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A Real-Time Monitoring and Contamination Detection in Water Distribution Systems using 32-Bit Microcontroller

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Abstract :-The aim of the Proposed Project is a Microcontroller based Low-Cost Sensor Network for Real-Time Monitoring and Contamination Detection in Potable and non- Potable Water Distribution Systems and also updates the information to the consumers and concerned authorities by using GSM module. In the existing system, it is just monitor the water level and electrical conductivity manually (off-line) and report to concerned authorities only in metropolitan areas. The objective of the project is to present a conceptual model of embedded based real time monitoring the water quality and also contamination detection for both potable and non-potable water distribution systems. In this proposed system we are using different sensors for water level and contamination detection. The main goal is the design and development of low cost system that can be used at the premises of consumers. This system can also be used in customer oriented manner to continuously monitor qualitative water parameters and fuse multi parametric sensor data for assessing the water quality.A 32-bit Microcontroller and associated sensor network can detect water contamination continuously according to water conductivity and temperature. Depends on these parameters microcontroller computes the other related contaminants and transmits same data to consumers and some authorities by using GSM module. Our approach is based on the development of low cost sensor nodes for real time and in-pipe monitoring and assessment of water quality on the fly. The main sensor node consists of electrochemical and optical sensors which can be used to monitor the water quality. From the sensor node we are sending monitored values to control room (ARM board) through RS232 serial cable.

Keywords: Water quality monitoring, flat surface sensors, Oxidation reduction potential sensor (ORP) and multisensory system, and sensor networks, arsenic & bacterial contamination detection.

I. INTRODUCTION

Immaculate drinking water is a critical for the wellbeing and prosperity of all people and creatures. In addition, it is additionally essential for farming utilization for good product yielding and natural way of life linkage (root zone) wellbeing issues. An ease and comprehensive methodology is a microcontroller based sensor system for continuous observing and pollution recognition for both drinking and non-drinking water dissemination frameworks and in addition for customer locales.

It is critical for accurate on-line (real-time) water quality observing frameworks than the current lab based techniques, which are too ease back to create operational reaction and don't give a level of general wellbeing security continuously.

Conventional strategies for water quality checking and control include the manual accumulation of water tests at different areas and at diverse times, trailed by research centre scientific procedures keeping in mind the end goal to portray the water quality.

Such methodologies are no more thought to be productive. It has a few disadvantages:

a) The absence of continuous water quality data to empower discriminating choices for general wellbeing security (long time holes in the middle of testing and identification of defilement).

b) Poor spatiotemporal scope (little number areas are tested).

c) It is work serious and has generally high expenses (work, operation and hardware).

In this way, there is a reasonable requirement for nonstop on-line water quality checking with proficient spatio-fleeting determination.

The proposed framework comprises of a top of the line 32-bit microcontroller, sensor hub comprises of a few in-channel electrochemical and optical sensors and accentuation is given on minimal effort, lightweight execution and dependable long time operation. Such execution is suitable for huge scale arrangements empowering a sensor system approach for giving spatiotemporally rich information to water purchasers, water organizations and powers. Exploratory results show that this economical framework is equipped for identifying these high effect contaminants at genuinely low fixations. The outcomes show that this framework fulfils the on-line, in-channel, low organization operation expense and great location precision criteria of a perfect early cautioning framework.

Broad writing and statistical surveying is performed to distinguish minimal effort sensors that can dependably screen a few parameters, which can be utilized to gather the water quality. Taking into account chose parameters a sensor cluster is produced alongside a few Microsystems for simple sign moulding, handling, logging, and remote presentation of information.

At long last, calculations for intertwining on-line multi sensor estimations at neighbourhood level are created to evaluate the water tainting danger. Investigations are performed to assess and approve these calculations on deliberate tainting occasions of different amassing of Escherichia coli microscopic organisms and substantial metals (arsenic).

Drinking water utilities (water investigation and dispersion) are confronting new difficulties in their ongoing operation as a result of restricted water assets, escalated spending plan necessities, developing populace, maturing framework, progressively stringent regulations and expanded consideration towards protecting water supplies from inadvertent or conscious sullying.

Fast recognition (and reaction) to occasions of tainting is basic because of the possibly extreme results to human wellbeing. Ruptures in physical and pressure driven respectability of a water conveyance framework can prompt the deluge of contaminants crosswise over channel dividers, through breaks, and by means of cross associations. The mixture of dangerous (small scale organic, concoction, and so forth) specialists which can deliver unfavourable impacts on people because of various courses (ingestion, inward breath and dermal) of presentation. US Environmental Protection Agency (USEPA) has completed a broad trial assessment of water quality sensors to survey their execution on a few sullying.

The main conclusion was that many of the chemical and biological contaminants used have an effect on many water parameters monitored including Turbidity (TU), Oxidation Reduction Potential (ORP), Electrical Conductivity (EC) and pH. Thus, it is feasible to monitor and infer the water quality by detecting changes in such parameters.

Water quality monitoring systems should provide good balance between cost and ease of implementation-maintenance, however to ensure their survival must demonstrate operational benefits (such as better water quality, decreased operating costs or reduced customer complaints).

The objective of the project is to present a conceptual model of embedded based real time monitoring the water quality and also contamination detection for both potable and non-potable water distribution systems. In this proposed system we are using different sensors for water level and contamination detection. This approach can achieve more reliable quality monitoring due to the large spatiality distribution development and possibility of correlating quality measurements from various sensors.

II. PROPOSED METHOD:

The main goal is the design and development of low cost system that can be used at the premises of consumers. This system can also be used in customer oriented manner to continuously monitor qualitative water parameters and fuse multi parametric sensor data for assessing the water quality. A 32-bit Microcontroller and associated sensor network can detect water contamination continuously according to water conductivity and temperature. Depends on these parameters microcontroller computes the other related contaminants and transmits same data to consumers and some authorities by using GSM module.A user/consumer can view the presented data regarding quality of water and it will be used accordingly. The below shows a functional block diagram proposed the low cost system for both potable and non-potable water comprising of multi sensor network and 32-bit microcontroller development board, GPRS/GSM module etc.

A preliminary version of this article has appeared. In this article, we present an improved hardware platform, develop a new advanced contamination event detection algorithm and provide an experimental evaluation and validation of system and event detection algorithms in the presence of Real microbiological and chemical contamination events. In addition, several water monitoring micro systems (sensor nodes) have been developed for large scale water monitoring based on wireless sensor networks (WSNs) technology. A sensor hub is created for checking saltiness in ground water and the water temperature in surface waters. We have built up a WSN and a vitality gathering framework (in view of a sun powered board) to screen nitrate, ammonium and chloride levels in streams and lakes. Vitality reaping systems alongside hibernation techniques assume a critical part in expanding the lifetime of sensor hubs. A study on vitality collecting for WSNs is given. a self-governing vessel furnished with water sensors is proposed to gather tests from lakes utilizing the A∗ look calculation. More productive route calculations for a gathering of vessels with impediment shirking are introduced. Aside from the progressing examination towards the configuration and advancement of sensors and small scale frameworks another parallel Research heading is that of the improvement of programming and calculations for the identification of water quality irregularities and tainting occasions. At present openly accessible instrument is CANARY programming created at Sandia National Laboratories in a joint effort with the USEPA. CANARY shows conceivable defilement occasions by utilizing a scope of Mathematical and measurable procedures to distinguish the onset of atypical water quality occurrences from online crude sensor Data. Other occasion recognition and information acceptance approaches are given and references therein.

Software Requirements:

- Kiel compiler.
- Embedded C.
- Flash Magic.

Hardware Requirements:

- Microcontroller unit.
- Temperature sensor.
- Conductivity sensor.
- Oxidation Reduction Potential sensor(ORP)
- Power supply.
- LCD.

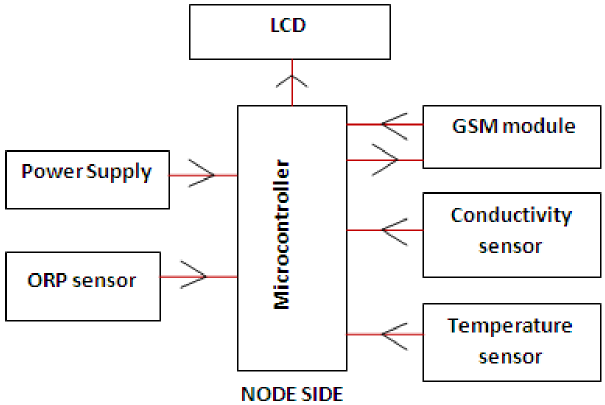

Fig 1. Block Diagram

III. SENSORS WORKING PRINCIPLE

A. Oxidation Reduction Potential (ORP)

Oxidation refers to any chemical action in which electrons are transferred between atoms. Oxidation and reduction always occur together. ORP is a reliable and cost effective method to measure the effectiveness of water disinfection sanitizers (chlorine, sodium hypochlorite, bromine and ozone) in real time.

As the measured value of ORP increases, the solution has more potential to oxidize and thus to destroy any unwanted organisms. WHO adopted an ORP standard for drinking water disinfection of 650 mV. Research has shown that at 650-700 mV of ORP, bacteria such as E.coli and Salmonella are killed on contact.

ORP level can also be viewed as the level of bacterial activity of the water because a direct link occurs between ORP level and Coliform count in water. The table 4.2 represents ORP levels and relative Coliform counts. Level of coli form count (E.coli) in drinking water indicates the water has been contaminated with faecal material that may contain disease causing microorganisms, such as certain bacteria, viruses, or parasites.

Fig 2: ORP Sensors

B. pH sensor implementation:

The pH value is a good indicator of whether water is hard or soft. The pH of pure water is 7. In general, water with a pH lower than 7 is considered acidic, and with a pH greater than 7 is considered basic. The normal range for pH in surface water systems is 6.5 to 8.5, and the pH range for ground water systems is between 6 and 8.5.

The modern pH electrode is a combination electrode composed of two main parts: a glass electrode and are reference electrode as shown in below Figure. pH is determined essentially by measuring the voltage difference between these two electrodes. At the tip of the electrode is the thin membrane that is a specific type of glass that is capable of ion exchange. It is this element that senses the hydrogen ion concentration of the test solution. The reference electrode potential is constant and is produced by the reference electrode internal element in contact with the reference-fill solution that is kept at a pH of seven.

The output of the pH electrode produces DC voltage (mV),1pH indicates ±59.4mV for full scale range. An ideal electrode at 25°C will produce 0 mV when placed in a solution with a pH of seven.

Fig 3 pH sensor

C. Temperature Sensor

LM35 is a precision IC temperature sensor with its output proportional to the temperature (in oC). The sensor circuitry is sealed and therefore it is not subjected to oxidation and other processes. With LM35, temperature can be measured more accurately than with a thermistor. It also possesses low self heating and does not cause more than 0.1oC temperature rise in still air. The operating temperature range is from - 55°C to 150°C. The output voltage varies by 10mV in response to every oC rise/fall in ambient temperature, i.e., its scale factor is 0.01V/ oC. The sensor generates an output voltage proportional to the suspended particles and has a linear response.

Advantages & Applications:

Quality of water delivered to consumers Using low cost, low power and tiny in-pipe sensors. The main contribution of this project is the design and development of a low cost system that can be used at the premises of consumers to continuously monitor qualitative water parameters and fuse multi-parametric sensor response in order to assess the water consumption risk.

III. RESULTS

A modular but holistic approach is adopted for the design and development of the system. Modularity enables the simultaneous instrumentation and sampling of all parameters and the decomposition of several operations like calibration, upgrades and repair or replacement of faulty parts. The overall system architecture under discussion in presented in Fig. 1 and is comprised of the following three subsystems: a central measurement node (LPC2148 MCU based board) that collects water quality measurements from sensors, implements the algorithm to assess water quality and transmits data to other nodes, a control node (ARM/Linux web server based platform) that stores measurement data received from the central measurement node in a local database and provides gateway to the internet, visualize data (charts), and sends email/sms alerts and finally a tiny notification node(s) (PIC MCU based board) that receives information from the central measurement node through an interconnected Zig Bee RF transceiver and provides local near-tap notifications to the user (water consumer) via several interfaced peripherals (LED, LCD, Buzzer). It should be noted that the central measurement node serves as the sensor node. The idea is to install these sensor nodes in many consumer sites in a spatially-distributed manner to form a WSN that will monitor the drinking water quality in the water distribution system from the source to the tap.

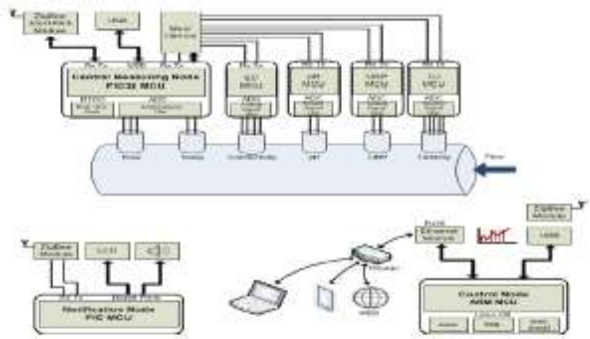

Fig 4 System architecture

The objective of the event detection algorithms is to activate a trigger event (alarm) when normalized sensor outputs exhibit sudden and significant changes, given that these changes are bounded within the quality ranges suggested by drinking water quality standards (see Table II, quality range). The detection of water quality changes that are outside the expected quality ranges (min/max violations) is easier and can be done by a weighted multi-parameter cost function in the form of RO =i wOiJi, where Ji are binary variables that indicate -hether parameter i has been violated and wOi are non negative weights which imply the significance of the violation of each parameter i. If RO = 0 no violation is assumed, however as RO > 0 increases the water contamination risk is also increases. As previously indicated, the objective in this paper is to detect anomalies when water quality changes are inside the expected quality ranges by fusing the multi-sensor data. Therefore a risk indicator RI function is defined that takes a value RI = 1 if a contamination event is detected or RI = 0 otherwise. The first event detection algorithm is denoted as Vector Distance Algorithm (VDA) and the risk indicator RV DA I function used in this algorithm is estimated based on the Euclidian distance between the normalized sensor signal vector **N** and the normalized control signal vector **N0** of pure (clean) water In fact, developing and deploying sensors for all contaminants would not be feasible (too many contaminants which translates to very high cost). On the other hand, many contaminants cause changes in some parameters of the water that can be easily monitored. Therefore, by monitoring these changes we can infer possible contamination events, even though this approach may suffer from some false alarms, it can be compensated/eliminated by the large scale deployment and the possibility of correlating the decisions from various sensor nodes which is the topic of our future work.

Microbiologically (E.coli) contaminated drinking water:

The first experiment considers the case of microbiologically (E.coli) contaminated drinking water. Most E. coli strains are in general harmless to humans, but some types can cause serious food and water poisoning. However, the presence of E.coli is used to indicate that other pathogenic organisms may be present (often of faecal origin). According to WHO guidelines & EU Drinking Water Directive E.coli parametric value is 0 CFU/100mL. Fig. 10(a) presents the measurements received using the developed sensor node when the following concentrations of E.coli were injected: 5x10□2, 5x10□1, 5x100, 5x101, 5x103, 5x104, 1x107 CFU/mL. It is evident that TU and EC sensors responded well when microbiological contaminants injected in chlorinated potable water. ORP sensors have responded with delay and pH sensor has a spiky type of response. Fig. 10(b) presents the output signals of the Vector Distance Algorithm (VDA) and Polygon Area Algorithm (PAA). The results of Fig. 10(b) indicate that both algorithms miss the detection of 5x10□2CFU/mL because sensors responses were very close to background levels (no anomalies occurred). It should be noted that the performance of PAA algorithm is better and given that it utilizes less information, PAA algorithm is better than the VDA algorithm.

2) Chemically (Arsenic) contaminated drinking water:

The second experiment considers the case of chemically (Arsenic) contaminated drinking water. Water contamination by toxic heavy metals and especially arsenic contamination is a common problem encountered in many countries due to undue deposition of mining, agricultural, industrial and urban wastes in water resources. Arsenic is known to affect negatively the mental and central nervous system function, to damage the blood composition, lungs, kidneys, liver, and other vital organs, as well as it contributes to certain neurological

(b) E.Coli bacteria contamination detection.

Fig.10. Experiments with E.coli bacteria degenerative processes and causes skin cancer. According to WHO guidelines & EU Drinking Water Directive Arsenic parametric value is 10_g/L (it was 50_g/L in the previous directives). Fig. 11(a) presents the measurements received using the developed sensor node when the following concentrations of Arsenic were injected: 5, 10, 25, 50, 125, 500, 1000 _g/L. Arsenic solutions created from a standard solution of 1000mg/L As. Unfortunately, almost all sensors did not respond at low arsenic contamination. However, at concentrations above 25 _g/L ORP and pH sensors have responded and at higher concentrations (above 500_g/L) all sensors responded well. Fig. 11(b) presents the output signals of the Vector Distance Algorithm (VDA) and Polygon Area Algorithm (PAA). The results of Fig. 11(b) indicate that both algorithms miss the detection of 5 and 10 _g/L because sensors responses were very sluggish and close to background levels and that the VDA algorithm exhibits two false alarms. Therefore, the performance of PAA algorithm is again better (sharp response, no false alarms) than the VDA algorithm.

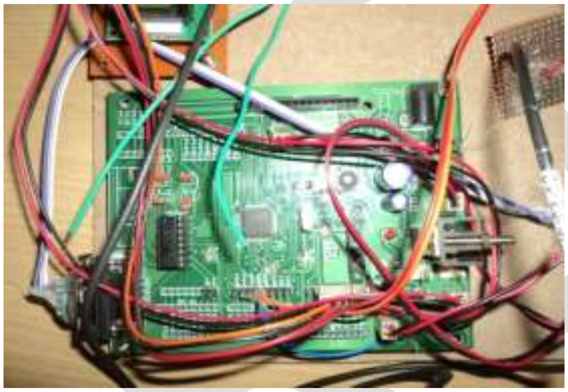

Fig 5 LPC 2148,32 bit-Microcontroller board

Fig 6 GSM module.

Fig 7. Final Result

IV. CONCLUSION

In this article, the design and development of a low cost sensor node for real time monitoring of drinking water quality at consumer sites is presented. The proposed sensor node consists of several in-pipe water quality sensors with flat measuring probes. Unlike commercially available analyzers, the developed system is low cost, low power, lightweight and capable to process, log, and remotely present data. Moreover, contamination event detection algorithms have been developed and validated to enable these sensor nodes to make decisions and trigger alarms when anomalies are detected. Such implementation is suitable for large deployments enabling a sensor network approach for providing spatiotemporally rich data to water consumers, water companies and authorities. In the future, we plan to investigate the performance of the event detection algorithms on other types of contaminants (e.g. nitrates) and install the system in several locations of the water distribution network to characterize system/sensors response and wireless communication performance in real field deployments. Finally, we plan to investigate network-wide fusion/correlation algorithms to assess water quality over the entire water distribution system.

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