The GND and RESET pins of the ESP8266 Wi-Fi are linked to the GND pins of the power supply board, while the 3.3V and Enable (EN) pins are connected to the 3.3V pin of the Arduino Uno. The Arduino Uno's RXD and TXD pins are linked to the RX and TX pins of the ESP8266 Wi-Fi, respectively. A 12V adaptor now powers the power supply board. It is necessary to connect the ESP8266 Wi-Fi module to the network that the software specifies. The meal that will be evaluated is positioned close to the MQ-4 gas sensor. Food is considered rotten if its methane gas surpasses 300 parts per million. Upon testing the meal, the results are shown on the serial monitor and LCD, and the user receives an email message.

A. Result for Solid Food

Test Case-1: When Stored Food is Tested

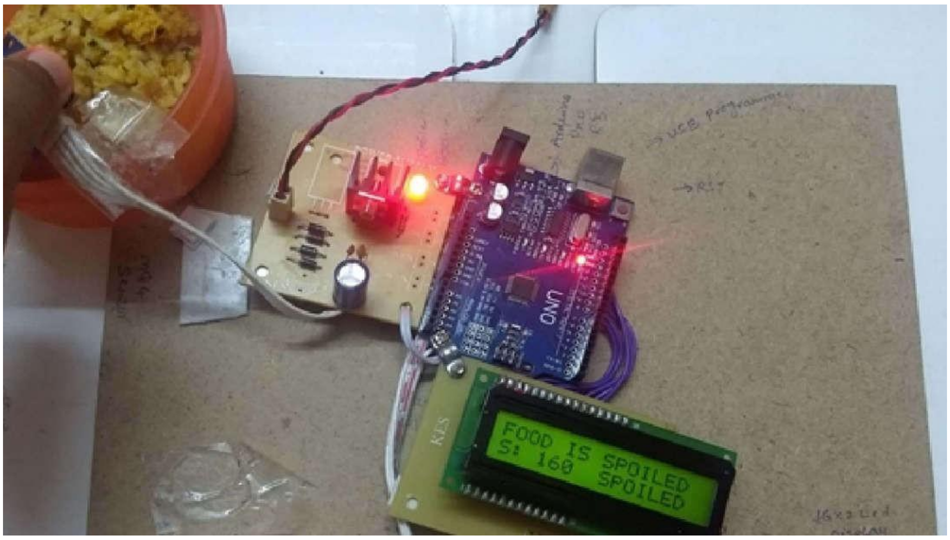

Figure 1. Output on LCD Display

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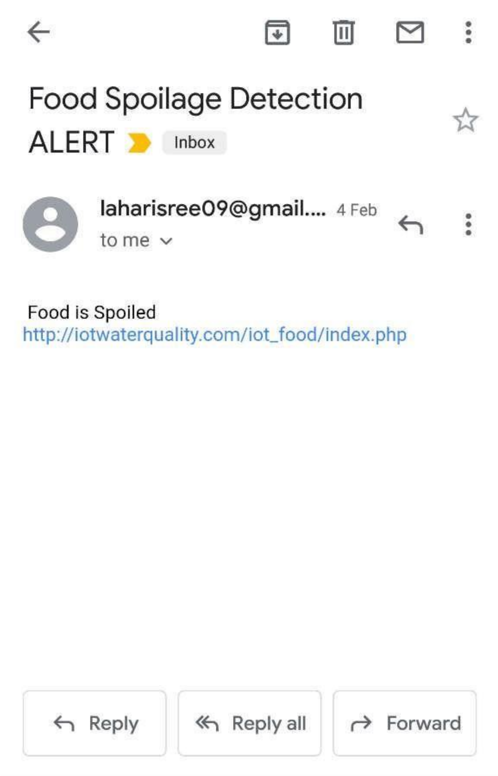

Figure 2. Output in Mail

Test Case-2: When Fresh Food is Tested

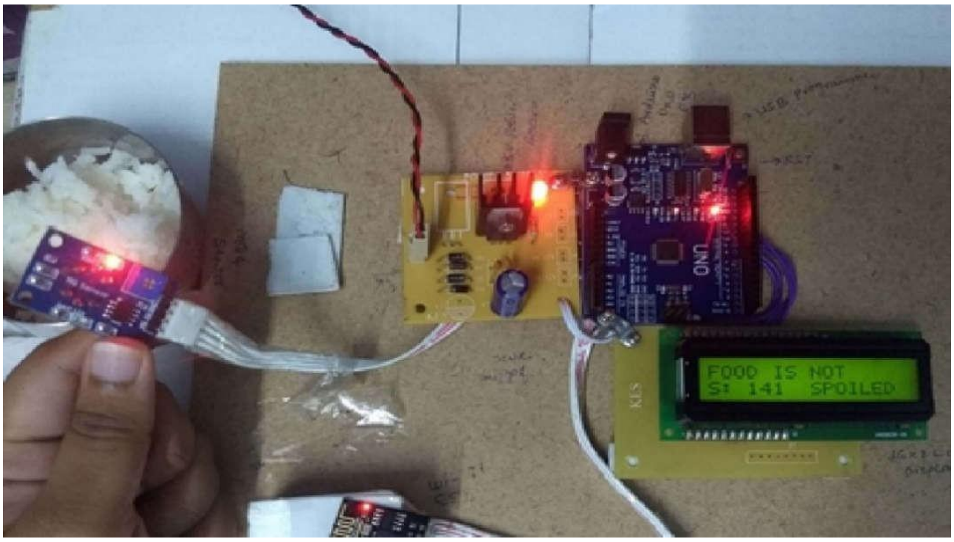

Figure 3. Output on LCD Display

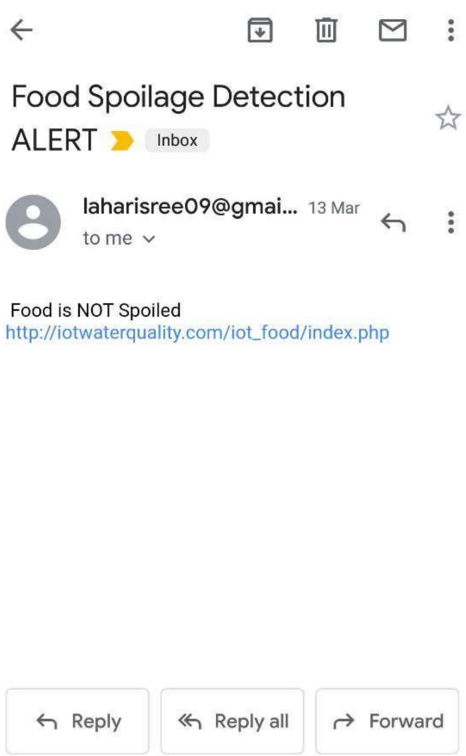

Figure 4. Output in mail

Technique for Detection of Liquid Food Spoilage

The food's liquid component is identified by its pH value. If the food liquid is spoilt, it indicates that its pH value is outside of its normal range. So, we utilize a pH sensor to find out a liquid's pH value.

The hardware needed to design the system is an Arduino Uno, a pH sensor, a buzzer, a Node MCU, and an ESP8266 WiFi module. The 5V and GND pins of the Arduino are linked to the VCC and GND pins of the pH meter, respectively. The analog pin A0 of the Arduino is linked to the analog output pin of the pH meter.The TX and RX pins of NodeMCU are connected to the digital input/output pins D2, D3, and D2 of Arduino, respectively, and the GND pin of NodeMCU is connected to the GND pin of Arduino.The Arduino's D13 digital input/output pin and GND pin are linked to the buzzer's VCC and GND wires, respectively.The Blynk application and the Arduino IDE are the necessary software.

Open the Blynk application first, then enter pH meter as the project name. After that, choose Nodemcu by clicking on Choose Device. Make sure the connection type is set to wifi, then click the "create" button. An authentication token will then be provided to your email address; all you have to do is copy and paste it into your code.To add the LCD widget, click the screen, search for it, and select it. Click the LCD, choose Advanced, click the pin, and choose Virtual Pin V2.The Blynk application is now available for usage.

Test Case-1: When Stored Milk is Tested

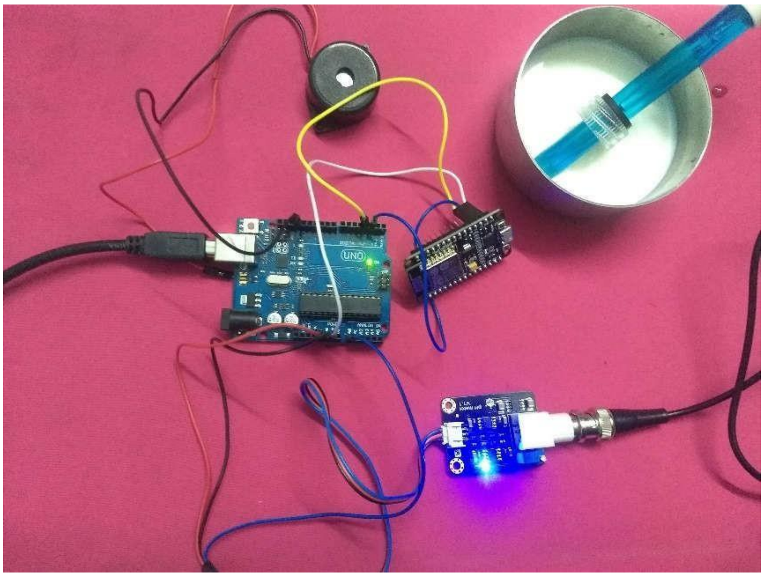

Figure 5. Testing Stored Milk

When the stored milk is tested the pH value of milk is displayed on the serial monitor and LCD widget and the buzzer rings as the milk is spoiled.

```
COM5 (Arduino/Genuino Uno)

19:36:15.168 -> 5.25,
19:36:16.267 -> 5.55,
19:36:17.380 -> 5.47,
19:36:18.508 -> 4.57,
19:36:21.629 -> 4.26,
19:36:24.735 -> 4.10,
19:36:27.844 -> 4.08,
19:36:30.974 -> 4.12,
19:36:34.070 -> 4.19,
19:36:37.193 -> 4.22,
19:36:40.328 -> 4.30,
19:36:43.435 -> 4.38,
19:36:46.539 -> 4.49,
19:36:49.673 -> 4.42,
19:36:50.770 -> 4.55,
19:36:51.900 -> 4.55,
19:36:52.990 -> 4.56,
19:36:54.119 -> 4.62,
19:36:55.252 -> 4.57,
```

Figure 6. Output on Serial Monitor

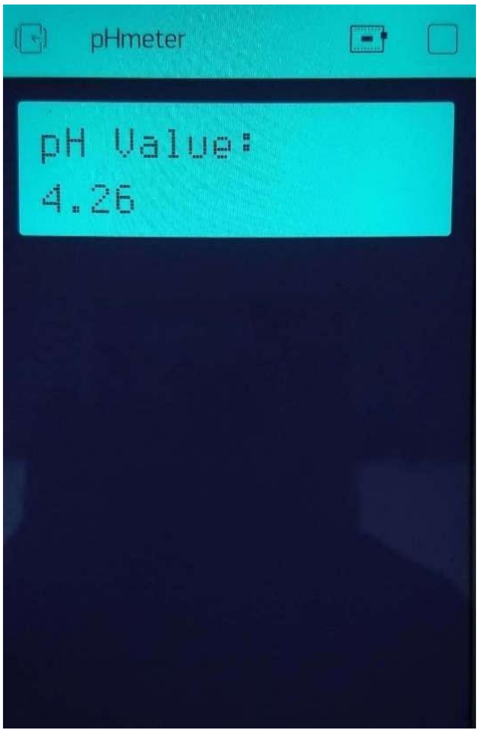

Figure 7. Output on LCD Widget in BLYNK Application

Test Case-2: When Fresh Milk is Tested

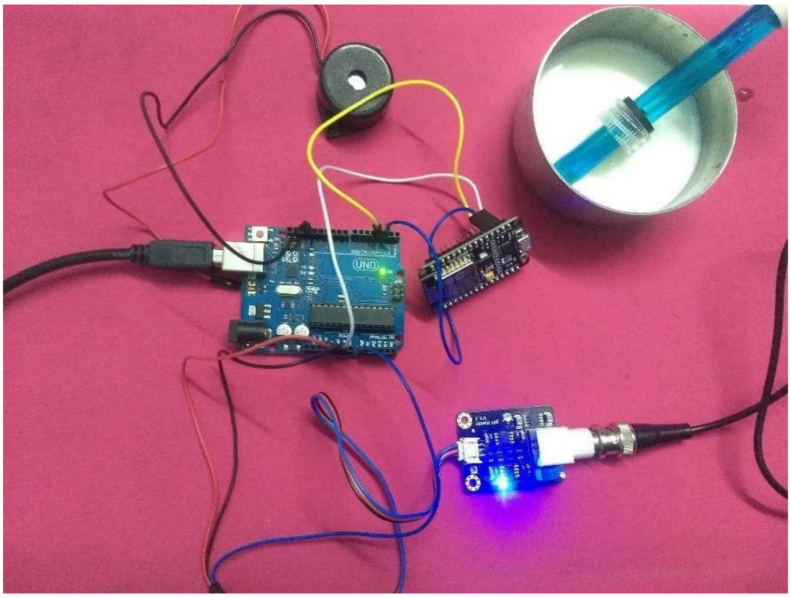

Figure 8. Testing Fresh Milk

When fresh milk is tested the pH value of milk is displayed on the serial monitor and LCD widget and the buzzer does not ring as the milk is not spoiled.

```
19:37:06.393 -> 6.63,
19:37:07.511 -> 6.66,
19:37:08.627 -> 6.65,
19:37:09.709 -> 6.65,
19:37:10.839 -> 6.65,
19:37:11.954 -> 6.65,
19:37:13.082 -> 6.65,
19:37:14.175 -> 6.66,
19:37:15.315 -> 6.67,
19:37:16.409 -> 6.67,
19:37:17.518 -> 6.67,
19:37:18.650 -> 6.68,
19:37:19.753 -> 6.68,
19:37:20.863 -> 6.69,
19:37:21.993 -> 6.70,
19:37:23.127 -> 6.70,
19:37:24.236 -> 6.70,
19:37:25.336 -> 6.72,
19:37:26.469 -> 6.72,
19:37:27.573 -> 6.72,
19:37:28.671 -> 6.73,
19:37:29.802 -> 6.73,
19:37:30.911 -> 6.74,
19:37:32.043 -> 6.75,
19:37:33.142 -> 6.67,
```

Figure 9. Output on Serial Monito

Figure 10. Output on LCD Widget in BLYNK Application

Test Case-3: When Tap Water is Tested

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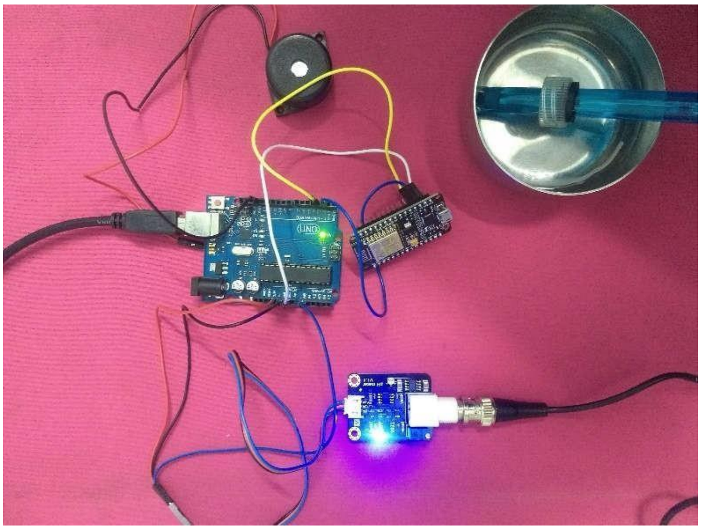
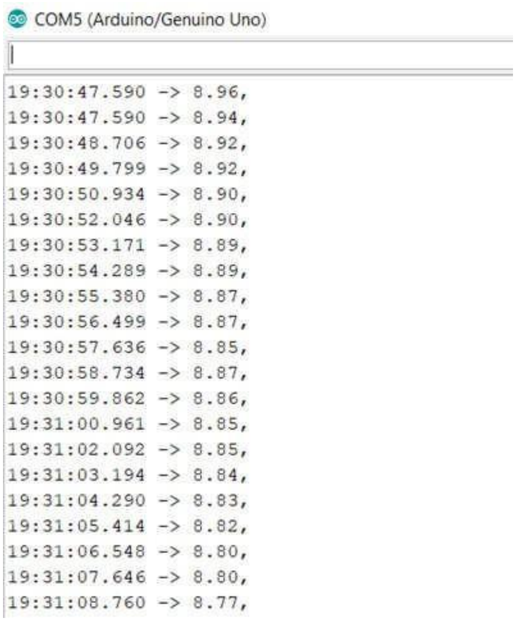


Figure 11. Testing Tap Water

When tap water is tested the pH value of water is displayed on the serial monitor and LCD widget and the buzzer rings as the water is not suitable for drinking.



```
COM5 (Arduino/Genuino Uno)

19:30:47.590 -> 8.96,
19:30:47.590 -> 8.94,
19:30:48.706 -> 8.92,
19:30:49.799 -> 8.92,
19:30:50.934 -> 8.90,
19:30:52.046 -> 8.90,
19:30:53.171 -> 8.89,
19:30:54.289 -> 8.89,
19:30:55.380 -> 8.87,
19:30:56.499 -> 8.87,
19:30:57.636 -> 8.85,
19:30:58.734 -> 8.87,
19:30:59.862 -> 8.86,
19:31:00.961 -> 8.85,
19:31:02.092 -> 8.85,
19:31:03.194 -> 8.84,
19:31:04.290 -> 8.83,
19:31:05.414 -> 8.82,
19:31:06.548 -> 8.80,
19:31:07.646 -> 8.80,
19:31:08.760 -> 8.77,
```

Figure 12. Output on Serial Monitor

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Figure 13. Output on LCD Widget in BLYNK Application

Test Case-4: When Drinking Water is Tested

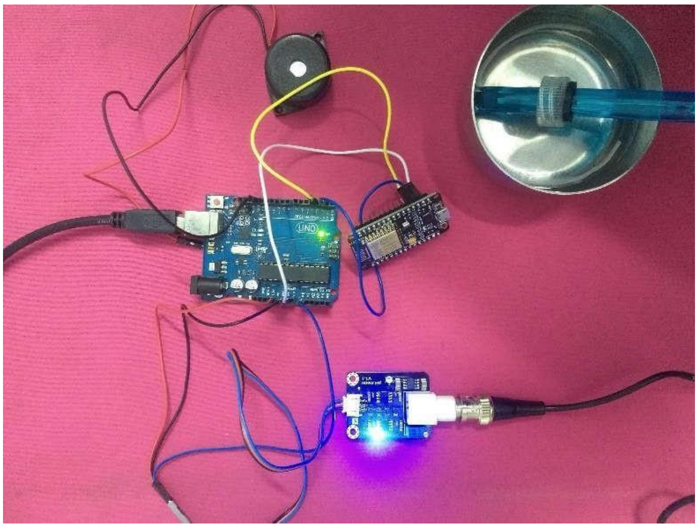

Figure 14. Testing Drinking Water

When drinking water is tested the pH value of water is displayed on the serial monitor and LCD widget and the buzzer does not ring as the water is suitable for drinking.

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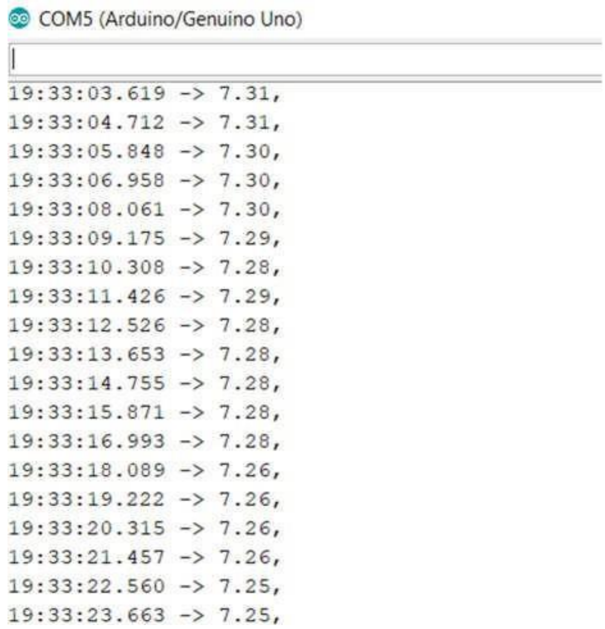

Figure 15. Output on Serial Monitor

Figure 16. Output on LCD Widget in BLYNK Application

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