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Study on pH Sensor Device using Conventional and Plasma Treated pH Sensor

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Abstract: Every living thing on Earth requires water to survive. Water supplies to taps in urban residences and water sources available in more rural areas, on the other hand, are not always suitable for drinking. In this project, plasma treatment was used on the surface of the pH sensor to monitor the difference in pH measurements between treated and untreated sensors to evaluate the accuracy of a pH sensor before and after plasma treatment. The plasma treatment is used to treat the sensitive glass membrane of the pH sensor in the Atmospheric pressure plasma needle jet (APPJ). The sensor undergoes surface plasma treatment and measures the pH value of five different samples in a proposed prototype. From the Arduino, the information is passed to the microcontroller and transferred to the android application, and show the result in excel through PLX-DAQ platform. Finally, the accuracy will be determined by comparing the data from treated and untreated sensors. The most suited sensor for monitoring the pH value is a conventional sensor. According to the results of the experiment, an untreated sensor reads more accurately than a treated sensor. Furthermore, data from an untreated sensor is not delayed. The reading was obtained sooner than the treated sensor. As a consequence, it is acceptable to conclude that an untreated sensor is preferable to a treated sensor. Apart from plasma treatment, have new approaches such as atomic force microscopy AFM or X-ray diffraction analysis XRD techniques.

Keywords: Plasma Treatment, pH Sensor, Atmospheric Pressure Plasma

1. Introduction

Every living creature needs water to live on earth. Water supplies to taps in urban houses and water sources available in more rural regions are not always safe for consumption. Although the government must ensure that clean water is delivered to its people, the constantly maturing foundation, which is ineffectively maintained up, and the continual growth in population place a burden on the supply of clean water [1]. The requirement to preserve water quality is critical because water is utilized or ingested in a variety of ways by living creatures. Whether for humans, aquatic plants, or fish, well-kept water is critical for optimal sustainability [2]. Currently, 20% of the world's population does not have access to clean drinking water. In other underdeveloped nations, the situation is considerably worse with unclean or polluted water being consumed without being adequately cleaned [3].

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Among all sensors, pH sensors have gained the most attention because of the importance of pH measurement in various scientific studies and practical applications [4]. pH is a measurable parameter and the electronic device that is used for measuring the pH of a liquid is called a pH sensor. Measuring pH is essential in finding the chemical characteristics of a substance or determining the quality of water [5]. Plasma is made up of electrons, molecules, or neutral gas atoms, positive ions, UV light, and excited gas molecules and atoms, and it has a lot of energy. Plasma treatment begins when all of these molecules, ions, and atoms come together and engage with a specific surface [6].

In this project, we use plasma treatment on the surface of the pH sensor to monitor the difference in pH measurements between treated and untreated sensors and evaluate the accuracy of a pH sensor before and after plasma treatment. The purpose of this experiment was to test the accuracy of a pH sensor in monitoring the accuracy of pH readings. In order to prepare the pH surface for further processing, plasma treatment can be performed, increasing surface energy and simultaneously removing impurities.

2. Materials and Methods

The details of hardware components, software tools, and block diagram of the project were discussed. The block diagrams showed the development of the project. On the other hand, the functionality of each component and the software tools used were discussed too.

2.1 Materials

- *Microcontroller Arduino Uno*
  Arduino Uno is known as a microcontroller as it consists of a physical programmable circuit board. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header, and a reset button [7]. Arduino uses hardware known as the Arduino development board and software for developing the code known as the Arduino IDE (Integrated Development Environment). Built-up with the 8-bit Atmel AVR microcontrollers that are manufactured by Atmel or a 32-bit Atmel ARM, these microcontrollers can be programmed easily using the C or C++ language in the Arduino IDE [8].

- *pH Sensor*
  pH sensor that is used to measure the quality of water to find out either that water is acidic or basic. In this project, we used a gravity analog sensor as a pH sensor. The value is between 0 to 14 [1]. Values more than 7 represent a basic or alkaline solution, whereas values less than 7 indicate an acidic solution. It works on a 5V power source and is simple to connect to an Arduino. The Bronsted-Lowry hypothesis states that an acid is a proton donor and a base is a proton acceptor. When an acid is dissolved in water, it produces H+ ions and counteracts negative ions, but the solution remains neutral. As a result, water with an overabundance of H+ ions become more acidic. Similarly, when a base is dissolved in water, it produces OH- ions, which causes the entire solution to becomes more basic, showing proton accepting behavior [9].

- *PLX-DAQ Platform*
  PLX-DAQ, which stands for parallax Data Acquisition, is a parallax microcontroller data acquisition tool for Microsoft Excel. Any microcontroller linked to a sensor and a PC's serial connector will transfer data directly into Microsoft Excel. PLX-DAQ allows for quick spreadsheet analysis of field data, laboratory analysis of sensors, and real-time equipment monitoring. The spreadsheeting function of the parallax data collecting software application allows for the examination of gathered data from sensors. The incoming data is processed by the parallax tool, which then records it in an Excel file [10]. Aside from that, it includes a few capabilities such as the ability to plot graphs in real-time using Microsoft Excel, record up to 26 columns, and so on. [11]. Using this system can show the data of pH values detected by the sensor in real-time.

- *Arduino IDE*

  The software for Arduino is known as the Arduino IDE (Integrated Development Environment) [12]. It is used for creating code, compiling it to check for problems, and uploading it to Arduino boards. The code that supports Arduino boards such as the Arduino Mega, Arduino Leonardo, Arduino Ethernet, and others. The C/C++ programming language is supported by the Arduino Ide software. For this project, Arduino IDE 1.8.15 version was used to write the source of code of the project [13].

2.2 Methods

The block diagram of the project is shown in Figure 1. The Gravity Analog is used as pH sensor and the pH signal conversion board is used to amplify and convert to analog value from pH electrode to Arduino board. A plasma system creates a flame plasma field when flammable gas and air are combined and combusted to form a blue flame [6].

The input voltage supply is adjusted to a maximum of 220v for plasma lengths ranging from 24-36 mm. The working gas, Argon is distributed into the quartz tube and was manually controlled the mass flow that fixed at 40 sccm. The sensor was treated around the sensitive glass membrane within 2 to 4 seconds. Then, the treated sensor is placed into the prototype and measure the pH value of five different samples. To ensure reliable output measurements, each interval is set to 20 seconds to wash the probe before testing the subsequent samples.

From the Arduino, the information is passed to the microcontroller and transferred to the android application and microcontroller that connected to the treated sensor and the serial port of a PC, it will send the data directly into Microsoft Excel through PLX-.DAQ platform. Other than that, it has a few features such as plot graphs in real-time using Microsoft Excel. Using this system can show the data of pH values detected by the sensor in real-time. The process for the untreated sensor, which is the conventional sensor, will be the same as for the treated sensor with the exception that the untreated sensor will not be exposed to plasma treatment. Finally, the accuracy will be determined by comparing the data from treated and untreated sensors.

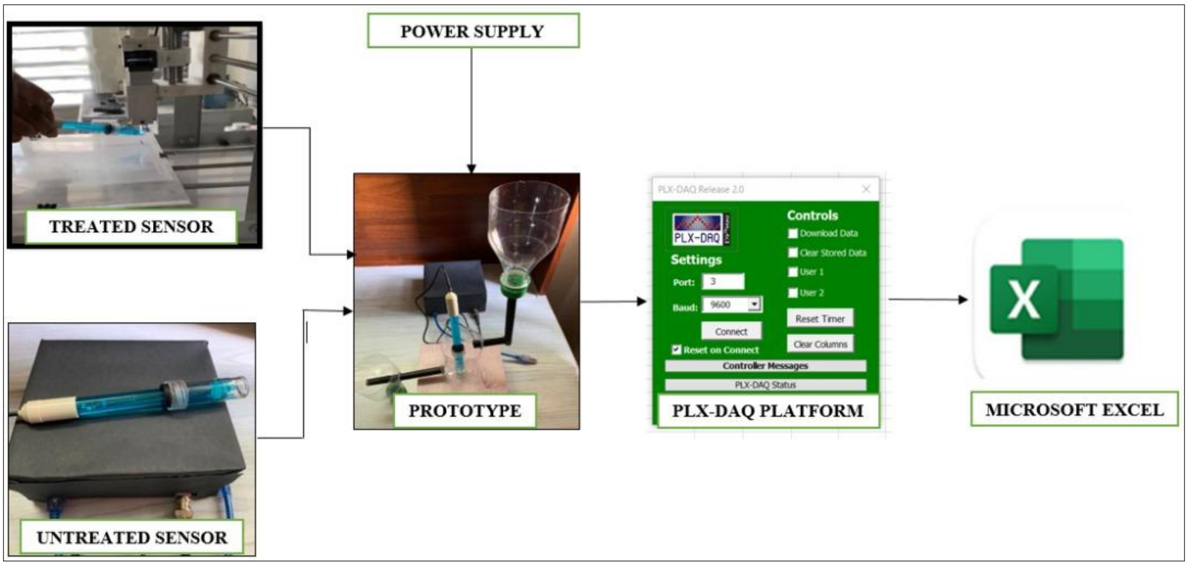

Figure 1: Block diagram of the project

3. Results

The result focuses on the data achieved by testing the samples using the treated and untreated sensors. Orange juice, filter water, lemon juice, tap water, and saline water are chosen as the sample to undergo this testing process. Before testing the samples, the sensor undergoes plasma surface treatment in the plasma jet machine for the treated experiment only. Both experiments were carried out using the prototype of the project. The measured data directly display in Microsoft Excel through the PLX-DAQ platform. On other hand, the achieved result will be used to evaluate the accuracy of a pH sensor before and after plasma treatment and determine a suitable pH sensor device. The graphs of samples were used to compare the result of both treated and untreated sensors. The blue line graph represents an untreated sensor, whereas the red line graph represents a treated sensor. The x-axis represents time in seconds and the left y-axis represents the reading of pH value using treated sensor while the right y-axis represents the reading of pH value using an untreated sensor. Graph of pH against time for orange juice, filter water, lemon juice, tap water, and saline water are shown in Figures 2, 3, 4, 5, and 6, respectively.

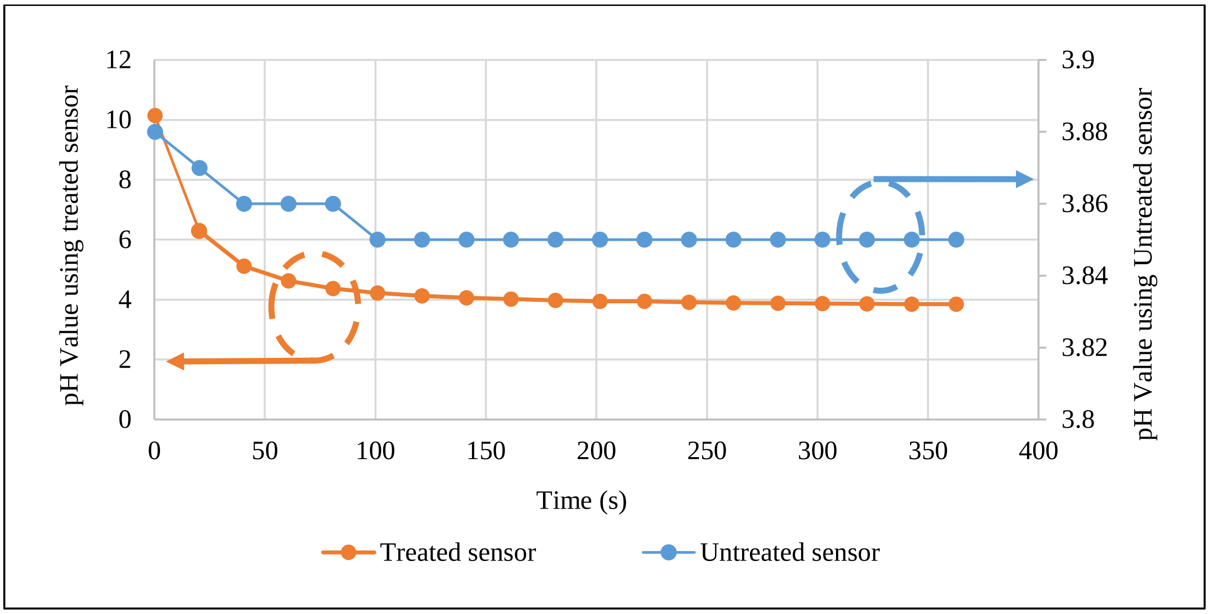

Figure 2: Graph of pH value against time for orange

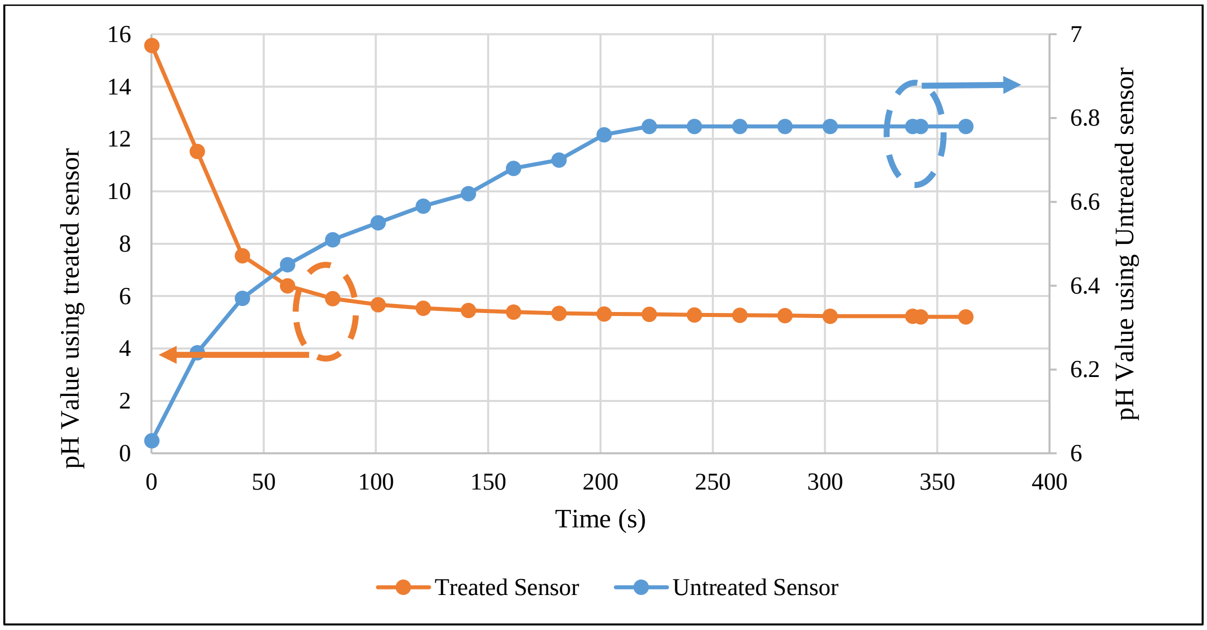

Figure 3: Graph of pH value against time for filter water

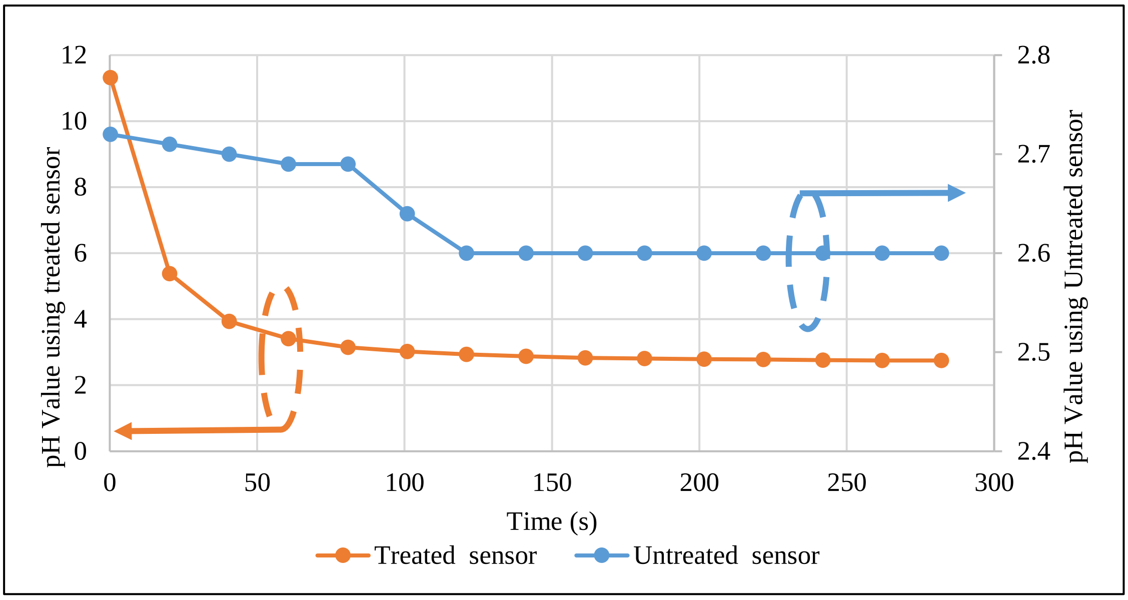

Figure 4. Graph of pH value against time for lemon

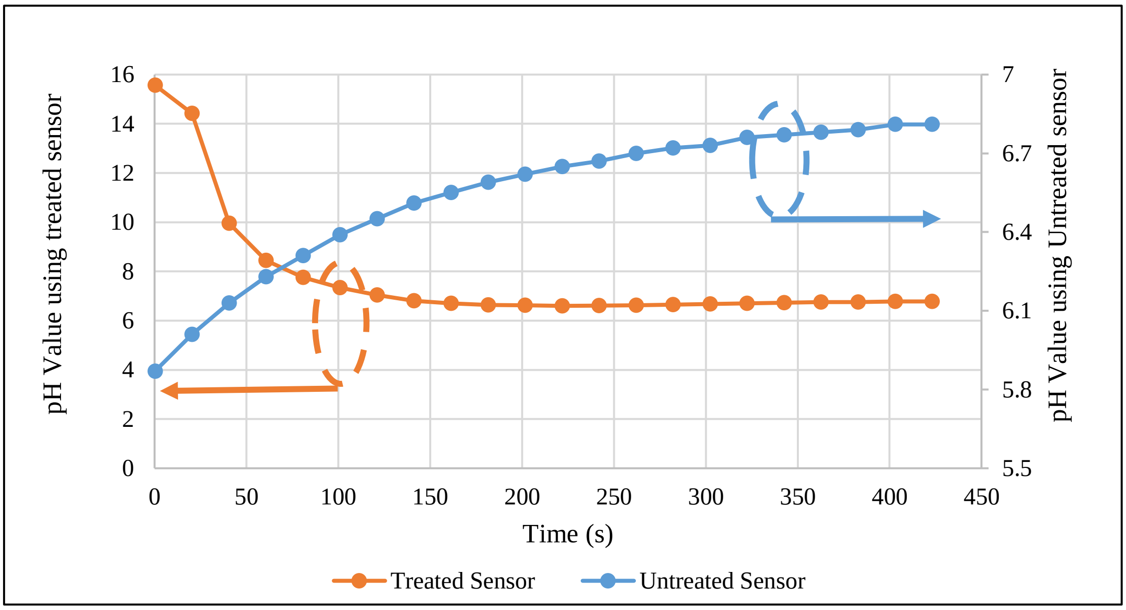

Figure 5: Graph of pH value against time for tap water

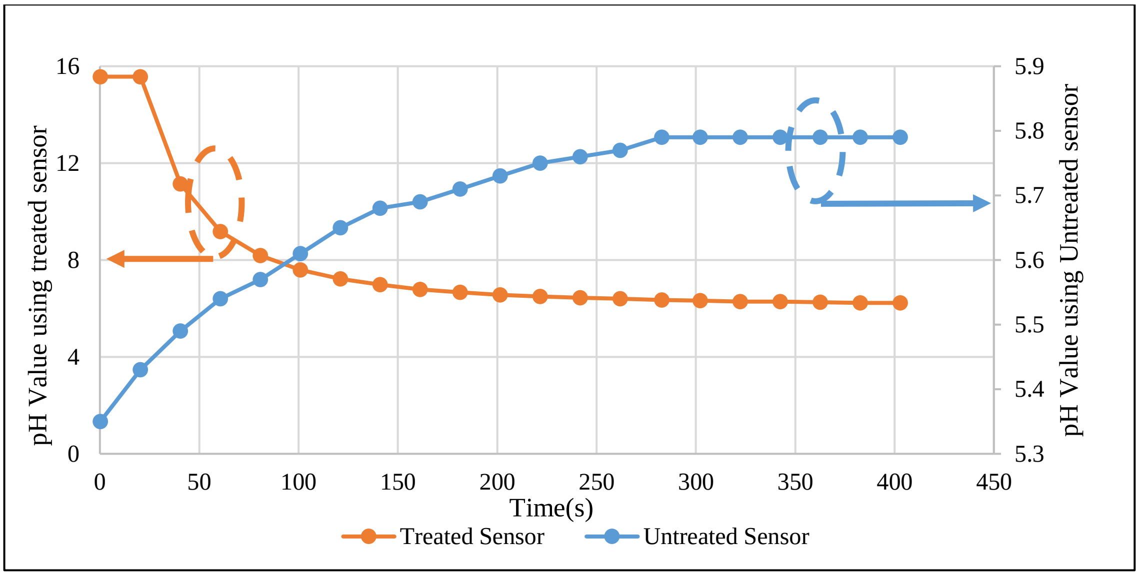

Figure 6: Graph of pH value against time for saline water

4. Discussion

4.1 Overall Discussion of Untreated and Treated Sensor Measurements

According to the result obtained from the five samples, there is a difference between the sensitivity of the sensor before and after plasma treatment. The changes in sensitivity of the sensor caused to obtained different pH values after the plasma treatment. The pH value from 1 to 7 indicates acidic while 7 is neutral and 7 to 14 is alkaline [14]. Few reasons affect the treated graph reading which causes the reading to be higher at the beginning and takes a longer time to obtain a stable pH value.

The untreated sensor shows accurate readings when the probe is exposed in a hydrogen rich acidic environment where the glass membrane is absorbed by hydrogen ions, which generate a positive potential on the detecting electrode such as lemon and orange samples which has acidic properties. Similarly, when the probe is immersed in an alkaline environment, there is a greater hydrogen concentration within the probe than outside of the probe. This causes hydrogen ions within the probe to move outside of it, leaving an excess of hydroxide ions within it. The pH sensor detects a negative potential as a result [15].

The pH sensor consisted of an equal amount of hydrogen and hydroxide ions exist in the glass membrane. The free electrons gain energy from the imposed high-frequency electric field, colliding with neutral gas molecules and transferring energy after undergoing the plasma treatment. The resultant plasma is a partially ionized gas with high concentrations of excited atomic, molecular, and ionic species. Excitation of the gas molecules is achieved by treating the gas, generally at high frequency which allows the treated graph to increase at the beginning of the experiment [6]. Besides that, the pH value took more time to stabilize after plasma treatment. This is due to the interaction of these excitons with the glass membrane positioned in opposition to the plasma, which causes a chemical alteration between the excited electrons, hydrogen, and hydroxide ions inside the sensitive glass membrane. The pH value will be stabilized after more hydrogen ions are attained into the glass membrane for orange and lemon samples since the sample has acidic properties while for tap water and filter water equal hydroxide and hydrogen ions attained into the glass membrane indicate a neutral medium which is around 7 [6].

As a result, the pH probe took a longer time to detect the pH value for the treated sensor. The treated sensor's detection level being significantly slower than that of a commercial sensor. When utilizing the commercial sensor for measuring the pH reading, it shows high accuracy for the five samples used. Hence, an untreated sensor has an accurate reading of pH value with less consumption time than a treated sensor.

4.2 Analyses the Accuracies Between an Untreated and Treated Sensor

In this project, orange juice, filter water, lemon juice, tap water, and saline water were used as samples to carried the experiment with the treated and untreated sensor. A total of ten experiments were carried with the use of these five samples.

Firstly, the reading of orange juice obtained with an untreated sensor and a treated sensor are equivalent, but the time needed to attain the pH value with a treated sensor is longer than with an untreated sensor. The pH value for lemon should be in the range of 2.0 to 2.6 [16]. Hence, an untreated sensor reading is accurate in a short time. The second experiment was carried out for filter water. The reading showed for an untreated sensor is 6.78 while for the treated sensor is 5.21. The pH range of filter water is between 6.5 to 8.5. Hence, an untreated sensor results more accurately with a reading of 6.78.

The next experiment was carried out for lemon juice. The reading showed for an untreated sensor is 2.60 while for the treated sensor is 2.75. The lemon has more acidic properties than other samples. As a result, the pH reading is more acidic and an untreated sensor is measured more accurately than a treated sensor without delay. The next experiment was conducted for tap water. The actual pH value of tap water is in the range of 6.5 to 7.5 [17]. The reading showed for an untreated sensor is 6.81 whereas for the treated sensor is 6.78. Although both readings are within range, an untreated sensor value is closer to the neutral side, which is 7. As a result, the measured reading for an untreated sensor is more precise. The saline water has a pH value of around 4.5 to 7[18]. Based on the experiment, the reading showed for an untreated sensor is 5.79 while for the treated sensor is 6.23. The time needed to attain the pH value with a treated sensor is longer than with an untreated sensor.

Hence, an untreated sensor reading is accurate in a short time. From the result, it is possible to conclude that untreated sensor values are more accurate than treated sensor readings without delay.

4.3 Determine suitable pH Sensor Device

The most suited sensor for monitoring the pH value is a conventional sensor. According to the results of the experiment, an untreated sensor reads more accurately than a treated sensor. Furthermore, data from an untreated sensor is not delayed. The reading was obtained sooner than the treated sensor. As a consequence, it is acceptable to conclude that an untreated sensor is preferable than a treated sensor for measuring the chemical characteristics of a substance or to determine the quality of water**.**

5. Conclusion

The pH sensor device using conventional and treated pH sensor constructed and could perform the functions of measure chemical characteristics of the samples according to the purpose of the research. A total of ten experiments were carried with the use of these five samples. When the difference in pH measurements between treated and untreated sensors was examined, there were slight differences in pH value readings of tests conducted over different lengths of time. The time taken by the treated sensor to read the pH value is longer than an untreated sensor. On the other hand, when analyzing the accuracies between an untreated and treated sensor the majority of experiments proven that an untreated sensor reading is more accurate within a short period of time. The most suited sensor for monitoring the pH value is a conventional sensor. According to the results of the experiment, an untreated sensor reads more accurately than a treated sensor. Furthermore, data from an untreated sensor is not delayed. The reading was obtained sooner than the treated sensor. As a consequence, it is acceptable to conclude that an untreated sensor is preferable to a treated sensor for monitoring the pH reading of any aqueous solution.

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