Proceedings of Science and Mathematics
Faculty of Science, Universiti Teknologi Malaysia

Vol. 6, 2022, Page 6-9

Development of a Portable Spectrophotometer Employing Arduino Microcontroller System for Pollutant Analysis

Anis Nur Shasha Abdul Halim[a], Aemi Syazwani Abdul Keyon[b]*, Nur Safwati Mohd Nor[c]
[a,b]Department of Chemistry, Universiti Teknologi Malaysia, 81310 UTM, Johor Bahru, Johor, Malaysia
[c]Department of Engineering, Faculty of Mechanical Engineering, Universiti Teknologi Malaysia, 81310 UTM, Johor Bahru, Johor, Malaysia
*Corresponding author: aemi@utm.my

Abstract
The purpose of this study was to demonstrate a simple, portable, and inexpensive spectrophotometer for on-site chemical analysis. Different from other spectrophotometers, the present instrument consisted of double light sources which are 1W white LED and UV LED, a Light Dependent Resistor (LDR) as light detector, a DVD disc as monochromator and Arduino UNO microcontroller as an acquisition system and also MySQL database system to store data. To maintain a UV and visible range wavelength, a white LED and UV LED emitting a 190-370 nm and 320- 1100nm continuous spectrum was employed. Software was written in Arduino IDE to control spectrophotometer through a USB interface and for data transfer to the computer. This makes the present instrument feasible for chemical analysis device in developing countries because of its affordable cost. The effectiveness of the portable spectrophotometer for screening pollutants will also demonstrate. Different from commercially available standard spectrophotometers that have limitations in data analysis, this portable spectrophotometer also consists of database system to allow data storage and easier for on-site analysis to get immediate result.
Keywords: UV-Vis Spectrophotometer; arduino; portable

Introduction
Ultraviolet-visible spectroscopy (UV-Vis), atomic absorption spectroscopy (AAS) and chromatographic-based instruments are commonly being used for analysis of pollutants. Complementary to these definitive instruments, on-site chemical analysis may reduce the overall analysis cost since it only requires simpler definitive analysis to validate the on-site testing data. On top of that, it is impractical to bring bulky and sensitive instruments for on-site analysis. Due to ecological considerations, there is an increasing demand of simple techniques for on-site pollutants analysis in industrial wastes, leachates, landfills and other sources of pollution. The presence of a cheap portable instrument to do the pollutants analysis on-site is seen as a promising complementary aspect in a chemical analysis. For environmental monitoring as well as forensic applications fast response is needed for decision-making. In order to get fast screening result and outcomes, a portable device for analysis of pollutants on-site is needed. Thus, the development of compact and easy-to-achieve sensors for the identification of these pollutants is desirable. On-site portable promises several advantages such as low manufacturing costs, ease of use, fast production, and low power consumption (Singh et al., 2020).

Several literatures have focused on developing a portable and compact screening device that could be used on-the-go. For example, as mentioned by Widiatmoko and co-worker (2011), their portable spectrophotometer using cardboard, cardboard and digital camera as the hardware, photodiode sensor and a microcontroller was able to measure optical wavelengths with a theoretical resolution as high as 0.2 nm using image processing. Zhang et al (2006) made a portable water analyser using LED as light source and a photodiode sensor for detection of selected peak of wavelength.

However, most of these in-situ devices have been designed to produce very low-cost prototypes, generally to be used for educational purposes or to obtain simple and restricted information and not to acquire scientifically relevant data that needs reproducible and accurate information. Moreover, they are not equipped with pre-determined database embedded in the system to achieve semi-quantitative analysis. Essentially, database is a collection of data in an organized way. Exploring database is fundamentally important because i) large number of records can be stored efficiently; ii) information can be searched in few seconds and iii) as a reference in chemical analysis especially pollutants analysis.

Materials and methods

Chemical analysis made on-site is on demand nowadays especially in environmental monitoring for fast decision making. Thus, it is unfeasible to bring bulky and sensitive instruments for on-site analysis. An automated portable screening device for pollutants analysis will be developed. The main approach of this study is to build up an automated semi-quantitative device equipped with Arduino platform as a microcontroller, whereby a database for various pollutants will be created and stored for a comparison purpose. Portability in this case is not only referring to the ability of the device to move but also in relation to software. It is a measure of how easily an application can be transferred from one computer environment to another. Exploring database is fundamentally important because i) large number of records can be stored efficiently; ii) information can be searched in few seconds and iii) as a reference in chemical analysis especially pollutants analysis.

General design of the spectrophotometer is shown in Figure 1. However, in this study, hardware device for home-built spectrophotometer will be assembled as shown in Figure 2. In this research, there will be two light sources that will be used in this research namely White LED and UV LED. Next, the “entrance slit” for the photometer is made with a piece of cardboard. The dispersion device or monochromator is made by assembling a cut up DVD with a 28byj-48 stepper motor which allows movement of the diffracted light. Two pieces of slits with the same length measured precisely with a ruler will be placed side by side. Furthermore, the sample holder (also known as cuvette) will be filled with sample solution followed by the detection using Light Dependent Resistor (LDR) sensor as its photoresistor detector.

For the sample preparation of the azo dyes, first the river water sample will be filtered using Whatman glass microfiber filters, 4.7 cm. Then, the river water sample will be spiked with a dye mixture and acidified with 0.1 M hydrochloric acid to give pH 3. The dyes will be extracted using SPE cartridges from these samples. 1 ml of methanol followed by 2 ml of water would be pre-conditioned. Using a peristaltic pump at 2 ml /min, the sample (100 ml) is transferred through the cartridge. The dyes would then be eluted with 2 ml of methanol, evaporated to dryness, and 250 ml of electrophoresis buffer reconstituted. The recoveries will be calculated as the ratio of the peak areas obtained for the samples processed over the peak areas of matrix-matched standards.

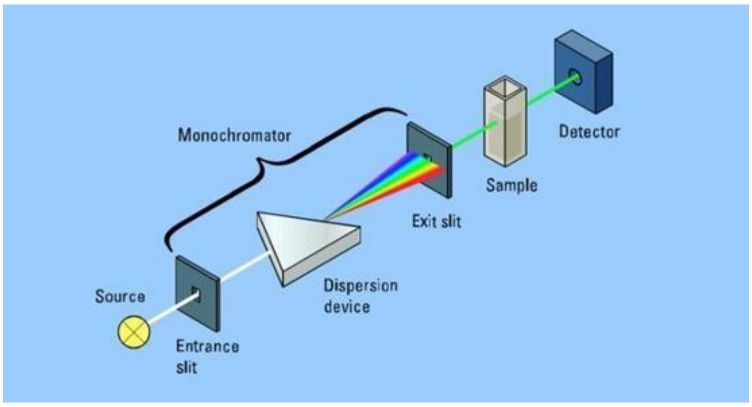

Figure 1 The design of spectrophotometer (Miramar, 2012)

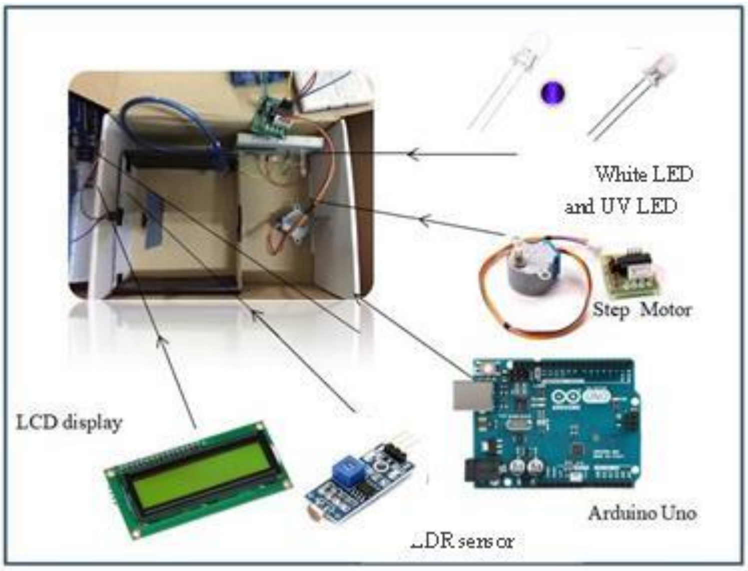

Figure 2 Portable spectrophotometer hardware arrangement.

Results and discussion

A portable photometer is expected to be successfully built by equipping it with miniaturized light source, light detector based on photodiode array, data display and database system. The Arduino microcontroller is expected to be programmed with measurement algorithm, calibration functions and drift correction needed for the full instrument operation, with the numeric result displayed on screen. The pre-written scripts can be successfully uploaded onto the Arduino printed circuit board (PCB) via the USB port. The absorption graph in Figure 3 and Figure 4 is to observe the effectiveness of the lux meter and LDR which detects light from different concentration of food dye.

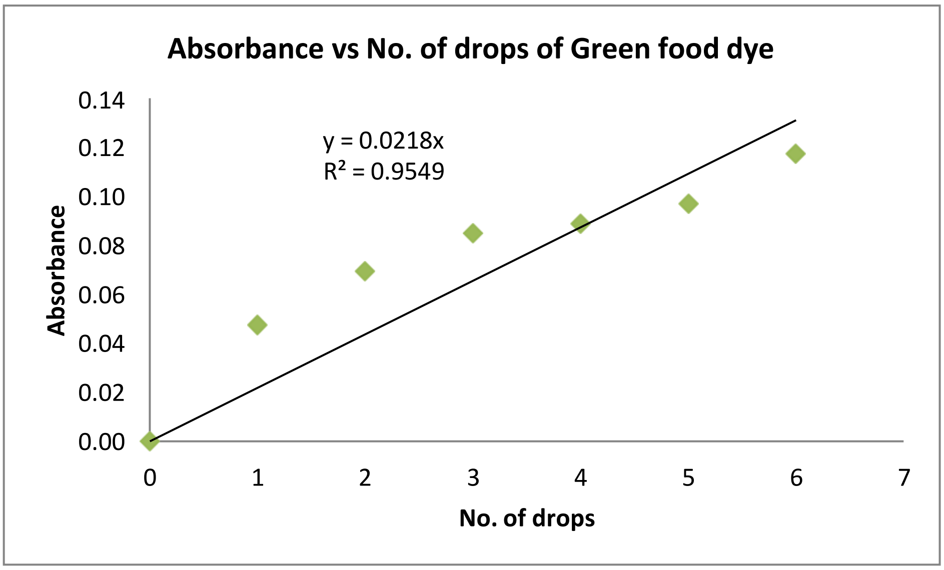

Figure 3 Plotting of absorbance of green food dye.

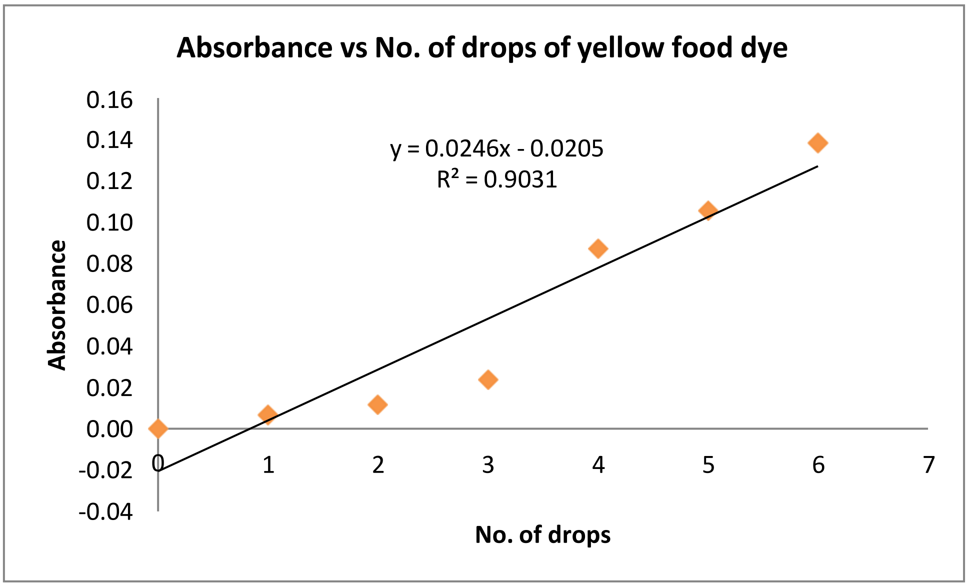

Figure 4 Plotting of absorbance of yellow food dye.

Database system for several pollutants data will be developed. The data can be easily and quickly stored and updated in the MySQL database system. Results from screening of pollutants in wastewater samples are expected to automatically display.

Pollutant detection is expected to be a result of wavelength of coloured compound from the database. Since the coloured compound possess high molar absorptivity, the Pollutants will yield high signal in a sample cuvette within the photometer system. The signal will be reliable at low concentration range (i.e. part per million, ppm), which will be construed true by an analytical calibration curve. The signal from the photometer is expected to be valid and comparable with the signal detected within a commercially available spectroscopy instrument.

Conclusion

An innovative portable photometer for pollutants analysis by screening as an output and automated by an Arduino microcontroller is proposed to be developed. It will be a simple and low-cost assembly, that will enable it to be used as on-site analytical tool for heavy metal content in environmental, quality control applications to name a few. In addition, it is believed that this approach may serve as a foundation for development of more Arduino-based instrumentation as analytical tool for various other analytes and samples having the features required to become a field instrument. This project is foreseen to enable collaboration with national/international agency/company for product improvement and utilization. The portable photometer could be utilized and further developed as an on-site analytical tool for government agency (Department of Environmental Malaysia) and industries (during QC). Thus, this proposal is presented for project approval from the panel.

Acknowledgement

I would like to express their appreciation for the support of the sponsors with UTM Shine.

References

Eko Widiatmoko, Widayani, Maman Budiman, Abdullah, M., & Khairurrijal. (2011). A simple spectrophotometer using common materials and a digital camera. *Journal of Physical Education*.

Singh, H., Singh, G., Mahajan, D. K., Kaur, N., & Singh, N. (2020). A low-cost device for rapid 'color to concentration' quantification of cyanide in real samples using paper-based sensing chip.*Sensors and Actuators B: Chemical*, 322.

Zhang, Y., Causserand, C., Aimar, P., & Cravedi, J. P. (2006). Removal of bisphenol A by a nanofiltration membrane in view of drinking water production. *Water Res*, 40(20), 3793- 3799.

Miramar, http://faculty.sdmiramar.edu/fgarces/LabMatters/Instruments/UV_Vis/Cary50.htm, last accessed 2020/08/09.