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Arduino-based Spectrometer Design for Measurement of Liquid Absorbance

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Abstract: The Spectrometer is an important common analytical equipment that measures the concentration of analytes via their absorbance of light at specific wavelengths. However, many laboratories with limited resources cannot afford such equipment. A Spectrometer utilizes the wavelength of the electromagnetic spectrum. The main component of the spectrometer is the sensor detector. The BH1750 sensor is used to detect the absorbance of the sample after being irradiation with a Light Emitting Diode Red Green Blue (LED RGB). If the RGB light irradiated the sample, the sensor will read the output value according to the Arduino Programming. This study used Congo red samples with various concentrations of 20, 30, 40, 50, and 60 ppm. the tool can be developed at low cost and the performance of the tool is highly satisfactory in terms of accuracy and precision.

Keywords: Spectrometer, LED RGB, Absorbance, Arduino Nano

1. Introduction

Advances in industry, pharmacy, and technology have provided various aspects, including in the field of the measurement methods. Spectroscopic analysis is based on the interaction of radiation which is based on the principle of using light/magnetic to affect the chemical compounds to get responses. The response can be measured to determine the amount or type of compound [1]. Spectroscopy is a method used to examine the matter and its attributes based on the light emitted, absorbed, or reflected by the materials. Spectroscopy is a term used for the science (theoretically) that studies the relationship between radiation energy which has a wavelength function and objects. So there are 3 different terms: spectroscopy, spectrometry, and spectrometer [4].

A Spectrometer is a measuring device for quantitative analysis generally used to characterize chemical substances by determining the amount of light that is partially absorbed by the analyte present in the solution [2]. They can be classified to the spectral region of work, such as ultraviolet spectrometer (UV), from 190 nm to 380 nm; visible spectrometer (Vis), from 400 nm to 700 nm.

According to their use, they are classified as stationary devices for analysis in laboratories and portable devices for determining the absorbance value of samples in fieldwork [1]. Along with the relative high costs of commercial spectrometers, additional software and computer for data collation and analysis are required for spectrometric analysis. Such requirements are obstacles to less well-off laboratories. Even when costs are not an intrinsic barrier, the stationary nature of such a device restricts spectrometric predominantly to the laboratory environment [3].

There are spectrometers that work for visible range, there are several devices that include a Light Emitting Diode (LED) as radiation source [5], mainly because they have low costs and allow easy implementation. It is worth mentioning the developments presented in references [6,7] which made analyses for four wavelengths and that reported in references [8-10] for seven fixed wavelengths which can be selected by the user with the help components. This Spectrometer research is designed and built based on Arduino. The spectrometer system made up of a light source, optical system, control, sensor system, signal conditioning, microcontroller, and data display [11]. Light source used is a visible light source, namely an RGB LED [12]. Arduino was chosen as an acquisition system because it was easy to use, so it can be used simply. Arduino is programmed to implement the algorithms required in the spectrometer process. In addition, Arduino can transmit display information more efficiently.

2. Materials and Method

This study is part of engineering research. Engineering research is research that incorporates science into a design to achieve performance that meets specified criteria. Problem inquiry (literature review), design idea, design execution (manufacturing), design validation, and design assessment are some of the techniques used in the research [13]. The flowchart in Figure 1 depicts the design form software of the spectrometer. The instrument was tested to determine the characteristics of the sensor, accuracy, and precision. The sensor characterization was carried out using a lux meter to measure light intensity. Meanwhile, measuring the accuracy of the tool is done by comparing the measurement results of standard tools using UV-VIS. In this study, Congo Red was used as the test fluid. To see changes in absorbance, the concentration of the Congo red liquid was varied, consisting of 20 ppm, 30 ppm, 40 ppm, 50 ppm, and 60 ppm.

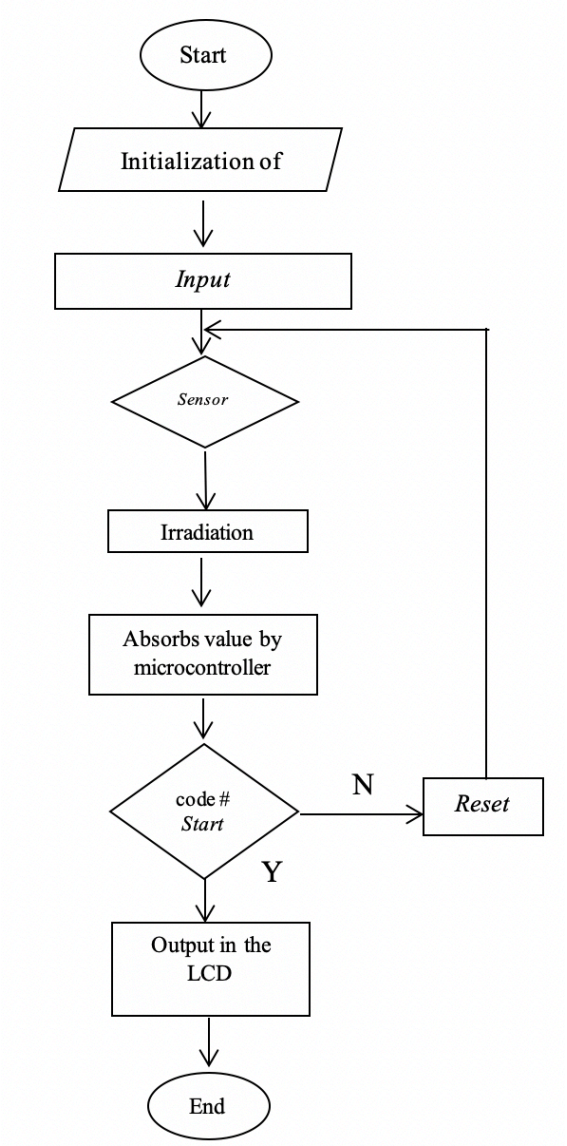

Figure 1. Flowchart design for software of the Spectrometer

3. Results and Discussion

3.1. Hardware system

The spectrometer has dimensions of a length of 15 cm, a width of 13 cm, and a height of 17 cm. The appearance of the spectrometer is shown in Figure 2. Figure 2 shows a sets of developed spectrometer with the LCD display. All the electronic circuit part is in the black box.

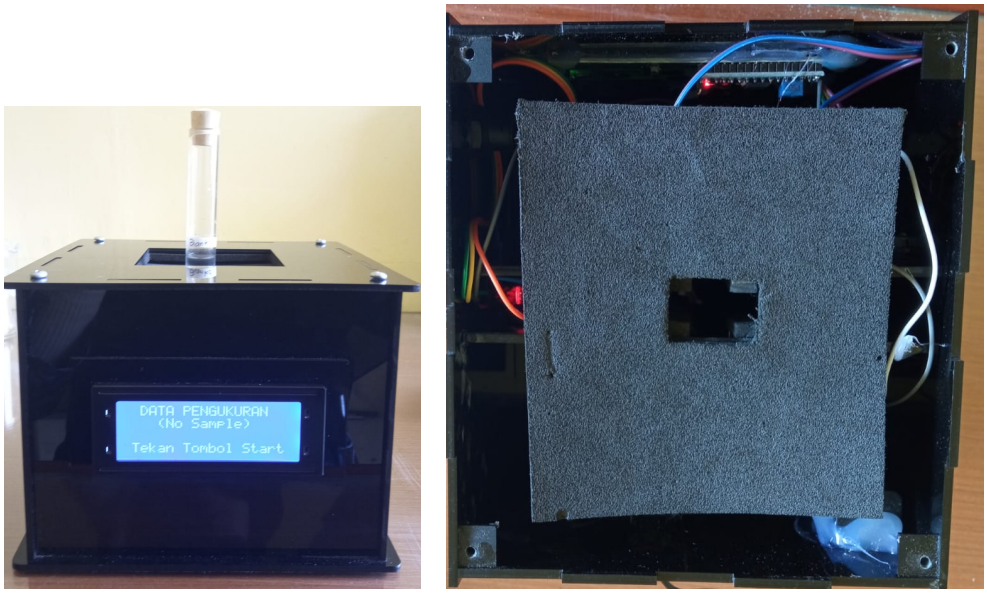

Figure 2. Photograph of an assembled spectrometer

The spectrometer is built using Arduino Nano, BH17 sensor, RGB light, and battery. In addition, the box has an LCD, start and reset button, and an ON/OFF button. Arduino Nano is used as a controller and data processor. The form of the overall spectrometer mechanical circuit can be seen in Figure 3.

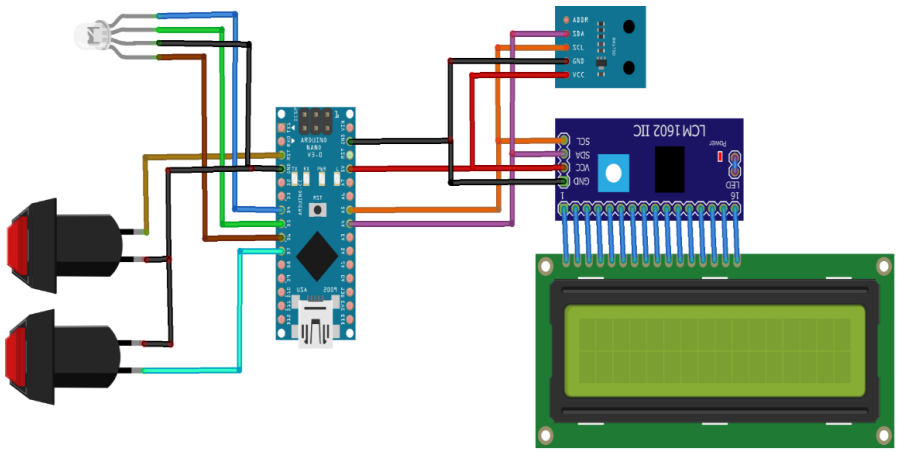

Figure 3. Complete spectrometer circuit

3.2. Data results

The design specifications of the tool display the sensor characteristics, accuracy and precision of the tool. For sensor characteristics, the LED light has 4 wavelengths with different intensities. The intensity of each LED is shown in Figure 4. From Figure 5 it can be seen that the white light has a very high intensity. While the lowest intensity is the blue light.

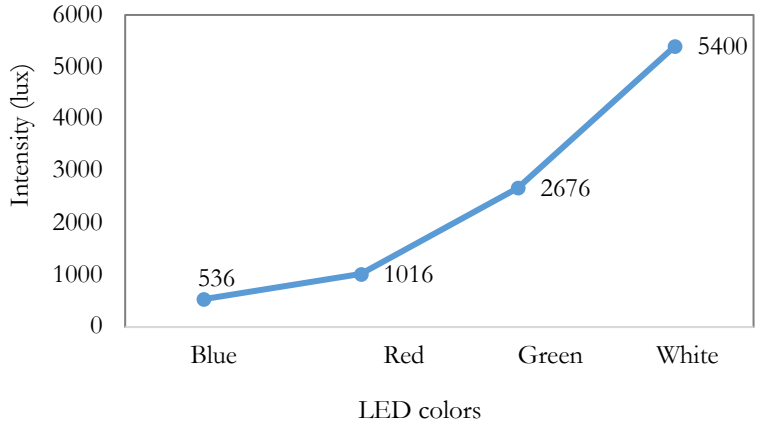

Figure 4. The value of the intensity emitted by each colour of the lamp

Measurement of accuracy is obtained by comparing the results of the spectrometer measurements made with a standard tool spectrometer. Tool testing was carried out on 5 variations of Congo red concentration, namely 20, 30, 40, 50, and 60 ppm. Each concentration was measured using 4 variations of wavelength (4 colors). Absorbance measurements were carried out 10 times for each wavelength and the average value of the measurements was taken. For a concentration of 20 ppm Congo red, the results of the spectrometer measurement are close to the results of the standard instrument measurements with an average accuracy of 0.95. The results of the absorbance measurement (A) as a variation of wavelength are shown in Figure 5. Based on Figure 5, it can be seen that the green wavelength (521 nm) has the highest absorption (peak) of 0.6 A.

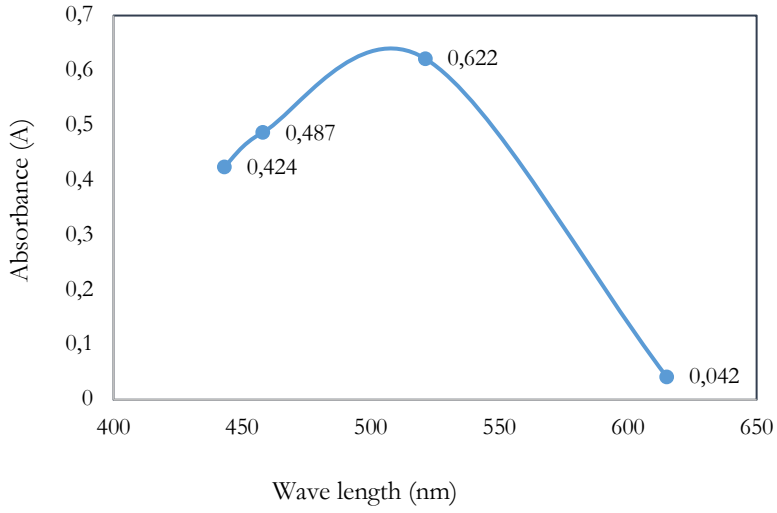

Figure 5. The relationship between wavelength and absorbance for a concentration of 20 ppm.

The second variation for a concentration of 30 ppm Congo red, the results of the spectrometer measurement are close to the results of the standard instrument measurements with an average accuracy of 0.95. The results of the absorbance measurement (A) as a variation of wavelength are shown in Figure 6. Based on Figure 6, it can be seen that the green wavelength (521 nm) has the highest absorption (peak) of 0.89 A.

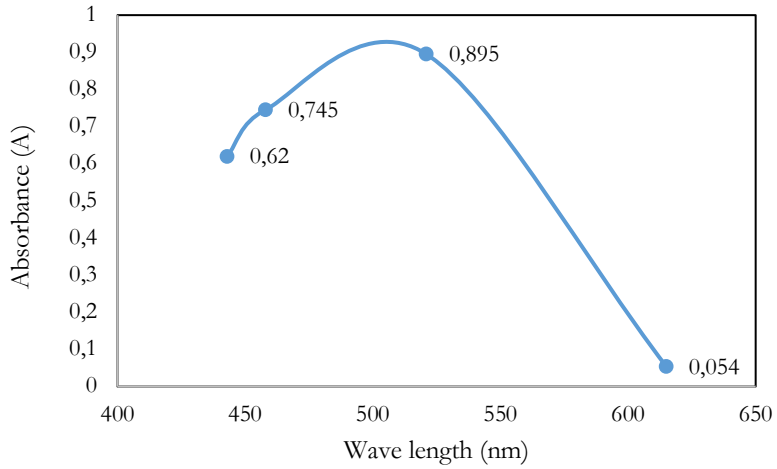

Figure 6. The relationship between wavelength and absorbance for a concentration of 30 ppm.

The next variation for a concentration is 40 ppm Congo red, the results of the spectrometer measurement have better accuracy and follow the measurement results of standard instruments with an average accuracy of 0.97. The results of the absorbance measurement (A) as a variation of wavelength are shown in Figure 7. Based on Figure 7, it can be seen that the green wavelength (521 nm) also has the highest absorption (peak) of 1,06 A.

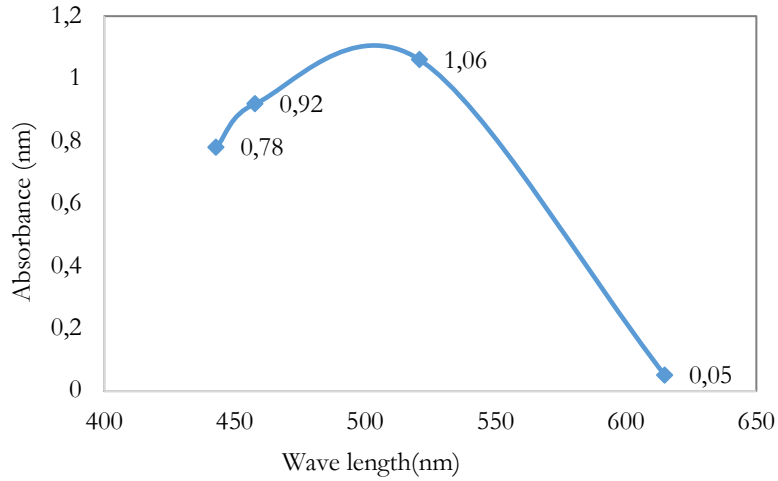

Figure 7. The relationship between wavelength and absorbance for a concentration of 40 ppm.

The fourth variation of concentration is 50 ppm Congo red, the results of the spectrometer measurement are close to the results of the standard instrument measurements with an average accuracy of 0.96. The results of the absorbance measurement (A) as a variation of wavelength are shown in Figure 8. Based on Figure 8, it can be seen that the green wavelength (521 nm) also has the highest absorption (peak) of 1,34 A.

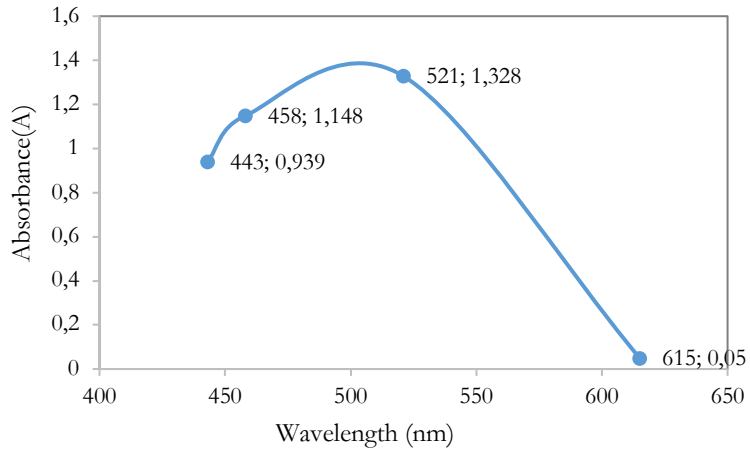

Figure 8. The relationship between wavelength and absorbance for a concentration of 50 ppm.

Then the variation that has a high concentration is 60 ppm Congo red, the results of the spectrometer measurement have better accuracy and follow the measurement results of standard instruments with an average accuracy of 0.97. The results of the absorbance measurement (A) as a variation of wavelength are shown in Figure 9. Based on Figure 9, it can be seen that the green wavelength (521 nm) also has the highest absorption (peak) of 1,5 A.

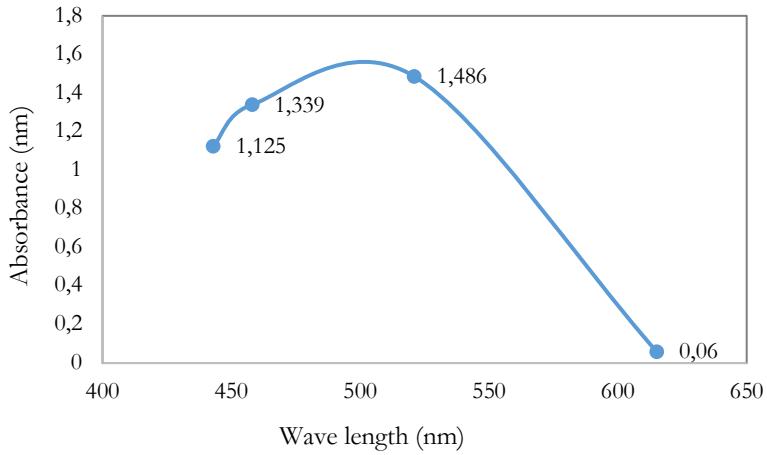

Fig. 9. The relationship between wavelength and absorbance for a concentration of 60 ppm.

Measurement of accuracy has been carried out by using the same measurement method 10 repetitions with variations in the concentration of Congo Red at one wavelength. The wavelength used is 443 ppm which is also called the white spectrum. The results of Accuracy measurement with concentration variations in white light are shown in Table 1.

Table 1. The Result of Accuracy in white light

No	Absorbance (A) for concentration					Accuracy				
	20	30	40	50	60	20	30	40	50	60
1	0.39	0.65	0.82	0.87	1.12	0.920	0.952	0.963	0.927	0.996
2	0.45	0.63	0.79	0.87	1.13	0.939	0.984	0.999	0.927	0.996
3	0.45	0.63	0.78	0.97	1.12	0.939	0.984	0.986	0.967	0.996
4	0.42	0.62	0.79	0.97	1.13	0.991	1.000	0.999	0.967	0.996
5	0.42	0.61	0.80	0.96	1.12	0.991	0.984	0.989	0.978	0.996
6	0.43	0.63	0.77	0.95	1.13	0.986	0.984	0.973	0.988	0.996
7	0.41	0.60	0.76	0.92	1.12	0.967	0.968	0.961	0.980	0.996
8	0.42	0.63	0.78	0.96	1.13	0.991	0.984	0.986	0.978	0.996
9	0.42	0.60	0.80	0.95	1.12	0.991	0.968	0.989	0.988	0.996
10	0.43	0.60	0.82	0.97	1.13	0.986	0.968	0.963	0.967	0.996
Average	0.42	0.62	0.79	0.94	1.13	0.970	0.977	0.981	0.967	0.996

The accuracy measurement has been carried out at a wavelength of 443 nm. as shown in the precision table, each concentration is quite good. the results of the spectrometer measurement are close to the results of the standard instrument measurements the average precision of absorption is 0.97 with a standard deviation for the white lamp of 0.011. Because the microcontroller selection can affect the result of data measurements, the accuracy and precision obtained by the Arduino are also used. this is because the microcontroller is the component's brain or controller, allowing it to function in accordance with the desired goal [14]. According to the result of research on accuracy and precision, the spectrometer has good specifications and an Arduino-based Spectrometer can make it easier and portable and also can use for absorbance of the sample.

4. Conclusion

A simple spectrometer using a visible light source has been developed to measure the absorbance of a solution. This device consists of a light source, samples, sensors, and Arduino. The highest absorptivity is obtained if the source used is a green LED (521 nm). An Arduino-based spectrometer design criteria yield precision and accuracy. the average accuracy is 99.97 percent and the precision absorbance value at the white lamp is 0,97.

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