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Turbidity Measurement System for Aquaculture Effluents Using an Open-Source Software and Hardware

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ABSTRACT

The use of MyOpenLab as free software was proposed in this research as an alternative to manage the turbidity data acquisition system. A thermometrics turbidity sensor TSW-10 was adapted to the Arduino system, this platform was used for the data acquisition system. Communication with the PC was established through MyOpenLab. Measurements of samples with different known values of turbidity were taken to determine the voltage value equivalent to each NTU value, and then these measurements were compared with a commercial T-100 turbidity meter, duly calibrated. The following values were obtained for the applied regressions: Linear regression with R^2 value of 0.9421, logarithmic and exponential regression with R^2 values of 0.9511 and 0.8972, respectively. A non-parametric Wilcoxon test was applied, obtaining a value of P = 0.881, determining that there were no significant differences between the turbidity measurement prototype of this study and the T-100 commercial equipment. The creation of a turbidity data acquisition system, completely open-source, without losing reliability was demonstrated. The use of free software and hardware, reduced the costs compared to the use of licensed software and hardware, representing a viable economic option, to use as a tool in research studies.

INTRODUCTION

Turbidity is a water parameter that affects its transparency due to fine dispersion of the light beam passing through it. This phenomenon is directly associated with suspended solids in water. The suspended solids are a combination of clay, salts as well as organic and inorganic matter (Bray 2008). Turbidity is also an important parameter in process control, since it can indicate problems in different treatments, mainly coagulation, sedimentation and filtration (WHO 2011). It is known that particles that cause turbidity can significantly reduce disinfection processes. For example, in chlorination treatment, higher doses of chlorine are required for the same portion of treated water (Spellman 2013). In the case of UV disinfection, particles suspended in water provide shelter to pathogens, reducing the effectiveness of this type of treatment (Masschelein & Rice 2016). Turbidity is recognized as an indicator of water quality and its contamination (Bilotta & Brazier 2008). Turbidity is usually measured in Nephelometric Turbidity Units (NTU) or its equivalent, the international standard unit called Formazin Nephelometric (Srinivasan 2009). Nephelometry refers to the dispersion of light in a liquid medium caused by suspended particles, measured at 90 degrees from the incident light path (Wagner et al. 2005).

Turbidity in aquaculture effluents is originated mainly from the organic matter present. The disproportionate administration of food causes deterioration of water quality. This is due to the contribution of nutrients by food, which is not fully exploited by the species in cultivation (Boyd & McNevin 2014, Gross et al. 2000). The discharge of aquaculture effluents into bodies of water or soil alter the physicochemical composition of these, affecting the balance of the ecosystem (Lucas & Southgate 2012). It is important to know the physicochemical conditions of the effluents before being discharged and if necessary, those effluents shall be treated (Desbonnet et al. 2005).

However, measurement and monitoring systems have a very high cost (Zennaro et al. 2009). It requires the purchase of licensed software and hardware for data acquisition on physicochemical parameters such as turbidity. LabVIEW software is commonly used in projects where a physical parameter acquisition system is required. Its license is owned by National Instruments (Herrera et al. 2014). Therefore, in this research, in order to reduce costs, MyOpenLab, which

Fig. 1: Sensor TSW-10.

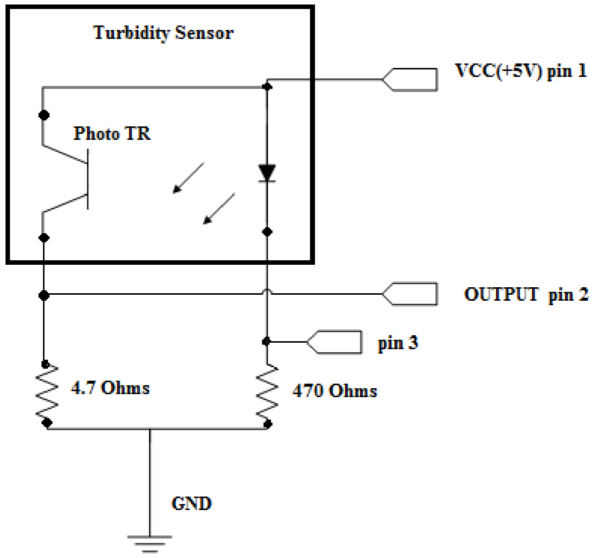

Fig. 2: Conditioning circuit of the sensor TSW-10.

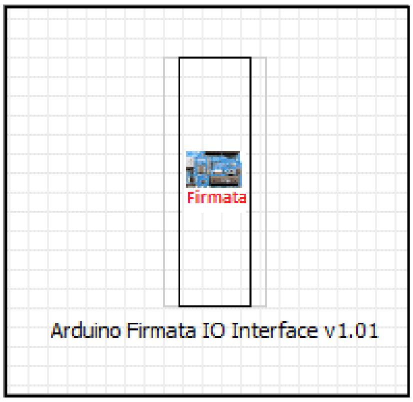

Fig. 5: Representation of the Firmata protocol in MyOpenLab.

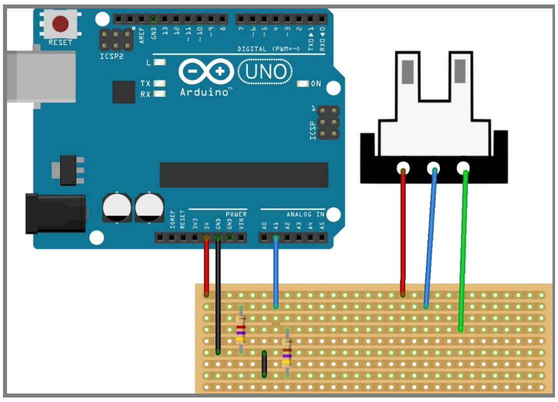

Fig. 3: Sensor TSW-10 connected to the Arduino Uno board.

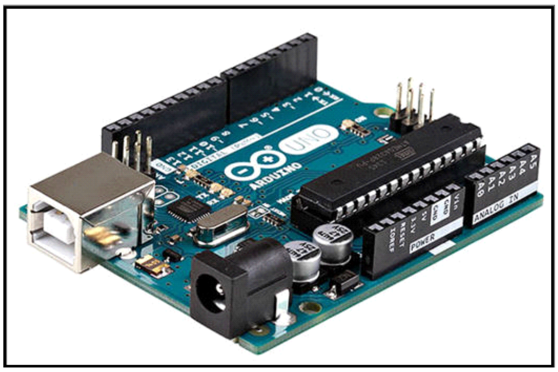

Fig. 4: Arduino One Board.

manages the turbidity data acquisition system, was proposed as an alternative, as a free software. In addition, the use of the Arduino Uno board that being an Open-Source hardware is cheaper than the use of a common data acquisition card in the market.

MATERIALS AND METHODS

Description of the system: The functioning of the monitoring system for turbidity in aquaculture effluents depends on three main parts:

1. The turbidity sensor
2. The system of data acquisition
3. The software of the data acquisition system

The chosen turbidity sensor is the Thermometrics TSW-10 (Fig. 1). This sensor has a voltage differential of 1.2 V +/ - 20%. It operates at a temperature range of -30 to 80°C and a turbidity measurement of 0 to 2000 NTU.

This sensor was adapted to the Arduino system, due to having an analog output between 0 and 5 V. The condition-

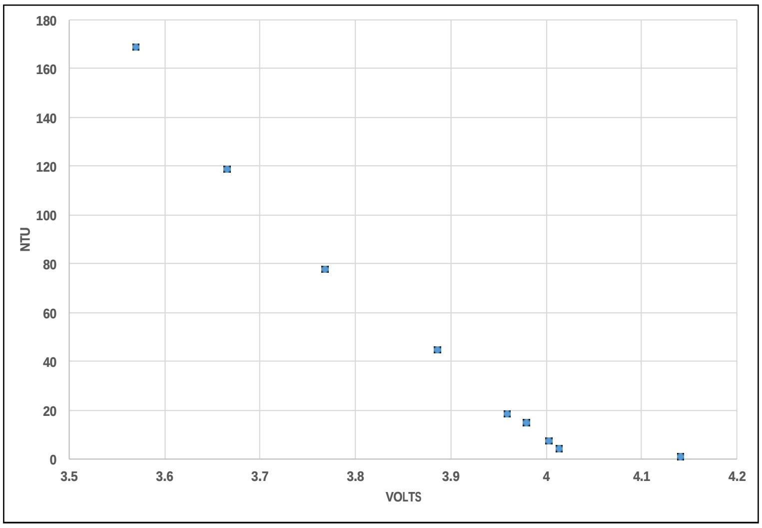

Fig. 6: Comparison of the measurements made in the prototype for the voltage and NTU variables.

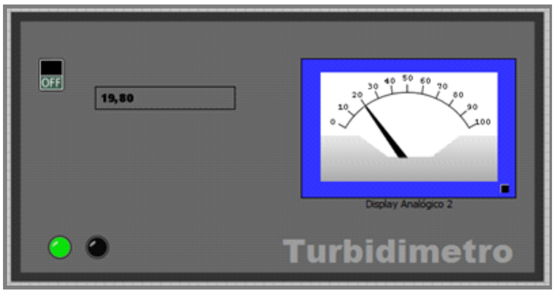

Fig. 7: Front panel of our system as shown in MyOpenLab for turbidity in NTU.

ing circuit was performed before connecting the sensor to an analog input of an Arduino Uno board, which can be observed in Fig. 2. Pin 2 was connected to the analog input A1 of the Arduino board (Fig. 3).

The Arduino Uno board (Fig. 4) was used for the data acquisition system. This is a prototype card designed in accordance to the ATMega 328 microcontroller environment (Arduino 2016).

Wheat (2011), described the Arduino board as a high-performance 8-bit integrated circuit. This device is basically a computer within the integrated circuit itself. It contains a central processing unit (CPU), memory, arrays, clocks, inputs and outputs, on the same chip. On the other hand Lock (2013) and Pearce (2014) mention that the advantage of being an Arduino Open-Source Hardware, is because it is cheaper than the proprietary hardware. In addition, it is flexible to be modified with respect to the needs of the user, without infringing copyright, since all its schematic diagrams are public.

MyOpenLab, was the data acquisition software used, developed in free license Java language, however, it is a powerful platform for modelling and simulation of physical, electronic and control systems (MyOpenLab 2016). Its programming is in its software graphical language and has important similarities with the recognized LabVIEW software. MyOpenLab has the advantage of being completely open-source.

Communication between system components: In order to be able to control the Arduino board parameters and also establish communication with the PC using the software MyOpenLab; the code was loaded on the Arduino Uno board, which activated the protocol Firmata through the Arduino IDE. The above is a communication protocol between the microcontroller and the PC. This allowed to customize the Arduino card firmware, without having to create a proper protocol for each component of the system (Firmata 2016). Fig. 5 shows the block representing the activation of the Firmata protocol within MyOpenLab.

Once the data acquisition system operated as expected, measurements of samples with different known values of turbidity were carried out. This in order to know which voltage value equals each value in NTU. The manufacturer of the TSW-10 sensor provides a ratio curve between NTU and voltage, as well as the mathematical function associated with this curve, to convert voltage values to NTU. This function was obtained by using different linear and nonlinear regressions, choosing the most appropriate one.

RESULTS AND DISCUSSION

The first measurements made by the prototype were carried

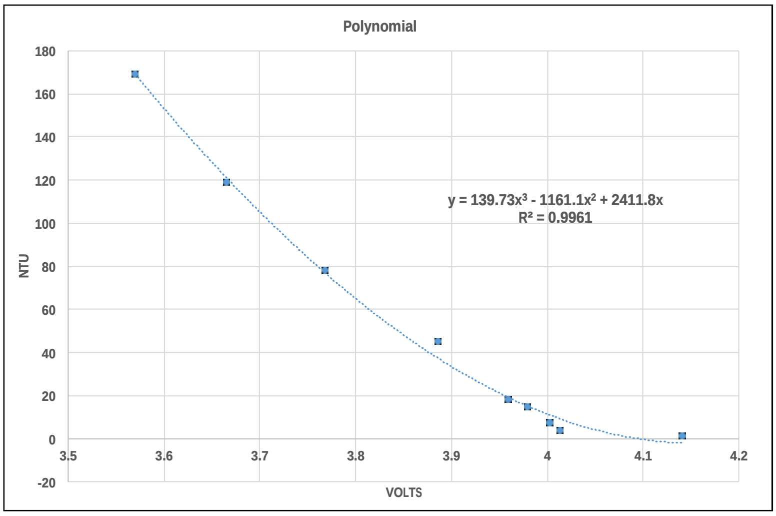

Fig. 8: Polynomial regression graph.

out to know the trend of the output variable (voltage). Fig. 6 shows the results of the measurements performed with the turbidimeter T-100, which served to compare the samples turbidity value in NTU and the voltage values obtained in the prototype for the same samples.

According to Freund et al. (2006), regression techniques study the relationship between two or more variables. This relationship is expressed by a mathematical model, given by the regression equation. In this work, the mathematical function that represented the relationship between the Volts and NTU was determined through linear, exponential, logarithmic and polynomial regressions. The obtained function was programmed in the MyOpenLab software so that the voltage values obtained from the sensor were shown as NTU values on the PC screen. Fig. 7 shows the front panel of the prototype, within the programming environment of MyOpenLab. In which, it can be seen the simulation of an analog indicator and a digital one, showing turbidity in NTU values.

Table 1 gives the results obtained from the regressions performed to determine the function between volts and NTU values.

According to Hilbe (2009), a perfect fit would give an R^2=1 value, where a value close to 1 means a very good fit.

Table 1: R^2 values for applied regressions.

Regressions	R^2 Values
Linear	0.9421
Logarithmic	0.9511
Exponential	0.8972
Polynomial	0.9961

An R^2= 0.9961 value was reached with the obtained polynomial regression. The trend curve and its equation are shown in Fig. 8.

Orwin & Smart (2005) and Kelley et al. (2014), achieved linear mathematical models in their works. The model presented by Ortmanis et al. (1991) showed a logarithmic trend. Roman et al. (2016) and Rojas & Sastoque (2007), obtained the polynomial type model in their research, since it was the one that reached greater relation between its variables, as in this work. The equation obtained through the polynomial regression $Y = 139.73X^3-1161.1X^2+ 2411.8X$ was programmed into MyOpenLab software. The system was prepared with this equation to perform calculations. Measurements of 50 samples were taken from 10 Aquaculture Production Units (APU). Each sample was measured with the T-100 model and the prototype, obtaining relative errors (%) between measurements, which are summarized in Table 2.

Table 2: Relative error between T-100 and our system.

APU	Relative error (%)
1	3.6500504
2	4.13249961
3	3.25556982
4	2.09422325
5	4.94148619
6	3.43183721
7	4.29528635
8	3.61030103
9	4.88432968
10	4.29273265
Average	3.85883162

It can be seen from Table 2 that the average relative error is 3.889%. According to Creus (2011), the accuracy of systems with transmission sensors (direct absorbed light) as used in this research, was between 5% and 10%. For their part, Ortmanis et al. (1991), established the accuracy of turbidity measurement systems based on microcontrollers, it was in a range of 2-11% throughout its measurement scale. In more recent work, Kelley et al. (2014), developed an open-source portable turbidimeter obtaining an accuracy of +/- 3%. The difference between the portable turbidimeter and the prototype carried out in this research is that the data obtained in this work are sent to a computer where it can be processed and analysed for various applications. However, both studies demonstrate that the use of open-source technologies, are a reliable option for the development of parameter measurement systems such as turbidity. In addition to these results provided in Table 1, and according to the nature of our data, a Wilcoxon's nonparametric test was performed, from which a value of $P = 0.881$ was obtained. This identified that there are no significant differences between the turbidity measurement prototype of this work and the T-100 commercial equipment.

CONCLUSIONS

This research demonstrated that a completely open-source turbidity data acquisition system can be created without losing reliability. The use of free software and hardware reduced the costs compared to the use of licensed software and hardware. This represents a viable and lower cost option for researchers who require to make measurements of some variable within their research. The use of the Firmata communication protocol facilitated the configuration of the Arduino board, in order to manipulate the data obtained with the prototype. MyOpenLab software represents an efficient and viable option for the design of a data acquisition system, such as the one created in this research. The mathematical regression that best fits the obtained data must be applied to obtain a greater precision in measurements.

REFERENCES

Arduino, 2016. An open-source electronics platform based on easy-to-use hardware and software. Online at https://www.arduino.cc.

Bilotta, G. and Brazier, R. 2008. Understanding the influence of suspended solids on water quality and aquatic biota. Water Research, 42: 2849-2861.

Boyd, C. and McNevin, A. 2014. Aquaculture, Resource Use and the Environment. John Wiley & Sons.

Bray, R. 2008. Environmental Aspects of Dredging, Taylor & Francis, The Netherlands.

Creus, A. 2012. Instrumentación Industrial. MARCOMBO.

Desbonnet, A., Edwards, P. and Baker, D. 2005. Urban Aquaculture. CABI.

Firmata 2016. Firmata Library. Online at: https://www.arduino.cc/en/Reference/Firmata.

Freund, R., Wilson, W. and Sa, P. 2006. Regression Analysis. Academic Press.

Gross, A., Boyd, C. and Wood, C. 2000. Nitrogen transformations and balance in channel catfish ponds. Aquacultural Engineering, 24: 1-14.

Herrera, J., Barrios, M. and Pérez, S. 2014. Design and implementation of a wireless scada system using zigbee and arduino technology. Prospective, 12(2): 65-72.

Hilbe, J. 2009. Logistic Regression Models. CRC Press.

Kelley, C., Krolick, A., Brunner, L., Burklund, A., Kahn, D., Ball, W. and Shirk, M. 2014. An affordable open-source turbidimeter. Sensors, 14: 7142-7155.

Lock, J. 2013. Open Source Hardware: Can embedded electronics companies thrive through the use and/or development of open source hardware? Master Thesis, Göteborg: Chalmers University of Technology.

Lucas, S. and Southgate, C. 2012. Aquaculture: Farming Aquatic Animals and Plants. John Wiley & Sons.

Masschelein, J. and Rice, G. 2016. Ultraviolet Light in Water and Wastewater Sanitation. CRC Press.

MyOpenLab 2016. Software for the graphic progrmming based on Java. Online at: https://myopenlab.de/

Ortmanis, A., Patterson, W. and Neufeld, R. 1991. Evaluation of a new turbidimeter design incorporating a microprocessor controlled variable pathlength cuvette. Enzyme and Microbial Technology, 13: 450-455.

Orwin, A., Patterson, W. and Neufeld, R. 2005. An inexpensive turbidimeter for monitoring suspended sediment. Geomorphology, 68: 3-15.

Pearce, J. 2014. Open-Source Lab: How to Build Your Own Hardware and Reduce Research Costs. Elsevier, Amsterdam.

Rojas, S. and Sastoque, Y. 2007. Development of a prototype of a nephelometric instrument to measure turbidity. MSc Thesis, University of San Buenaventura, Bogotá, Colombia.

Román, C., Loza, D., Segura, L. and Daribian, R. 2016. Construction with open technology of a low cost turbidity sensor. Iteckne, 13(1): 17-22.

Spellman, F. 2013. Handbook of Water and Wastewater Treatment Plant Operations. CRC Press.

Srinivasan, D. 2009. Environmental Engineering. New Delhi: PHI Learning Private Limited.

Wagner, R., Boulger, R. and Smith, B. 2005. Guidelines and standard procedures for continuous water-quality monitors: Site selection, field operation, calibration, record computation, and reporting. The U.S. Geological Survey Techniques and Methods.

Wheat, D. 2011. Arduino Internals. Apress.

World Health Organization 2011. Guidelines for Drinking-water Quality (Vol. 1), World Health Organization.

Zennaro, M., Floros, A., Dogan, G., Tao, S., Zhichao, C., Chen, H. and Bagula, A. 2009. On the design of a water quality wireless sensor network (wqwsn): An application to water quality monitoring in Malawi. International Conference on Parallel Processing Workshops (ICPPW 09). IEEE.