AUTOMATED ELECTROCOAGULATION SYSTEM FOR WASTEWATER TREATMENT

Eugenia P. Ramirez[1]

[1]Department of Information Technology, University of Santo Tomas, Manila, Philippines

ABSTRACT

There are two major ways to treat wastewater; it is either through chemical or non-chemical treatment. Both improve water quality, but do not make water safe for domestic use. Most firms or companies use coagulation treatment or chemical treatment. But the problem for this treatment is the selection of the best chemical to be used; it is expensive and frequent dosage adjustments are required to ensure good water treatment results. All coagulation chemical add specific elements to the water, improper doses and application generally pose problems (health risks). Hence, it requires extra preventive measures. A more cost-effective method to clean a wide range of polluted water on-site, and with minimal additives, is required for sustainable water management. Electrocoagulation treatment of water may fit this description [1]. Electrocoagulation is most widely used in other countries but not in the Philippines. Hence, the device readily available in the market is very expensive. The paper focuses on the automation of the Electrocoagulation process by using microcontroller, sensor, relays, and sacrificial anodes.

KEYWORDS

Microcontroller, Automation, Sensor, Electrocoagualtion, sacrificial anodes, relays

1. INTRODUCTION

The country is endowed with rich natural resources, including water, which are essential for the country's economic development and in meeting its Millennium Development Goals (MDGs). Therefore, water should be recognized as a great priority.

By the year 2050, some four billion people (that's over half of the entire world's population) will be facing severe water shortage. This is not a far-fetched scenario from a science fiction movie, as it may sound but this information comes from NASA, the World Health Organization (WHO) and other agencies worldwide. When you consider the facts, it is not hard to understand why there is a problem: The world's population tripled in the 20th century, and is expected to increase by another 40-50 percent in the next 50 years. Meanwhile, the use of renewable water resources has grown six-fold. There is not any more fresh water in the world today than there was one million years ago. Water cannot be replaced (such as alternative fuel sources can replace petroleum). It is almost guaranteed that, once water supplies become even scarcer, conflict will break out across the globe [2][3].

Access to clean and adequate water remains an acute seasonal problem in urban and coastal areas in the Philippines. The National Capital Region (Metro Manila), Central Luzon, Southern Tagalog, and Central Visayas are the four urban critical regions in terms of water quality and quantity. The Government's monitoring data indicates: (1) Just over a third or 36 percent of the country's river systems are classified as sources of public water supply: (2) Up to 58 percent of groundwater sampled is contaminated with coliform and needs treatment; (3) Approximately 31 percent of illness monitored for a five-year period were caused by water-borne sources; and (4) Many areas are experiencing a shortage of water supply during the dry season [4].

The key to saving the limited water supply that is left is by re-using wastewater as the World Water Council points out. Wastewater is used water.

2. Objectives

General Objective

This study aims to develop an Automated Electrocoagulation System that would treat wastewater in order to reuse it.

Specific Objectives:

- To design hardware that interconnects the relays, LCD display, pumps and other electronic components,
- To program the microcontroller to automate the entire system,
- To utilize electric current in replacement of chemical coagulants and
- To test the effectiveness of the system in terms of accuracy and reliability.

3. Scope and Limitations

The study focused on the development of a system that treated wastewater through an Automated Electrocoagulation controlled by the microcontroller. The microcontroller automates Electrocoagulation treatment. It controls the relays, LCD display, and the timer for the treatment as well as the transfer of the wastewater from the holding tank up to the output stage. The system had separate power supply: for the microcontroller (5V) and for the Electrocoagulation process (13V). The system also offered two modes: automatic and manual. For the automatic mode, after the treatment time was completed, the treated wastewater was transferred immediately to the filtration stage then to the output (sample) tank; while for the manual mode, the system asked a confirmation to continue from the user every after each process. The filtration was composed of a filter paper, activated carbon and zeolite stones. After the wastewater had been completely treated, the system asked a confirmation if the user wanted to repeat process or take sample.
The tank had a limited volume of six litres and a maximum current of 6A for the Electrocoagulation process. The system allowed the user to input the desired amount of wastewater in litres to be treated as well as the conduction time using the keypad module. Probe was integrated in tank 1 (holding tank) to set limit for the amount of water to be transferred. A limit switch was also used in the filtration tank to avoid overflowing of water. The user can override the treatment time; he/she can cancel/stop/continue the operation anytime. The system can treat wastewater with multiple contaminants. The conduction time depends on the desired turbidity for the output, nature of the contaminant of the concentration, volume of the concentration, amount of the supplied current, and area of the electrodes. Switching/ reversing the polarity took placed periodically to assist in the cleaning of the electrodes.

An external firm (e.g. SGS Philippines, Inc.) was in-charge of the testing and analysis of the treated wastewater. Only qualitative data (e.g. concentration of the different parameters and removal efficiency of the electrocoagulation process itself) was obtained and analyzed through experimental testing. COD and turbidity were the parameters used in the analysis of the treated wastewater. Parameters for testing were based on the Standard Methods for the examination of Water and Wastewater, 21st Ed (refer to Appendix B). The end product (i.e. treated wastewater) can be used again (reused) solely for external applications and will not be suitable for food preparation and drinking [5].

The system does not include pH meter. The system was not functional without power source. Limited samples (two wastewater samples) were tested by the external firm due to limit costs.

4. Project Design

4.1. Block Diagram

The system utilizes the principle of Electrocoagulation and made used of a microcontroller that automates the entire process (see Figure.1). The input- wastewater- will be held at a specified holding tank which has been filtered to remove the large particles that may cause problems (such as blockage) to the system. Probe is utilized to set limit for the transfer of selected amount of wastewater. System allows automatic and manual mode. Controlled by a series of pumps and relays, the wastewater that was transferred from one stage to the other (to treatment unit where Electrocoagulation takes place then to a series of filtration then finally, to the output reservoir) [6]. The amount of wastewater and time duration was set using the keypad module. Electrodes polarity changes every after one minute to help in cleaning the electrodes. As time progresses and desired turbidity is achieved, the wastewater would be further treated through a series of filtration with the aid of filter paper, activated carbon and zeolite stones. Finally, the filtered wastewater would be held at the output reservoir.

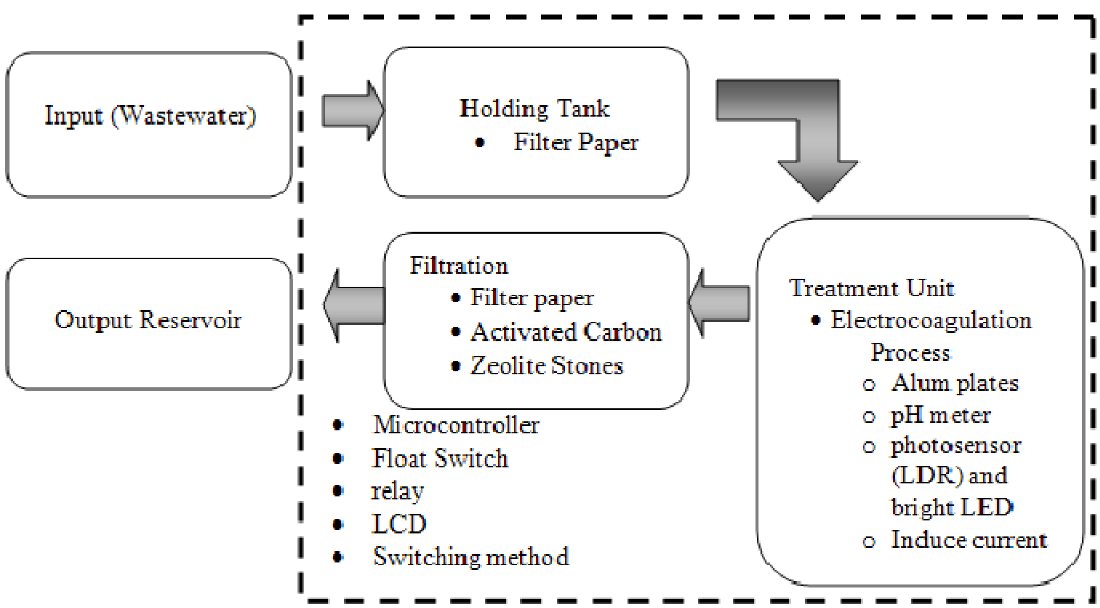

Figure 1. Block Diagram

4.2. System Flowchart

Figure 2 shows how the system operates. When the system is up, the microcontroller stabilizes the pumps, which requires five seconds. The LCD displays a message that asks the user for the desired treatment time, amount in wastewater in litres, and the mode to perform: automatic or manual. As to the latter part, it displays the other processes. A confirmation message is displayed before it performs the desired operation.

Upon choosing which option to partake, the system transfers the selected amount of wastewater from holding tank to the electrocoagulation tank. The system then checks if the transferred amount equal to the input wastewater amount. If equal, transferred wastewater will be treated. Otherwise, repeat transfer of wastewater.

During treatment, the microcontroller switches electrodes polarity every minute to clean the electrode plates. After treatment time has elapsed, the system will evaluate if the mode used is manual or automatic. If manual, the system requires the operator's assistance. The system asks if the user wants to extend treatment time or proceed to the next operation. If automatic, the system automatically transfers the treated wastewater to the next stage (filtration to output tank). After which, the system then asks if the user wants to take sample or repeat entire process.

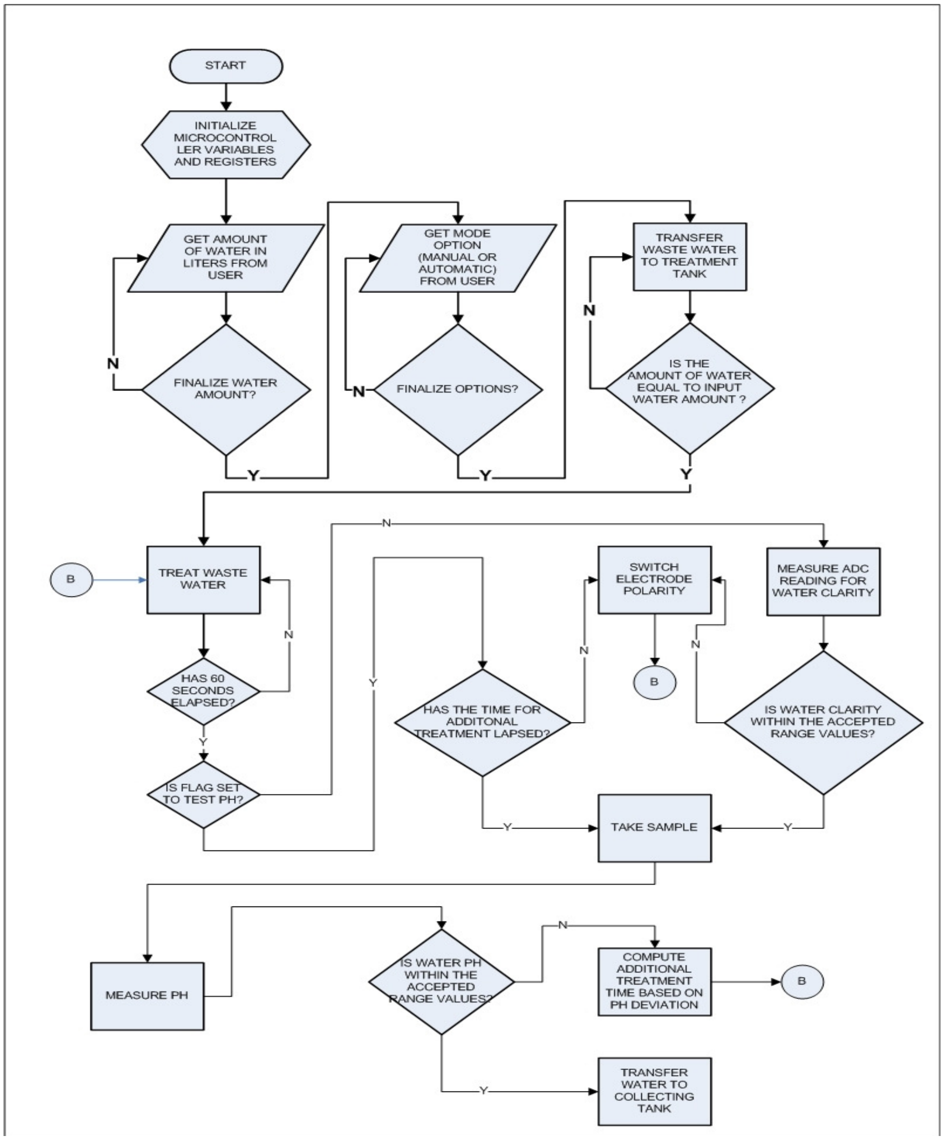

Figure 2. System flowchart

4.3. Statistical Treatment of Data

Percentage error was the statistical tool applied for the treatment of data and information. The formula below was used to measure the system's reliability or percentage error.

Percentage error = (|expected value –actual value|) / expected value x 100 %

The formula is:

$$\overline{x} = (\sum x / N)$$

Where:

$\bar{x}$ = mean
Σx = sum of all percentage error
N = number of data items

4.4. Automated Electrocoagulation System Circuit

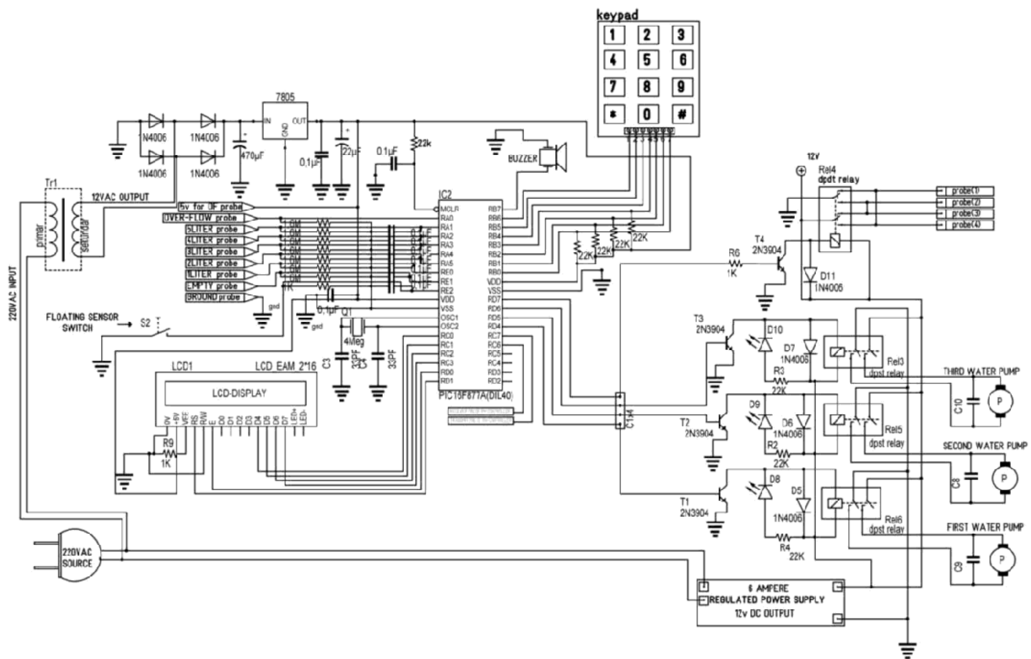

Figure 3. Automated ElectrocoagulationCircuit

5. Discussion of Results

Test Cases:

Table 1. Turbidity Tests (Day 1 July 1, 2012)

Trial	Time	Volume (L)	Initial Turbidity (c)	Expected Output (Turbidity)	Actual Output (Turbidity)
1	08:00	6	700	150	150
2	09:30	3	450	150	150
3	11:00	6	710	150	150
4	12:30	4	550	150	150
5	14:00	6	700	150	150
6	15:00	3	680	150	150
7	16:30	3	680	150	150
8	18:00	5	860	150	150
9	20:00	3	680	150	150
10	22:00	6	813	150	150

Table 2. Turbidity Tests (*Day 2:* July 2, 2012)

Trial	Time	Volume (L)	Initial Turbidity	Expected Output (Turbidity)	Actual Output (Turbidity)
1	08:00	6	990	150	150
2	09:00	3	350	150	150
3	10:30	6	580	150	150
4	11:30	2	407	150	150
5	14:00	3	205	150	150
6	15:00	4	525	150	150
7	16:30	4	600	150	150
8	18:00	3	590	150	150
9	20:00	2	813	150	150
10	22:00	4	620	150	150

* Reference: Based on DENR Administrative No. 35; Table 2A – Effluents Standards (see Appendix B)

Table 3. Overall System Tests

Trial	Date / Time	Amount in liters	Induced current	Is wastewater transferred from tank1 to tank2?	Is the selected amount equal to transferred amount?	Treat-ment time	Is treated waste H_2O transferred to tank filtration tank?	Is desired amount transferred?	Remarks
1	June 26, 2012 6pm	6	2.54	yes	No	1 hr	Yes	Yes	**Inaccurate**- due to wrong method (formula) used. Time delay was not reliable.
2	June 26, 2012 9pm	6	2.54	yes	Yes	1 hr	Yes	Yes	**Accurate**- instead of using time delay, computation of flow rate was determined.
3	June 27, 2012 8am	6	2.48	No	No	1hr	No	no	**Inaccurate**- probe is integrated to the system but it is connected to the wrong pins of the microcontroller. The pins are interchanged which differs from what is set in the program.
4	June 27, 2012 11am	6	2.48	No	no	1 hr	No	No	**Inaccurate**-Conflict in the supply source between the probes installed in tank2 with the supply of Electrocoagulation process.
5	June 7, 2012 9 am	5	1.25A	yes	Yes	1 hr	Yes	Yes	**Accurate**- due to proper connection
6	July 7, 2012 11 am	4	<=1A	yes	Yes	2 hr	Yes	Yes	**Accurate**
7	July 7, 2012 5 pm	3	1A	yes	Yes	2 hr	Yes	Yes	**Accurate**
8	July 7, 2012 7 pm	1	<=1A	yes	Yes	1 hr	Yes	Yes	**Accurate**
9	July 10, 2012 8am	5	2.34A	yes	yes	2 hr	Yes	Yes	**Accurate**
10	July 10, 2012 1pm	2	2A	yes	yes	3 hr	Yes	Yes	**Accurate**
11	July 10, 2012 5pm	1	<=1A	Yes	yes	3 hr	Yes	Yes	**Accurate**
12	July 17, 2012 1pm	5	2.34A	yes	yes	1 hr	Yes	No	**Inaccurate**- the wastewater overflows from the filtration tank due to tube connected which was changed with tube of smaller diameter.
13	July 17, 2012 2pm	1	<=1A	yes	yes	3 hr	Yes	Yes	**Accurate**- re-computation of flow rate.
14	July 17, 2012 6pm	3	2A	yes	yes	3 hr	Yes	Yes	**Accurate**
15	July 23, 2012 2pm	4	2A	Yes	yes	1 hr	Yes	Yes	**Accurate**

The average error of the whole system based from the formula (see Section 3.3):

$\overline{x} = (\sum x / N)$ = 4/32 x 100= **12.5%** **or** $\overline{x} = (\sum x / N)$ = 28/32 x 100= **87.5% reliable**

Based from the computation performed, the system is said to be 87.5 % percent reliable. 28 out of 32 testing were successful

- COD and Turbidity test results conducted by SGS Philippines.

Table 4. New York Creek's COD Test Results

Analysis Name	Optimum value(s)	Results	Methodology
COD, mg/L (Untreated)	≤ 100	228.2	5220B
COD, mg/L (Treated)	≤ 100	75.1	5220B

Table 5. New York Creek's Turbidity Test Results

Analysis Name	Optimum value(s)	Results	Methodology
Turbidity, NTU (Untreated)	≤ 50	31.5	EL 7.2021
Turbidity, NTU (Treated)	≤ 50	4.8	EL 7.2021

* Reference: Based on Standards Methods for the Examination of Water & Wastewater, 21st Ed.

Table 6. Kamuning Creek nearby squatters' area COD

Analysis	Optimum value(s)	Results	Methodology
COD, mg/L (Untreated)	≤ 100	356.9	5220B
COD, mg/L (Treated)	≤ 100	98.6	5220B

Table 7. Kamuning Creek nearby squatters' area Turbidity

Analysis	Optimum value(s)	Results	Methodology
Turbidity, NTU (Untreated)	≤ 50	25.0	EL 7.2021
Turbidity, NTU (Treated)	≤ 50	5.0	EL 7.2021

* Reference: Based on Standards Methods for the Examination of Water & Wastewater, 21st Ed.

Table 8. System's Accuracy

Sample	COD, mg/L (Optimum Value)	COD, mg/L (Acquired Value)	Turbidity, NTU (Optimum Value)	Turbidity, NTU (Acquired Value)	Remarks
New York Cubao Creek (Treated)	≤ 100	75.1	≤ 50	4.8	Accurate
Kamuning Cubao Creek nearby Squatter's Area	≤ 100	98.6	≤ 50	5.0	Accurate

Legend: Accurate = Acquired Value ≤ Optimum Value; Inaccurate = Acquired Value ≥ Optimum Value

* Reference: Based on DENR Administrative No. 35; Table 2A – Effluents Standards (see Appendix B)

In general, the achieved values of the treated wastewater for turbidity (150c) achieved the optimum value and upon undergoing series of laboratory tests at the SGS Philippines Inc. follow accordingly the effluent standards based on the DENR Administrative order No. 35 (see Appendix B); thus, the developed Electrocoagulation system performed on its optimum level which means the system was accurate.

6. Conclusions and Recommendations

6.1. Summary of Findings

In accordance with the obtained values from testing and from the different analysis performed by SGS Philippines, Inc., and the discussions of its components, here is the review of its respective findings:

The microcontroller automates the wastewater treatment. The relay controlled the pumps for wastewater transfer. Computation of flow rate was used to measure the amount of wastewater volume to be transferred with the aid of the probes. Float switch was also used to measure the amount of treated wastewater; separating the colloids or sludge when dispensed in the filtrating tank. Photosensor (LDR) and LED monitored the turbidity of the wastewater. When the accepted turbidity level was reached, the treatment stopped (see Table 1, Table 2 and Table 3). The amount of induced current has a maximum of 6A but the acquired current during the operation is ranging from 1A – 3A which depends on the load; its volume and conductivity level of the wastewater, number and spacing of electrodes (see Table 3).

The analysis for the COD level has been obtained through 5220B methodology; the optimum value(s) for this, in accordance with the DENR Administrative Order No. 35, was less than or equal to 100 mg/L.The acquired value for the COD (in mg/L) for Wastewater from New York Cubao Creek and Kamuning Creek are 75.1mg/L out of 228.2mg/L of Untreated Wastewater, and 98.6 mg/L out of 356.9 mg/L of Untreated Wastewater respectively (see Table 4 and Table 6).

Hence, the analysis for the turbidity has been obtained through EL 7.2021 methodology; the optimum value(s) for this, in accordance with the DENR Administrative Order No. 35, was less than or equal to 50 NTU; the acquired data is 4.8 NTU (treated) from 31.5 NTU (untreated) for New York Cubao Creek and 5.0 BTU (Treated) from 25.0 NTU (Untreated) for Kamuning Creek (see Table 5 and Table 7).

6.2. Conclusion

In light of the summary of findings discussed earlier, here are the generalizations for this study:

1. A microcontroller automated the entire system. The automation was further compounded with the use of a photosensor (LDR) and bright LED.

2. The induced current depends on the volume and conductivity level of the wastewater, number and spacing of electrodes, area of electrodes, and contaminants present on it. The more electrodes used; the higher supplied current was needed. And the higher the induced current, the faster the treatment would be. Physical and chemical issues were factor to be considered [8] [9].

3. The analysis for the COD level and Turbidity level has been obtained through 5220B and EL 7.2021 methodology; samples subjected for testing which entered the range of the optimum value(s) as cited in the DENR Administrative No. 35 (Appendix B) .However, any wastewater

that has undergone treatment was not safe for intake and food preparation but it can be reused for agricultural and recreational purposes.

4. The system is 92% reliable and accurate (see Table 3).

6.3. Recommendations

In view of the generalizations previously discussed, the following recommendations are hereby suggested:

1. Integration of pH meter to determine if the wastewater obtains the optimum pH level.

2. Additional parameters such as BOD and pH level will be tested by the external firm.

3. Incorporation of additional sets of filtering system.

4. Incorporating solar or wind sources energy for rural areas.

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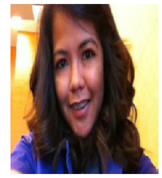

Eugenia P. Ramirez was born on October 17, 1983 at Cagayan, Philippines. She took Bachelor of Computer Engineering. She received her Masters of Engineering with Specialization in Computer Engineering from Pamantasan ng Lungsod ng Maynila, Manila City, Philippines last 2011. Currently, she's enrolled in Doctor of Information Technology at Ama Computer University, Quezon City, Philippines. She recently took her Comprehensive Exam and is working on her Dissertation. She is a Full-time Faculty in University of Santo Tomas,Philippines.