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Development of a device based on the respirometric principle for long-term monitoring of BOD and pH: a novel approach in wastewater characterisation

Thanh Dam Nguyen[1], My Linh Hoang[1], Hong Anh Duong[1], Hung Viet Pham[1*], Anh Tuan Do[2], Jean-Luc Vasel[3]

[1]Key Laboratory of Analytical Technology for Environmental Quality and Food Safety Control, University of Science, Vietnam National University, Hanoi, Vietnam

[2]Institute of Information Technology Vietnam Academy of Science & Technology, Vietnam

[3]EcoService Company, Libramont, Belgium

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Abstract:

Biochemical oxygen demand (BOD) and pH are two important parameters in environmental analysis that allow the assessment of water quality. Although the long-term determination of BOD and pH can provide more useful information about the wastewater characteristics, present commercial BOD devices do not usually meet this demand. This research has successfully developed a novel BOD/pH device based on the respirometric principle, which can simultaneously and continuously monitor both BOD and pH of wastewater for about 20 days. The performance of the proposed device is evaluated in the laboratory by comparison to that of a commercial device (BOD Trak II, HACH). This solution not only follows the variation of BOD and pH over a long period of time, but also shows low cost and high potential for a wide variety of applications in Vietnam.

Keywords: **BOD, characterization, pH, respirometric, wastewater.**

Classification number: **2.2**

Introduction

BOD and pH are important parameters that assess water quality [1]. BOD tests can be considered as a miniature aerobic biological treatment process, in which microorganisms use organic compounds for food while consuming oxygen and producing CO_2 and H_2O [2]. Those metabolic reactions induce pH changes. While pH changes can be easily followed by a pH meter, BOD curves, which tally the cumulated oxygen consumption, is a complicated and time-consuming process that usually takes five days for a BOD_5 test.

In recent years, some studies have developed different methods to rapidly measure BOD [3, 4], however, long-term monitoring of BOD can bring interesting results about the kinetics of biodegradation [5, 6] and even odour [7]. Current commercial BOD measuring devices can be classified into two major categories: (1) the measurement of dissolved oxygen (DO) consumption in the liquid phase by an optical/DO sensor and (2) the determination of O_2 consumption in the gas phase by monitoring pressure depletion with a pressure sensor (manometry or respirometry) [8]. The biodegradation process takes place in the liquid phase, so the first type of BOD device may seem more favourable. However, the measurement of oxygen in the liquid phase is not suitable for long-term BOD monitoring because the electrodes consume a small amount of oxygen and that will cause compound errors if measured continuously. For this reason, the respirometric method is the preferred option for the purpose of long-term BOD measurement.

[*]Corresponding author: Email: phamhungviet@hus.edu.vn

The combination of BOD and pH data with mathematical models can be a novel approach to the characterization of wastewater for simulating and optimizing the treatment process. However, the requirement of continuous BOD and pH data (sampling frequency can be every 5 minutes) for a long time (about 20 days) is not met by current equipment. Therefore, in this study, a novel device has been developed based on the respirometric principle that is capable of simultaneous and continuous measurement of both BOD and pH.

Materials and methods

Chemicals and materials

To absorb CO_2 in all tests, solid KOH (Merck, Germany) was used. Besides, the pH buffers (4.01, 7.00, and 10.01 from HACH, USA) were used to calibrate the pH sensor of the device.

The BOD Trak II device (HACH, USA) was used as a reference to make the comparison between the developed BOD/pH device and the commercial BOD equipment.

The samples used in the test of the proposed BOD/pH device and BOD Trak II were real wastewater samples collected from a pig farm in Hanoi. The samples were taken in glass bottles at the location of the waste gate and then stored at 4°C before analysis.

Instrumentation

The development process of the BOD/pH device included defining its features, selecting its components, designing electronic circuits, assembling the equipment, and finally calibrating the device before applying it in practice. The electronic components that were used to build the device include a microcontroller (STMicroelectronics, USA), pressure sensors (TE connectivity, Switzerland), pH sensors (Rika, Taiwan), temperature sensors (Sensirion AG, Switzerland), an 8×2 LCD display screen (Newhaven Display Intl, USA), 64 KB ROM storage memory (Adesto Technologies, USA), and a 12 VDC power supply unit.

The principal circuit of the components used in the BOD/pH device were designed on OrCAD software. The printed circuit board (PCB) to connect the components was designed with PADS2015 software. After assembly, the device was calibrated by measuring the signal of the standard values for pressure and pH, establishing a calibration curve and feeding the microcontroller.

Software

Software was developed for graphical displays, BOD calculation, online data acquisition, and other calculations. The BOD data logger software, which was developed in C#, has two main parts:

(A) In the first part (tab Setup), the users provide parameters like information COM port (name, baud rate, etc.), sample description (volume of bottle, volume of liquid phase, range of BOD), maximum time for taking readings, time interval between readings, and output file name to the software. This form has four command buttons i.e. Open, Close, Start, and Exit. By pressing the Open button, the program opens the COM port that connects to the device through a USB interface. By pressing the Start button, the program starts acquiring data from the device.

(B) The second part (tab BOD data) provides users with the values of the date and time, pressure, temperature, pH, as well as BOD value. All these data are saved in the file that the users assign in the first part.

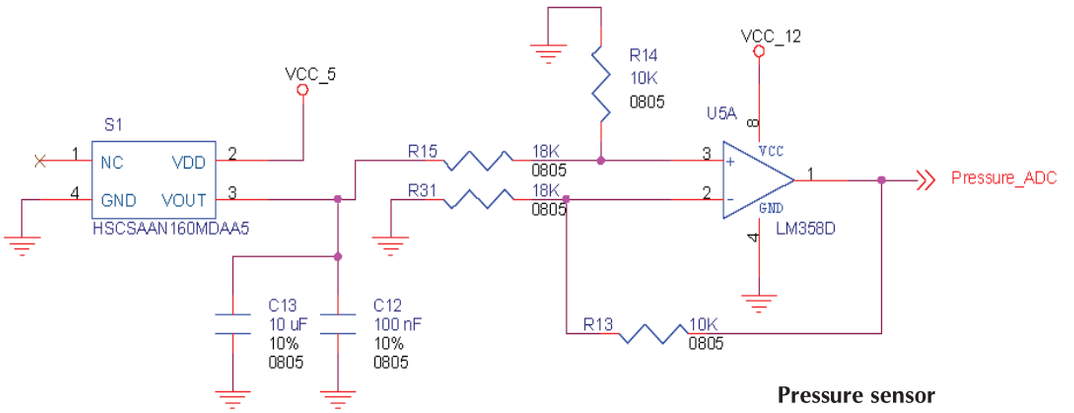
BOD and pH monitoring

To confirm the operation of the device in practice, BOD and pH data of wastewater samples were monitored by both BOD/pH and BOD Trak II devices. In the experiment, the sample was diluted 5 times (BOD after dilution in the range of 0-350 mg/l) with deionized water. BOD values were continuously monitored for 20 days on the BOD/pH device and 10 days on BOD Trak II device (10 days is the maximum period of measurement on this device) with the frequency of 3 measuring points/hour. On the BOD/pH device, the pH values were recorded with the same frequency. The obtained results were processed in Microsoft Excel.

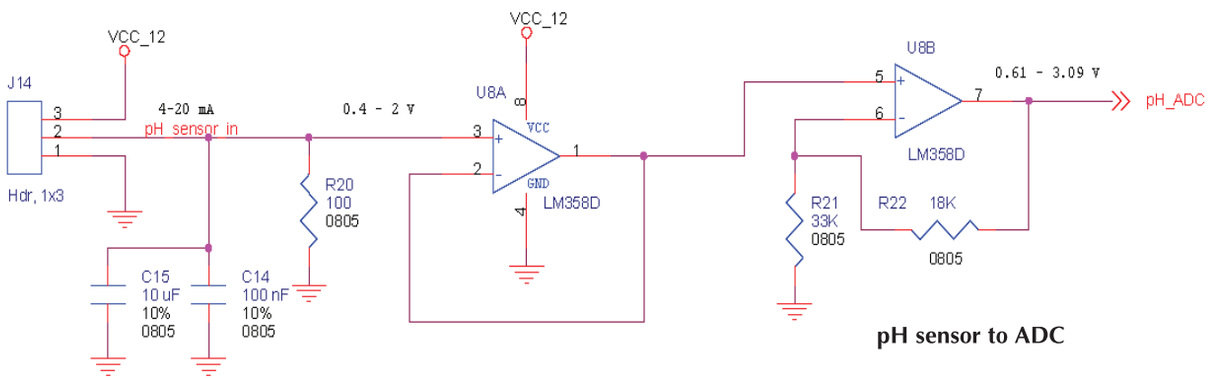
Result and discussion

System design and operation

The principal circuits for the components of the BOD/pH device were designed by OrCAD software, including the ports of supply, algorithm amplifier (if needed), and the connection to the microcontroller. The PCB circuit was designed on PADS2015 to ensure the components are arranged harmoniously, the connection signals are not overlapping, and to reduce noise. The principal circuit of the pressure sensor, pH sensor, and PCB is shown in Fig. 1.



(A)



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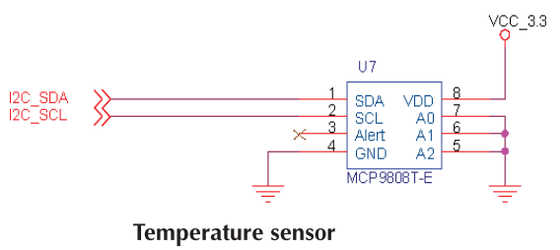
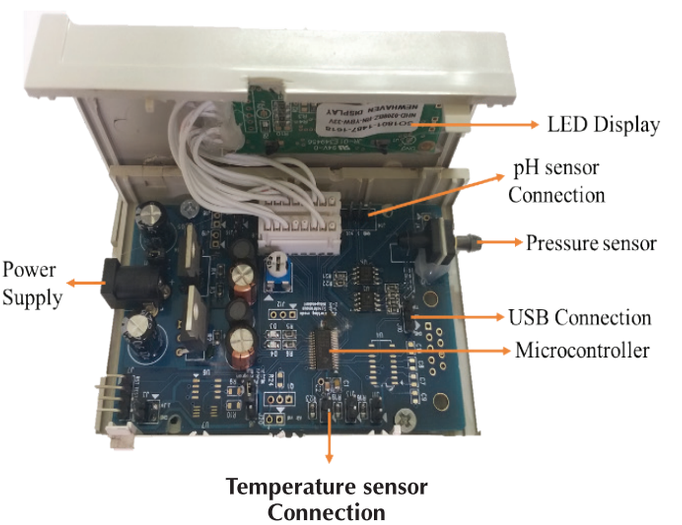


(C)



(D)

Fig. 1. Design of principal circuit and PCB of BOD/pH device. (**A**) Circuit for the current power supply and amplifier of the pressure sensor; (**B**) Receiving circuit for the pH sensor; (**C**) Circuit to connect temperature sensor; and (**D**) Electronic circuit of the BOD/pH device.

The cap of the bottle was specially designed by lathing a Teflon block to ensure that it can fit to other components in the device and remain airtight. Fig. 2 shows the 3D design and real photos of the cap.

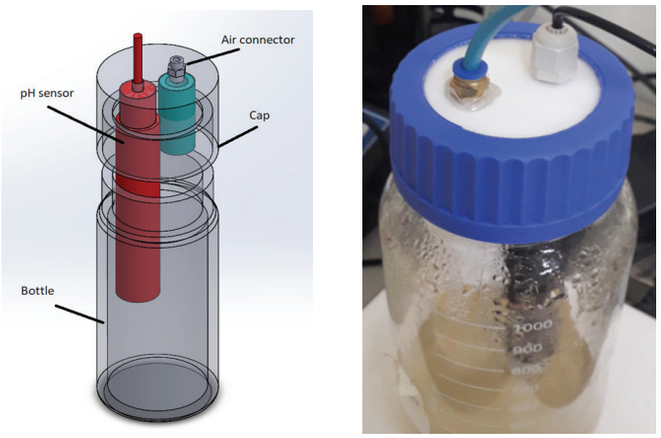


Fig. 2. 3D design and photo of the bottle in BOD/pH device.

After fabrication, the BOD/pH device is calibrated by obtaining the linear equation between the measured signal (the values from the analog-to-digital converters i.e. ADC) and the pressure as well as pH values (Figs. 3 and 4). The results show that there are good linear correlations between the signal obtained from the sensors and the values of BOD and pH as the correlation coefficients of the two calibration curves are both 0.9999.

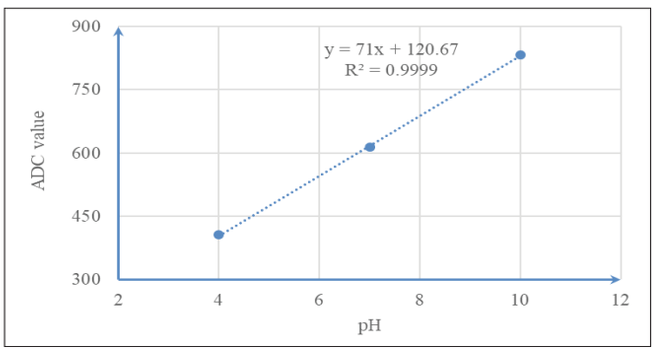


Fig. 3. Calibration curve of pH measured by BOD/pH device.

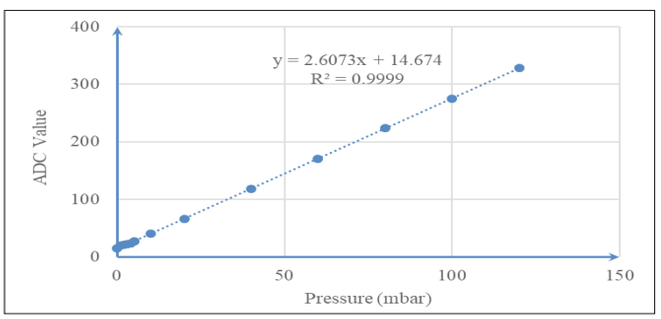


Fig. 4. Calibration curve of pressure measured by BOD/pH device.

BOD and pH monitoring

After calibrating the device and building the data logger software, the BOD/pH device was applied to continuously monitor the BOD and pH in a wastewater sample collected from a pig farm. The results obtained on the BOD/pH device and the BOD Trak II device are shown in Fig. 5.

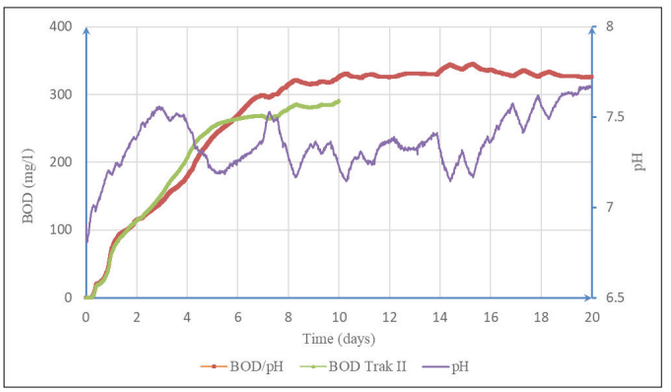


Fig. 5. Comparing results between the prototype BOD/pH device and commercial device (BOD Trak II, HACH).

The results show that the BOD/pH device has good reliability as the BOD values obtained between this device and the commercial device are almost identical during the test and the errors do not exceed 15% during the measurement period. Besides, it can be seen that HACH's equipment could only monitor BOD continuously for 10 days while the device developed in this study can monitor 20 days or more.

In this case the pH of the sample changed slightly between 7.0 and 8.0, which is a suitable range for the growth of bacteria [9, 10]. Some decreases of pH can be associated with the nitrification process in the bottle, and this will be verified in a future study. These results show that the BOD/pH device can operate efficiently and reliably for a long time period with a high frequency of sampling.

Conclusions

In this study, a novel BOD/pH device based on the respirometric principle that is capable of long-term monitoring both BOD and pH was successfully developed. The fabrication process included steps to define its features and select its components, design of its electronic circuit, calibration, and testing. The data logger software was built in C#. The cross-check with a BOD Trak II equipment (HACH) on a wastewater sample from the pig farm showed that the developed BOD/pH could work stably for up to 20 days and the results obtained from the device are reliable given its similar values to the commercial equipment.

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REFERENCES

[1] S.P. Gorde, M.V. Jadhav (2013), "Assessment of water quality parameters: a review", *Journal of Engineering Research and Applications*, **3(6)**, pp.2029-2035.

[2] N. Horan (2003), "Suspended growth processes", *The Handbook of Water and Wastewater Microbiology*, pp.351-360.

[3] U. Latif, F.L. Dickert (2015), "Biochemical oxygen demand (BOD)", *Environmental Analysis by Electrochemical Sensors and Biosensors*, pp.729-734.

[4] S. Jouanneau, L. Recoules, M.J. Durand, A. Boukabache, V. Picot, V. Primault, A. Lakel, M. Sengelin, B. Barillon, G. Thouand (2014), "Methods for assessing biochemical oxygen demand (BOD): a review", *Water Research*, **49**, pp.62-82.

[5] N. Basant, S. Gupta, A. Malik, K.P. Singh (2010), "Linear and nonlinear modeling for simultaneous prediction of dissolved oxygen and biochemical oxygen demand of the surface water-a case study", *Chemometrics and Intelligent Laboratory Systems*, **104(2)**, pp.172-180.

[6] I.S.A. Abeysiriwardana-Arachchige, N. Nirmalakhandan (2019), "Predicting removal kinetics of biochemical oxygen demand (BOD) and nutrients in a pilot scale fed-batch algal wastewater treatment system", *Algal Research*, **43**, DOI: 10.1016/j.algal.2019.101643.

[7] G. Onkal-Engin, I. Demir, S.N. Engin (2005), "Determination of the relationship between sewage odour and BOD by neural networks", *Environmental Modelling & Software*, **20(7)**, pp.843-850.

[8] M.S. Rahman, M.A. Islam (2015), "A simple cost-effective manometric respirometer: design and application in wastewater biomonitoring", *Applied Water Science*, **5(3)**, pp.241-252.

[9] A.W. Alattabi, C. Harris, R. Alkhaddar, A. Alzeyadi, M. Abdulredha (2017), "Online monitoring of a sequencing batch reactor treating domestic wastewater", *Procedia Engineering*, **196**, pp.800-807.

[10] J. R. Taricska, Y.T. Hung, K.H. Li (2008), "Advances in aerobic systems for treatment of food processing wastewater", *Handbook of Water and Energy Management in Food Processing*, pp.720-754.