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Monitoring input and output water quality of home water purifier

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ABSTRACT

This paper describes work that has been done on the design and development of a water quality monitoring system, with the objective of notifying the user of the real-time water quality parameters. The system is able to measure physiochemical parameters of water quality, such as flow, temperature, pH, conductivity and the oxidation reduction potential. These physiochemical parameters are used to detect water contaminants. The sensors which are designed from first principles and implemented with signal conditioning circuits are connected to a microcontroller-based measuring node, which processes and analyses the data. In this design, ZigBee receiver and transmitter modules are used for communication between the measuring and notification node. The notification node presents the reading of the sensors and outputs an audio alert when water quality parameters reach unsafe levels. Various qualification tests are run to validate each aspect of the monitoring system. The sensors are shown to work within their intended accuracy ranges. The measurement node is able to transmit data via ZigBee to the notification node for audio and visual display. The results demonstrate that the system is capable of reading physiochemical parameters, and can successfully process, transmit and display the readings.

Index Terms—Water quality monitoring, flow sensor, pH sen- sor, conductivity sensor, temperature sensor, ORP sensor, ZigBee, Wireless Sensor Networks.

INTRODUCTION

Clean water is one of the most important resources required to sustain life and the quality of drinking water plays a very important role in the well-being and health of human beings [1]. Water supply to taps at urban homes and water sources available in more rural areas, is however, not necessarily safe for consumption. Even though it is the government’s responsibility to ensure that clean water is delivered to its citizens, ever aging infrastructure, which is poorly maintained, and continual increase in population puts a strain on the supply of clean water. It is thus paramount to monitor the quality of water which will be used for consumption. In monitoring is defined as the collection of information at set locations and at regular intervals in order to provide data which may be used to define current conditions, establish trends, etc. Traditional water quality monitoring methods involve sampling and labo- ratory techniques. These methods are however time consuming (leading to delayed detection of and response to contaminants) and not very cost effective. There is thus a need for more extensive and efficient monitoring methods. [2-4].

Water quality monitoring can be achieved through microbial measurements as well as physiochemical measurements. Physiochemical parameters include electrical conductivity, pH, oxidation reduction potential (ORP), turbidity, temperature, chlorine content and flow. These

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parameters can be analysed quickly and at less cost than the microbial parameters and can also be measured with on-line instrumentation. Studies conducted by the United States Environmental Protection Agency (USEPA) have shown that water parameters are affected by contaminants in specific ways and can be de- tected and monitored using appropriate water quality sensors. Commercially available products capable of monitoring such parameters are usually bulky and quite expensive. Monitoring with sensor technology is still not very effective, as they do not always meet the practical needs of specific utilities; although cheaper than traditional equipment, cost, reliability and maintenance issues still exist; and data handling and management can also be improved. In this paper the development of a a low-cost, wireless, multi-sensor network for measuring the physicochemical water parameters; enabling real-time monitoring, is presented. The system implements flow, temperature, conductivity and pH sensors from first principles. All the data from the sensors are processed and analyzed, and transmitted wirelessly to a notification node. Algorithms are developed to detect possible contaminations. The notification node informs the user as to whether the water quality parameters are normal or abnormal. The rest of this paper is organised as follows. [5-7].

RELATED WORK

Various studies involving the implementation of water quality monitoring systems using wireless sensor network (WSN) technology can be found in literature. In a distributed system for measuring water quality is designed and implemented. Temperature, conductivity, pH and turbidity sensors are connected to a field point, wherefrom data is sent using a GSM (global system for mobile communications) network to a land based station. The focus of this study is however on the processing of the sensor data using Kohenen maps (auto-associative neural networks).

A WSN-based water environment system which senses and monitors video data of key areas and water parameters such as temperature, turbidity, pH, dissolved oxygen and conductivity is presented. Data is sent from the data monitoring nodes and data video base station to a remote monitoring center using ZigBee and CDMA (code division multiple access) technology. The water monitoring system implemented in analyses and processes water quality parameters (pH, conductivity, dissolved oxygen and temperature), and also sounds an alarm when there is a water contamination, or change in water quality. The parameters are measured with off-the shelf sensors and data is sent to a base station via GPRS (general packet radio service).[8]

In a ZigBee based WSN water quality monitoring and measurement system is presented. The system enables remote probing and real-time monitoring of the water quality param- eters and also enables observation of current and historical water quality status [9-11].

A river basin scale WSN for agriculture and water monitor- ing, called SoilWeather is implemented in. The network uses GSM and GPRS technology for transmission of sensor data. A turbidity system is proposed in, which is low-powere, small-sized, easy-to-use and inexpensive. The DEPLOY project is introduced to monitor the spatial and temporal distribution of water quality and environmental parameters of a river catchment. It is intended to demonstrate that an autonomous network of sensors can be deployed over a wide area and the system measures parameters such as pH, temperature, depth, conductivity, turbidity and dissolved oxygen.[12].

A microcontroller-based WSN system is proposed in to measure pH, chlorine concentration and temperature in a pool. Data is transmitted using GSM and in sleep mode the sensor nodes are shown to consume 27 µA. In a WSN system is used to measure the water quality of fresh water and uses solar daylight harvesting for optimised power management. The data collected from the various sensor nodes are sent to a sub-base node and from there to a monitoring station using a GSM network.

A low-cost, real-time, in-pipe sensor node with a sensor ar- ray for measuring flow, pH, conductivity, ORP and turbidity, is designed and developed in [8]. Contamination event detection algorithms are also developed to enable sensor nodes to make decisions and trigger alarms when contaminants are detected [13].

METHOD

To design the proposed water quality monitoring system, various water quality sensor design principles (since the sensors are deigned from first principles), wireless communication systems and water quality parameters were investigated. A. Instrumentation and Water Quality Parameters The first step was to determine which water quality parameters would be monitored for the assessment of the drinking water quality, to accurately determine whether the water quality is within the specified regulations of the World Health Organization (WHO). It was determined from that water parameters such as nitrate levels, free chlorine concentration and dissolved oxygen are too expensive to monitor and/or require frequent maintenance and calibration to sustain accurate readings over long periods of time. This would not be feasible for a long-term, real-time water quality monitoring system.

The water parameters which are the focus of this project are pH, temperature, conductivity, flow, and ORP. These physicochemical parameters can be used to detect certain water contaminations. Conductivity gives an indication of the amount of impurities in the water, the cleaner the water, the less conductive it is. In many cases, conductivity is also directly associated with the total dissolved solids (TDS). The pH of the water is one of the most important factors when investigating water quality, as it measures how basic or acidic the water is. Water with a pH of 11 or higher can cause irritation to the eyes, skin and mucous membrane. Acidic water (pH 4 and below) can also cause irritation due to its corrosive effect. ORP is a measure of the tendency of a solution to either gain or lose electrons. A positive ORP reading indicates that water is an oxidizing agent, and a negative reading indicates a reducing agent (or antioxidant). Normal tap water has an ORP value of between 200-400 mV. ORP is a non-standardized water quality indicator, but WHO recommends that the ORP of drinking water should not exceed 60 mV. Both the pH and ORP parameters are difficult to measure accurately as reference electrodes are required. These reference electrodes typically hold a solution with a known pH or ORP value and require recalibration when used over long periods of time. The flow and temperature measurements of the water are required for compensation, as these parameters can have an effect on other parameters.

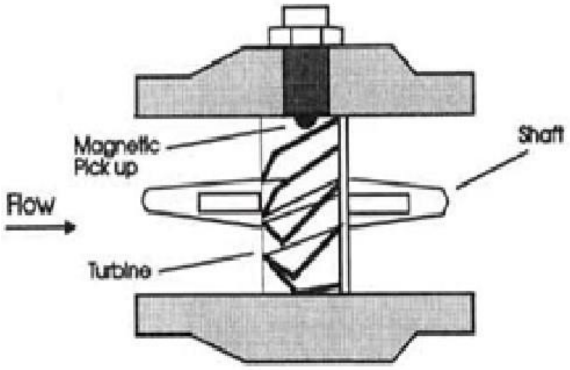

Fig. 1. The turbine flow meter

In this study the turbine flow meter Figure 1 is considered as it is able to make digital readings, is readily available and cheaper than the Venturi tube flow meter. The turbine flow meter translates the mechanical action of a rotating turbine inside the pipe into readable measurements with a magnetic pickup that is used to produce the output signal.

Temperature Sensor: A temperature sensor is used to measure the temperature of the water. There are various temperature sensor types: a thermocouple, thermistor or a solid state temperature sensor.

A thermistor temperature sensor is considered in this study as there is better design control and designing such a sen- sor from first principles is easier. Thermistors are generally used for applications below 300 ◦C and would therefore be sufficient for a system that operates at ambient temperatures. A thermistor is essentially a resistor with a temperature dependent resistance. Due to its resistive nature, an excitation source is required to read the voltage across the terminals. The measured voltage is proportional to the temperature with either a negative temperature coefficient (NTC) or a positive temperature coefficient (PTC). This correlation is not linear, especially for large temperature regions, but can be compen- sated for with the Steinhart-Hart equation. Thermistors are inexpensive and widely used for many types of applications due to the small size and reasonable accuracy.

Conductivity Sensor: The conductivity of water is an indication of the amount of ions and/or free flowing electrons that are present for the conduction of electricity. This is usually measured in Siemens per meter (S/m) or micro-Siemens per centimeter (µS/cm). The conductivity sensor is designed using the two- or four- electrode method is based on Ohms law. With a known resistor, voltage and current the resistance of the water solution can be calculated accordingly. This calculation also requires the cell constants which are the length and area of the water sample.

The resistance of the water is measured by using two or four electrodes with a known cell constant. Cell constants usually range from about 0.1 cm-1 to 10 cm-1, where higher cell constants work more effectively for higher conductivity solutions. To determine the resistance between the electrodes, a voltage is applied across the electrodes.

The two-electrode method is considered in this study as it is easier to maintain and more economical.

pH Sensor Alternatives: The pH of water is an important parameter to monitor because high and low pH levels can have dangerous effects on human health. The pH of a solution can range from 1 to 14. One method of measuring pH is through the use of a conventional glass electrode with a reference electrode setup, the other is using an Ion-Selective-Field- Effect-Transistor (ISFET).

Fig. 2. The pH electrode sensor used to carry out measurements.

SYSTEM OVERVIEW

The microcontroller is chosen so that multiple analogue signals can be read and processed. The signal is converted to fit within the allowable ADC (analog-to-digital converter) voltage range of 0 to 3.2 V. In the case of the flow sensor a pulsed signal is conditioned to interface with the microcontroller’s interrupt pin. Once the various signals have been read by the microcontroller the applicable equations can be used to process the raw data into usable measurements. The microcontroller then converts the measured values in float variables to char variables. The char values can then be transmitted across the wireless modules through serial communication.

To inform the user of the current state of the water, a notification node was required as a user interface. In Figure 6 the transmitted data from the measurement node is received via the wireless receiver module. These char values are then recon-structed back into to float values.

The user interface requires both a visual and audible element. The visual element is for relaying information on each water parameter and the audible element is for warnings. These values are then displayed on the LCD (liquid crystal display) with their respective name and units. The microcontroller also checks if the water parameters are within safe limits, if they are not, the buzzer is activated for a short period of time when the applicable parameter is displayed.

SYSTEM DESIGN

The sensing node; the measurement node; the wireless node; and the notification node. The sensing node contains all the water quality sensors, as well as the signal conditioning circuits required to interface with the measurement node.

The measurement node consists of a microcontroller that processes the raw sensor data and then transmits the data to the wireless transmitter module. The wireless transmitter and receiver modules are part of the wireless node

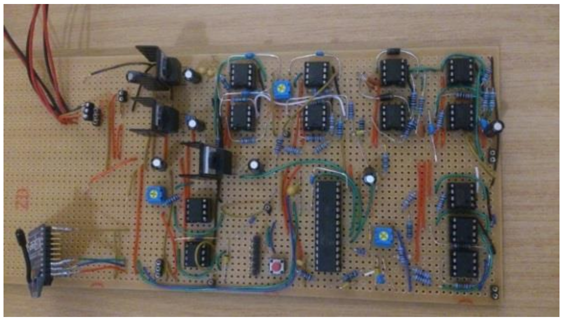

Fig. 3. Module 1: the measurement and sensing node setup.

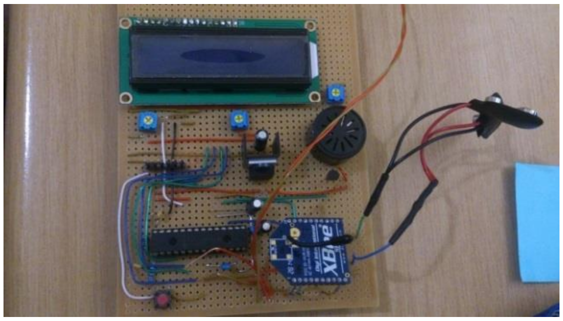

Fig. 4. Module 2: the notification node setup.

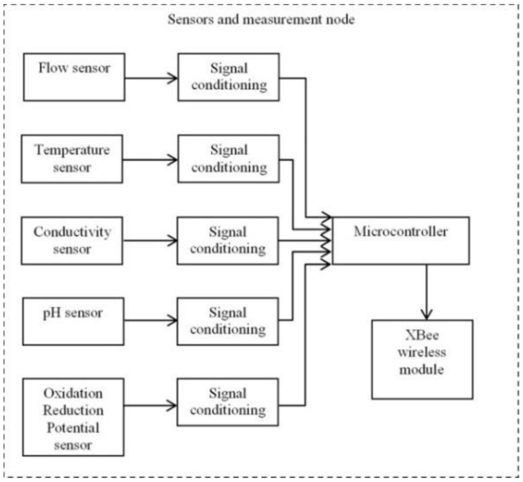

Fig. 5. Module 1: the measurement and sensing module block diagram.

Temperature Sensor

The main concern of a thermistor is the non-linear relationship between the temperature and the resistance. For this project a temperature range of 0 ◦C to 40 ◦C is considered. Thermistors are useful up to temperatures of 300 ◦C, thus the smaller operating range assists in counteracting the non- linearity. The resistance can however be scaled using the general form of the Steinhart-Hart thermistor third order approximation.

CONCLUSION

A sensor node with a temperature, conductivity, pH, ORP and flow sensors was designed and constructed on a Vero- board, which also included the respective signal conditioning circuits. The temperature sensor was completed using a thermistor based design. The conductivity sensor design was based on a two-electrode method. The signal conditioning circuit yielded acceptable results. The conductivity cell/electrodes were however not verified. The pH sensor made use of a glass electrode and yielded acceptable results. The flow sensor design made use of a turbine flow meter and yielded good results. The ORP sensor signal conditioning as a whole was a success and had acceptable accuracy. The ORP electrode itself was not calibrated. A measurement node consisting of a microcontroller was implemented to process the raw sensor data into usable measurement values. The microcontroller then transmitted the measurements wirelessly to the notification node via the wireless XBee modules. A wireless node was implemented using two XBee modules configured for peer- to-peer communication. A notification node consisting of a microcontroller, LCD and buzzer was implemented as a user interface to display the different water quality parameters. The buzzer was used as an audible alert when a specific parameter was at an unsafe level. The accuracies of the different sensors and other findings are as follows. Temperature sensor: 2.5◦C. Conductivity sensor: 14.71% (unverified). Flow sensor: 6.28%. pH sensor: 0.51. ORP sensor: 24.14 mV (uncalibrated). The raw sensor data was processed successfully. Wireless communication between the measurement and notification nodes with a maximum non-line-of-sight wireless range of 13 m was achieved. The water parameters were displayed clearly on the LCD and audible warnings were heard from the buzzer when parameter is at an unsafe level. Future work could include the design and implementation of a turbidity sensor, as this a also an important quality monitoring parameter. The current design is able to display the parameters in real-time, however a history of the readings is not available, thus data logging of the sensor measurements could also be considered.

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