Embedded Based Real Time Monitoring and Detection of Bacterial Contamination in Drinking Water using ORP Measurement

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Abstract
This article demonstrates a low cost real time monitoring and bacterial contamination detection in drinking water at water treatment plants, water distribution systems and consumer sites using Oxidation Reduction Potential (ORP) measurements. In traditional system measures ORP values manually at source end and report to concern officials at selected locations in irregular intervals. In the proposed system has a low cost 32-bit-microcontroller based ORP sensor module and GSM modem was used to detect the bacterial contamination in real time (on-line) continuously .The collected information will be verified with pre defined allowable range and updates the water quality information to consumers as well as water board authorities and water companies. A two element/electrode ORP sensor module was used to monitor the Redox potential. A sensor assembly consists of a reference electrode made up of Ag/Agcl and measuring electrode made up of platinum tip for stable and accurate measurements. The experiment results were demonstrated the ORP levels for effective utilisation of water for both drinking and non-drinking purposes.

Keywords — *Bacterial contamination, Chlorination, Health protection, Operational response, Redox potentials, Safeguarding of water distribution systems, Potable water.*

I. INTRODUCTION

Clean potable water is very important for health and well being of humans as well as animals. Drinking water utilities are facing new challenges from exploration, storage, treatment and safeguarding of drinking water distribution systems in their real time operations [2]. There is clear and essential need of real time monitoring and control the potable water from artificial and deliberate contaminations in water distribution systems. The existing traditional laboratory water quality monitoring systems are having several disadvantages, like slow operational response, poor spatio-temporal coverage, high cost, less efficient, laborious, high infrastructure requirement and low level of public health protection in real time [1]. Generally water gets contaminated due to natural and artificial processes. In natural (process) contamination, water is infiltrates through soils, organic and inorganic compounds, rocks, minerals and metals that it touches, absorbs and stored in aquifers. In the case of artificial drinking water contaminations due to improper septic and sewerage discharges, storm/rain water run-off, leaching of animal manures, domestic and wild life. During and after precipitation, bacteria and other harmful microorganism from any of these sources may be washed into rivers, lakes or ground water. Bacterial contamination cannot be detected by sight, smell or taste. The only way to know if a water supply contains bacteria is to have it tested. There are three groups of coli form bacteria. Each is an indicator of drinking water quality and each has a different level of risk. Measuring ORP[3] directly reflects the sanitizing power of free chlorine or any other oxidizing or reducing chemicals. The measurement of ORP is precise, empirical and requires no user interpretation, making it ideal for water quality and industrial process control. Though the measurement of free chlorine concentration is often indicated for the disinfection of water and disinfectant by product control. Because free chlorine works through oxidation, ORP instrumentation can be used to monitor and control its effectiveness. ORP [5]measures the actual oxidation power of the solution, specifically the strength and number of oxidation and reduction reactions in solution. This yields a clear picture of the efficacy of the chlorine present, regardless of the concentration or ratio of chlorine species in solution. Moreover, it is also very important to know the bacterial contamination in drinking water, in order to save the health of human being and protect from intestinal infections, dysentery, hepatitis, typhoid fever, cholera, and other illnesses. Further, ORP measurements are very useful to control and monitoring for chlorination process at water treatment and storage plants.

II. ORP MEASUREMENT PRINCIPLE

Oxidation Reduction Potential (ORP or Redox Potential) [3] measures system’s capacity to either release or accept electrons from chemical reactions and it is in mV. When a system tends to accept electrons, it is an oxidizing system. When it tends to release electrons, it is a reducing system. Examples of oxidizers are: chlorine, hydrogen peroxide, bromine, ozone, and chlorine dioxide. Examples of reducers are sodium sulfite, sodium bisulfate and hydrogen sulphide. 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. A combined ORP electrode is used and temperature compensation is not needed for ORP measurements. ORP sensors work by measuring the dissolved oxygen. More contaminants in the water result in less dissolved oxygen because the organics are consuming the oxygen and therefore, the lower the ORP level. The higher the ORP level, the more ability the water has to destroy foreign contaminants such as microbes, or carbon based contaminants.

- ***Coli form bacteria Vs ORP measurement values***

ORP level can also be viewed as the level of bacterial activity [19]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 fecal material that may contain disease causing microorganisms, such as certain bacteria, viruses, or parasites.

The below table shows the ORP values and contamination of water due to coliform bacteria.

TABLE-1

ORP Value(mV)	Coliform count in 100 ml of water
200	300
300	36
400	3
600	0

Table 1. ORP value and level of bacteria activity.

From a water treatment perspective, ORP measurements are used often to control disinfection with chlorine or chlorine dioxide in cooling towers, swimming pools, potable water supplies, and other water analysis applications. For example, studies have shown that the life span of bacteria in water is strongly dependent on the ORP value. In wastewater, ORP measurement is used frequently to control treatment processes that employ biological treatment solutions for removing contaminants. The table 2 shows different ORP levels and corresponding water usage.

TABLE-2

ORP level(mV)	Applications
0-150	No practical use
150-250	Aquaculture
250-350	Cooling towers
400-475	Swimming pools
450-600	Hot tubs
650-800	Normal drinking water

Table 2: ORP levels and applications.

III. ORP SENSOR AND WORKING PRINCIPLE

A two electrode system makes a potntiometric measurement. The ORP[3] electrode serves as an electron donor or electron acceptor, depending upon the test solution. A reference electrode supplies a constant stable output for comparison. Electrical contact is made with the solution using a saturated potassium chloride (KCl) solution. The principle behind the ORP measurement is the use of an inert metal electrode (platinum, sometimes gold), which is used due to its low resistance, will give up electrons to an oxidant or accept electrons from a reductant. The ORP electrode will continue to accept or give up electrons until it develops a potential, due to the build up charge, which is equal to the ORP of the solution. The reference electrode used for ORP measurements is typically the same silver-silver chloride electrode to supply constant reference voltage for measuring the difference potential of the solution (ORP).

- **Specifications of ORP Sensor**

- Output voltage: 0-2000mV, linear.
- Reference electrode: Ag/AgCl
- Measured electrode: Platinum.
- Physical dimension:Length:150 mm,dia:12mm
- Body: Sealed unbreakable epoxy body.
- Model No:CP88B, from vanira instruments technologies ltd.

Fig .1: Physical Appearance of the ORP Sensor

IV. TECHNOLOGY IMPLEMENTATION

The proposed method is low cost sensor, 32-bit Microcontroller and GSM module [2] was used for detection of Bacterial contamination in drinking water at storage tanks, water treatment plant and distribution systems.

Hardware Requirements

- LPC 2148-32bit microcontroller
- ORP sensor(CP88B)
- GSM module(SIM 900)
- LCD display(HDD2248)
- Power supply(3.3V,5V)

Software requirements

- Keil compiler
- Embedded C
- Flash magic.

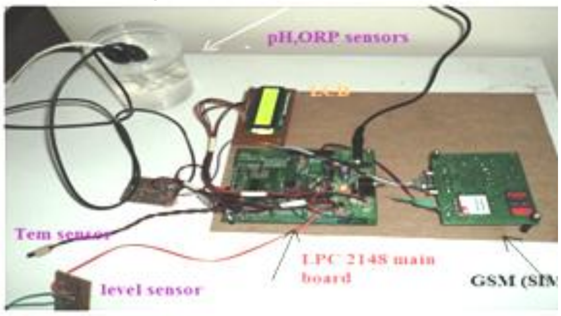

Fig.2: Full measurement setup of ORP.

The figure. 2 represent the full test setup and schematic circuits for ORP measurements. The LPC 2148 32-bit microcontroller has initiated by applying power source3.3V.Before starting measurement, SIM 900 GSM module has to be registered in network. Once the modem initialized command is received in to registered mobile than, we will start getting continuously ORP values, which are compared with predefined acceptable limits and results are presents at locally(LCD) and remotely(registered mobiles).If the values are found abnormal, than it sends caution message (SMS) to consumers, water board authorities and water companies[3].

V. 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 replacement of faulty parts. The overall system architecture under discussion in presented in Fig.2 and is comprised of the following three subsystems: a central measurement node (LPC2148 MCU based board) that collects water quality measurements from sensors, GSM module for transmitting data remotely and sensor assembly for collecting data.

The ORP measurements were observed and collected the data (ORP values) of contaminated, pure drinking water and the values as follows.

- Normal tap water:400mV
- Cleaned Water: 550mV
- High Salty water:900mV
- Contaminated water:200mV
- ORP standard (200) solution: 190mV.

Moreover, it was also observed the pH of both contaminated and pure drinking water using CL51B sensor, which is also combined electrode and results are as follows. The pH values were within acceptable limits as per WHO.

- Normal tap water: appox 7
- Pure drinking water :7.5

The following are some of the snap shots are evident that, the system was detected different concentration and, it was noticed that the values are very close to expected one.

The following snap shots are locally presented data.

Fig.3: Output of pure drinking water

Fig.4: Output of contaminated drinking water

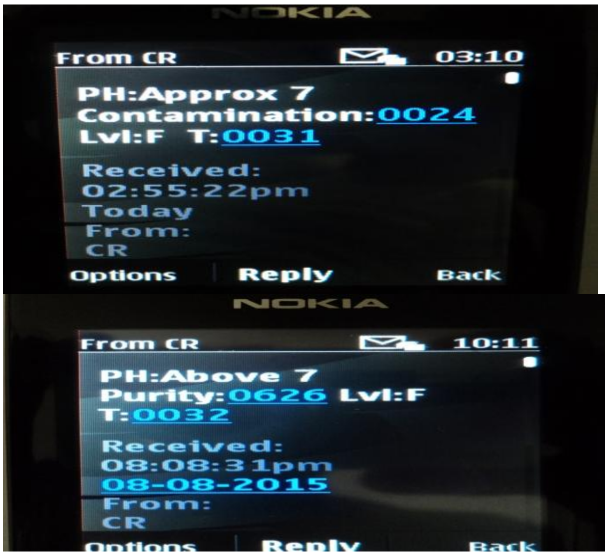

Fig.5: Messages received through GSM module of both drinking and contaminated water parameters.

VI. CONCLUSIONS

The bench model was designed and tested in detection of bacterial contamination in real time (on-line) at water treatment plants, water storage tanks, drinking water distribution systems and consumer sites. The main goal is that, low cost sensors, which will measured at fairly low concentration with highly reliable and consistent measurements was observed. The developed system is low cost, low power, lightweight and capable to process, log, and remotely present data. In future, we plan to develop event algorithms to trigger on low concentrations with high accuracy and install the system in several locations of drinking water distribution systems for improve the operational response and high spatio-temporal coverages.

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