A Wireless Sensor Network (WSN) To Remotely Monitor An Artificial Aquatic Ecosystem

By

Mustamin Bin Mustaffa

FINAL PROJECT REPORT

Submitted to the Department of Electrical & Electronic Engineering

in Partial Fulfillment of the Requirements for the Degree

Bachelor of Engineering (Hons)

(Electrical & Electronic Engineering)

Universiti Teknologi PETRONAS

Bandar Seri Iskandar

31750 Tronoh

Perak Darul Ridzuan

ABSTRACT

This project is the implementation of wireless sensor network (WSN) in monitoring the artificial aquatic ecosystem. Water pollution is one of the biggest worldwide crisis that leads to limited fresh water supply. Current methods used for monitoring the aquatic ecosystem are time consuming and not flexible. In this project, a more accurate method for collecting and analysing data from the aquatic ecosystem using a wireless sensor network (WSN). Developing a reliable and low power WSN for data transfer from the artificial aquatic tank to a base station is a critical part of this project. The wireless sensor node that monitors the aquatic ecosystem must be water-proof. The parameter used to analyse the aquatic ecosystem from the aquatic tank was ph. The analysed data will be record and if any potential hazard detected, the system will warn the user.

ACKNOWLEDGMENT

This project would not possible without involvement and contribution from certain parties and individuals. First and foremost, the author would like to thanks Dr Azrina, my supervisor for giving me the opportunity for the project, continuous assistance, supervision and advice during the entire final year project. She provided guidance constantly until this dissertation completed.

Special thanks as well to Dr Michael for providing equipment and tools required for this project. This project also would not possible without him. The author would also like to thank Dr. Nazreen Bt Badruddin, the FYP coordinator, for conducting several seminars and briefings to assist the FYP students as well as helping to arrange the schedule for ELECTREX and Viva for students by inviting external examiners to evaluate the students. Besides that, the author wishes to express his gratitude to his colleagues and beloved family for their support and encouragement throughout the duration of the project.

Finally, the author would like to thank all parties involved once again for making this Final Year Project a success.

CONTENTS

LIST OF ABBREVIATION

WSN	=	Wireless Sensor Network
WQI	=	Water Quality Index
COD	=	Chemical Oxygen Demand
BOD	=	Biochemical Oxygen Demand
SS	=	Suspended Solid
DO	=	Dissolved Oxygen
AN	=	Ammonia Nitrogen

List of Figures

List of Table

1. INTRODUCTION

1.1 Background Studies

Water is one of our main sources of living and currently, we are facing worldwide water pollution crisis. In Ghana, Ghana Urban Water Company Limited is facing losses and having hard time to treat all those distribution polluted water due to illegal miners' activities using mercury and cyanide in water bodies of Ghana [1]. This becomes one of the major problems, as the cost of the treatment is expensive.

In 2007, 8,000 people died to water pollution in four major cities in China during year 2011. Some citizens do not drink from the water tap anymore. 60,000 more people die prematurely with 1,700 pollution accidents every year. Currently, 20% of the rivers are rated as very toxic followed by 40 % rated as seriously polluted [2].

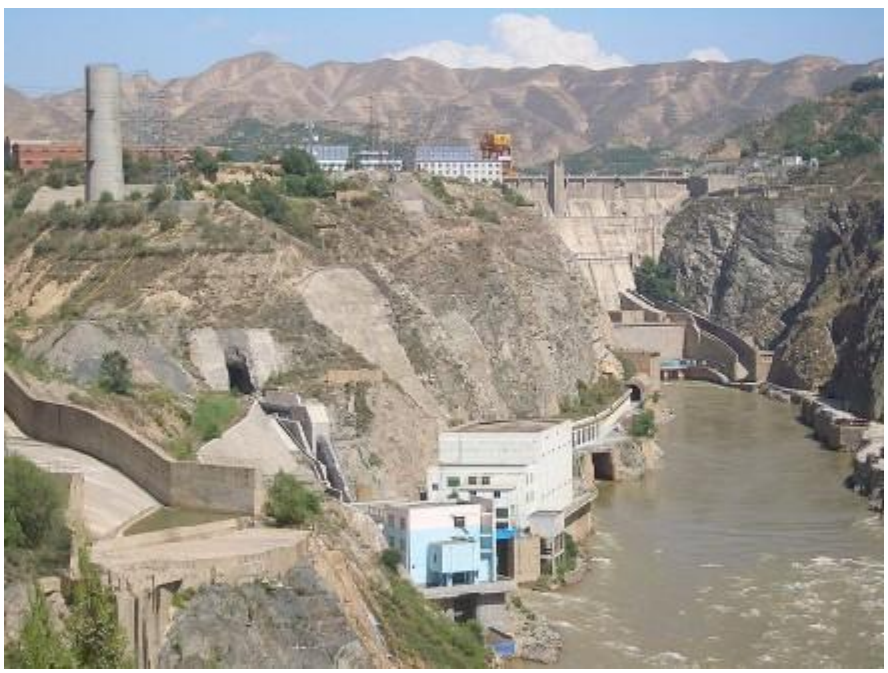


Figure 1 One of China's polluted river [2]

From 1990-1999, the number of clean rivers drop from 48 to 32 rivers. In 2001, about 60% of rivers in Malaysia are regulated for domestic, agricultural and industrial usage and most of these rivers are polluted by sewage disposal which doesn't go through proper treatment [6]. Longing, mining, and urban development also lead to soil erosion which later causing waterways polluted with silt. Pesticide and fertilisers which contain heavy metal phosphate were disposed on water by agriculture practices. Palm oil and natural rubber also become the major source of aquatic environment quality reduction during 1960's, 1970's and until 1990's [5].

Water quality index (WQI) determines the water quality of the aquatic ecosystem. Some of the water quality parameters are as dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), suspended solids (SS), ammonia (AN) and pH [6]. These parameters are constantly monitored to ensure the water quality.

Wireless sensor network (WSN) is one type of wireless technologies which consists of sensor nodes that communicate each other to collect and transmit data from the surrounding environment. It's been used widely for monitoring habitat, natural disaster and many more. Those collected data will be transmitted to base stations. These small sensor nodes are equipped with multiple sensors and they are capable of transmitting data at the same time. And more importantly, they can be configured to be low or high power to save power and they are small in size compared to other type of wireless device [7].

This project uses the WSN technology to monitor the artificial aquatic ecosystem on real time basis. The data monitored all be transmitted to a remote base station (personal computer) to allow data analysis take place. Based on the analysed data, the quality of the polluted waste can be identified and a solution to improve the quality can be proposed [8].

1.2 Problem Statement

Aquatic environment quality has been decreasing. All the traditional approaches used for monitoring aquatic ecosystem are not flexible, cannot operate unattended, not cost efficient, and the data collected became inaccurate over time. In this project, the solution is to implement a WSN in the aquatic ecosystem monitoring system. The monitoring system will become more flexible, provide real time system and can be done remotely.

1.3 Objectives

The objectives of this project are to:

- Design data collection method from the aquatic ecosystem by using certain tools and sensors.

- Develop a reliable and low power WSN to transfer the collected data from one location to a base station.
- Design data analysis technique and alert system as part of the automated monitoring system.
- Design a water-resistance casing for the wireless sensor node to be placed in wet condition.

2. LITERATURE REVIEW

2.1 INTRODUCTION TO WSN

WSN's are MEMS technology devices provide wireless communication systems which are very small with variety of multifunctional sensor nodes available. These devices come with very low-cost and consume low power. There were two most usual methods in application of the technology. First, sense perception method is placing the nodes far from the target phenomenon and this technique is quite complex and much noises are present. Second, they are used for sensing and performing simple calculation and transmitting data to the base station. The base station then will do the computation of the data and fuse those data from multiple nodes [10].

2.2 APPLICATION OF WSN

In the market, the cheapest wireless sensor nodes or pico nodes cost only $1 compared to other wireless technology such as Bluetooth which cost around $10. However, the functionality provided by devices that based on sensors node became an issue, as the applications were too vast. As the result, the cost became very difficult issue [10].

WSN is largely deployed for many applications. As they production are so dense, they do not have the global identification (ID) as other wireless devices do. Due small in size, the power consumption & capacities, computation capabilities and memory storage become limited. Due to sensors node capabilities, a dense deployed are possible. It can gives accurate result as the higher number of sample data collected, the more precise of the outcome. Unlike others wireless communication, sensor nodes applied broadcast communication paradigm instead of point to point communication [10].

Wireless sensors network had been widely used on variety of sensing input such as lightning condition, noise levels, temperature, visual, infrared, magnetic, acoustic radar, seismic, soil makeup, pressure, vehicle movement, humidity, presence or absence of an object, mechanical stress & speed, direction and size of an object [10].

2.3 CHARACTERISTIC OF WSN

A wireless sensor network (WSN) consists of gateways, sensor nodes and a base station. All the sensor nodes have limited range up to 30 meters. In order to achieve long distance, the sensor node needs to communicate with gateways to transmit data to the base station, then the gateways forward those data to the base station and vice versa [12].

The unique capability of WSN is that the sensors nodes can collaborate with each other and send raw data to base station. It is also capable of computing simple computation in order to reduce data traffic in transmission by transmitting the only necessary processed data or data that needed for higher level computation. The applications of WSN are very broad. Stealth type was used commonly which requires transmission over small power signal. Military, security, and health most often use stealth type [10].

In order to cover large area, the sensors nodes between the base station and other further reach sensor nodes will transmit data on multi-hop communication. The transmission range of the sensor node is very small. With the multi-hop communication, it does not only overcome the issues but also surpass the range of point-to-point communication with very effective data transmission [10].

The cooperative capability of WSN is very useful for environmental monitoring application. In pollution monitoring, it can identify the presence of foreign chemical over the air or in the water. It is also able to provide the location too [10]. The disadvantage of WSN is that it is prone to failure as it can run out of battery and the network topology is continuously changing.

Figure 2 TelosB Mote

Figure 3 Tmote Sky

Figure 4 Mica2/MicaZ family mote

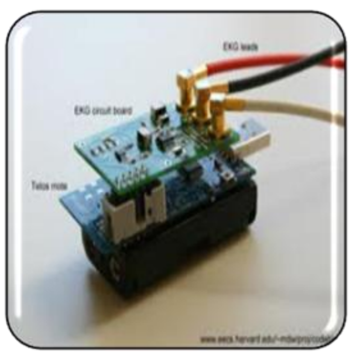


Figure 5 SHIMMER

Figure 6 Sun SPOT

Figure 7 EZ430-RF2480/2500

A WSN device or a sensor node is made up of microcontroller, transceiver, memory, power source, and sensors. Current available motes are TelosB/Tmote Sky, Mica2/MicaZ, SHIMMER, IRIS, Sun SPOT, and EZ430-RF2480/2500. These motes are categorised by their parameters, processor, memory, communication capabilities, supported sensors and power consumption [13].

2.4 IRIS MOTE

IRIS mote is from Crossbow. It is the latest WSN technology which has been improved from the Mica2 and MicaZ family products. The improvements include increasing of transmission range, computing capabilities and storage. This mote is chosen for this project [13].

IRIS mote embedded with processor of Atmel ATmega 1281 with bus speed 8-bit and speed of clock 8MHz. The RAM provided is 8Kbyte, larger than its predecessor Mica family mote with only 4Kbyte. The flash memory provided is 640Kbyte, the second largest in WSN family. It allows more instruction could be programed onto this mote even though the processing capacities quite limited as RAM quite small. However, EEPROM provided is very small, which is only 4Kbyte. The mote uses IEEE 802.15.4 protocol and they are packet level radios with packet length up to 127 bytes [13].

IRIS mote does not provide on board sensors but it has an expansion slot of 51-pin expansion slot that allows other Crossbow sensor board to be used. Same as other Mica family motes, it uses two AA batteries.

2.5 AQUATIC ECOSYSTEM QUALITY PARAMETERS

Currently, aquatic ecosystem monitoring done by traditional ways by taking samples and bring to lab for analysis [2]. Some WQI parameters such as DO, BOD, COD, SS, AN and pH was used for spatial water quality assessment at Langat River Basin [6]. Some additional parameter which are Electrical Conductivity (EC), Colour, Turbidity, Ammonia Nitrogen, Fluorides, Chlorides, Sulphate, and Phosphorus was taken into consideration for measuring WQI for man-made aquatic reservoir in Mexico[9].

Measurement of pH is critical to ensure survival aquatic organism. The ideal condition is neutral. For slight acidic or alkaline, some organism might not survive. If DO over 110%, the aquatic life is in harm. However, if it drops below 5mg/L, the organism will be in stress. Heavy metal existences in water are always bringing harms to all organisms. If the amount too high, it can be seen as mud and milky look on the water. At certain level of AN, it become toxic to aquatic organism. High BOD level shows larger amount of organic waste in the aquatic ecosystem. The decomposition agent which is bacteria required high oxygen during the process of decomposition. This will result insufficient oxygen for other aquatic organism. COD is used to determine the capacity of water to consume oxygen during decomposition of organic matter and the oxidation of other chemical. Faecal Coliform colonies are a type of pathogen exist in water which harm to human for consumption and cause insufficient oxygen for aquatic organism [11].

3. METHODOLOGY

This chapter describes the tools, software's and steps taken for this project.

3.1 TOOLS

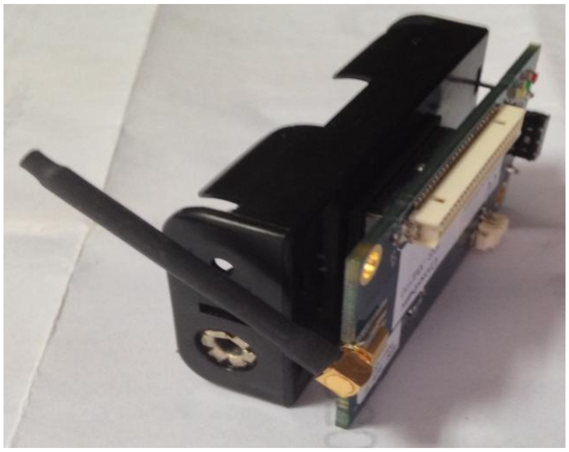


Figure 8 XM2110

- MEMSIC XM2110 as sensor nodes

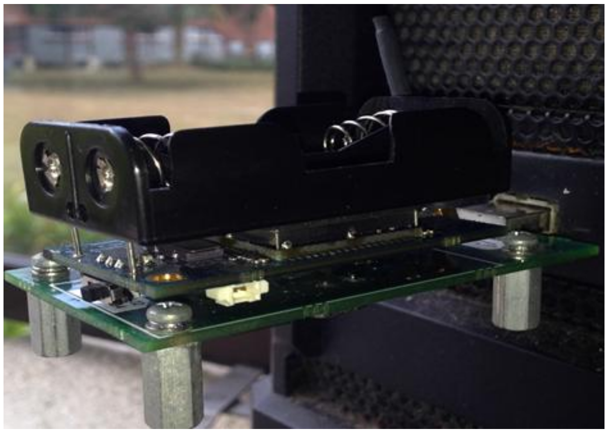


Figure 9 MIB620 provide interface between PC and XM2110.

- MEMSIC MIB620 to provide USB interface for the sensor nodes to communicate with PC.

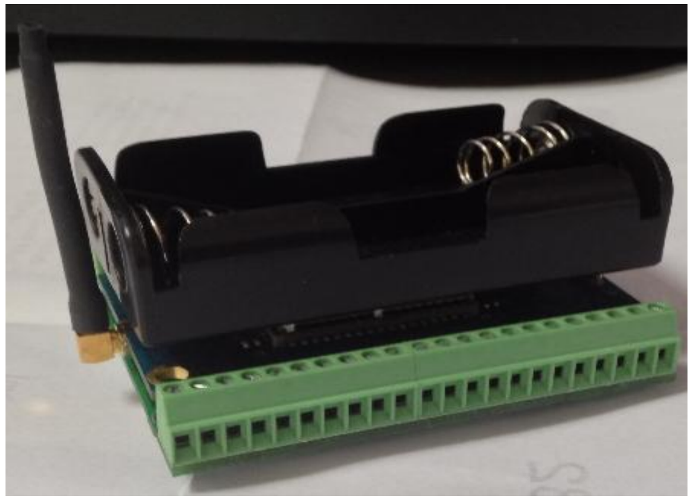


Figure 10 MDA300CA provide interface to external sensors.

- MEMSIC MDA300CA as data acquisition board to control input from external sensors.
- Water resistance box.
- PH-BTA pH sensor.

3.2 SOFTWARE

- Mote Work is main interface of software tools for MEMSIC products.
- Mote View to monitor current network and hardware detail.
- Mote Config use for any configuration on sensor nodes.

3.3 STEPS TAKEN IN THIS PROJECT

For this project, three IRIS MEMSIC XM2110 sensor nodes were used. Theoretically, the transmission range extends up to 1500 meters without any amplifier.

The typical WSN requires three types of nodes which are base station, gateway, and sensor nodes. However, the IRIS mote can be used to represent any type of these nodes.

The nodes are configured using Mote Config through USB port on personal computer (PC). For the nodes to communicate with a PC using USB port, it requires MIB 620 to act as an interface board. A node was first programed with Over-the-Air (OTA) option enabled and then they can be re-program again wirelessly.

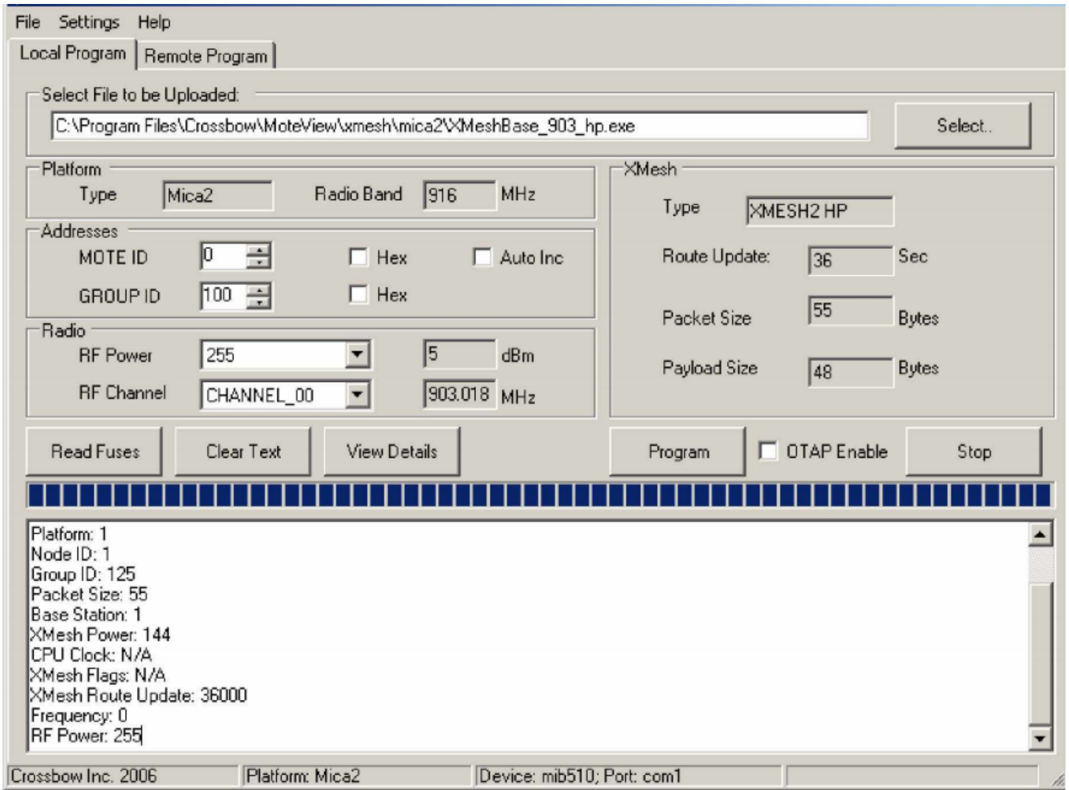


Figure 11 Mote Config software

Figure 11 show the window of Mote Config software. Configuration of network id, node id, radio frequency channel, radio frequency and operating mode were done by using the software.

The IRIS mote doesn’t provide built in sensors. However, MDA300CA connected on 51-pin slot extension of the mote for up to 12-bit channels of analogue input was used.

In this project, a WSN for monitoring aquatic ecosystem remotely was implemented. The project is using a real time system. In this case, the sensor nodes continuously send the data collected from the ecosystem to the base station which later can be analysed.

An artificial aquatic ecosystem is a sample water taken from nearby and place in a tank. This project needs to use an artificial aquatic environment because of too many uncertainties.

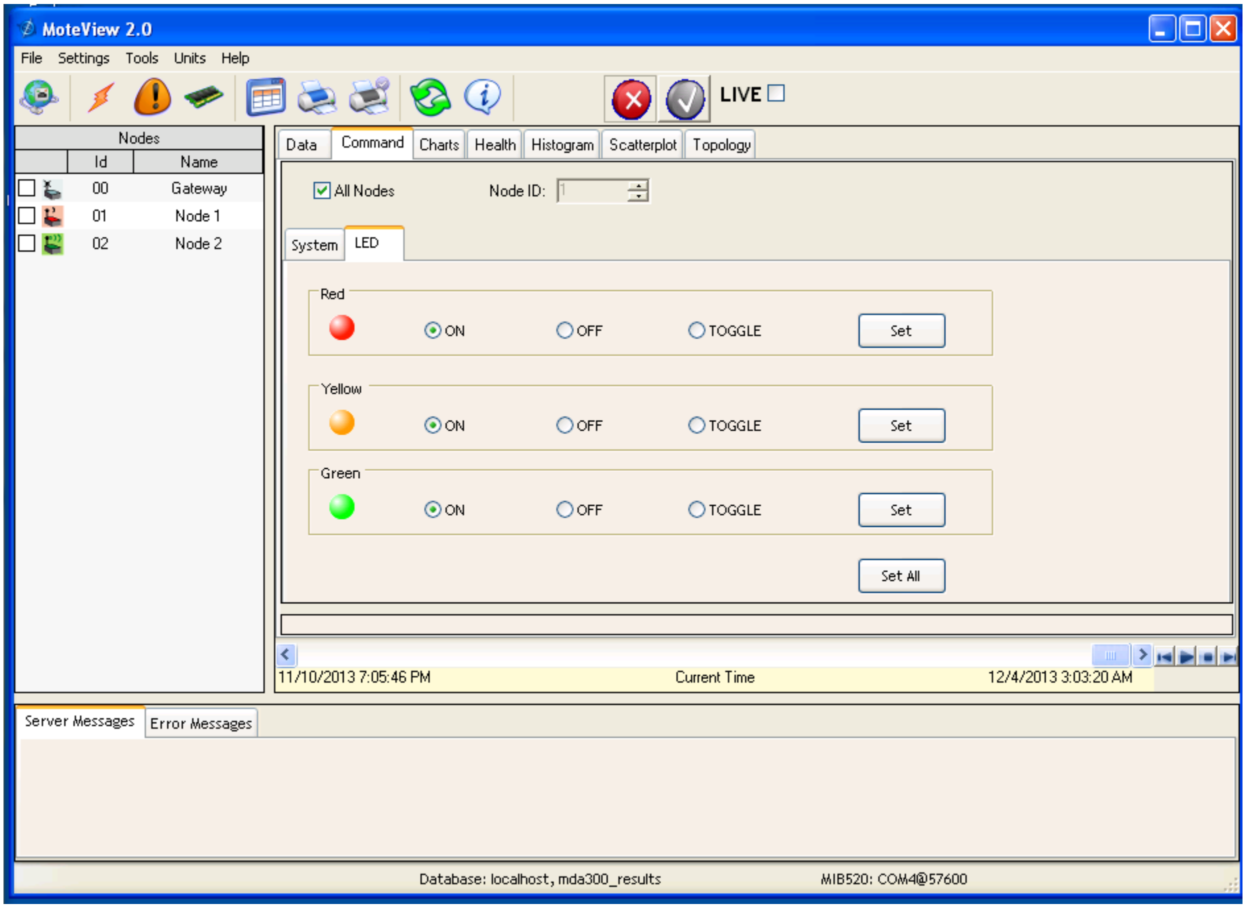


Figure 12 LED tab in command window of Mote View software

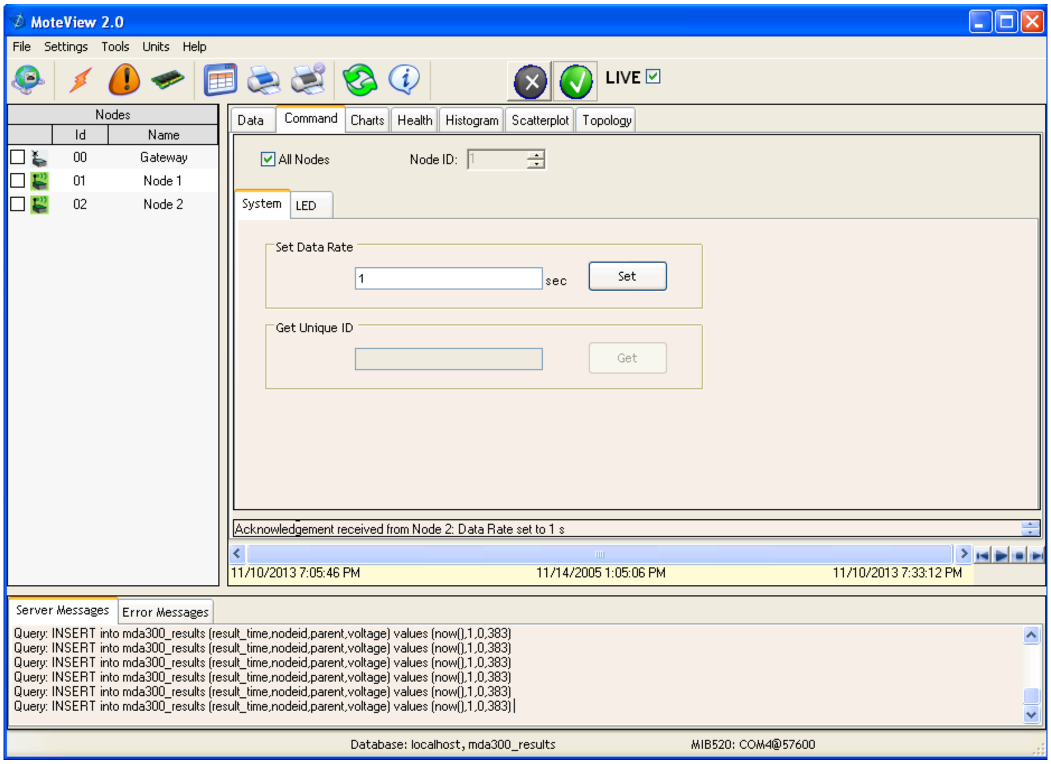


Figure 13 system tab in command window of MoteView software

Battery is the only power source used in this project. Therefore, minimal power consumption is important. To save power of the mote, the base station and nodes were set to be in low power mode using Mote Config software. Figure 13 shows the data rate of the node can be control. Figure 12 shows the LED also can be control. By reduce the data rate and turn off unnecessary LED also could reduce the power consumption of a node.

For water quality index (WQI) parameter measurement, external sensor is required to measure the WQI. MDA300CA built in sensors are uses for only safety purposes. The external sensor used was the PH-BTA pH sensor shown in Figure 14 PH-BTA pH sensorFigure 14.

Figure 14 PH-BTA pH sensor

Due to a limited budget, this pH sensor is used because pH is the most important parameter in determining the quality of ecosystem. By determining pH alone we could indicate most dangers of the water ecosystem. This sensor output is 1.75V for pH 7. Every increment of pH value will decrease the voltage reading by 0.25V. On the other hand, the voltage reading will increase by 0.25V for every decrement of pH value.

This pH sensor was connected to an analog port of MDA300CA. The output of the sensor is in term of voltage level and this value is transmitted to a base station.

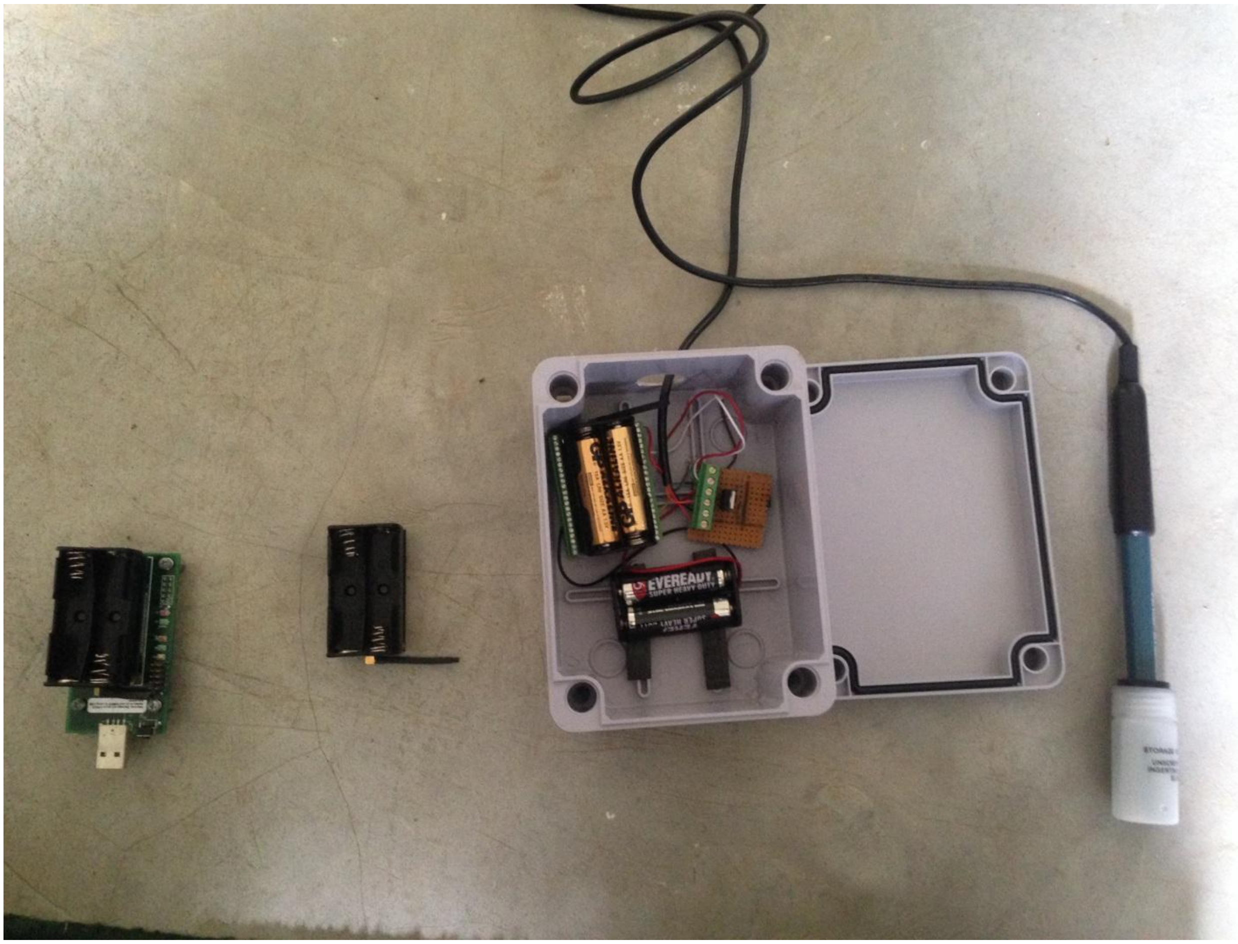


Figure 15 Complete setup of system

Figure 15 shows that the sensor node requires additional circuit to interface with the pH sensor. The sensor required 5V power supply to operate. Therefore, additional batteries were used to supply power for the sensor.

The analysis method is by comparing the data received with database as show in Table 1.

Table 1 The WQI legend [14].

Range	**Quality**
90-100	Excellent
70-90	Good
50-70	Medium
25-50	Bad
0-25	Very bad

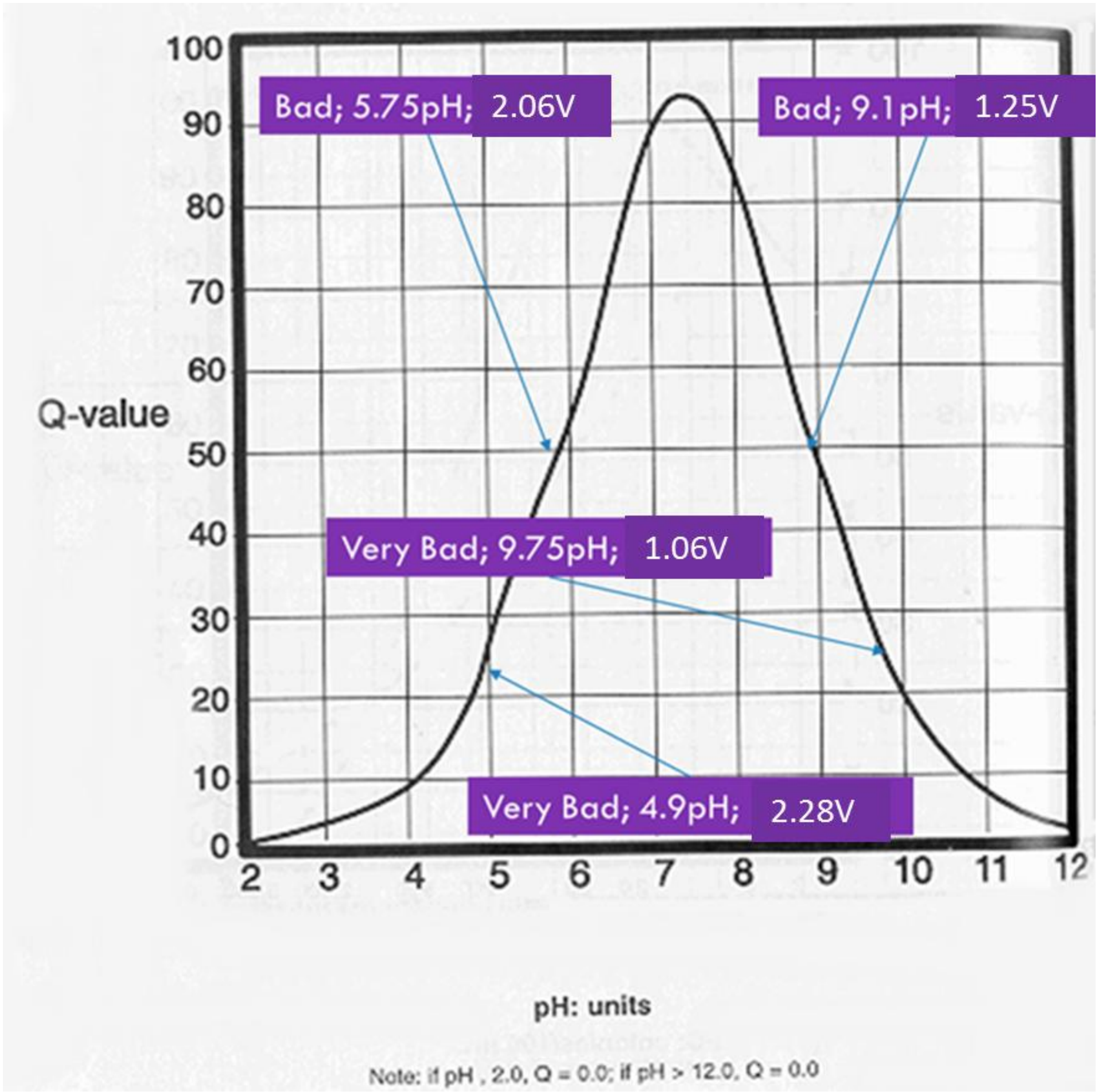


Figure 16 Quality and pH Unit Relationship [14].

Graphs in Figure 16 provides the relationship between water quality levels with pH parameter together with sensors output voltage for certain water quality level which is calculated based on the data sheet of the pH sensor and Table 1.

PC will analyse the data received through base station. If any hazard detected, the alarm or notification will be given. These processes require using Mote View software. Figure 17 Alerts manager shows the alert manager windows in Mote View used for setting the alert parameter. The alert parameters are adjusted according to data on Figure 16.

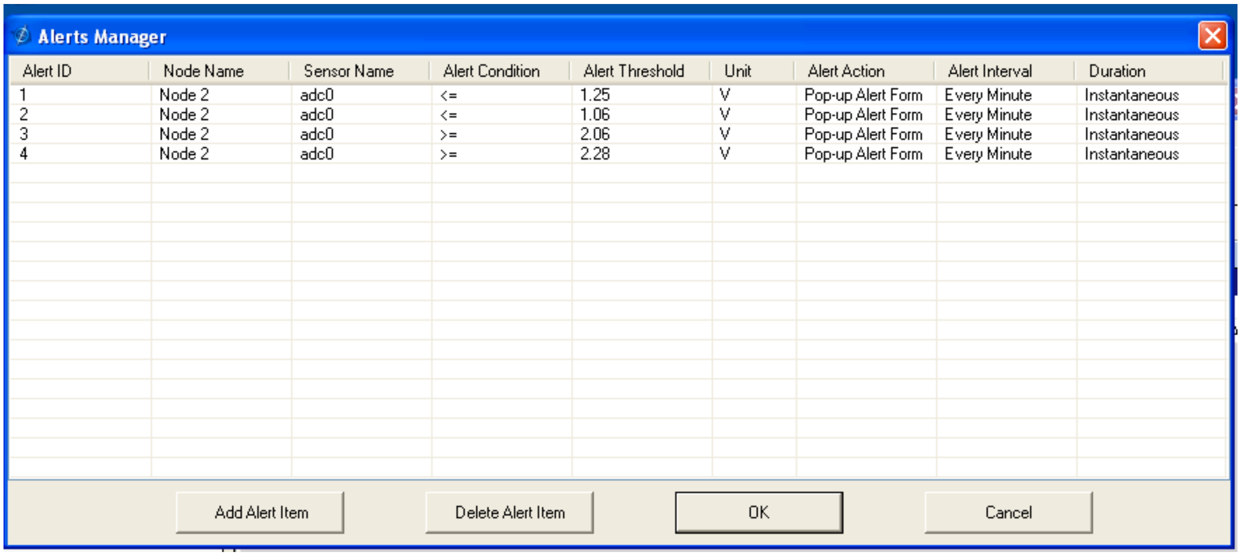


Figure 17 Alerts manager

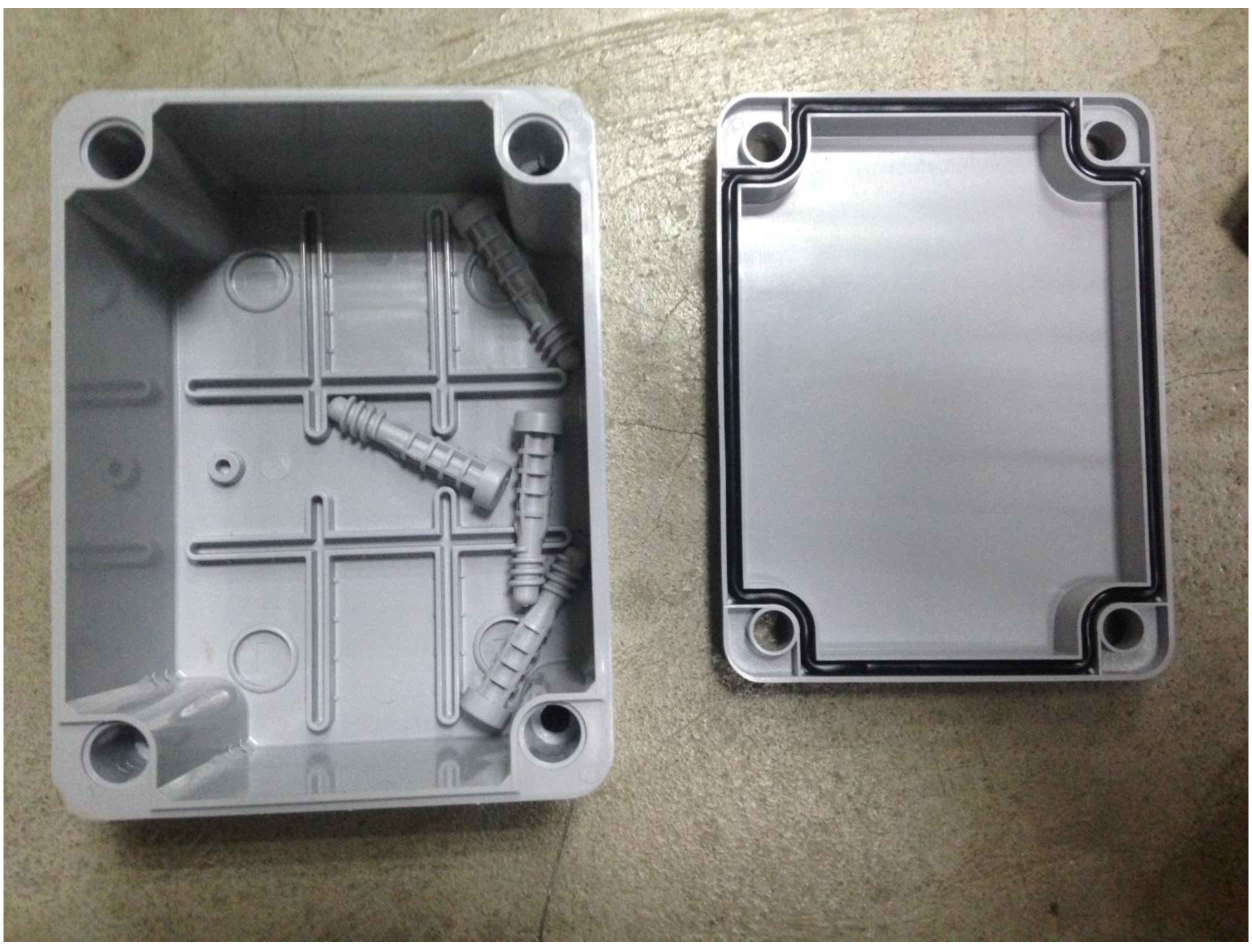


Figure 18 Water Resistance Box

The sensor nodes are supposed to work in open environment which is exposed to any weather condition. A sensor node located near to water ecosystem that needs to be monitored. To avoid damage of the sensor node, it is placed in water-resistance box as shown in Figure 18.

3.4 Flow Chart

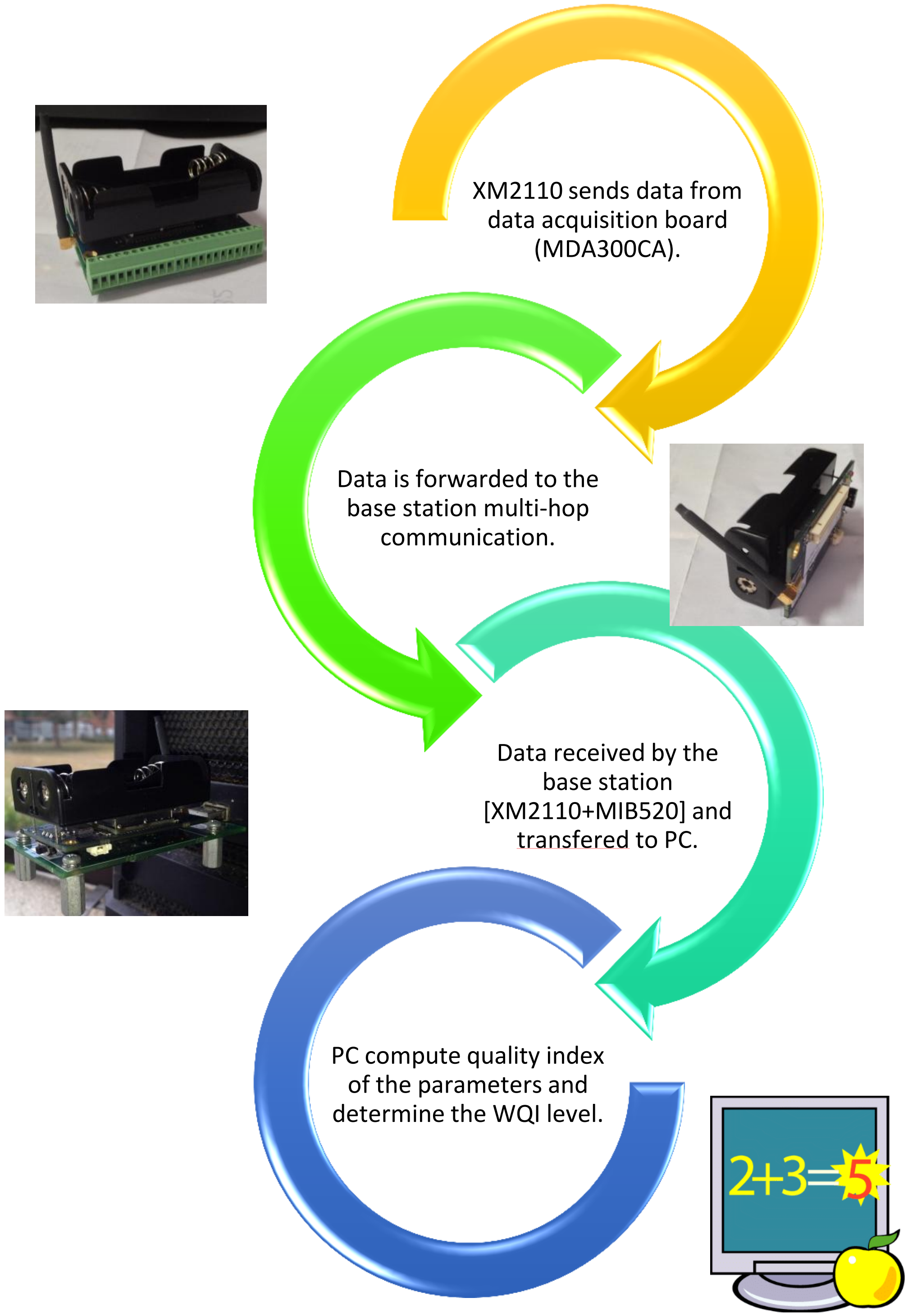


Figure 19 The Monitoring System Flow Process

3.4 The System Design Diagram

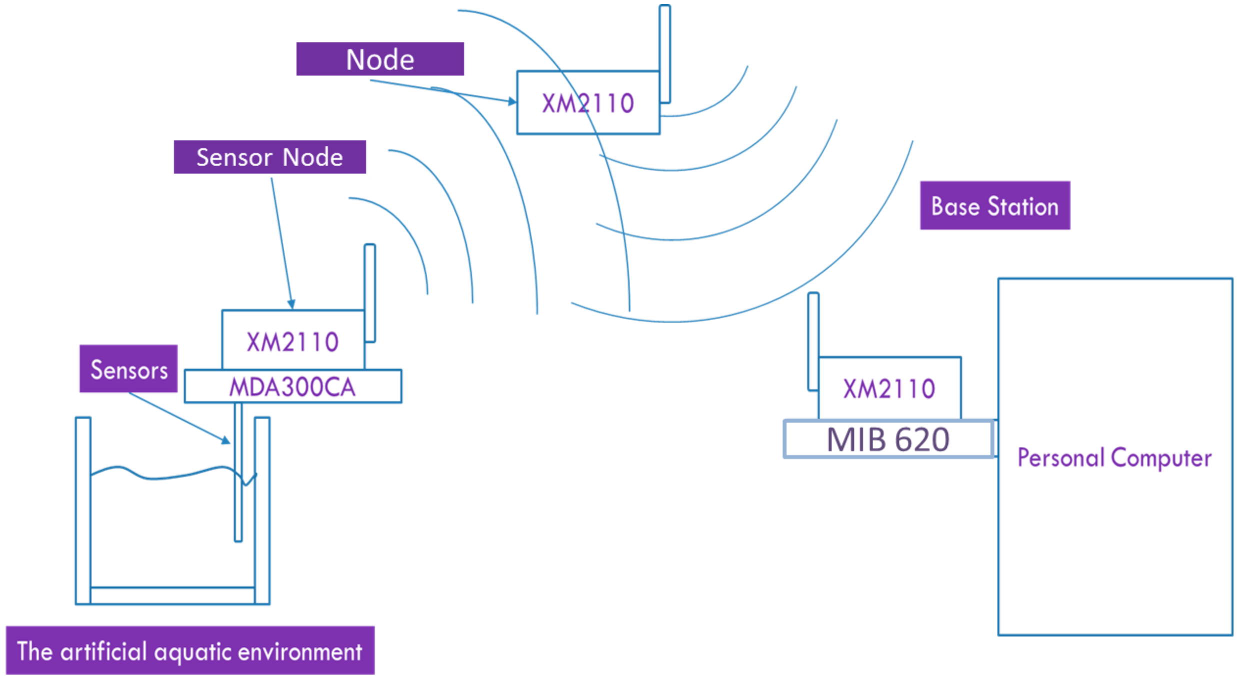


Figure 20 The System Design Diagram

Figure 20 indicates the configuration of the wireless sensor network (WSN) which is used to monitor the aquatic environment.

4. KEY MILESTONE

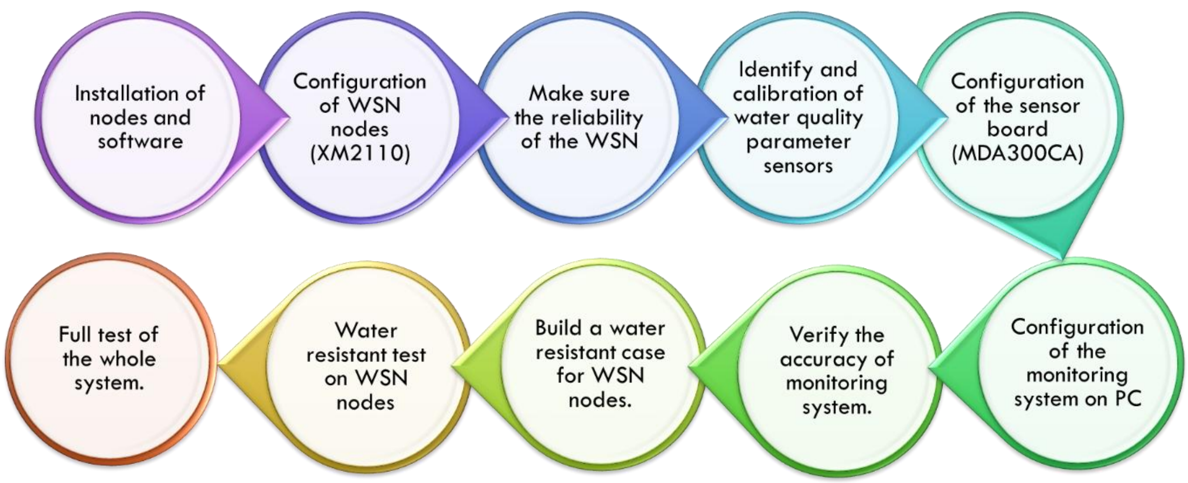


Figure 21 Key Milestone of This Project

Figure 21 describes the key milestone of this project. It starts with the installation of nodes and software. Then, configuration of the WSN nodes and make sure it's reliability. A water quality parameter sensor was identified and calibrated. Then, the sensor board and the monitoring system were configured and verified. Lastly, a water-resistance case was used to place the sensor nodes which later had been fully tested.

5. GANTT CHART

Table 2 Gantt chart of FYP1

	Week													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Title selection/ proposal	■													
Literature Review	■	■	■	■	■	■								
Extended Proposal						■								
Working on Project						■	■	■	■	■	■	■	■	
Viva: Proposal defense and Progress Evaluation									■					
Draft Report													■	
Final Report														■

Table 3 Gantt char of FYP2

	Week													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Identifying sensors	■	■	■											
Waiting for sensor delivery				■	■	■	■							
Sensor calibration								■	■					
Sensor implementation										■	■			
System monitoring testing												■		
Water-resistance box implementation													■	
Full testing of the system														■

6. RESULTS AND DISCUSSION

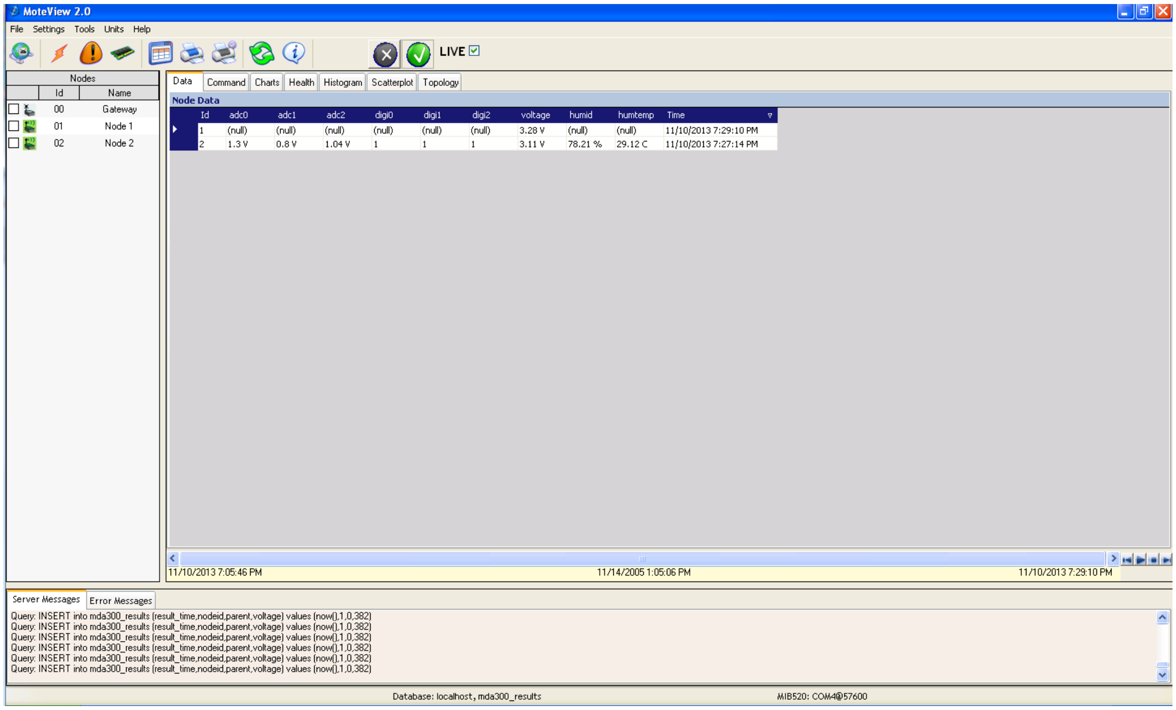


Figure 22 Main Windows of MoteView

Figure 22 shows three nodes, node 0, node 1 and node 2. Node 0 acts as base station which receives data from other nodes within the same network and same network id. The data tab of the window shows the reading of two nodes. It shows node 1's reading from all ports were null. This is due to unused 51-pin slot extension. Therefore it cannot provide any value. For node 2, it's reading all input, humidity and temperature from the sensor board.

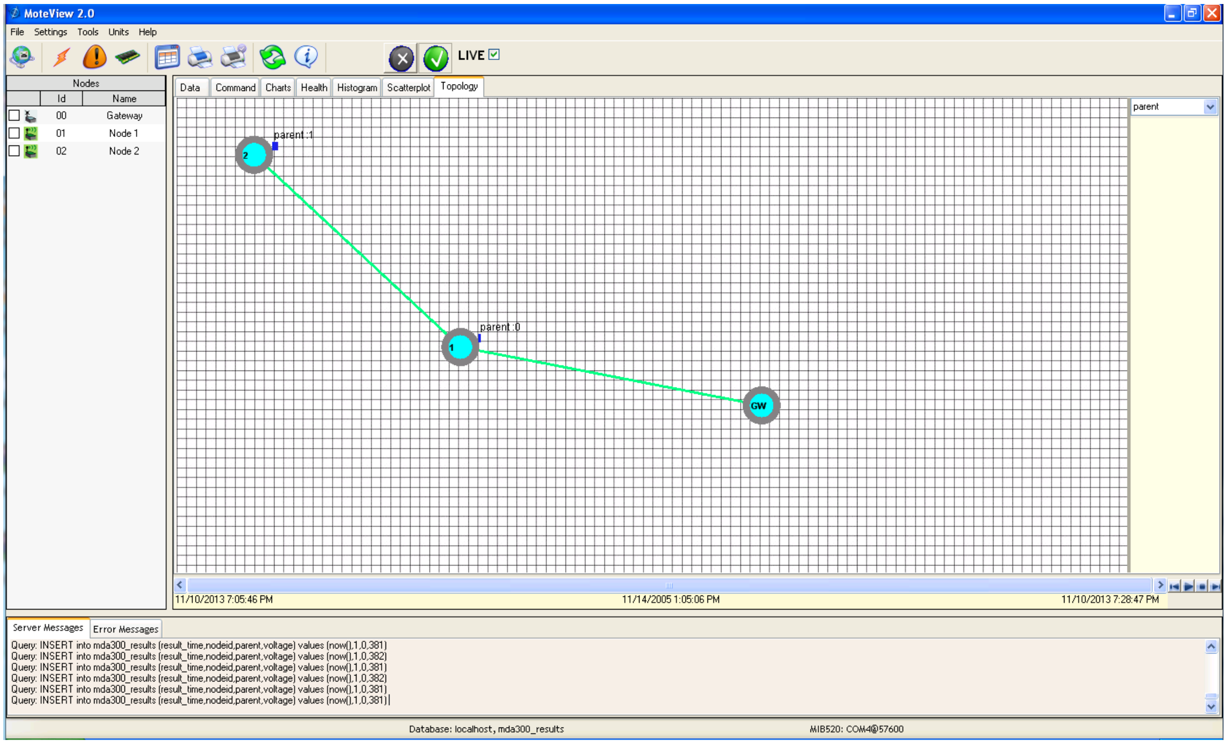


Figure 23 the WSN topology

Figure 23 shows the network topology of the wireless sensor network. There were three nodes, node 0, node 1 and node 3 which labelled as GW, parent 1 and parent 2 respectively. This shows that node 1 interconnect between node 2 and base station. All data from node 2 were passing through node 1 before reach the base station. It proves that transmission distance limit can be overcome due to multihop operation.

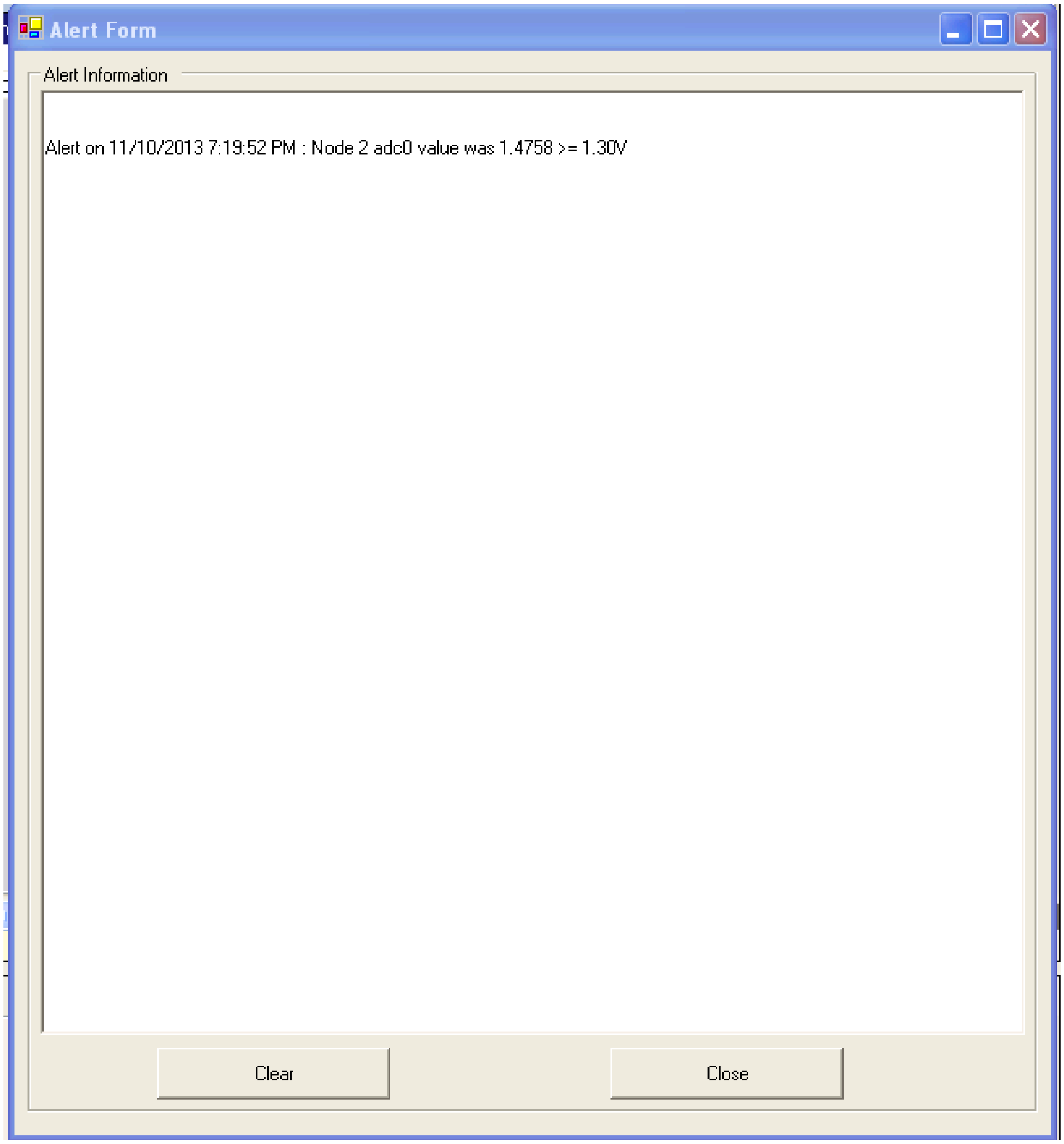


Figure 24 Alert form or logs.

By setting up some alert parameter as shown in Figure 17, I had given a random input voltage to the sensor board. Figure 24 shows alert been triggered. This shows the alert system worked.

7. CONCLUSION AND RECOMMENDATION

The main purpose of this project is to maintain the quality of aquatic ecosystem and avoid any live loses. This project could be implemented by multiple types of industries.

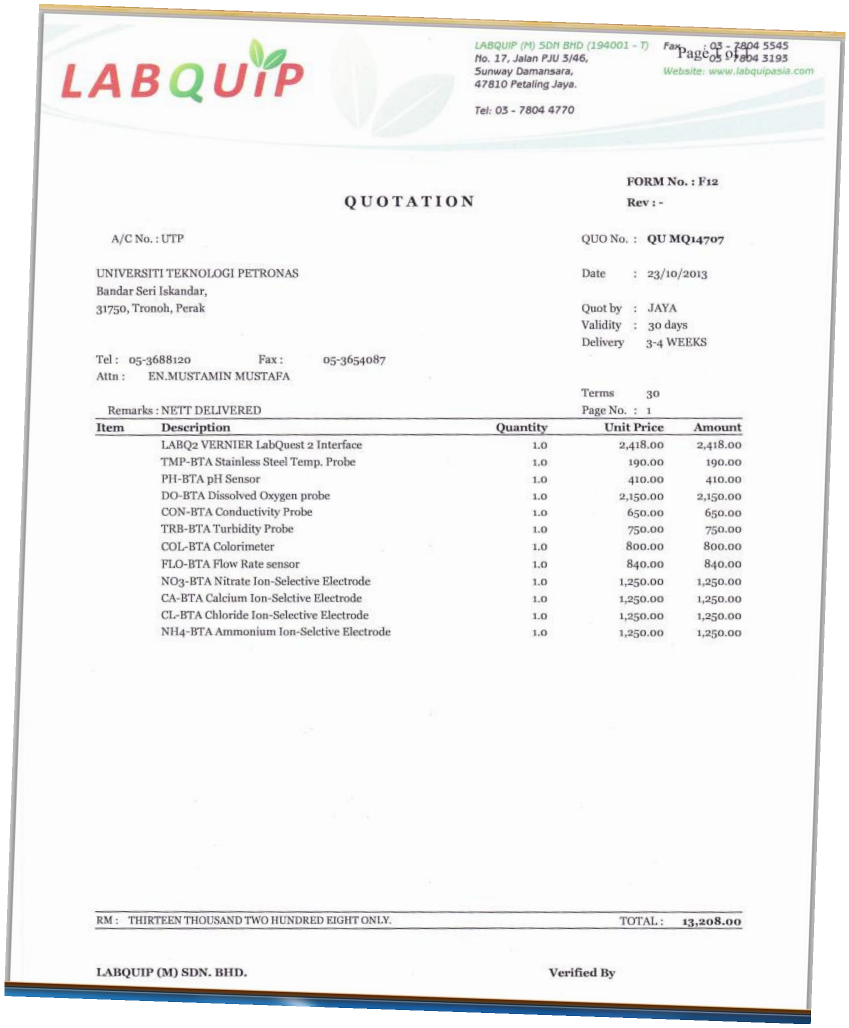
In the industrial sector, it would save more resources. No longer on hands measurement and sampling needed. It saves a lot of time which almost in instant monitoring system.

Government sector should use it for monitoring the rivers or lake in Malaysia which will greatly improve the aquatic ecosystem in Malaysia. It will not only saves million aquatic lives but also whole ecosystem in the world. By preserving the quality of aquatic ecosystem, tourism industries also will greatly improve.

By using the system in industrial areas, we could detect almost instantaneously the dangers to the aquatic ecosystem before it even brings further harm. Plus, this system wills saves a lot of lives including humans, aquatic lives, and animals.

Currently the quality of aquatic environments is really critical, this project become more important especially for the community in the area.

Because of the system characteristics, the implementation is really easy. No deep research are needed are special training and certificate required handling the system.



LABQUIP

LABQUIP (M) SDN BHD (194001 - T)
No. 17, Jalan PJU 3/46,
Sunway Damansara,
47810 Petaling Jaya.

Tel: 03 - 7804 4770

Fax : 03 - 7804 5545
03 - 7804 3193
Website: www.labquipasia.com

Page 1 of 1

FORM No. : F12
Rev : -

QUOTATION

A/C No. : UTP

QUO No. : **QU MQ14707**

UNIVERSITI TEKNOLOGI PETRONAS
Bandar Seri Iskandar,
31750, Tronoh, Perak

Date : 23/10/2013

Quot by : JAYA
Validity : 30 days
Delivery 3-4 WEEKS

Tel : 05-3688120 Fax : 05-3654087
Attn : EN.MUSTAMIN MUSTAFA

Terms 30
Page No. : 1

Remarks : NETT DELIVERED

Item	Description	Quantity	Unit Price	Amount
	LABQ2 VERNIER LabQuest 2 Interface	1.0	2,418.00	2,418.00
	TMP-BTA Stainless Steel Temp. Probe	1.0	190.00	190.00
	PH-BTA pH Sensor	1.0	410.00	410.00
	DO-BTA Dissolved Oxygen probe	1.0	2,150.00	2,150.00
	CON-BTA Conductivity Probe	1.0	650.00	650.00
	TRB-BTA Turbidity Probe	1.0	750.00	750.00
	COL-BTA Colorimeter	1.0	800.00	800.00
	FLO-BTA Flow Rate sensor	1.0	840.00	840.00
	NO3-BTA Nitrate Ion-Selective Electrode	1.0	1,250.00	1,250.00
	CA-BTA Calcium Ion-Selctive Electrode	1.0	1,250.00	1,250.00
	CL-BTA Chloride Ion-Selective Electrode	1.0	1,250.00	1,250.00
	NH4-BTA Ammonium Ion-Selctive Electrode	1.0	1,250.00	1,250.00

RM : THIRTEEN THOUSAND TWO HUNDRED EIGHT ONLY. TOTAL : **13,208.00**

LABQUIP (M) SDN. BHD. **Verified By**

Figure 25 List available sensors

Figure 25 shows the list of available sensor from Vernier Company that could be used in this project. Due to limited budget, one sensor which is pH sensor was bought. The reason for choosing pH sensor is because pH is the most important parameter compared to others.

In the future project, all those sensors required can be used to determine complete water quality parameter and become a complete monitoring aquatic ecosystem using wireless sensor network.

However, the water resistance box needs modification to accommodate the sensor node and the additional circuit appropriately. Some security measure also is needed for the box to avoid stolen or misused of the sensor before implementing in open environment. Perhaps some security and encoding technique are required for some industries to avoid network breach and hacker.

8. REFERENCE

[1] Nyavor, G. *Pollution of water bodies: Experts predict severe water crisis in Ghana by 2025*. 2013 [cited 2013 24 June]; Available from: http://edition.myjoyonline.com/pages/news/201303/103466.php.

[2] Economy, E.C. *China's Water Pollution Crisis*. 2013 [cited 2013 24 June]; Available from: http://thediplomat.com/2013/01/22/forget-air-pollution-chinas-has-a-water-problem/.

[3] Geman, B. *EPA abandons study that linked fracking, Wyoming water pollution*. 2013 [cited 2013 24 June]; Available from: http://thehill.com/blogs/e2-wire/e2-wire/306961-epa-wont-confirm-fracking-link-to-wyoming-water-pollution-.

[4] Singh, S. *India's Water Nightmare*. 2010 [cited 2013 24 June]; Available from: http://thediplomat.com/2010/09/22/india's-water-nightmare/.

[5] Abdullah, A.R., *Environmental pollution in Malaysia: trends and prospects.* TrAC Trends in Analytical Chemistry, 1995. **14**(5): p. 191-198.

[6] Juahir, H., et al., Spatial water quality assessment of Langat River Basin (Malaysia) using environmetric techniques. Environmental Monitoring and Assessment, 2011. **173**(1-4): p. 625-641.

[7] Marcelloni, F. and M. Vecchio, An efficient lossless compression algorithm for tiny nodes of monitoring wireless sensor networks. The Computer Journal, 2009. **52**(8): p. 969-987.

[8] O'Flyrm, B., et al. SmartCoast: a wireless sensor network for water quality monitoring. in Local Computer Networks, 2007. LCN 2007. 32nd IEEE Conference on. 2007. IEEE.

[9] Rubio-Arias, H., et al., *An Overall Water Quality Index (WQI) for a Man-Made Aquatic Reservoir in Mexico.* International journal of environmental research and public health, 2012. **9**(5): p. 1687-1698.

[10] Akyildiz, I.F., et al., *Wireless sensor networks: a survey.* Computer Networks, 2002. **38**(4): p. 393-422.

[11] *Water Quality Study Report*, E.R.A. Laboratory, Editor. 2008.

[12] Alippi, C., et al., A robust, adaptive, solar-powered WSN framework for aquatic environmental monitoring. Sensors Journal, IEEE, 2011. **11**(1): p. 45-55.

[13] Johnson, M., et al. A comparative review of wireless sensor network mote technologies. in Sensors, 2009 IEEE. 2009.

[14] Oram, B. *Monitoring the Quality of Surfacewaters*. The Water Quality Index [cited 2013 24 June]; Available from: http://www.water-research.net/watrqualindex/waterqualityindex.htm.