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Design and Implementation of Cost Effective Water Quality Evaluation System

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***Abstract*— Embodiment of low cost and immensely proficient water quality monitoring system is very crying need for those people living in the outlying territory where immune drinking water is not plethoric. This paper illustrates a microcontroller based water quality monitoring system with high degree of accuracy and susceptible to determine several parameters of water such as temperature, turbidity and potential of hydrogen (*pH*). Detection of those parameters of water is very important and indispensable in order to lead healthy life as different source of water are being tainted due to excess population. Various analytical schemes are subsist for ascertainment of the quality of water where several are time-consuming and few are used for industrial applications that are not applicable for simple water quality monitoring system. Consequently, it is needless to model a simple device that track out various parameters of water unerringly. In this project based research work, a simple microcontroller is used as central processing unit (CPU) and multiple sensors that detect various parameters and send the data to microcontroller and finally the LCD gives the results.**

***Keywords*— water quality; pH; turbidity; temperature.**

I. INTRODUCTION

Water is life but when drinking water that taken for drinking purpose is corrupted, it leads to death. With the exponential swelling of the world's population, the surface water is being polluted day by day which is very concerning topic for sustainable development in health issues. According to an assessment commissioned by the United Nations, 4 out of every 10 do not have clean water to drink that shows the challenges of sound health. For why, it is mandatory to check the water used for drinking purpose in a regular time interval.

Many researchers are working to develop water quality monitoring system in order to overcome the barrier of identifying pure drinking water in a smart cost effective way through measuring instruments. Sarita B. Dhoble et al. developed a sensor based water quality monitoring system that detects *pH* and hardness of water [1]. A microcontroller based device was developed by Deepesh Kumar Jain et al. [2] consists of sensor arrays and multiplexer [2]. A WSN based water quality monitoring system was introduced by Gong and Wang [3]. Chinese researcher's Ji Wang et al. [4] and Ashwini V. Mulay et al. [5] designed a system based on wireless networks to monitor the water quality. IOT based water quality monitoring system was designed by Bhatt and Patoliya [6] as well as Vijayakumar and Ramya [7]. A zigbee based water quality monitoring system was developed by Rasin and Abdullah [8] that used for detecting *pH* level, temperature and turbidity. Purohit and Gokhale [9] designed a GSM based system to measure the water quality at real time. A group of Australian researchers [10] designed a low cost autonomous water quality monitoring system.

In this project based research work, the developed water quality monitoring system is portable and consists of microcontroller, some simple sensors as well as a display unit which is very useful for detecting the appropriate *pH*, temperature and turbidity of water. In addition, the implemented system is highly efficient, cost effective and consequently, the accuracy of the measuring device is in convenient level.

II. VARIOUS PARAMETERS OF WATER

A. Temperature

Temperature measures the warmth or coldness of the water. It is a critical water quality parameter and directly influences the amount of dissolved oxygen that is available for aquatic organisms. Temperature measurement can also determine the kinds of aquatic organisms that can survive in the water.

B. Turbidity

Turbidity is a measure of the clearness of the water. This measurement determines how many particulates are floating around in the water, such as plant debris, sand, silt, and clay, which affects the amount of sunlight reaching aquatic plants. Excess turbidity can reduce reproduction rates of aquatic life.

C. Potential of Hydrogen (pH)

pH is a measurement of the concentration of hydrogen ions in the water. A pH sensor measures how acidic or basic the water is, which can directly affect the survival of aquatic organisms. *pH* range is from 0 (acidic) to 14 (basic) and most water *pH* range is from 5.5 to 8.5. Changes in *pH* can affect how chemicals dissolve in the water. High acidity can be deadly to fishes and other aquatic organisms.

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III. METHODOLOGY

The implemented device performs based on the electrical properties of water and consists of microcontroller, LCD display, differential amplifier, power amplifier, thermistor, turbidity sensor, *pH* electrode and other components.

Microcontroller is the major part of the developed system used for measuring water quality. Voltage difference across sensor is collected through the port A of the microcontroller and port B of the microcontroller is connected to the LCD display which expresses the value of the parameter of water as digital number. An oscillator is used to give clock pulse to the microcontroller. The block diagram of the developed system to measure water quality is shown in Fig. 1.

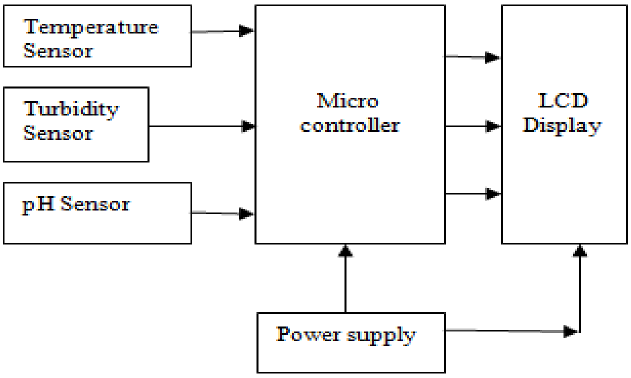

Fig. 1: Block diagram of the system to measure water quality

A. *Thermistor :*

Thermistor is used as a temperature sensor in this device. A thermistor is composed of semi-conductor materials which exhibit a large change in resistance proportional to the small change in temperature. It has a negative temperature co-efficient. Analogue voltage difference across the sensor is taken through the port A of the microcontroller which is converted in binary value for processing. After processing the binary value, LCD display shows the temperature in Celsius scale as digital number. Fig. 2 shows the relation between the temperature and resistance of thermistor is vice-versa. The schematic temperature sensor is shown in Fig. 3.

$$Temperature = -25.62x+148.43 \qquad (1)$$

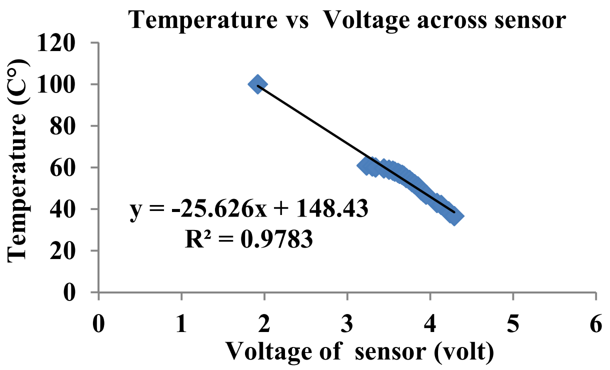

Fig. 2: Relation between temperature reading and voltage across the thermistor

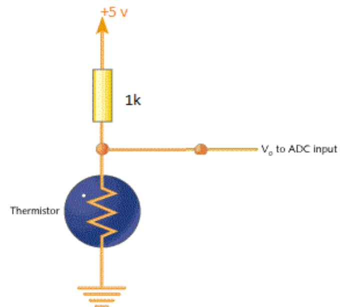

Fig. 3: Schematic of temperature sensor (thermistor)

B. *Turbidity Sensor:*

Turbidity sensor consists of IR transmitter and IR detector whereas IR transmitter consists of resistor and IR LED. IR detector has to place exact right angle of IR LED and it consists of resistor and IR detector diode. Fig. 4 and Fig. 5 show the top view and side view of turbidity sensor. In this project work, the IR detector is reversed biased and breakdown voltage of it depends upon the scattering incident IR rays found from the solution. The voltage across the IR detector will be changed with the variation of scattering IR radiation from solution particle and then sends to the microcontroller for processing. The whole sensor is placed in one side open dark pot to avoid the effect of surrounded IR of environment. The voltage across the IR detector is sensed to the ADC input. Fig. 6 shows the relation between turbidity and voltage across the sensor. A turbidity sensing circuit is shown in Fig. 7.

$$\text{Turbidity} = 552.54x-1169.6 \qquad (2)$$

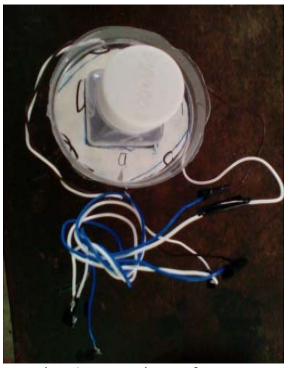

Fig. 4: Top view of sensor

Fig. 5: Side view of sensor

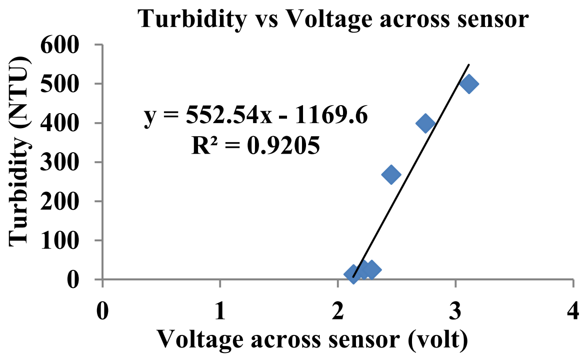

Fig. 6: Relation between turbidity reading and voltage across the sensor

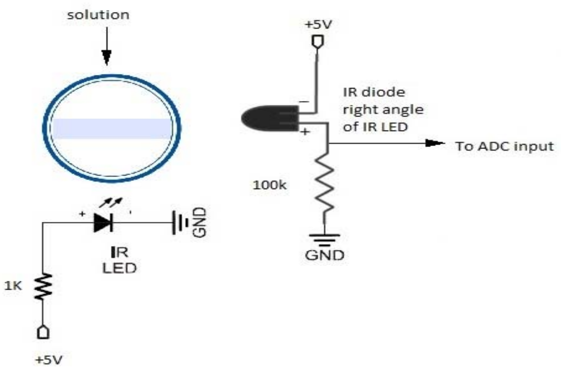

Fig. 7: Turbidity sensing circuit

C. pH probe:

pH is basically a electro-chemical cell and *pH* sensor consists of a plastic tube contains two electrodes that made of silver wire. One is submerged in AgCl solution having *pH* 7 which contains in inner glass tube and reference electrode is submerged in saturated AgCl solution. Fig. 8 and Fig. 9 show the schematic of *pH* sensor and *pH* electrode respectively.

$$pH = 42.261x - 95.121 \quad (3)$$

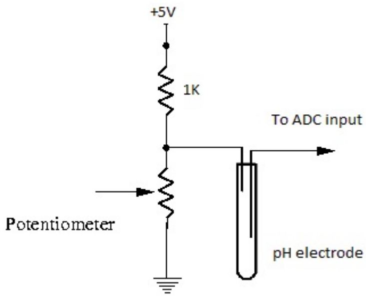

Fig. 8: Schematic of pH sensor

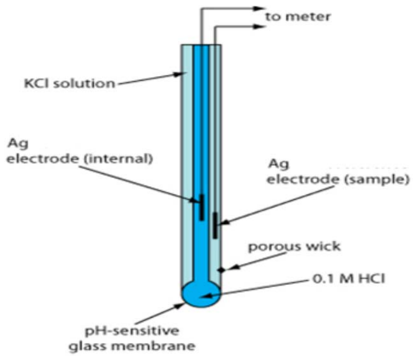

Fig. 9: pH electrode

The main part of the sensor is the pH sensitive glass membrane. It responds to particular ion as Hydrogen ion. The voltage difference across the electrode is created due to the attraction and repulsion between the inner solution of glass tube and tested solution. When *pH* probe submerged in a solution having *pH* 7, then ion concentration of inner membrane and tested solution will be same.

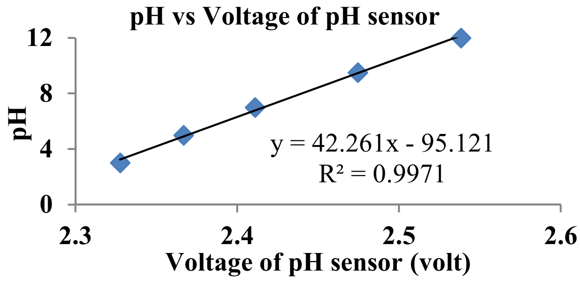

Fig. 10: Relation between *pH* reading and voltage across sensor

The voltage difference across the electrode will change due to the attraction and repulsion of H+ ion between the inner glass membrane and the tested solution. *pH* of the alkaline solution is more than 7, consequently the OH- ion attracts the H+ ion of inner glass membrane. The voltage difference will be differing than previous and reverse case will be happened for the acidic solution.

IV. RESULTS AND DISCUSSION

The Fig. 11 shows the implemented device to measured water quality which is compared to the standard meter of CUET Environment Lab. The main circuit of the device is designed in a printed circuit board and switching panel is connected to the micro-controller. A 9V battery is used as a power supply of the device which is converted to 5V DC for operation of the microcontroller and LCD display.

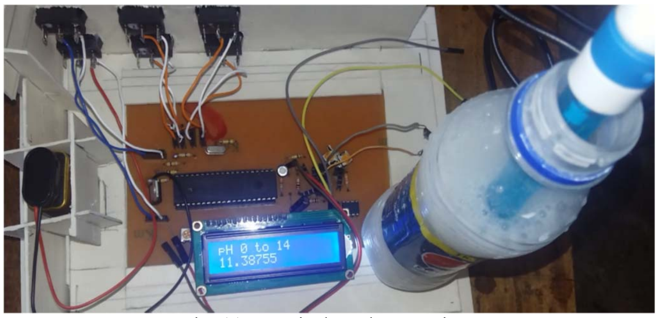

Fig. 11: Practical Implementation

A. Result of Temperature Sensor :

The thermistor responds as it is expected. The result showed by the device almost same as the thermometer reading and the level of accuracy is good enough. Table I shows the result of the thermistor.

TABLE 1: ERROR CALCULATION OF TEMPERATURE SENSOR

No. of Obs.	Temperature Reading (°C)	Thermometer Reading (°C)	Percentage Error (%)
1	95	98	3.06
2	58	61.5	5.69
3	58	60	3.33
4	56	57	1.75
5	52	53	1.88
6	48	49	2.04

Average percentage of error = 2.96%

It is noticed that error of the thermistor in acceptable range which is around 2.96%.

B. Result of Turbidity Sensor :

Normally in a white pot, sensor doesn't work properly. But in a dark pot, it works properly though some fluctuations are observed. The output of the sensor is nearly same to the expected result. After every use, the sensor should be clean properly with distilled water for getting proper reading in future. The result of the turbidity sensor is shown in Table II.

TABLE II: ERROR CALCULATION OF TURBIDITY SENSOR

No. of Obs.	Turbidity from Device (NTU)	Turbidity from Meter (NTU)	Percentage Error (%)
1	7.32	5.86	25
2	16.7	23	29
3	215	247	12.9
4	399	309	29.1
5	462	543	14.9

Average percentage of error =22.18%

From above Table II, it is clear that the percentage of error of the turbidity sensor little bit high. Designed Turbidity sensor is homemade and if it is designed in lab then accuracy can be improved.

C. Result of pH Probe:

The output of the *pH* electrode changes with the variation of *pH* within few millivolt (mv). It is little bit tough to get accurate output from the circuit. The accuracy is not so much high. The Table III shows the performance of pH electrode.

TABLE III: ERROR CALCULATION OF PH ELECTRODE

Name of the Substance	pH reading from device	pH reading from meter	Percentage of error (%)
Lemon juice	2.33	2.2	5.6
Vinegar	2.78	2.65	4.9
Black tea	5.37	4.77	12.5
Milk of magnesia	8.7	8.21	5.9
Soda	9.12	8.61	5.92

Average percentage of error = 6.95%

With the help of Table III, it is noticed that the accuracy of the device for pH detection is in reasonable range.

V. COST ANALYSIS

From Table IV, it is seen that the designed device is cost effective and economical. This device can detect three parameters of water but total price of this device lesser than any other device and it will be helpful for developing country to measure water quality.

TABLE IV: COST OF EQUIPMENTs

NAME OF EQUIPMENT	Cost of Equipment (BDT)
Micro-controller	220
LCD display(16x2)	180
Input port & pH sensor	1200
Turbidity sensor	80
AD620 amplifier	220
Switches, battery & Others parts	870
Total amount	2770

VI. APPLICATIONS

It can be used as a portable water quality detecting device and will be helpful during the journey through the jungle while some water is found for drinking, then it can detect the suitability of water to drink. In impassable camp, this device will be helpful also. It will be helpful to measure the quality of water aiming to determine the suitability of water for aquatic animal.

VII. CONCLUSION

The polluted water could be responsible for our death or other dangerous diseases. For this reason, pure water detection becomes crying need in our life to avoid illness or unnecessary death. This implemented device is cost effective and the accuracy of this device is not so much high but remains in convenient level. In this research paper, a system is developed and discussed which can evaluate the three parameters of water. The detection of water parameter could reduce the rate of illness and unnecessary death as well as create consciousness to people for healthier life.

ACKNOWLEDGMENT

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