

REAL-TIME WATER QUALITY MONITORING SYSTEM FOR RIVERS

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Abstract: Rivers are the major sources of water supply in any city. These rivers have witnessed severe degradation of water quality owing to heavy industrialization, agriculture, and anthropogenic activities. A consistent rise in pollution is reported due to disposal of industrial effluents, domestic sewage, and agricultural runoffs into the rivers. Since, rivers are the major freshwater sources to any city and the high levels of pollution can be health threatening. Therefore continuous monitoring and analysis of their quality status enable us to send a report to the concerned authorities and further suitable measures can be thereby implemented to reduce the pollution levels. Also, such a system can draw public attention to the water quality status and aid in creating public awareness, also facilitating remote monitoring of water sources, data storage, and analysis in a cloud system. This paper proposes an Internet of Things (IoT) based design for real-time surface water quality monitoring and notification system, measuring the basic water parameters such as pH, temperature, dissolved oxygen, electrical conductivity, total dissolved solids.

Keywords: Real-time water quality monitoring, Internet of Things (IoT), Mula-Mutha

I. INTRODUCTION

Water is one of the most precious natural resources needed for the survival of all living beings. Water scarcity is one of the major burning issues across the globe. Since the last two years, several states in India faced deficient rainfall making them fall into the clutches of drought like condition. Moreover, the freshwater sources are heavily polluted by mixing of industrial effluents, domestic sewage, and agricultural wastes into the water bodies and due to other anthropogenic activities. With the increasing population, there is an enormous demand for potable water. In order to address the problem of water pollution and resultant health hazards, it is necessary to implement efficient water quality monitoring and surveillance systems. Several unpredicted events like the accidental release of toxic chemicals and materials into the water bodies can be responsible for the severe disaster. Therefore, to address the above issues and devising solutions under critical situations, continuous monitoring of water quality parameters is required.

In this project, it was proposed to develop an online multi-parameter water quality monitoring system for the study of various physicochemical water quality parameters like pH, temperature, electrical conductivity, total dissolved solids (TDS), dissolved oxygen of water bodies. Further, the measured data was uploaded to a cloud server enabling data access and analysis. For experimental purpose, a case study of some locations of Mula, Mutha rivers of Pune city, Maharashtra, India was conducted during Monsoon season.

Mula river originating in the Western Ghats of Maharashtra is dammed at Mulshi whereas, Mutha river also originating at the Western Ghats, is dammed at Panshet and at Khadakwasla on their way downstream to the main city. The confluence of Mula River and Mutha River at Sangam ghat in Pune city forms the Mula-Mutha River which further meets the Bhima River. But during their journey into the city, the rivers get highly polluted.

A recent report by the Maharashtra pollution control

board has revealed that the major river stretches in Pune city like Bhīma, Pavana, Mula, Mutha, and Mula-Mutha is faced with the problem of severe pollution [1]. Considering the prevailing water scarcity, water contamination is one of the major concerns for us now and the problem has acquired a critical stage. The establishment of various industries like chemical, automotive, pharmaceutical, etc. along the banks of Mula-Mutha Rivers has significantly affected their water quality.

II. EARLIER WORK

Many systems have been researched, designed and implemented across the world for the real-time monitoring of a variety of water quality parameters. Internets of things (IoT) environment based reconfigurable water quality monitoring networks with smart sensors have been proposed by many researchers from different institutions [2] [3]. Several research groups and government agencies have studied and analyzed the water quality of Mula, Mutha Rivers. A recent study report by Maharashtra Pollution control board in October 2018, states that the water quality index of Mula River at Aundh Bridge and Harrison Bridge; Mutha river near Veer Savarkar Bhavan and at Deccan Bridge; Mula-Mutha River at Sangam bridge and Mundhawa Bridge is bad[4].

According to Environment Status Report (ESR) 2017-2018 published by Pune Municipal Corporation there is a consistent rise in the Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) levels of Mula, Mutha Rivers. BOD and COD are considered as measures of organic matter contamination and chemical matter contamination in water bodies respectively. Low BOD and COD values indicate good water quality [5].

Many researchers supported the fact that water quality parameters of river Mula before entering Pune city was well within the acceptable limits but subsequently deteriorated on its progress into the city[6][7][8].

Vaishnavi et al. mentioned in their research work that all the water quality parameters are dependent on the climatic conditions and seasons. They inferred that water quality of Mula, Mutha Rivers remains within the acceptable standards during the spring season [9].

Each of the proposed work aforementioned used traditional sample collection and lab testing methods. Moreover, the commercially available multi-parameter water quality monitoring systems are very expensive and not easily accessible. Our project takes note of all such problems enabling remote wireless access to sensor data.

III. SOME OF THE BASIC WATER QUALITY PARAMETERS AND THEIR IMPORTANCE

Temperature: The temperature of the water body affects its various physical, chemical and biological processes, thereby alter the concentration of substances in the water bodies. A rise in temperature increases the evaporation of the water substances, the solubility of gases like O₂, CO₂ and the rate of chemical reactions in water. In warm waters, the aquatic organisms show an increased respiration rate consuming more dissolved oxygen. Water turbidity increases due to the temperature hike since they accelerate the growth rate of micro-organisms, algae blooms.

pH: It is defined as "A negative logarithm of the hydrogen ion activity in a solution and indicates the degree of acidity or alkalinity of the solution". pH value ranges from 0-14. The pH of pure water is neutral with a value close to 7. Solutions with the pH value less than 7 are considered as acidic in nature and those with a pH greater than 7 are considered as alkaline. pH is a very basic and important property playing an important role in many chemical and biological reactions. Water having low pH values (less than 6) can corrode pipes and concrete. High pH water hastens scale formation in water heating apparatus, reduces the germicidal potential of chlorine and affects the taste. Neutral to slightly alkaline water is recommended for many industries. □

Conductivity: Conductivity, or specific conductance, is defined as "A measure of the ability of water to conduct an electric current. Conductivity in water is affected by the presence of inorganic dissolved solids (metals, salts, etc.) such as chloride, nitrate, sulfate and phosphate anions or sodium, magnesium, calcium and iron cations". Conductivity is measured to identify and locate a pollution region, e.g. near a possible source of effluent discharge, or water runoff.

Total dissolved solids (TDS): TDS mainly consists of "Bicarbonates, carbonates, sulfates, nitrates, and phosphates of calcium, magnesium, sodium, and potassium with traces of iron, manganese and other minerals". The amount of dissolved solids is an important consideration in determining its suitability for irrigation, drinking, and industrial uses. High dissolved solids may lead to impairment in physiological processes in the human body.

Salinity: It is defined as "The sum of weights of different salts such as sodium chloride, magnesium, calcium, and bicarbonates". The presence of excess salt leads to severe health issues and taste of drinking water.

Turbidity: Turbidity according to the International Standards Organization (ISO) is defined as "The opaqueness of liquid due to the presence of un-dissolved, suspended solid matter, like silt, clay, algae, and other microorganisms; organic matter and other minute

particles". Turbidity of drinking water promotes the rise in population of harmful microorganisms and affects the effectiveness of disinfection processes like chlorination, UV irradiation treatments, leading to increased health issues [10].

Dissolved Oxygen: It is defined as "A measure of the amount of free oxygen dissolved in water". It is a major indicator of water quality and the variations in the DO level can affect aquatic life.

The basic water quality parameter standards for drinking, according to the Bureau of Indian Standards (BIS) is mentioned in table-2.

Table-2: Water quality parameter standards by BIS

Sl.No.	Parameters	BIS (Acceptable limit)
1	pH	6.5-8.5
2	Turbidity(NTU)	10
3	Electrical Conductivity(μ S/cm)	400
4	TDS(mg/l)	500
5	Ca(mg/l)	75
6	Mg(mg/l)	30
7	Cl ⁻ (mg/l)	250
8	Iron(mg/l)	0.3
9	Total hardness(CaCO ₃ ,mg/l)	300
10	Dissolved Oxygen(mg/l)	5

IV. REAL-TIME WATER QUALITY MONITORING – THE CONCEPT

Any water quality monitoring program is designed with the following objectives:

- To assess the quality of the desired water bodies.
- To identify the degradation of water quality.
- To identify the major polluted areas in the water body.
- To determine the cause, quantity, and effect of pollution in the water body.
- To design suitable and effective water quality management program by estimating the status and trends of pollution in the water body.
- To formulate guidelines and regulations for water usage and waste discharges.[10]

The designed platform housed the battery unit, electronic data acquisition, and the wireless communication systems as shown in Fig-1. The built system measured the water quality parameters like temperature, pH, conductivity, total dissolved solids (TDS), dissolved oxygen (DO).

The electronic circuits installed in the system include solar powered power supply 12V for the source of energy to the sensor unit and the other electronic circuits; Data acquisition system box comprising of the set of sensors and their signal conditioning units, processor and memory, a communication module for GSM connectivity as indicated by Fig-1. The set up used in the proposed system enables the real-time visualization and analysis of the water quality.

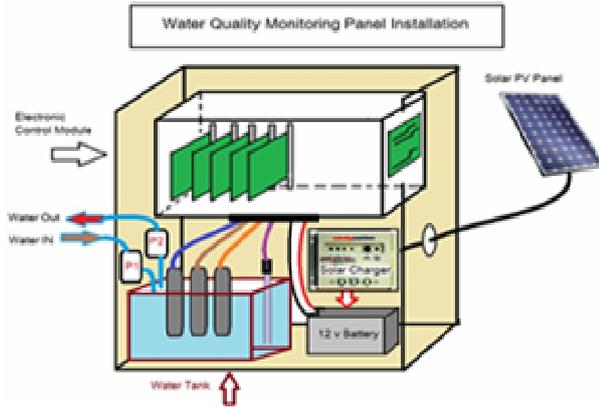


Figure 1. System Setup.

IV. SYSTEM BLOCK DIAGRAM

Fig-2 shows the block diagram of the proposed water quality monitoring system.

Sensors and their conditioning unit: The sensor unit comprised of analog sensors - an RTD temperature sensor (Pt-100 Simplex-3 wire), Micro set make pH probe, electrical conductivity probe and dissolved oxygen probe. The pH sensor used was a combination type and had ranged from 0 to 14pH. The sensor output variation recorded was 59.4 mV/pH at 25°C. The conductivity sensor with a cell constant $k = 1.0$ was suitable for the range 0 to 10,000 $\mu\text{S/cm}$. The dissolved oxygen sensor had a measuring range of 0 to 200% with a Temperature range of 0 to 40°C.

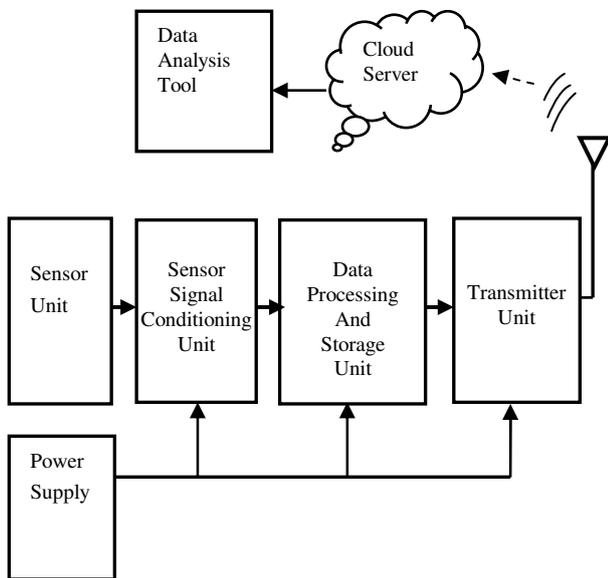


Figure 2. Block Diagram of the System [13]

The operating pressure was 1 Bar and the sensor output varied from 0 mV in Zero solution to 35-55mV in air. Each of these sensors was immersed in the tanks containing the water samples and measurements were recorded. The magnitudes of the sensor outputs were relatively small therefore special signal conditioning circuits were needed to process those signals by performing functions like Amplification, filtering, linearization, level shifting,

impedance transformation, etc. The data acquisition system developed in this project was calibrated for the input voltage range of 0-5V.

All the needed signal conditioning circuits were designed, developed and tested in the laboratory.

Data Processing and storage: The processing unit was responsible to control the entire operation of the proposed system. A data logger board comprising of Atmega 328 as the central data processor, SD memory card interfacing unit for data storage and data communication interfaces were designed and developed in this project. The analog signals from the signal conditioning unit were fed to the ADC pins of the data logger board, getting converted into an equivalent digital quantity and were further processed. The processor board acted as a coordinator for wireless communication.

Transmitter unit: It had a GSM module that established a wireless connection between the processor unit and the remote cloud server. All the processed sensor data were collected and information was uploaded a cloud server (Thingspeak) using the GPRS network connection. The variation in parameters like temperature, conductivity, dissolved oxygen and pH of the water was sensed by the respective sensors [13]. The wireless transmitter unit had high power consumption as compared to other units.

V. WATER SAMPLING LOCATIONS FOR STUDY

Water samples from various locations (Fig-3-7) of Mula and Mutha river as shown in table-3, were tested using the system developed. These measurements were made and recorded during the monsoon season.

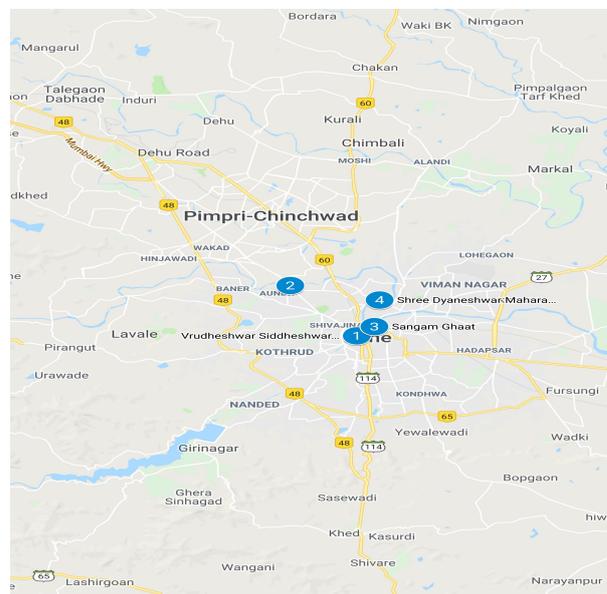


Figure 3. Mula-Mutha river sampling locations in Pune city [courtesy-Google Maps]

Table-3: Monitoring locations of Mula, Mutha Rivers

Location no.	Location Name	River (downstreams)	Pollution sources
1	Sri Vrudheswar Siddheshwar Ghat, Deccan	Mutha river	Domestic sewage and other human activities
2	Rukmini Vittal Mandir, Aundhgaon	Mula river	Domestic waste and human activities.
3	Shree Dyaneshwar Maharaj Visarjan Ghat	Mula river	Discharge from the Ammunition factory □
4	Sangam Ghat	Mula-Mutha	Domestic sewage, Ganapati immersion, and other human activities □



Figure 6. location 3: Shree Dyaneshwar Maharaj Visarjan Ghat



Figure 7. location 4: Sangam Ghat



Figure 4. location 1: Sri Vrudheswar Siddheshwar Ghat, Deccan



Figure 5. location 2: Rukmini Vithal Mandir, Aundhgaon

The water quality index has been calculated considering the water quality standards recommended by the Indian Council of Medical Research (ICMR) and the Bureau of Indian Standards(BIS). For the calculation, we have used four quality parameters:pH, electrical conductivity, total dissolved solids, and dissolved oxygen. Calculation of the WQI has been made according to the Weighted Arithmetic Index Method.

Quality rating of the nth water quality parameter (q_n) is given by:

$$q_n = 100 * (V_n - V_{in}) / (S_n - V_{in}) \quad (1)$$

where V_n is the measured value of n^{th} water quality parameter at a sampling site.

S_n is the standard permissible value of n^{th} water quality parameter prescribed by ICMR/BIS.

V_{in} is the ideal value of n^{th} water quality parameter prescribed by ICMR/BIS (7.0 for pH and 14.6 mg/l for Dissolved oxygen). [11][12]

Unit weight is calculated as:

$$W_n = D / S_n \quad (2)$$

where D is the proportionality constant.

$$\text{Water quality index (WQI)} = \sum q_n w_n / \sum w_n \quad (3)$$

Table-4 displays the values of the WQI and Water quality status.

Table 4: WQI and water quality status

WQI value	Water quality status
0-25	Excellent
26-50	Good
51-75	Poor
76-100	Very poor
>100	Heavily polluted

VI. EXPERIMENTAL RESULT AND DISCUSSION

The experimental setup for the measurement of water temperature, pH, dissolved oxygen and conductivity was established in the lab as shown in fig- 8. Surface water of four locations (no. 1 to 4) of Mula-Mutha in the monsoon season was considered for quality analysis. Field measurement arrangement of the parameters using the developed system was made as shown in fig-9.

In this project, the temperature sensor- pt100 displayed a linear variation in resistance with temperature. In the current system, the designed signal conditioning unit produced output variation of 10mV with 1°C change in temperature. It was observed that within the temperature range of 0°C to 100°C, the output voltage varied from 0V to 0.88V. The sensitivity observed was approximately 10mV/°C. At 25°C, pH sensor output was noticed to be 0 mV at pH 7 and 59.2mV response per unit pH change. The pH signal conditioning unit displayed an output voltage variation of 0.177 V per pH change. □

For conductivity measurement, voltage (a low amplitude AC sine wave signal of low kHz frequency) was applied to the sensor probes and the resulting current was measured. The conductivity range was measured between 0-3300µS/cm with a resolution of 10µS/cm. The output voltage variation of the signal conditioning unit was observed to be 66mV per 10µS/cm. The calibration of these sensors with respect to standard instruments was established this was reported by the author in the earlier research publication. The comparison of the observed outputs of the signal conditioning units of various sensors with the standards indicated a close proximity between the two values. The sensors’ outputs were sampled every 10 seconds [13]. Table 5 displays the values of the several water quality parameters measured by the designed system.

Table 5: Measured water quality parameters

Location No.	pH	EC (µS/cm)	TDS (mg/l)	Temp (° C)	DO (mg/l)
1	7.3	599	213	27	3.56
2	7.3	528	249	26.9	4.19
3	7.4	412	172	27	4.13
4	7.4	429	186	26.9	4.46

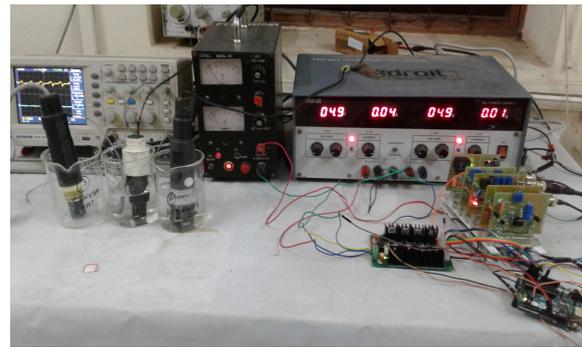


Figure 8. Experimental Set-up in the laboratory for measurement of basic water quality parameters.



Figure 9: Sensor and instrument setup for Field measurement

Table-6 shows the calculation of Water quality index (WQI) of various samples collected during the Monsoon season. Fig-10 shows the real-time plots obtained for the basic water quality parameters at thingspeak web server at <https://thingspeak.com>.

The study conducted on the various locations of Mula-Mutha in the monsoon season indicated that (as seen in Table 5) the pH of the water samples varied from 7.3 to 7.9 and were found to be in the acceptable limit prescribed by BIS (6.5 – 8.5). The high value of electrical conductivity 412 µS/cm to 600µS/cm, more than the acceptable limit (300µS/cm) of potable water was observed. Also, TDS values were found to be in the acceptable range between 172 to 299 mg/l.

The present investigation indicated that the concentration of dissolved oxygen (DO) fluctuated between 3-4.5 mg/l. The overall water quality indexes of the samples were found to be in the range 100 to 115 which indicated poor quality water and the presence of pollution.

Table 6: Water quality index (WQI) calculation

Quality Parameter	Standard values by ICMR (Acceptable limits)	Unit Weight	S1			S2			S3			S4		
			V _n	q _n	W _n q _n	V _n	q _n	W _n q _n	V _n	q _n	W _n q _n	V _n	q _n	W _n q _n
pH	6.5-8.5	0.219	7.3	20	4.38	7.3	20	5.84	7.4	26.67	5.841	7.4	26.67	4.38
EC(μS/cm)	300	0.371	599	200	65.3	528	176	53.1	412	137.3	50.94	429	143	74.1
TDS(mg/l)	500	0.0037	299	60	0.184	249	50	0.14	172	34.4	0.127	186	37.2	0.22
DO	5mg/l	0.3088	3.56	115	33.49	4.2	108	32.6	4.1	109.1	33.68	4.5	105.6	35.5
	□W _n =	0.9025	□W _n q _n =			103.4			91.68			90.58		
		WQI= □W _n q _n /□W _n =	114.5			102			100.4			101.5		

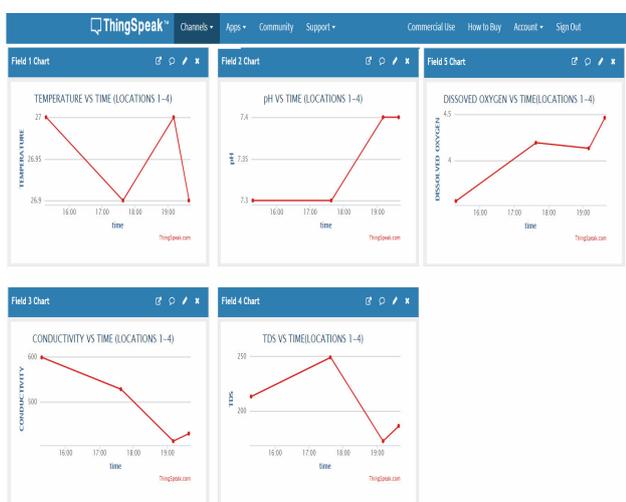


Figure 10: Measurements of locations recorded on thingspeakchannel

VII. CONCLUSION

The water quality of rivers as it progresses into the city deteriorates due to disposal of domestic sewage, effluents from factories, and agricultural wastes into the river. The system developed constitutes of three main units, namely, data acquisition, processing, and wireless transmission. The developed sensor node is battery powered and it was observed that the transmission module requires more power owing to wireless data transmission than data acquisition and processing modules of the system.

The water quality monitoring system presented in this paper allows studying and reporting the basic quality parameters of water bodies like lakes and rivers in real time thereby, giving a fair idea about their various pollution levels. Further, under critical conditions and emergencies, SMS alerts can be generated and sent to the concerned authorities for devising early solutions.

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