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A Review on Real Time Embedded System for Asscessment of Potable Water Quality

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Abstract- This paper presents review on design and development of proposed embedded system for real time monitoring of potable water quality at user sites. The intended system may consist of several optical and electrochemicalsensors like turbidity, pH, electrical conductivity, temperature *etc*. and special attention has given on making system light weight, reliable and durable. This kind of system is required for collecting the large spatiotemporally rich data to local government, water development board and water companies. Extensive literature and market research has performed to find water quality parameter and its respective sensor. Based on selected parameterswireless sensor node is developed along with several microsystem required for analog signal conditioning, processing and remote representation of data. Finally various event detection algorithmsfor fusion of differentdata collected by sensors in real time are studied so as to find outthe anomalies and different contaminant present in drinking.Also the hazardous effect of these parameters on human health is discussed when specific parameter related to quality of water crosses their prescribed limit.

Keywords- Water quality, optical and electrochemical sensor, WSN, Local authority

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I. INTRODUCTION

Pure drinking water is one of the most essential needs of all human beings for good health and well-being. Drinking water utilities facevarious challenges in their operation in real time because of various factors like draining water resources, rapid population growth,aging infrastructure of water distribution systems, water pollution caused by industries, pesticides used in agriculture [1].Many times in rural areas the drainage systems and drinking water supply are closely distributed. It increases the deliberate or accidental contamination risk in water supply system. Ongoing water crisis is identified as prime global risk based on the impact on society as measured in devastation and ranked eighth global risk based on likelihood (Likelihood occurred within 10 years announced by world economic forum, January 2015). Nearly 750 million people around the world have lack of access to safe drinking water which approximates to 1 in every 9 people. Diarrhea which is caused by contaminated drinking water and hand hygiene kills an estimated 842,000 people every year globally [2][5].

To resolve all these problems the need of better online monitoring systems arises over existing laboratory methods. Laboratory based methods are too slow to develop operational response, they require more labor force and do not provide result in real time.Micro Electro Mechanical system(MEMS) and wireless sensor network (WSN) system allows the monitoring process to be conducted remotely and real time [4].

Limited number of on-line reagent-free water monitoring systems are commercially available [12] (eg. Hach HST Guardian Blue, J-MAR Biosentry, etc). These systems are bulky and remain cost prohibitive for large scale deployment (cost tens of thousands of dollar per unit). Such systems can take frequent samples of the water quality at very limited number of locations. However, substantial proportion of contamination problem is within distribution systems and due to the limited spatiotemporal sampling, it is impossible to know the quality of potable water delivered to consumer household.

US environmental protection agency (USPEA) has carried out an extensive experimental evaluation of water quality sensor to access their performance on several contaminations. The main conclusion was that Turbidity (TU), Hydrogen Ion concentration (pH), Electrical conductivity (EC), Oxidation Reduction Potential (ORP) are main water parameters by monitoring these parameters, it is possible to find out the water quality [1][3].

This paper provides the information related to previous work that had been done and the shift in the current monitoring model and processes. The flow of work is to monitor water quality using low cost and light weight embedded system and then send the event information remotely to concern local authority.The rest of this paper has been structured as follows. In section II, literature reviews are discussed. In section III, gives a detail of proposed system. Followed by conclusions in section IV.

II. LITERATURE REVIEW

The total literature review is divided into two parts. First part consists of selection of water quality parameter and overviews the various hazardous effects on human health when the parameter is not in specified range. Second part consists of detailed performance wise study of different sensor and output signal processing.

A. Overview of Water Quality Parameters

Water quality standard are determined according to World Health Organization (WHO) and other pertinent

organizations (likeEU, USPEA) [3]. These organizations set the standard for quality parameters ofdrinking water and indicate which microbiological, chemical parameter should be tested regularly in order to protect the health of living things.Table I specifies the parameters to be monitored suggested byWHO.

TABLE I PARAMETERS TO BE MONITORED SUGGESTED BY WHO [1]

	Parameter	Units	Quality Range
1	Turbidity	NTU	0 – 5
2	Ph	pH	6.5-8.5
3	Electrical Conductivity	µS/cm	500-1000
4	Temperature	˚C	-
5	ORP	mV	650-800
6	Nitrates	mg/L	<10
7	Dissolved Oxygen	mg/L	-
8	Free Residual Chlorine	mg/L	.2 – 2

1. **Hydrogen Ion Concentration (pH):** It gives the acidic or basic nature of water. It indicateswhether water is hard or soft. The pH value of pure water is 7. The normal safe range of drinking water is 6.5 to 8.5. When the pH value is not in prescribed range the mucous membrane present in eyes, mouth, nose and abdomen may get damaged.
2. **Turbidity:** It provides the information about cloudiness or clarity of water. It is generally measured in Neptholometric Unit (NTU). The turbidity sensor consist of light sensitive device i.e. a photo-resistor (LDR) and power LED. The LED and the photo-resistor are placed at a short distance in such a way that water can flow between them.
3. **Electrical Conductivity (EC):**It is a measure of electric currentcarrying capacityof water and can be used to estimate amount of dissolved solid, mineral ion and salinity of water and it is measured in *µS/cm*. Generally intake of high EC water causes kidney related diseases.
4. **Nitrates:** Nitrate is one of the most common ground water contaminant. Excess level of nitrate in drinking water may cause methemoglobinemia or blue baby disease. When nitrate is present, hemoglobin can be converted to met-hemoglobin, which cannot carry oxygen and adversely effect on platelet count in human body. The general observation to find outincreased nitrate concentration in water is that the growth rate of algae increases. The safer limit of nitrates in drinking water is less than10*mg/L*
5. **Oxidation Reduction Potential (ORP)**: Thechemical process in which electrons are transferred between atom is called as an oxidation. Oxidation and reduction always occur together hence it also called Redox reaction. ORP gives the ability of water to destroy the foreign contaminants such as microbe or carbon base contaminant.WHO adopted an ORP standard for drinking water that states minimumORP required for disinfection to be 650mV.

   Bacteria like E.coli (Coliform) and salmonella cannot survive when the ORP level of water is in the range 650-750mV. This is due to the fact that higher ORP indicates greater number of oxidizing agent. It also indicates the effectiveness of sanitizer mixed in water. Coliform count in water shows the water is getting contaminated with faecal material that contain disease causing microorganism.

B. Overview of Water Quality Sensor Technology

A number of bare multi-parametric sensor arrays have been developed and presented in the literature based on various sensor technologies.

Thick film (Screen Printed) sensor array technique shows development of multi-parametric probe in cost effective manner. However thick film chemical sensorssuffer limited life time (few month), electron drift (due to salt loss) and also development of stable reference electrode is not possible so far [6].

ISFET based micro sensor (developed using MOSFET semiconductor technology) offers numerous advantages such as small size, robustness, low output impedance and rapid response. It has some limitations as it requires glass reference electrode (REFET) to operate effectively thus encapsulation of electrode is difficult which increases the final cost of sensor [7].

Nano sensor based on Nanostructure of noble metals and their oxides (Pt, Ru, Ir) is recent promising concept however it suffers from several drawbacks like temperature dependent delay response and nondeterministic potential drift [8]. Despite of recent advances in sensor development technologies the reliability and performance of conventional glass electrodes and solid state sensors (TU, EC, T) stand out among many sensors available. Same shall be used in the proposed system to provide most reliable technology [4].

Water sensors installed in-line require periodic and effective cleaning of probes to ensure reliable measurement. Different cleaning mechanism are studied [9] and stated that best suitable cost effective method is flat surface probe method because of its passiveself-cleaning based on the mechanical package and design of probe.

C. Overview of Contamination Event Detection Algorithm

Two event detection algorithms have been discussed in [4] to fuse online multi-sensor measurement in order to assess the water contamination risk. An event detection algorithm acts as an early warning system for the possible potable water quality deterioration at point of installation. Both algorithms are based on normalized sensor output given by equation 1

$$N_i = \frac{|Si - \mu i|}{\tau i\ \sigma i} \quad \ldots..1$$

Where S_i is the current measurement of sensorsparameter.μ_i, τi are the mean and standard deviation over a moving time window.τi is sensor based parameter associated with measurement accuracy of each parameter i.

The objective of the event detection algorithm was to activate an alarm when normalized sensor output exhibit sudden and significant change, given that this change is bounded within the quality range suggested by drinking water quality standards.

The first event detection algorithm is denoted as Vector Distance Algorithm (VDA) which is based on the Euclidian distance between the normalized sensor signal vector Nand the normalized sensor control signal vector N_0 of pure (Clean) water. The risk indicator R_1^{VDA} is given by equation2

$$R_1^{VDA} = \begin{cases} 1, & if \left|\left|N - N0\right|\right| 2 > d \\ 0, & otherwise \end{cases} \quad \ldots\ldots 2$$

Where'd' is predefined threshold

The second event detection algorithm is denoted as Polygon Area Algorithm (PAA) the risk indicator R_1^{PAA} function is based on the ratio of the polygon area $A_N$formed by N vector component to the polygon area A_1 formed by the 1 ones vector component.
The risk indicator R_1^{PAA} is given by equation 3

$$R_1^{PAA} = \begin{cases} 1, & if \frac{AN}{A1} > 1 \\ 0, & Otherwise \end{cases} \quad \ldots\ldots 3$$

Another algorithm is simply based on the predefined threshold value. When sensor output crosses this value then alarm is activated.

III. PROPOSED SYSTEM ARCHITECTURE

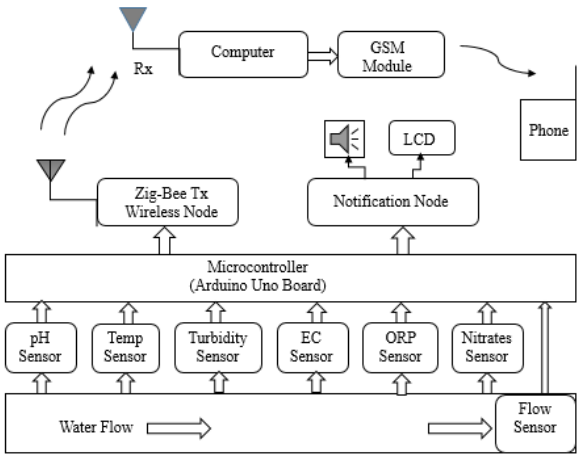

Fig.1 Block diagram of Proposed System

Fig.1 shows Block diagram of Proposed Systemwhich consists of microcontroller, Zig-Bee, GSM, LCD and different kind of sensors. Wireless node formed with the help of Zig-Bee. Arduino controller collect the data form these sensorsthen zig-Bee transmitter module send the collected data to receiver section. The Zig-Bee receiver will receive the data from microcontroller and feed it to the computer. Computer process the data with the help of installed software and resulted data is displayed in readable form. On the basis of this result messagesare sent to the corresponding government authority through GSM 300 module to take necessary precautionarymeasure. Notification node consist of LCD display which shows the reading of sensor and buzzer rings when the sensor output cross the predefined threshold level.

Computer with installed software like MATLAB R2013a for creating GUI and Arduino1.6.12are used for microcontroller programming.

Flow Sensor: Flow sensor is used to measure the water flow. By using this sensor the fluidic flow through pipes can be measured. The unit of the flow is cubic milliliters per second. The flow sensor has three pins, one is for measuring signal, other for input voltage and ground.

IV. CONCLUSION

This paper summarizes study of various methods for monitoring the water qualityby considering parameters like turbidity, pH, Conductivity, temperature. It also includes study of the hazardous effect of these parameters on human health when these parameters crosses the prescribed safety standards. Comparative study of different sensors shows that conventional glass electrodes and solid state sensors provide better reliability and self-cleaning mechanism.Embedded system based on proposed architecture having wireless sensor node and notification node can provide real time data of different sensors. GSM module shall help to send notifications to concerning local authority for taking precautionary measures.

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