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A Portable and Low Cost Multi-sensor for Real Time Remote Sensing of Water Quality in Agriculture

Sandeep Bansal[1]* and G. Geetha[2]

[1]*Department of Electronics and Communication Engineering, Lovely Professional University, Jalandhar, 144401, Punjab, India*
[2]*Department of Research and Development, Lovely Professional University, Jalandhar, 144401, Punjab, India*

ABSTRACT

Water is an important natural resource for all living organisms. Due to increase in population, industrial magnification and urbanisation, water gets contaminated these days. The aim of present study is to design a low cost and reliable system for the monitoring of real time water quality. This study includes monitoring of physiochemical parameters such as pH, Temperature, Turbidity and Total Dissolved Solids (TDS). Microcontroller based multi sensor system can measure the said parameters for detecting water contamination and incorporates communication technology for further processing and alerts. Data communication module can transmit the data received from system to intended user for making alerts regarding water quality. User can check the water quality information perpetually even from far away and he or she can take several safety measures to prevent health hazards. Facile design and low cost make this system captivating enough for large scale deployment.

Keywords: Automation, contamination detection, multi sensor system, turbidity sensor, water quality monitoring

INTRODUCTION

With rapid economic growth and industrialisation, there are serious concerns over their impact on the environment. Water pollution is one of the major concerns (CPCB, 2007). Water quality can be verified based upon basic parameters, such as pH, Turbidity, Biological Oxygen Demand (BOD), Temperature, TDS, Chemical Oxygen Demand (COD), nitrate, nitrite, and phosphate etc (Lambrou et al., 2014).

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E-mail addresses:
er.sandy029@gmail.com (Sandeep Bansal)
geetha.15484@lpu.co.in (G. Geetha)
*Corresponding Author

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Water quality monitoring is utilised to screen and decide the kind of water contamination, the amount of various water contaminants and the changing tendency (Fengyun, 2010). Level of contamination can be identified in time with such monitoring on water pollution, so that emergency situations can be resolved.

Traditionally water quality monitoring is based on laboratory methods, which includes manual sampling of water and to test these samples in dedicated labs (Das & Jain, 2017).

But these methods are very slow and time consuming due to transportation of samples from far places (Cloete et al., 2014). Also, more manpower is required in these methods, which makes them less suitable for effective monitoring. Hence automatic water quality monitoring is presented for speedy and accurate monitoring of water resources.

Looking at all these limitations, there is an obvious requirement of change in traditional monitoring system. So, our contribution through this research is to develop an intelligent, low cost and reliable system to provide accurate water quality information to intend user at their home using mobile device. Also, in agriculture applications, the requirement of good quality water is always there to enhance quality and productivity.

RELATED WORK

Postolache et al. (2002) developed a multi sensor that can evaluate water quality parameters. Additionally, this sensor has the capability to maintain online database of information. Authors have considered pH, temperature and turbidity of water. This GSM-enabled sensor is advantageous in avoiding manual intervention as well as enhance real time water quality tracking.

Breijo et al. (2002) designed a system to measure temperature, pH, conductivity, dissolved oxygen, turbidity, ORP and diverse ions. Basically, they focused on disadvantages of lab methods that are too slow and that continuous measurement is not possible in laboratory process. They addressed these limitations. Subsidiary et al. (2006) proposed a set of water parameters to be considered in healthcare units as well as methods to measure these parameters. Additionally, they developed computerised solutions for analyses of various water samples used in health sector.

O'Flynn et al. (2007) developed a "Smartcoast" sensor to evaluate various parameters i.e. phosphate, temperature, turbidity, pH, dissolved oxygen, conductivity and water level. They have employed wireless sensor network to incorporate plug and play feature in the sensor system. Jiang et al. (2009) designed a sensor to automate water quality monitoring process. The designed system can measure pH (1-14) and temperature (0-80°C) of water.

Regan et al. (2009) had designed a low power solution to measure various water quality parameters, namely temperature, pH, turbidity, conductivity and dissolved oxygen.

Tie-zhu and Le (2010) had developed a system to first measure the parameters i.e. temperature, pH and dissolved oxygen and then information is sent to monitoring centre using GPRS technology. Finally, proper analysis is performed at monitoring centre. Meng et al. (2010) had developed a hand-held device to measure 17 water parameters based on sensor of

YSI6600. The whole system is battery powered using MSP430F149. Basic advantage of this sensor was its speed, precision and small error.

Liu et al. (2011) had used Principal Component Analysis technique to find out important water parameters that may cause variances in the quality. They began with 13 parameters and came up with3 of them at the end of the process.

Nasirudin et al. (2011) employed economic power solution to evaluate water quality. They used green power source i.e. Solar energy to optimise power consumption and measured four parameters, namely pH, turbidity, temperature and dissolved oxygen. Deqing et al. (2012) provided low cost solution for water quality analysis i.e. they had employed DS18B20 to prepare their own sensor for temperature, pH and turbidity. Chou et al. (2012) proposed a solution to enhance life time of pH and chlorine sensor. Vaddadi (2012) had focused on quality of fish pond water. They had considered temperature, pH, conductivity, pressure and dissolved oxygen.

Damian et al. (2012) had discussed various parameters and their importance in various fields. They had suggested that salinity was the important parameter to differentiate between ocean water and fresh water. Turbidity is the parameter to specify changes in water quality and finally conductivity is inverse of resistance and it is also an important water quality parameter.

Miskam et al. (2013) analysed water quality in paddy fields that may affect level of production. They had considered temperature and dissolved oxygen.

WATER QUALITY PARAMETERS

Selection of WQ parameters is based upon the guidelines for water quality regulation by WHO (Gorchev et al., 2011) and other reputed organisations like USEPA, EU (Hall et al., 2007). These are the esteemed organisations, which set the permissible limits for all these water quality parameters for various purposes like human consumption, agriculture or other needs. Also, they designate which chemical or physical indicator parameters must be considered or targeted on priority basis and tested on daily basis to protect the health of the users and to make sure the water is whole some and safe. Mostly physiochemical parameters have been concentrated for monitoring.

List of some water quality parameters is listed in Table 1 along with the permissible limits where "-" represents unitless quantities.

Table 1
Suggested Water Quality Parameters for monitoring purpose (Lambrou et al., 2014)

Parameters	Units	Permissible limits
pH	-	6.5-8.5
Taste	-	Unobjectionable
TDS	mg/l or ppm	<= 500
Turbidity	NTU	0 – 5
Temperature	°C	Depends on application
Dissolved Oxygen	mg/l	Depends on application
Electrical Conductivity	µS/cm	500 – 1000

Parameters selected for the proposed study were Temperature, pH and Turbidity as these parameters were sufficient for the basic requirements of water quality monitoring for general purpose.

Temperature

Measurement of hotness or coldness is generally referred to as temperature. It can be measured in degree Celsius and Fahrenheit. Temperature is important because it impacts on water chemistry. At higher temperature, the rate of chemical reactions generally increases. Its effects in water are dissolved oxygen, diffusion rate or gases, marine life. The solubility of oxygen decreases as temperature increases and it affects the dissolved oxygen concentration. Rather than cold water, some doctors recommend that room or body temperature water is better to drink. Warm water helps aid in digestion, help your body detox, settle an upset stomach. Cold water tastes better, raises metabolism, lowers fever.

Due to changes in temperature, plants also have an impact on their growth. Some aquatic plants can withstand with cool water temperature, but some plants require warm temperature for growth. Tropical plants show hibiscus, orchids, gardenia show decrease in their growth, if the water temperature is below 21°C.

Aquatic life will also be affected when there are changes in water temperature. Water temperature also influences the movement of fish, their metabolism and their respiration. If the temperature of water is higher (warm water) there will be an increase in metabolism, movement and respiration rate of the fish. If the temperature of the water is less, the fish will become inactive. Temperature below 5°C can be harmful to the species. This is also applicable to other insects and small aquatic organisms.

Causes of changes in water temperature:

- Sunlight/Solar radiation
- Deforestation
- Seasonal changes
- Turbidity

Effects of unusual water temperature:

- Increase or decrease in temperature of water is strongly influenced by the solubility of dissolved oxygen. In warm water, less gas can be dissolved compared to cold water.
- Increase in water temperature may lead to reduction of oxygen amount for aquatic organisms to survive, ultimately leads to threat for marine life.
- Extreme water temperature i.e. too hot or too cold organisms become stressed, reducing their resistant to diseases and pollutants.

Turbidity

It is the measure of cloudiness or haziness in water. Cloudiness is mainly due to presence of air bubbles in water, after a few seconds they clean up. This cloudiness is caused due to small and tiny suspended particles, solids, organic and inorganic matter etc., which are not visible to our naked eye. These suspended particles mainly include clay, sand, silt, microscopic plants, bacteria/germs and chemical precipitates etc. Measuring turbidity is an important factor when we need to determine water quality. Higher levels of turbidity are caused mainly due to higher levels of bacteria and parasite which are sometimes attached to the dirt in water. Higher turbidity in drinking water is an indicator that water may contain disease causing organisms. Increased level of turbidity may lead to gastrointestinal diseases, health issues for new-borns and people with low immune systems such as those with HIV, and those undergoing chemotherapy among others.

Governments have set allowable levels for turbidity in drinking water. According to WHO, maximum permissible level value of turbidity should not be more than 5NTU. It should be ideally below 1NTU. The units of turbidity are NTU which stands for Nephelometric turbidity units and JTU which stands for Jackson turbidity units. Nephelometer is an electronic instrument in which NTU is measured.

Effects of unusual turbidity:

- Cost of water treatment may increase for drinking and food processing.
- High level of turbidity leads to gastrointestinal diseases.
- Damages valves and tapes because the high turbidity water which flows through them will fill them with mud and silt.
- Turbidity indicates the presence of disease causing organisms which causes symptoms, such as nausea, cramps and headache.

pH

pH is defined as –log[H+] and is the measure of concentration of hydrogen ion in water. Higher concentration of hydrogen ions indicates lower values of pH and lower concentration of hydrogen ions indicate higher values of ph. Pure water pH value is 7. pH values range from 0 to 14, where 0 is most acidic and 14 is most alkaline. pH of 7 represents neutral. According to WHO standards, recommended levels of pH are 6.5 to 8.5. The pH of water regulates the solubility in water.

Higher pH levels (>9.5) and lower pH levels (<4.5) are not suitable for most marine organisms. Aquatic bodies are more sensible and may die at low pH levels below 5. At high pH, toxic ammonia will be formed from ammonia. Also, higher pH levels which are greater than 9 can harm fish. Table 2 shows the effect on pH value due to natural/Man made factors.

Table 2
Factors effecting pH value (CPCB, 2007)

Factors	Effects on pH
Acid rain	If increases, pH level decreases
Temperature	If increases, pH level decreases
Dissolved minerals	If more, pH level increases
Concentration of carbon dioxide in water	If increases, pH level decreases
Releases from industries	°C
Depends on the acids and bases released	mg/l
Electrical Conductivity	µS/cm

Effects of lower pH levels:

- Water becomes acidic and soft.
- Heavy metal effects and hold metal ions such as copper, iron, lead, manganese and zinc.
- It can be a root for health problems like respiratory failure, seizures and shock.
- Have metallic taste or sour taste.
- Low pH levels can stain laundry and stains on drains and stinks (blue-green colour).
- Lower pH level can corrode pipes.

Effects of higher pH levels:

- Water becomes hard and cause aesthetic problems.
- Have alkali taste or bitter taste.
- Scale deposits can be formed on utensils, dishes and laundry basins.
- It can be a root of health problems, such as arrhythmia, coma and if potassium levels decrease, it can lead to problems in kidneys, heart and digestive system.

SYSTEM DESIGN HARDWARE/COMPONENTS

Temperature Sensor

The proposed study had used DS18B20 (Temperature sensor) for water temperature measurement. It measures temperature from -55°C (min) to +125°C(max) and has an accuracy of ±0.5°C, over a range of temperature from -10°C to +85°C. It is water proof temperature sensor. Figure 1 shows the temperature sensor used for this work.

Figure 1. Temperature sensor DS18B20

Turbidity Sensor

Turbidity sensor sen0189 as shown in Figure 2 was used for measuring the turbidity levels in water. Turbidity sensors help to detect water quality in streams, rivers, wastewater measurements, research and laboratory measurements. Sen0189 provides output modes in both analog and digital signals. Its operating Voltage is 5V DC and its operating temperature is 5°C-90°C.

Figure 2. Turbidity Sensor

pH probe

pH electrodes or probes were used to measure the values of pH in proposed work. It measures potential difference (or voltage) of the solution in which it is submerged using Nernst equation and gives output of pH value. Figure 3 shows the pH probe used for this work.

Figure 3. pH probe

Wi-Fi Module

ESP8266 (as shown in Figure 4) was used to upload the sensor data to the web server and stored data can be used for analysis in future. Additionally, it sends the parameter calculated value to user mobile which can be further used to take actions. It operates on 3.3 VDC having 16 GPIO pins. It allows the connection of microcontroller with Wi-Fi network.

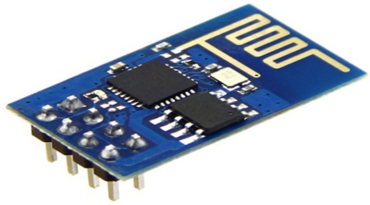

Figure 4. Wi-Fi module for data transmission

PROPOSED METHODOLGY

Following methodology have been adopted for carrying out this work as shown in Figure 5.

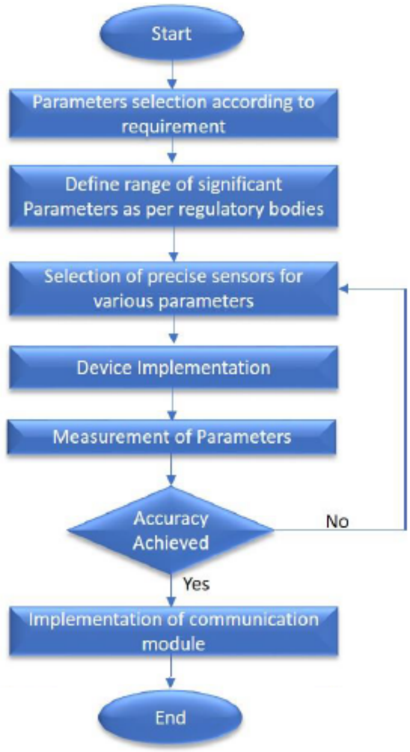

Figure 5. Flowchart of the system

Parameter Selection According to Requirement

The variables selection for any Water Quality (WQ) assessment system should be reflecting functions and issues in water (CPCB, 2007). Also, knowledge about polluting sources is an important part. The main objective of this step is to collect information about variables selection i.e. which WQ parameter to be monitored and for various uses, such as irrigation, drinking or livestock needs.)

Define Range of Significant Parameters as per Regulatory Bodies

Next, it is mandatory to decide the acceptable range of values that are allowed for parameters as per the standards established by organisations. Further, this decision needs to be taken by considering characteristics of water and pollution sources and amount of pollutants inserted in the water (Nasirudin et al., 2011).

Selection of Precise Sensors for Parameters

Based on the decision of selected WQ parameters to be monitored, the selection of sensors and techniques should be done while considering low cost and easy design. The situation is to make efficient use of technologies or sensors specifically to address the water quality issues.

Device Implementation

The implemented device greatly affects the quality of output. Therefore, proper attention is required while implementing the device by embedding sensors and other hardware which will be installed at the inlet and outlet of the source.

Measurement of Parameters

While measuring the parameters from intended source it is important to ensure the normal environmental conditions to make an actual measurement of selected parameters. Also, the other important things to be considered for this purpose are quantitative and qualitative sample.

Accuracy Check

Accuracy or Quality Assurance is one of the most desired thing while monitoring and analysing real time data. If device accuracy is achieved as required (can be mapped to laboratory checked samples) then the next step will proceed, otherwise, improvements in the circuit will be made for that parameter whose accuracy is not up to the mark.

Implementation of Communication Module

This module is responsible for sending parameter values to the mobile device using GSM/Wi-Fi technology. This will ensure the proper monitoring of water resources from any location.

RESULTS AND DISCUSSION

Figure 6 presents the implemented circuit as per proposed methodology. As circuit design was done after considering agriculture applications, we had chosen the sensors and made the hardware to detect WQM for dedicated application. Initially the setup had been installed at actual source and all readings observed by sensors are sent to mobile device (after processing) using Wi-Fi technology as represented in Figure 6. This feature helps update the users about current situation of water quality in the fields. If at any point the measured values go under non-acceptable range, intended user can also take actions accordingly.

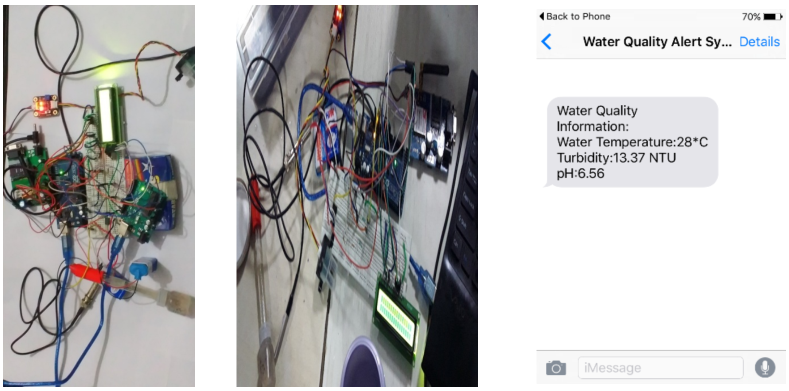

Figure 6. Working model snapshots

Finally, this circuit had been installed at local water body to carry out further experiments. Various samples had been taken from local water body used for agriculture purpose continuously for 15 days in pre-monsoon season. Figures 7, 8, and 9 show variations of pH, Temperature and Turbidity on different days respectively.

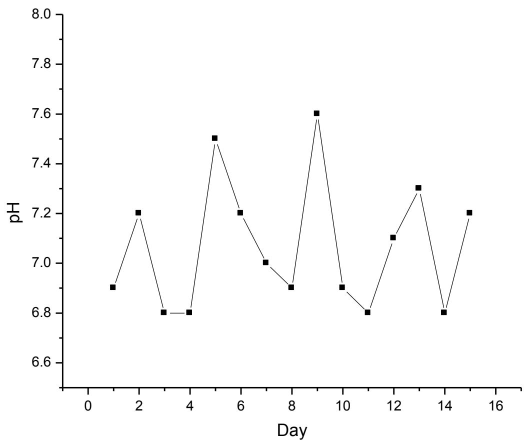

Figure 7. Average concentration of pH value

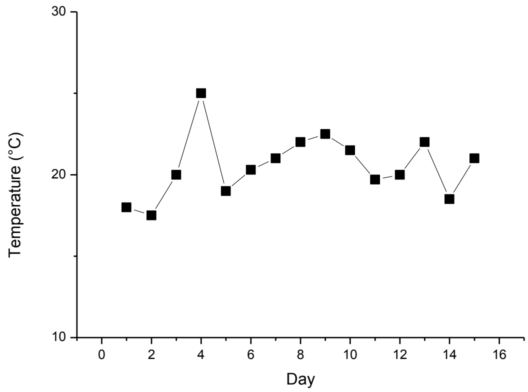

Figure 8. Average concentration of Temperature

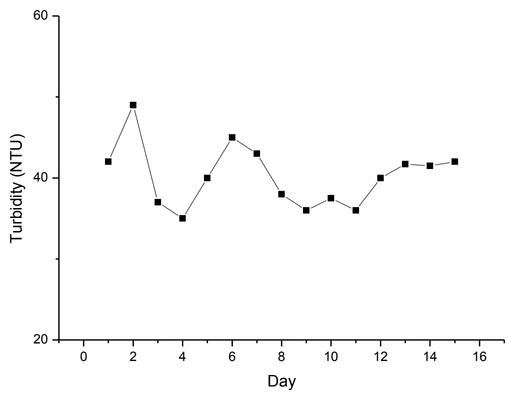

Figure 9. Average concentration of Turbidity

Overall pH value was normal during monitoring. But it could be observed that pH was high during high temperatures. The experimental results were compared with laboratory results of samples taken on field and it had been observed that the designed hardware was giving accuracy in measured results with minor variations of ±3%.

Finally, we had tried to find relation between all these physiochemical parameters as provided in Figure 10. For the same, various samples (S1 through S7) had been taken after a periodical time interval of 24 hours from a local water body under normal environment conditions in month of March. It has been observed from the samples taken on field that water turbidity affects temperature of water body. This happens because suspended particles in a water body absorb sunlight and hence, increases temperature (Miskam et al., 2013).

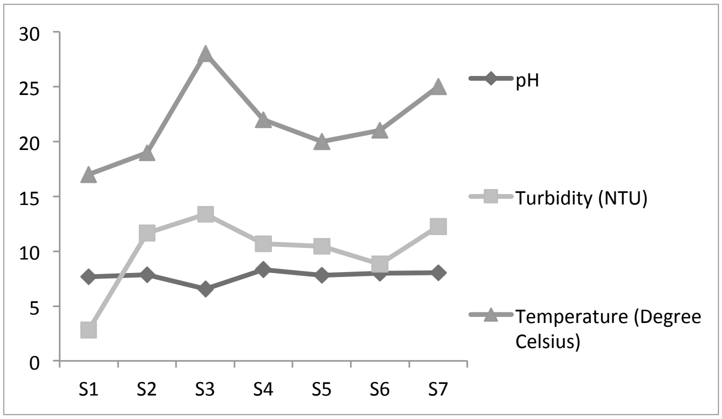

Figure 10. Representation of co-relation between WQM parameters

The results show that change in temperature causes change in ion concentration, ultimately shifting the pH value. As suggested by Le Chatelier's Principle, if a modification to reaction condition in dynamic equilibrium is performed, the equilibrium position moves to restrain the modification (Hall et al., 2007). Hence, if water temperature increases, the equilibrium will shift to decrease the water temperature. For this it will absorb the heat generated. It means the forward reaction will be adopted, and more concentration of hydroxide ions and hydrogen ions will be formed. Hence from the graph, we can see that the pH decreases with increases in temperature.

CONCLUSION

In this study, the pre-designed sensors are used to make a user-friendly hardware to monitor WQ parameters. This is an effective and innovative solution for water quality monitoring constantly. It can measure the various parameters of water quality using different sensors and communicates the results to the user automatically. In this paper, the focus is on the WQ parameters especially agriculture applications are, but the same can be applicable to other applications such as drinking water, water used for industries, domestic uses and all such applications where water quality is a concern. The system is simple and reduces human intervention. The future scope in this area is very vast and depending upon received data, actions for quality improvement can be taken automatically.

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