Rekayasa Sistem Pengawasan Online dan Peringatan Dini Lingkungan Perairan

System Engineering for Online Monitoring and Early Warning of Environment

Foni Agus Setiawan, Yuli Sudriani
Research Center for Limnology, Indonesian Institute of Sciences
masagus_setiawan@yahoo.com

Abstract

Measurement activity usually performed at a time or in a certain time period. In the case of measurements at one time, measurements manually by visiting the location of measurements, take measurements and write them down, then left the location is not a problem. However, measurements made within a certain period of time or year would be very draining, costly, and time consuming if perfomed manually. Thus, design and implementation of embedded system for online monitoring and early warning of water environment is proposed. The system consists of two parts i.e. monitoring stations (site) and monitoring center (server). A monitoring station is an embedded system that has interface with a logger. Monitoring center is a computer that runs the service that gets the data sent by the monitoring stations, process it and put it into the database. Monitoring center also runan http service to display data acquired from monitoring stations to end users both in tabular or graphical view . The system can perform continuous measurements and its results can be monitored remotely.

Keywords: online monitoring, early warning system, water environment.

Abstrak

Aktivitas pengukuran biasanya dilakukan pada satu waktu atau di waktu-waktu tertentu. Dalam kasus ketika pengukuran hanya dilakukan pada satu waktu, pengukuran yang dilakukan secara manual dengan mengunjungi lokasi, melakukan pengukuran, mencatatnya, dan kemudian meninggalkan lokasi tidaklah menjadi masalah. Akan tetapi, ketika beberapa atau banyak pengukuran harus dilakukan pada rentang waktu tertentu atau tahunan, pengukuran yang dilakukan secara manual akan melelahkan, memakan banyak biaya dan waktu. Desain dan implementasi sistem *embedded* untuk pemantauan dan peringatan dini bencana lingkungan perairan kemudian diusulkan. Sistem ini terdiri dari dua bagian: stasiun pemantau dan pusat pemantauan. Stasiun pemantau merupakan sebuah sistem *embedded* yang memiliki antarmuka dengan alat pengukur (*logger*). Pusat pemantauan adalah sebuah komputer yang menjalankan layanan pengambilan data yang dikirim oleh stasiun pemantau, memprosesnya, dan memasukkannya kedalam *database*. Pusat pemantauan juga menjalankan layanan *http* agar data dari stasiun pemantau dapat ditampilkan kepada pengguna baik dalam bentuk tabular ataupun grafik melalui *website*.Implementasi sistem ini dapat melakukan pengukuran secara kontinyu dan *online* serta hasil pengukuran tersebut dapat dipantau dari jarak jauh.

Kata kunci: pengawasan *online*, sistem peringatan dini, lingkungan perairan

1. Introduction

Measurement is an activity taken to look at the health of an environment in inland waters such as reservoirs, lakes, rivers, swamps, and shallow or deep groundwater. Monitoring of the water should be done to ensure that the aquatic environment is healthy, stable, and are not harmful to organisms living in the vicinity. This is important because the water environment, as well as other environmental elements like soil, organisms and atmosphere, etc., constitute an organic complex. Once a change or damage to the water environment is observed in this complex, changes to other environmental elements inevitably occurs [1].

Field measurement for monitoring the environment are expensive and difficult to conduct [2]. Understanding the response of lakes is importance in the monitoring of lake patterns as it can influence water quality and status of a lake. System engineering for monitoring quality status of lake become important because it can measure any changes in the lake and relate these changes to status of lake using analytical model.

Measurements usually done at a time or in a certain time period. In the case of single measurement, performing manual measurements

Received: 16 September 2015; Revised: 29 Oktober 2015; Accepted: 16 November 2015; Published Online: 30 Mei 2016 ©2015 INKOM 2015/15-NO422

by visiting the location of measurements, taking measurements and writing them down, then leavingthe location is not a problem. However, measurements performed within a certain time period or year would be very draining, costly, and time consuming if done manually. Therefore, it is necessary to build a system that is able to perform continuous measurements, online, and can be monitored remotely. The conclusion is presented in chapter five.

2. Related work

Early Warning System (EWS) is a system that links the instruments in monitoring technology. This technology can analyze and interpret monitoring result in real time [2]. The purpose of EWS is to identify accidental contamination event from small scale until large scale by giving warning to people who use the system. EWS must provide an accurate data and fast response. It can clearly identify lake's status such as normal, risk, or danger. It can also differentiate data of biochemical and physical interactions. It means that this technology can provide accurate identification and database of lake condition or environment in sufficient time, inexpensive, easy to integrate and maintain [2, 3].

In recent years, many studies have been conducted relating to early warning system and lake monitoring, such as early warning system of water shortage by using Stella software based on the system dynamics (SD) model [4]. This method has been believed to delineate clearly the coupling correlation between the water resource and the social economic system and aquatic ecosystem. The ecological flow was considered as an indispensable element in the water demand. So the calculation model of ecological flow was involved in the SD model, which distinguished it from traditional model of water resources supply and demand.

The government of China has pushed the development of early warning systems (EWS) for drinking water source protection [2]. The application of Data Driven Models (DDM) such as Artificial Neural Networks (ANN) has acquired recent attention as an alternative to physical models. A DDM based on genetic algorithm (GA) and ANN was tested to increase the response time of the city’s EWS. However, there are still many weaknesses in EWS such as the lack of pollution monitoring and advanced water quality prediction models.

The other research paper discuss tools for water quality monitoring and mapping i.e. using paper based sensors and cell phone [5]. This system was a combination of paper-based sensors and a novel smart-phone application for on-site quantification of colorimetric readouts as an ultra-low cost solution to monitoring water quality. The monitoring system also can be used for early warning bloom alert network for immediate notification and rapid response to algal blooms, characterizing fish movement behaviour, or detection of dead fish.

There are some technology applied to monitoring system related to lake as summarized in Table 1.

Table 1. Recent Technology Relating to Lake Monitoring System.

Name	Location	Problem	System View
Axys Technologies (2014) [6]	Lake Michigan, lake in Ilha Solteira, Brazil	How to monitor water quality	There are 3 modules in this system: Core module consists of analytical portal services. This technology is used to control a network of systems and sensors, as well as collecting, managing, analyzing, visualizing environmental data from sensor platforms. Monitoring module is a fully-automated system for continuous, year-round and real-time monitoring of lake water quality. Data Management module controls the configuration of sensors and collects data to be inserted into the database. Data dissemination through DBMS, serial, TCP/IP, email, SMS is also performed in this module. There is a desktop and also a web-based interactive application used to display data.
Water Quality Monitoring	Liming River in the eastern	How to monitor and control water quality for	This system use Chemical Oxygen Demand (COD) as the water quality parameter to

(2008) [7]	part of Daqing City of China's Heilongjiang province	environmental protection in the river area	represent total organic matter. The value of COD is measured by a real time analog sensor. A PLC (Programmable Logic Control) is used to convert the analog into digital signals. A Data Logger reads the measurement value supplied by the PLC and then carried it out by using SMS to a Control Center. The Control Center polls a request to each station every 30 minutes. The control center can connect to the internet by using a dial-up connection at any time to publish information to public.
Fish Culture Monitors (2009) [8]	China	How to monitor fish culture	The system is divided into two major parts: the Remote Monitoring Platform (RMP) and the Central Monitoring Platform (CMP). The system use CDMA services combined with IPsec-based VPN as its transport line to submit data from RMP to CMP. Data can be collected and analyzed via internet through web interface. The data do not contain only measurement values but also information about the status and changes of the system. The measurement variables include water temperature, room temperature, dissolved oxygen saturation, dissolve oxygen concentration, pH, electricity conductivity, and salinity. CMP receives, preprocess and analyzes the data from RMP and warn stakeholders through early audio warning or early message warning (SMS).
Wireless Sensor Network (WSN) Project (2009) [1]	China	How to monitor water quality using Wireless Sensor Network (WSN)	A WSN is a system used to monitor water quality by applying sensors as a network. The parameters measured are pH, DO (Dissolved Oxygen), electrical conductivity rate, and temperature. The measurement value is then sent to database station via GPRS network. The monitoring center process and analyzes the water quality data, give an alarm for emergencies (i.e. water contamination) and provides support for decision making in prevention of water contamination. End users can get the data via web interface and email.
LakeNet Project (2007) [9]	St.Mary Lake, University of Notre Dame, USA	How to monitor water quality	The parameters measured in this system are pH, DO, and temperature. Sensors are scheduled in interval 10-15 minutes to collect data and then save it automatically into database. The system is used to determine health condition of the lake, but it has no warning feature.

This study describes the process of design and implementation of inland water online monitoring system, including the early warning of water quality and mass mortality of fish. Some of the differences found in this study compared to other similar studies mentioned above are in terms of:

a) Measurements were made using wired sensors attached to a monitoring station. The system does not use the wireless sensor networks because it only retrieve data in a predetermined location. In the case in lakes and reservoirs, measurement is emphasized to capture temperature profile data vertically to see the stratification.
b) These are then combined with DO (Dissolved Oxygen) data for early warning analysis materials of mass mortality of fish. As in the case of mining, the measurements were made at the water

treatment facility outlet to see the quality of the mine water discharged into river.

c) The processor used to perform measurements is using ARM architecture that is able to work in multitasking mode but still saving power. This is intended to minimize the losses of measurement moment because the system can perform several tasks simultaneously (for example, the system can fetch the data from the logger/sensor, send the data to the server, and send an alert message at the same time).

d) The system has SMS Gateway feature which is able to answer the message sent by user (such as request for recent data) or process the commands given (such as to update or restart the system).

3. Design and implementation

3.1. System requirement

The system for online monitoring and early warning of water environment consists of two parts: monitoring stations (site) and monitoring center (server). A monitoring station is an embedded system that has interface with a logger. The logger has sensors such as pH, temperature, conductivity, DO, and depth. The embedded system also has an interface with the internet network (GPRS/3G) and a modem for SMS command, notification or warning. The GPRS/3G module's communication task is responsible for setting up the GPRS network and communicating with the data monitoring center. The system architecture is described in the picture below.

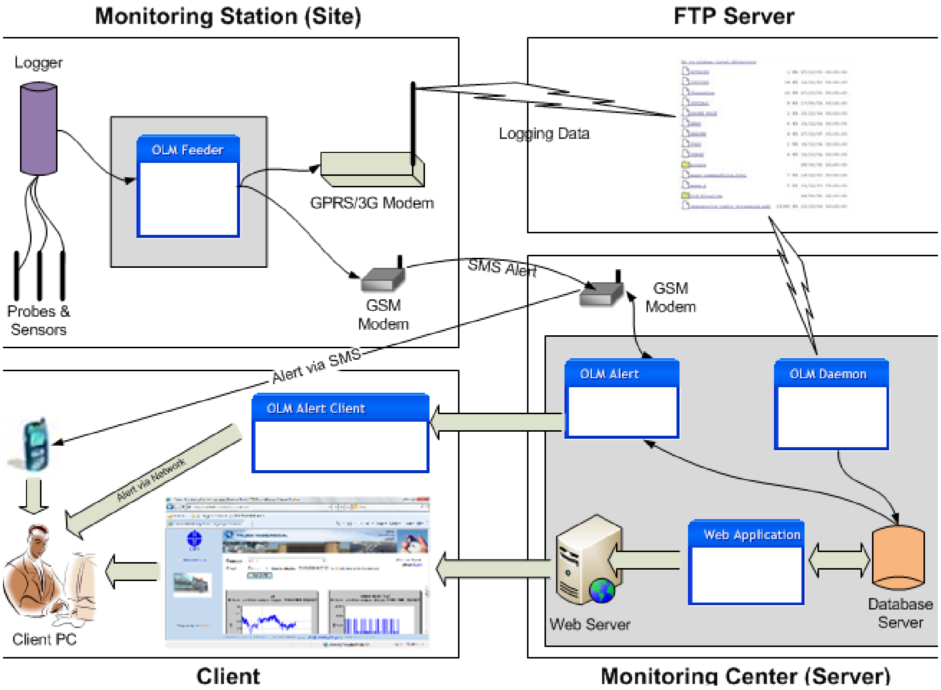

Figure 1. Architecture of the online monitoring and early warning system.

At a certain time period, the system will retrieve data from the logger. The data is then be parsed to get the value of each sensor/variable. If values found outside normal limits, such as if the pH is lower than 6.0 or the water level exceeds a certain limit the potential occurrence of floods, it will send an early warning of sirens and/or SMS to the number specified.

At a certain time period or as needed, monitoring stations will transmit data obtained from the logger to a monitoring center via the internet. Data is sent as a text file which if required can be encrypted for security reasons. The embedded system can also be controlled via SMS by sending appropriate command to do such a task, i.e. sending current data or restart the system.

Monitoring center is a computer that runs the service that gets the data sent by the monitoring stations, process it and put it into the database. Automated collection and web- based dissemination of data provide a centralized database for use and detailed data analysis by all water quality stakeholders. Monitoring center is also running an http service for the data from monitoring stations can be displayed to end users either in tabular or graphical view via website.

3.2. Design

There are several aspects that need to be considered in the system design process of an embedded real time system, such as:

a) Hardware that is placed in the site should be resistant to the weather.
b) Limited power supply must be able to maintain the system in order to keep running [6].
c) The software is designed to run continuously to retrieve the data and sends it to the server.
d) Availability of watchdog that could reset the system at any time in case of system failure or stagnation.
e) The system can be controlled remotely such as through SMS.

The hardware system at Monitoring Station is divided into four modules consisting of:

a) Main Module (ARM Board) − the main module where the processor exists. It has direct interface with GSM modem as SMS handler, GPRS/3G modem as internet connection handler, and control of data storage on the SD card.
b) Power Module − dealing with energy supply from solar cells to battery and from the battery to the central processor.
c) IO Module − handles command to the logger and capture data input from the logger.
d) Security Module − handle warning mechanism in case of security threats (theft) in the system, such as: the panel box door opened-closed, the logger connected-disconnected, and the solar cell connected-disconnected.

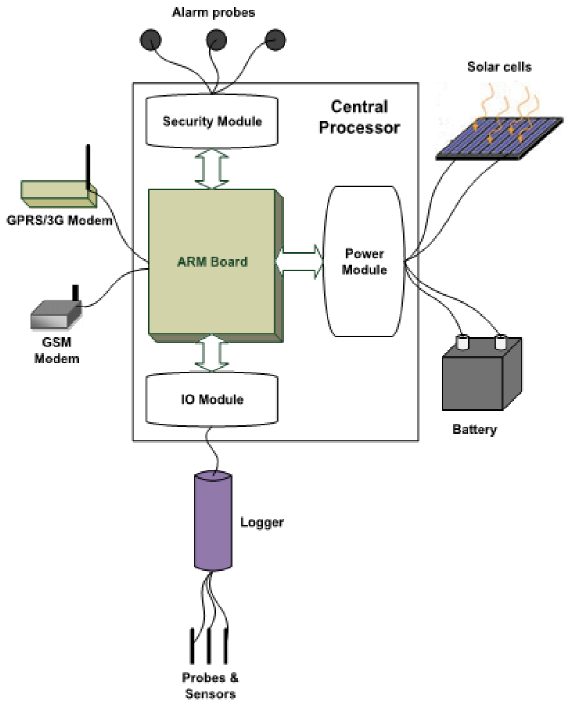

Figure 2. Modules in hardware system.

The software system at Monitoring Station is divided into four main programs with the following tasks:

a) Feeder: retrieves the data from the logger and save it to an encrypted file at a certain time period.
b) Uploader: delivers the data files to an FTP server.
c) SMS Engine: sends the alerts and information of current data to the number specified as an SMS Alert Server. SMS Engine is also in charge of answering remote SMS commands given, such as command requests the current data, configuration updates, or system restart command.
d) Watchdog: serving as a guard. If the system fails or stagnation occurs, then the Watchdog will reset the system in a way cut off power to the system and turn it back on.

Software architecture of the system can be described as follows.

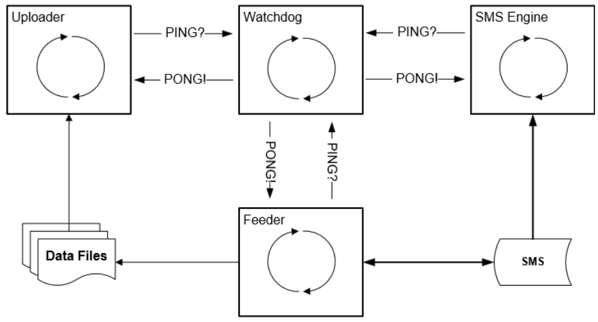

Figure 3. System software architecture.

Status checking of each program is conducted by Watchdog using PING-PONG mechanism. Watchdog waits PING? message of the Feeder within specified time interval. If there is a PING? message received, then the Watchdog will reply with PONG! and the time counter is set back to 0. The Watchdog considers that the Feeder are still actively working. This mechanism also applied equally to Uploader and SMS Engine.

Description of PING-PONG mechanism is described like in the flowchart below.

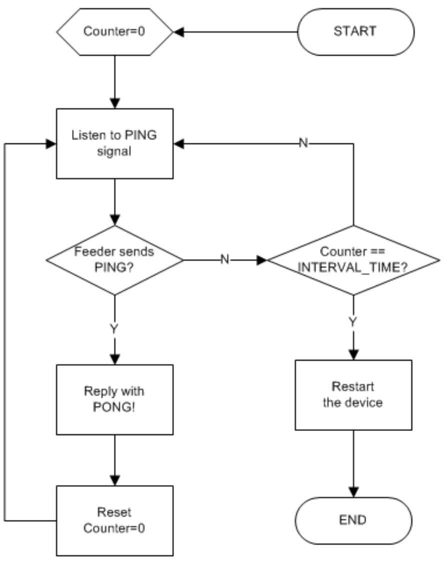

Figure 4. PING-PONG mechanism to control system continuity.

3.3. Implementation

The system is implemented using ARM-based hardware on the monitoring station. Embedded devices is then coupled to the hardware module IO converter to handle the input process output with peripheral equipment such as terminals, Logger, and SMS Modem. Power management module is also coupled to regulate the power supply comes from solar cells to accumulator to be used by the main processor.

Software and data are stored in the SD Card attached to the ARM Board. The operating system used is Windows CE 6.0. The programs are built using C # with SQL Server CE as its database server to store the settings, incoming and outgoing SMS. Data captured from the logger are stored in text files organized by day for easy archiving.
Preview of the system in the monitoring station is as follows.

Figure 5. Preview of the system in the monitoring station.

3.4. Testing

The system has been tested on a variety of terrain and conditions, such as in lakes and reservoirs for lake water quality monitoring and early warning mass mortality of fish; and in coal mines for monitoring mine waste. For lakes, we tested the system at Lake Limboto in Gorontalo and Lake Maninjau in West Sumatera; for reservoir, we tested it at Jatiluhur, West Java; and for coal mines, we tested it at PT Trubaindo Coal Mining, East Kalimantan and PT Adaro Indonesia, South Kalimantan.

There are several parameters tested, such as: hardware robustness to changes in environmental temperature; stability of the application (program feeder, uploader, sms engine, and watchdog); stability of data retrieval from the logger; successful delivery of the data from the site to the server;

suitability of data between the one captured in the site and the other received on the server that inserted into the database; and the web-based application as an interface to the user.

4. Result and findings

The system runs in an ambient temperature range between 22 - 41.5 °C in the panel box. The lowest temperature occurred at night in the lake and the highest temperature is in the daytime at the mine. In a fairly wide temperature interval, the hardware and applications can still function normally.

The stability of applications continues to increase along with improvements in system architecture and programming techniques used. Since it was first made in 2010 to the present, the application becomes more stable as can be seen from decreasing number of application hangs and restarts due to an error. Table 2 below shows the decreasing number of hangs and restarts due to an error in each of the applications built.

Table 2. Average number of hangs (H) and restarts (R) of each application in a week

Application	2010		2011		2012		2013	
	H	R	H	R	H	R	H	R
Feeder	16	10	9	2.7	3	1.2	0	0.5
Uploader	5	11	6	4	2	2	0	0.2
SMS Eng	3	7	3	4	1	0.8	0	0.3
Watchdog	7	17	8	12	4.5	1.8	0	0

The stability of data retrieval from the logger can be seen from the record of communication between the feeder with the logger. Reading failure sometimes occurs because of the communication protocol is fairly long enough (failed in one step led to the failure of the logger readout) or when the logger experiencing a jam (the logger stops for a moment while reading sensor data). Table 3 below shows the decrease in the instability of data retrieval from each logger.

Table 3. Average number of failure (F) of data retrieval from the logger in a week

Logger	2010		2011		2012		2013	
	F	%	F	%	F	%	F	%
Multiprobe	37	2.5	21	1.4	6	0.4	2	0.1
WaterLevel	76	4.6	47	2.8	19	1.2	5	0.3
Temperatur	41	2.5	33	2	9	0.5	7	0.4

The success transmission of data files from the server to the site depends on the sending algorithm and the condition of the lines of communication used. For urban areas such as Jatiluhur and Limboto, internet signal quality is adequate for the transmission of data files via FTP. But for the mining area, the quality of internet signal is poor causing in delay transmission of data files to the server. Sometimes in one day, only 2 to 4 hours internet signal quality is adequate for transmitting data. Severe condition occurs when data file is received at the server in 1 or 2 days later.

Inconsistency between the data captured from the logger in the field and the one contained in the database server can occur due to corrupted data i.e. inserted by other characters so that the daemon fails to parse the data. Inconsistency also can occur when there is a file that is initialized to be sent, but in the process of sending or before being transferred to a backup folder, the files are still written with new data. The results shows a decrease in inconsistency of the data of each logger.

Table 4. Average number of inconsistent data (I) in a week

Logger	2010		2011		2012		2013	
	I	%	I	%	I	%	I	%
Multiprobe	73	3.5	55	2.6	6	0.3	3	0.1
WaterLevel	99	4.7	82	3.9	13	0.6	7	0.3
Temperatur	31	1.5	18	0.9	3	0.1	2	0.1

The web application is an interface for users to view and download data in the field measurements. This application displays data in both tabular and graphical form. Registered users can log into the system and then download the required data. This application has been sufficient to help users acquire and manage the data as desired.

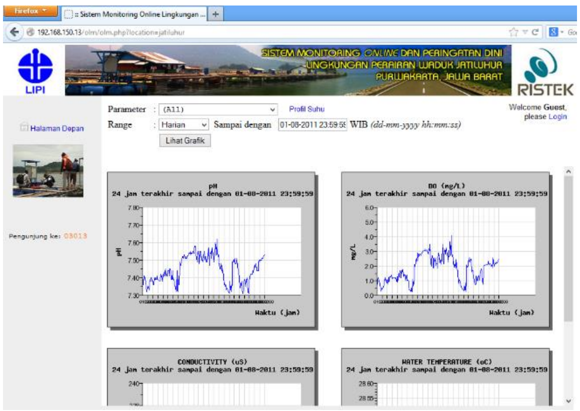

Figure 6. The interface of web application.

5. Coclusion

A system for online monitoring and early warning of water environment has been developed in the hope of tackling the problem of the lack of a practical environment monitoring system in Indonesia. This monitoring system consists of two parts: monitoring stations (site) and monitoring center (server). It has useful features such as on-demand data request, remote configuration, low power consumption, and low cost. This research is devoted to the explanation and illustration for new design of water environment monitoring and early warning system using embedded devices. The system successfully performed an online auto-monitoring of the water depth, temperature, conductivity, dissolved oxygen, and pH of several settling ponds in a mine area. All data from monitoring stations can be displayed to end users either in tabular or graphical view via website and can be downloaded if necessary. Sensors applicable to different water quality could be installed at the monitoring station to meet the monitoring demands in different water environments and to obtain different parameters. The monitoring system thus promises broad applicability. Based on efficiency analysis, the most suitable routing algorithm for Hybrid VMS is Spray and Wait Routing.

References

[1] Jiang, P., Xia, H., He, Z., and Wang, Z., *Design of a Water Environment Monitoring System Based on Wireless Sensor Networks,* Sensors Vol. 9 Issue 8, 2009, pp. 6411-6434.

[2] Storey, M. V., van deer Gaag, B. Burns, B.P., *Advances in on-line drinking water quality monitoring and early warning systems,* Water Research Vol. 45 Issue 2, 2011, pp. 741-747.

[3] Brussen, M., *On-line Water Quality Monitoring.* Review of Sydney's Current Status and Future Needs Sydney Water Report, Sydney, 2007.

[4] Tan, Y.Y., Wang, X., *An Early Warning Systems of Water Shortage in Basins on SD Model,* International Society for Environmental Information Science Annual Conference (ISEIS) Vol. 2, 2010, pp. 399-406.

[5] Sicard, C., Glen, C., Aubie, B., Wallace, D., G.T., *Tools for water quality monitoring and mapping using paper-based sensors and cellphones,* Water Research Vol. 70, 2015, pp.360-369.

[6] _, *Water Quality Monitoring* AXYS Technologies, 2014, http://axystechnologies.com/solutions/water-quality-monitoring/ accessed on 03-09-2015 09:51 AM.

[7] Yang, W., Nan, J., Sun, D., *An online water quality monitoring and management system developed for the Liming River basin in Daqing, China,* Journal of Environmental Management Vol. 88 Issue 2, 2008, pp.318-325.

[8] Zhu, X., Li, D., He, D., Wang, J., Ma, D., Li, F., *A remote wireless system for water quality online monitoring in intensive fish culture,* Computers and Electronics in Agriculture Vol. 71 Supp. 1, 2010, pp.S3-S9.

[9] Seders, L.A., Shea, C.A., Lemmon, M.D., Maurice, P.A., Talley, J.W., *LakeNet: An Integrated Sensor Network for Environmental Sensing in Lakes,* Journal of AEESP Vol. 24 Issue 2, 2007, pp. 183-191.

[10] Sommerville, I., *Software Engineering 9thEdition,* Addison-Wesley, 2011, p.539.