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Design of Online Data Measurement and Automatic Sampling System for Continuous Water Quality Monitoring

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***Abstract*— In this research, it has been designed a continuous water quality monitoring system consisting of sensors for measuring Dissolved Oxygen (DO) and pH, data acquisition based on a PCDuino microcontroller, a sample collection unit, and PC based graphical display. The main part of the system is the PCDuino microcontroller, that has a function of controlling the data transmission and the operation of the automatic sampling unit based on comparison of the measured parameter values against certain threshold. The automatic sampling unit was constructed from PVC holder, a 12V motor stepper, a 12V DC pump, and 8 glass tube sample storages. Experimental results showed that when the measured DO value dropped below 5 mg/l, or the pH values below 4 or above 9, the sample collection unit worked by filling up 20 ml sample in just under 650 ms. All the measured data can be displayed on a PC for further analysis. This prototype system is expected to find wide applications in the field of environmental and aquaculture monitoring.**

Keywords—water quality; online data measurement; automatic sampling; sensors; PCDuino

I. INTRODUCTION

Over the past decade, online water quality monitoring has been widely used in many countries known to having serious issues related to environmental pollution [1-3]. In such countries, accurate, reliable and real time water quality parameter data are required by environmental authorities to ensure that industrial and domestic pollutants are kept below the maximum threshold values. However, data provided by an online monitoring system sometimes must still be backed up by polluted water samples, as evidence by which disputes may be settlled using manual laboratory analysis. In addition, not all water quality parameters (including heavy metals) are measurable in an online system [4]. Thus the need for an automatic sampling mechanism is apparent in an online water quality monitoring system.

Previous works on water quality monitoring has been applied in agriculture [5], aquaculture [6], environmental monitoring [7-9], etc. Some of them were used to measure multiparameters [10], and capable of transmitting data over long distance stations [11]. However, none of them has employed an online autosampling mechanism. Therefore this research was aimed to address the above problem by designing a simple but automated sample collection unit based on an online water quality measurement.

II. THE CONCEPT OF ONLINE WATER QUALITY MONITORING USING AUTOMATIC SAMPLING SYSTEM

An online water quality monitoring system relies on the sensors to determine what parameters to be measured. In most river water condition and in many other applications, usually DO, pH, conductivity, and temperature are the parameters of interest, although ammonium, phosphate, and heavy metal ions are also common.

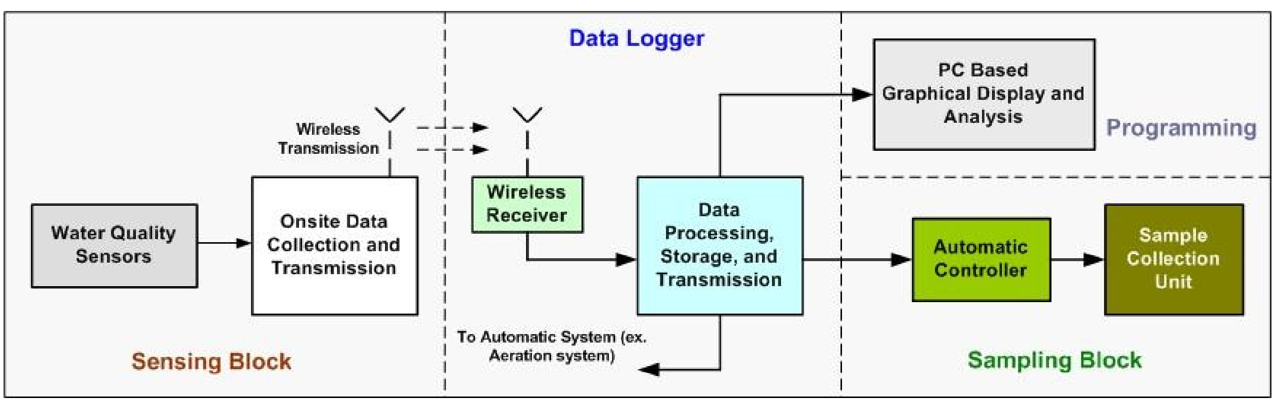

Fig. 1 The concept of online water quality monitoring employing an automatic sampling unit

As can be seen in Figure 1, the designed system consisted of sensing block, data logger, sampling block, and a PC based graphical display. Each part has been designed and constructed separately, thus allowing flexibility for further development or modification. The sensing block has the main function of performing initial data collection about the water quality parameters from the location of installation. The data logger then processed the data, deciding whether the automatic sampling system should be activated. Otherwise, the data will be stored or transmitted for display. The sampling block only operates under extreme water condition as specified by the data logger. In this case, only when certain threshold values are violated will the water sample be taken. All the measured data will eventually be sent to a Personal Computer (PC) where software has been developed to do the analysis on the water quality parameters.

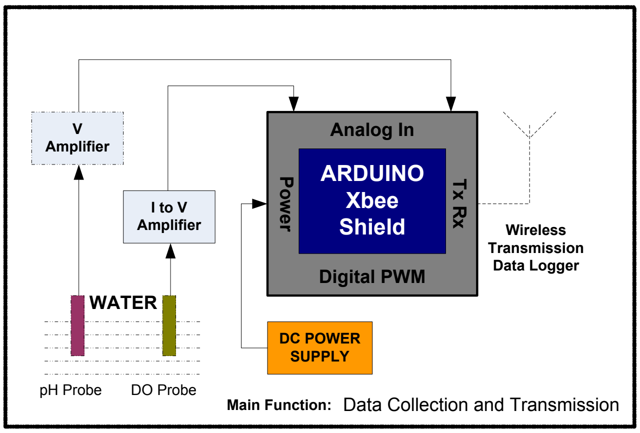

Fig. 2 Diagram of the sensing block consisting of DO and pH probes and Arduino Xbee shield

A. *The Sensing Block*

This part basically consists of sensors to measure DO and pH parameters and an Arduino Uno Rev.3 microcontroller with Xbee 2.4 GHz shield for wireless data transmission to the data logger. Figure 2 shows the diagram of the sensing block. The reason for choosing these two parameters was based on experience that the most widely required parameters in water quality analysis are DO and pH. The DO sensor probe (Lutron) produces 4 – 20 mA output signal, which is equivalent to DO values of 0 – 20 mg/l. The output current from the DO probe was converted to voltage before connected to the analog input part of the Arduino. The pH probe (Lutron) produces an output signal in the order of milivolts, thus a voltage amplifier was required.

The microcontroller of the Arduino serves to collect the measured data from the sensor probes and transmitting the values to the data logger. With an Xbee module, data can be transmitted to 100 ft indoor and 300 ft outdoor (with line-of-sight). For most water quality monitoring application where sensors must be installed in the field, this wireless communication coverage should be sufficient to give the flexibility of locating the data logger in a secured location.

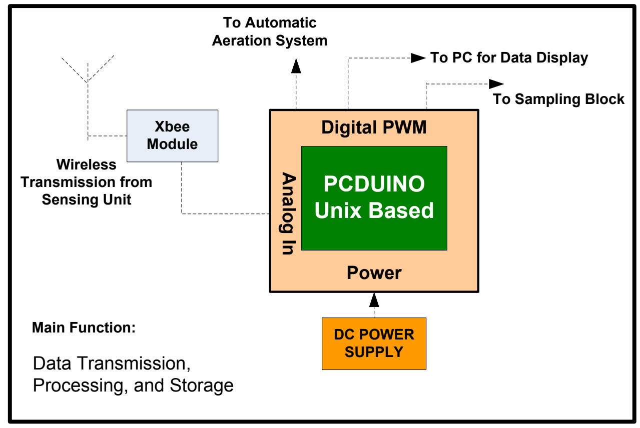

Fig. 3 Diagram of the data logger consisting of Xbee wireless receiver and PCDuino microcontroller

B. *Data Logger*

As shown in Figure 3, the data logger part consists of an Xbee wireless receiver and a PCDuino microcontroller modules. Data processing by the microcontroller was done to compare the measured DO values against a pre-defined threshold. In case the measured DO value falls below 5 mg/l, the microconroller will send a signal (logic 1) to activate the automatic sampling unit and other application such as an aeration system. The latter is aimed at online water quality monitoring in a fish aquaculture [12]. To avoid the microconroller from sending unnecessary signals to the automatic sampling unit in case of fluctuation around the threshold value, only when the measured DO dropped from 8 to below 5 mg/l will the microcontroller send a valid data. Likewise, once the microconroller sent a valid signal to the sampling block, it will remain idle until the mesured DO values reached 8 mg/l again.

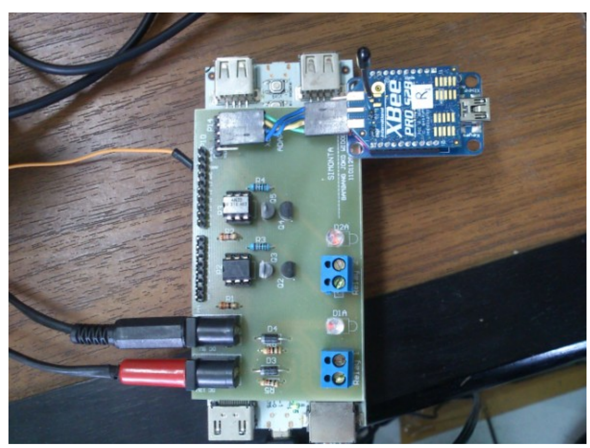

Fig. 4 PCDuino microcontroller with Xbee wireless receiver

In addition, the measured pH data were also compared against certain threshold values. In case the pH value falls below 4 or rises above 9, the microcontroller will send a logic

1 signal to activate the automatic sampling unit. In both cases, the automatic sampling will operate once until the pH value is back to 7. Actually, the predefined threshold values will depend on the real application, and therefore adjustment can be made to the microcontroller program if required.

All data being transmitted by the sensor block can be stored by the data logger. However, since the storage capacity of the data logger is usually limited, data storage was done periodically every 30 seconds. In most real application, 0.5 minute data interval for water quality monitoring application is still acceptable.

C. PC Based Graphical Display

To display the measured parameter data stored in the data logger, a software interface has been developed using Visual Basic programming. As can be seen in Figure 5, the basic structure of the software includes setting for serial connection to the data logger (PCDuino or Arduino based), screen for database and graphical display, and real time information on temperature, DO, and pH parameters. Using the software, all the measured data can be displayed using a time frame that can be adjusted as desired. In addition, each parameter can also be displayed either individually or simultaneously. A typical example of individual display for the measured parameter is shown in Figure 6.

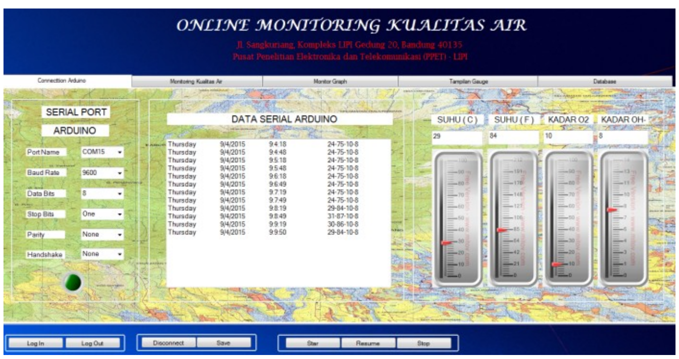

Fig. 5 Software interface from PC to data logger

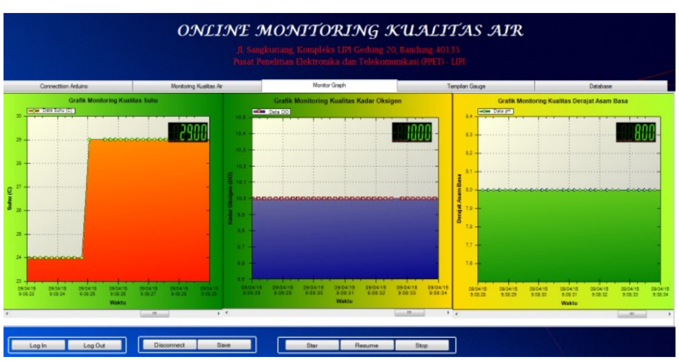

Fig. 6 Individual display of the measured temperature, DO, and pH parameters

III. The Design of the Automatic Sampling Unit

The automatic sampling unit has been designed to work with the data from the water quality sensors. Thus the operation of the automatic sampling unit is determined by the measured DO and pH values. Moreover, since the determination of these parameters against specific threshold values was done by the data logger, the operation of this unit is only determined by the input data from the data logger. Figure 7 shows the block diagram of the automatic sampling unit consisting of an Arduino Uno Rev. 3 microconroller, rotary sample holder, pumping system, circuits to control the stepper motor and pump, and a DC power supply.

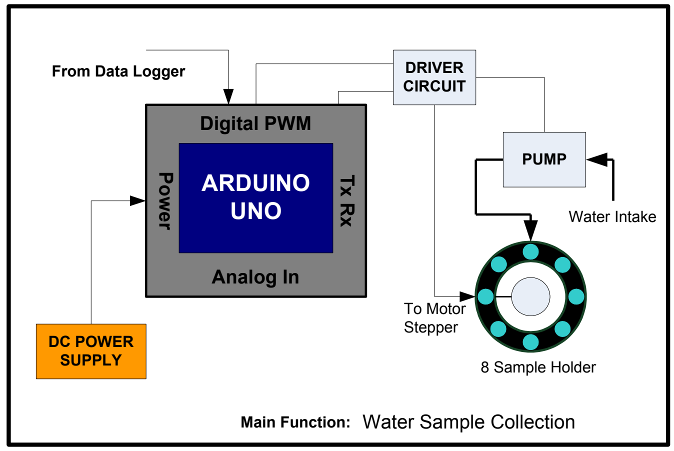

Fig. 7 Schematic of the automatic sampling unit consisting of Arduino Uno Rev.3, sample holder, water pump, driver circuits, and DC power supply

In this block, the microcontroller has the function of controlling the stepper motor, pump activation, and mode selection and duration of the water sampling. Thus after a valid data is received from the data logger, the microcontroller will execute a set of instruction that will activate the stepper motor, and almost at the same time, operate the pump for a certain the duration. In this research, it has been used a unipolar stepper motor type PM4222-09. To precisely control the stepper motor, the low output signals from the microcontroller has been connected to a driver circuit using IC ULN2004 Darlington array (Farnel). The stepper motor has a resolution of 7.5^{o} per step. Thus, for an 8 sample holder unit, it requires 45^{o} rotation for each holder, or equivalent to 6 steps from the full motor rotation. The number of steps and rotation is controlled by the Arduino, and since there are 8 sample holder in the unit, the system will automatically stop taking sample after reaching the 8^{th} holder until a reset button in the sampling unit is pressed.

On the other hand, connection to the pump from the Arduino microcontroller has be facilitated by a driver circuit consisting of transistor TIP3055 and optocoupler 4N33. A 12V DC submersible pump has been used in this research, so that in the future field application, the pump can be powered from a solar energy source. Using transistor TIP3055, the DC pump can be directly connected to the driver circuit (without relay), allowing a Pulse Width Modulation (PWM) signal to control the operation of the pump (its on/off and suction strength). The amount of sample taken by the pump was determined by the duration of the pump operation (the delay time). Thus, calibration was performed prior to setting the delay time in the microcontroller (i.e. for 10, 15, and 20 ml samples, it takes 440, 550, and 650 ms delay time, respectively).

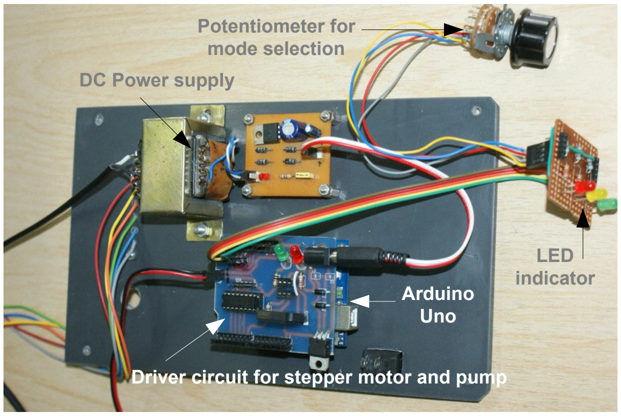

Fig. 8 Electronic block for the automatic sampling unit

The electronic block for the automatic sampling unit can be seen in Figure 8. It is mounted on the back side of the rotary sampling unit with Light Emitting Diode (LED) indicator and a potentiometer to select the volume of sample to be taken. Figure 9 shows the overall prototype of the automatic sampling unit. The unit was constructed from Polyvinyl Chloride (PVC), and measures approximately 30 x 40 x 40 cm. The rotary part can be taken of for cleaning and replacement of the sample holders.

Fig. 9 Rotary 8 sample holder capable of storing up to 25 ml for each sample

IV. Performance of the System and Analysis

At this phase of the research, the characterization of the entire system has been performed in the laboratory to determine the ability of displaying the measured water quality parameters on the PC based software, and the accuracy of the sampling unit in taking the sample upon an incoming data below or above the predefined threshold values. For this purpose, the sensors were dipped in various solutions including pH buffer and standard DO solutions, and analysis was performed based on the data collected from the data logger. Some of the measured data is shown in Figure 10 for graphical and Figure 11 for the bar chart.

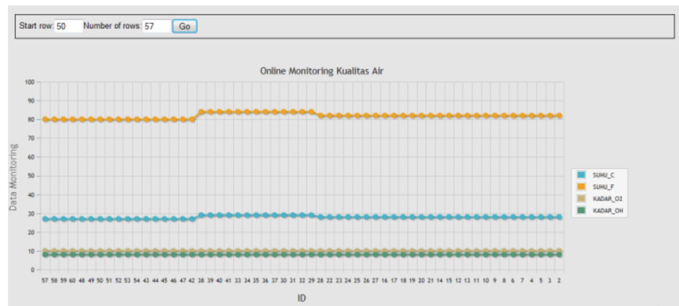

Fig. 10 Graphical display of the measured water quality parameters (temperature, DO, and pH)

Fig. 11 Bar chart display of the measured water quality parameters (temperature, DO, and pH)

When the data coming from the sensors were set below/above the threshold by using a solution that violates the threshold values, the automatic sampling has operated well in taking the sample solutions. Measurement was taken several times for each sample volume capacity, and the volume of sample was measured using a volumetric tube. The resulting accuracy of the automatic sampling unit in taking small volume sample has been summarized in Table 1. As can be seen, the small differences for each sample volume capacity exists that could be due to several reasons such as the pumping system or the delay time accuracy.

Table 1 The measured sample volume taken by the automatic sampling unit

Sample Volume (ml)	Delay time (ms)	Measured volume (ml)	% Difference
10	440	10.5	5
15	550	16.0	6
20	650	21.0	5

V. CONCLUSION

In this paper, the design of a continuous water quality monitoring system has been described. The system consisted of sensors for measuring DO and pH parameters, data acquisition based on a PCDuino microcontroller, a sample collection unit, and software for graphical display. The system was tested for its ability in data transmission and accuracy in sample collection. The results showed that all the measured water quality parameters can be successfully transmitted and displayed in real time by the software interface. The accuracy in sample collection has been demonstrated by the rotary sampling unit in filling the 25 ml sample capacity holder in just under 650 ms, upon the input parameter below the defined threshold values of 5 mg/l for DO and 4 or 9 for pH.

As this is the first prototype, the entire system still needs many improvement. In the future, the system will be modified by GPRS based communication, so that the data can be accessed and displayed from a remote application. In addition, testing the system in the field such as in the monitoring of river water or aquaculture will need to be conducted.

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