

**FABRICATION, CALIBRATION AND EVALUATION OF AN AUTOMATED
DISSOLVED OXYGEN CONTROLLER**

JIENESIS F. JARO

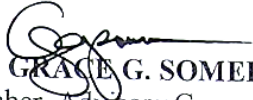
An Undergraduate Thesis Submitted to the Faculty of the Department of Agricultural and
Biosystems Engineering, College of Engineering, Central Luzon State
University, Science City of Munoz, Nueva Ecija, Philippines in
Partial Fulfillment of the Requirements
for the Degree of

**BACHELOR OF SCIENCE IN AGRICULTURAL AND BIOSYSTEMS
ENGINEERING
(Land and Water Resources Engineering)**

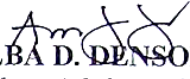
JUNE 2019

ACCEPTANCE SHEET

This undergraduate thesis entitled "FABRICATION, CALIBRATION, AND EVALUATION OF AN AUTOMATED DISSOLVED OXYGEN CONTROLLER" prepared and submitted by **JHENESIS F. JARO**, in partial fulfillment of the requirements for the degree of **BACHELOR OF SCIENCE IN AGRICULTURAL AND BIOSYSTEMS ENGINEERING (LAND AND WATER RESOURCES ENGINEERING)**, is hereby accepted:


CAROLYN GRACE G. SOMERA, M. Sc.
Member, Advisory Committee

06-14-19
Date Signed

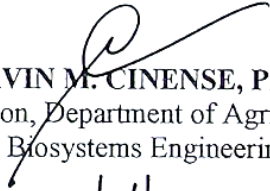

MELBA D. DENSON, M. Sc.
Member, Advisory Committee

06-13-19
Date Signed



MARVIN M. CINENSE, Ph.D.
Chairperson, Advisory Committee

06-13-19
Date Signed

Accepted as partial fulfillment of the requirements for the degree of **BACHELOR OF SCIENCE IN AGRICULTURAL AND BIOSYSTEMS ENGINEERING (LAND AND WATER RESOURCES ENGINEERING)**:


MARVIN M. CINENSE, Ph.D.
Chairperson, Department of Agricultural
and Biosystems Engineering

6/14/19
Date Signed


VICTORINO T. TAYLAN, Ph.D.
Dean, College of Engineering

06-14-19
Date Signed

BIOGRAPHICAL SKETCH

The author is currently residing at Barangay Pag-asa, Talavera, Nueva Ecija. She was born at Cabanatuan General Hospital, Cabanatuan City on the 8th day of March 1998.

She spent her elementary days at Talavera Central School, while her high school days at Talavera National High School. She was always included in the honor roll during her high school. She graduated and was given the recognition as class salutatorian of her batch in the curriculum Information Communication Technology (ICT).

In college, she enrolled at the Central Luzon State University (CLSU), Science City of Muñoz, Nueva Ecija, where she took up Bachelor of Science in Agricultural Engineering which was later replaced to Bachelor of Science in Agricultural and Biosystems Engineering with area of specialization in Land and Water Resources Engineering.

ACKNOWLEDGEMENT

The author wishes to express her sincere thanks to the people who help with their humble way of contribution in the success of this study and who helped making this piece of work in reality:

to Dr. Marvin M. Cinense, chair of the Advisory Committee for the supervising and priceless suggestions;

to Engr. Carolyn Grace G. Somera and Engr. Melba D. Denson, members of the Advisory Committee for the suggestions, comments and support which further improved the manuscript;

to department chairman of Agricultural and Biosystems Engineering Dr. Marvin M. Cinense and Dean of College of Engineering Dr. Victorino T. Taylan for approving the manuscript;

to Engr. Roldan Quitos and Engr. Christopher Pascual for helping her in fabrication and automation of her thesis study and to Emerson Pacol for sharing her the idea to come up with this study;

to all her classmates and friends, Cherrie, Jairies, Monette, Michelle, David, Joana and Jannah for the help, moral support, love, care, laughters and encouragement when all things seemed to be hopeless;

to her SAGES-PSAE Family for giving her fun experiences, and new family inside the campus;

to all faculty members of the College of Engineering especially in the Department of Agricultural and Biosystems Engineering for sharing the knowledge and ideas;

to her very supported boyfriend Marc Christian DC. Joson for the help, inspiration, understanding, support, patience, love, for not leaving her and being always there no matter what happen;

to her relatives, tita, tito and cousins especially Mommy Deck, Tito Gandhi, Tito Dag, Ninong Guiller and Mamita Joy for the moral and financial support and for guiding her in every step I made;

to her brother Jade, her sister Jaiellie and her sister's boyfriend Airwil for the inspiration, love and care;

to her parents, Jaime P. Jaro and Girlie F. Jaro for the unconditional love, support, understanding, moral and financial support, and for everything you have done to make her who she is today which propelled the author to persevere and finally finish the course;

And above all, to the Almighty God for His countless blessing, inspiration and guidance which gave courage and strength to the Author to complete and pursue this study.

TABLE OF CONTENTS

	PAGE
LIST OF TABLES	viii
LIST OF FIGURES	ix
LIST OF APPENDIX TABLES	x
LIST OF APPENDIX FIGURES	xi
ABSTRACT	xii
INTRODUCTION	1
Background of the Study	1
Statement of the Problem	2
Significance of the Study	2
Objectives of the Study	3
Scope and Limitation of the Study	3
Time and Place of the Study	3
REVIEW OF RELATED LITERATURE	4
Dissolved Oxygen	4
Range of Tolerance of Dissolved Oxygen in Fish	7
Methods of Measuring Dissolved Oxygen	11
Dissolved Oxygen Sensors	14
Dissolved Oxygen and Aeration	15
Microcontrollers and Agriculture	17
Root Mean Square Error (RMSE)	17
Normalized Root Mean Square Error (NRMSE)	19
Calibration of Dissolved Oxygen Sensor	19
Single Point Calibration	19
Dual Point Calibration	20
METHODOLOGY	22
Conceptualization of the Study	22
Materials and Equipment	24

Fabrication of Automated Dissolved Oxygen Controller and Installation of Arduino Microcontroller	26
Calibration of the Automated Dissolved Oxygen Controller	27
Evaluation of the Automated Dissolved Oxygen Controller	28
Determining Cost of the System	29
Validation of the Automated Dissolved Oxygen Controller	30
RESULTS AND DISCUSSION	32
Description of the System	32
Automated Dissolved Oxygen Controller	33
Calibrated Dissolved Oxygen Sensor	37
Evaluated Automated Dissolved Oxygen Controller	38
Cost of the system of the Automated Dissolved Oxygen Controller	39
Validation of the Automated Dissolved Oxygen Controller	40
SUMMARY, CONCLUSION AND RECOMMENDATION	42
Summary	42
Conclusions	44
Recommendations	45
LITERATURE CITED	46
APPENDICES	49

LIST OF TABLE

TABLE		PAGE
1	Materials and Equipment	24
2	Cost of the System	40

LIST OF FIGURE

FIGURE		PAGE
1	Typical dissolved oxygen ranges for fish populations	6
2	Typical membrane electrode used for measuring dissolved oxygen	10
3	Diagram of dissolved oxygen sensors	12
4	Pre-calibration of dissolved oxygen sensor	19
5	Unstabilized and stabilized for calibration command	20
6	Dissolved oxygen probe in dissolved oxygen solution	20
7	Conceptual framework	23
8	Schematic diagram of DO sensor with arduino	26
9	Arduino mega microcontroller	32
10	Set-up of the automated dissolved oxygen controller	34
11	Set-up of the system of automated dissolved oxygen controller	35
12	Measured dissolved oxygen during the on and off of aerator	38
13	Relationship between the DO sensor readings and standard DO meter readings	41

LIST OF APPENDIX TABLES

APPENDIX TABLE		PAGE
1	Dissolved oxygen measurement when the aerator turned on and turned off	50
2	Dissolved oxygen measurement using the DO sensor and standard DO meter and computed data for regression analysis computation	51

LIST OF APPENDIX FIGURES

APPENDIX FIGURE		PAGE
1	Automation of the Automated Dissolved Oxygen Controller	53
2	Set-up of the Automated Dissolved Oxygen Controller	53
3	Set-up for the Evaluation of the DO controller	54
4	Automating the DO controller	54

ABSTRACT

JARO, JHENESIS F. Department of Agricultural and Biosystems Engineering, College of Engineering, Central Luzon State University, Science City of Muñoz, Nueva Ecija, June 2019. **FABRICATION, CALIBRATION, AND EVALUATION OF AN AUTOMATED DISSOLVED OXYGEN CONTROLLER**

Adviser: MARVIN M. CINENSE, Ph.D.

An automated dissolved oxygen controller is an instrument used to measure the dissolved oxygen in a tank and releases a certain amount of oxygen from the aerator using the data measured. Maintaining and monitoring the right amount of oxygen in fish tank is hard to achieve. Checking the dissolved oxygen from time to time is very laborious and time consuming. The objective of this study was to fabricate and calibrate a locally dissolved oxygen meter with Arduino microcontroller and aerator. It also aimed to evaluate the automated dissolved oxygen and determine the cost of the system. It is envisioned by this study to automatically measure and monitor the dissolved oxygen and supply the oxygen needed by the fish in tank digitally to avoid over aeration. The study was conducted from March 2019 to April 2019 at the Land and Water Field Laboratory, Engineering Farm, College of Engineering, Central Luzon State University, Science City of Muñoz, Nueva Ecija.

The system composed of the Arduino microcontroller, dissolved oxygen sensor and aerator. The study uses the dissolved oxygen solution to calibrate the sensor. Calibration was monitored using the Arduino Program Application. The controller was set to operate the aerator when DO is below 4ppm and stop when it reaches 9ppm. The normalized Root Mean Square Error (nRMSE) was used for evaluation to get the acceptable range of

dissolved oxygen measurement when the aerator turns on and off. The result of the evaluation shows that the range from 3.90ppm to 4.00ppm is acceptable when turning on and 9.00ppm to 9.10 is acceptable for turning off the aerator. The system costs Php 19,531.

Keywords: Dissolved Oxygen; Aeration; Dissolved Oxygen Sensor; Arduino Microcontroller; Automation

LITERATURE CITED

- AMERICAN PUBLIC HEALTH ASSOCIATION (APHA). 1995. American Water Works Association (AWWA), and the Water Environment Federation (WEF). 1995. Standard Methods for Examination of Water and Wastewater. United Book Press, Inc. Baltimore, MD.
- ATLAS SCIENTIFIC: Environmental Robotics. 2019. EZO-DO Datasheet V 5.1. Atlas Scientific LLC retrieved from https://www.atlas-scientific.com/_files/_datasheets/_circuit/DO_EZO_Datasheet.pdf? On May 1, 2019
- BARNSTON, A., 1992. "Correspondence among the Correlation [root mean square error] and Heidke Verification Measures; Refinement of the Heidke Score." Notes and Correspondence, Climate Analysis Center. Retrieved from <https://www.swpc.noaa.gov/sites/default/files/images/u30/Barnston,%20Anthony%20G.,%201992.pdf> on February 8, 2019
- BOEHR, B & SCHULTZE, M. 2008. Stratification of Lakes. Helmholtz Centre for Environmental Research -UFZ, Magdeburg. Retrieved from Reviews of Geophysics, Vol 46.
- CHESAPEAKE BAY PROGRAM (CBP). n.d. Dissolved Oxygen Retrieved from <http://www.chesapeakebay.net/discover/bayecosystem/dissolvedoxygen>
- CLEAN WATER TEAM (CWT) 2004. Dissolved Oxygen Fact Sheet, FS-3.1.1.0(DO). In: The Clean Water Team Guidance Compendium for Watershed Monitoring and Assessment, Version 2.0. Division of Water Quality, California State Water Resources Control Board (SWRCB), Sacramento, CA.
- DISSOLVED GASSES-OXYGEN. n.d.. In Lecture – Water Chemistry . Retrieved from <http://www.esf.edu/efb/schulz/Limnology/Oxygen.html> on January 21, 2019
- DRS. FOSTER & SMITH EDUCATIONAL STAFF. 2013. Aquarium Aeration, the importance of. Retrieved from <http://www.drsfostersmith.com/pic/article.cfm?aid=442> on January 21, 2019
- ELECDESIGNWORKS (EDW). 2015. Atlas Scientific EZO Dissolved Oxygen Circuit. 2nd flr. CW Arcade Bldg., #20 Alcalde Jose St. Brgy Kapisigan Pasig City, Philippines 1600. Retrieved from <https://www.elecdesignworks.com/shop/prod0370/> on May 1

- ENVIRONMENTAL PROTECTION AGENCY (EPA). 2012. 5.2 Dissolved Oxygen and Biochemical Oxygen Demand. In Water Monitoring and Assessment. Retrieved from <http://water.epa.gov/type/rsl/monitoring/vms52.cfm> on January 21, 2019
- FLOYD, R.F. 2003. Dissolved Oxygen for Fish Production. Institute of Food and Agricultural Sciences (IFAS), University of Florida. Fact Sheet FA-27, p. 2.
- HOLMQUIST, D. D. Water Quality with Vernier: Dissolved Oxygen. SW Millikan Way Beaverton, United States of America. Computer 5, p. 5-1 – 5-6.
- KEMKER, C. n.d. Fundamentals of Environmental Measurements: Measuring Dissolved Oxygen. Retrieved from <https://www.fondriest.com/environmental-measurements/equipment/measuring-water-quality/dissolved-oxygen-sensors-and-methods/> on January 28, 2019
- MOHRMAN E. 2007. The Nest. Aquariums: What is Aeration and how does it help the Aquarium Ecosystem? Orlando, Florida retrieved from <https://pets.thenest.com/aeration-aquarium-ecosystem-12060.html> on January 28, 2019
- MONTANA SCIENCE PARTNERSHIP. 2019. Water Quality Parameters: Dissolved Oxygen. Retrieved from <http://www.sciencepartners.info/module-4-water/what-is-water-quality/water-quality-parameters-dissolved-oxygen/> on January 28, 2019
- ORAM B. 2014 Dissolved Oxygen in Water. Water Research Center. B.F. Environmental Consultants Inc. 15 Hillcrest Drive, Dallas, PA 18612 retrieved from <https://www.water-research.net/index.php/dissolved-oxygen-in-water> on January 28, 2019
- OXY TURBINE. 2017. Dissolved Oxygen-DO. Retrieved from <http://www.oxyturbine.com/general-information/dissolved-oxygen/> on January 28, 2019
- ROBOTSHOP. n.d. Arduino: Arduino Mega 2560 Datasheet. Retrieved from <https://www.robotshop.com/media/files/pdf/arduinomega2560datasheet.pdf> on May 1, 2019
- THE DISSOLVED OXYGEN HANDBOOK: a practical guide to dissolved oxygen measurements. n.d. YSI Incorporated. 2009 retrieved from https://www.fondriest.com/pdf/ysi_do_handbook.pdf on January 28, 2019

UNITED STATES OF AMERICA, ENVIRONMENTAL PROTECTION AGENCY (U.S. EPA). n.d. Dissolved Oxygen and Biochemical Oxygen Demand. Retrieved from <http://water.epa.gov/type/rsll/monitoring/vms52.cfm> on January 28, 2019

WILSON, P. S. 2010. Water Quality Notes: Dissolved Oxygen. Department of Soil and Water Science, Indian River Research and Education Center (REC)--Ft. Pierce FL; Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville.