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Design of Cost Effective Sensor Networks using Embedded System for Real Time Monitoring in Drinking Water Distribution Systems

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ABSTRACT: The paper proposes a design of cost effective sensor networks using embedded systems for real-time monitoring in drinking water distribution systems. It presents the various sensor devices connected to the systems in a lucid manner and updates the information to internet by the use of ETHERNET protocol and by using ZIBGEE to update in WEBPAGE. Data collected by various sensors at the node side such as ORP, pH, turbidity and oxygen level is sent via WSN to the base station. Data collected from the remote site can be displayed in visual format as well as it can be analysed using different simulation tools at base station. This proposed system has the compensation of significance such as low water contamination, zero carbon emission, mere power consumption, high elasticity to install at isolated spot and many more advantages.

KEYWORDS: Real Time Monitoring, Water Distribution Systems, Sensor networks, Ethernet, Embedded Systems, Zigbee.

I. INTRODUCTION

PURE drinking water is a significant source for the strength and safety to whole human beings. Drinking water utilities are facing new challenges in their real-time operation because of limited water resources, intensive budget requirements, growing population, ageing infrastructure, increasingly stringent regulations and increased attention towards safe- guarding water supplies from accidental or deliberate contamination. There is a need for better on-line water monitoring systems given that existing laboratory-based methods are too slow to develop operational response and do not provide a level of public health protection in real time. Rapid detection and response to instances of contamination is critical due to the potentially severe consequences to human health. Traditional methods of water quality control involve the manual collection of water samples at various locations and at different times, followed by laboratory analytical techniques in order to characterize the water quality. Such approaches are no longer considered efficient. Although, the current methodology allows a thorough analysis including chemical and biological agents, it has several drawbacks:

- The lack of real-time water quality information to enable critical decisions for public health protection of long time gaps between sampling and detection of contamination.
- Poor spatiotemporal coverage small number locations are sampled.
- It is labour intensive and has relatively high costs, labor, operation and equipment.

Therefore, there is a clear need for continuous on-line water quality monitoring with efficient spatiotemporal resolution. US Environmental Protection Agency has carried out an extensive experimental evaluation of water quality sensors to assess their performance on several contaminations. The main conclusion was that many of the chemical and biological contaminants used have an effect on many water parameters monitored including Turbidity, Oxidation Reduction Potential, Electrical Conductivity and pH. Thus, it is feasible to monitor and infer the water quality by detecting changes in such parameters. Given the absence of reliable, in-line, continuous and inexpensive sensors for

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monitoring all possible biological and chemical contaminants, our approach is to measure physicochemical water parameters that can be reliably monitored with low cost sensors and develop low cost networked embedded systems as well as contamination detection algorithms to fuse these multi-sensor data in order to 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.

The main contribution of this paper 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. In particular, the contributions regarding the low cost system is the design and development of low cost networked embedded systems as well as optical sensors for water quality monitoring, the development of event detection algorithms using fusion techniques and the experimental evaluation and validation of system performance in various concentrations of microbiologically and chemically contaminated drinking water.

II. RELATED WORK

In [1] – [4], the implementation of several on-line in pipe sensors that are used to determine the contamination of water has been discussed and the results were produced. By implementing the sensors with less cost than the entire system cost will get reduced. The information taken from each of the sensors are made available through the appropriate algorithmic techniques and are send directly to the mainframe computers without any kind of data loses and other packet switching losses. The data's are then transmitted to the system with increased efficiency. The message will also be sent to the mobile phones through GSM in case of any emergency. In [5] – [11], the paper presents the design of two portable and low-cost solutions for continuous monitoring of water quality. Firstly, we have explained the design of an autonomous mini boat aided autonomous water quality monitoring system for drinking water reservoirs. Then the purpose of using the non- portable devices with Ethernet line upon the sensor wireless network based interfaces for continuous monitoring of water quality. The paper presents the nonstop monitoring of the water quality by the need of real time monitoring system which enables us to find out the contamination present in the entire water. Then the cost was reduced by utilizing the non- identified cost imported by the system expenses. In [12] – [16], Sensor networks with battery-powered nodes can seldom simultaneously meet the design goals of lifetime, cost, sensing reliability and sensing and transmission coverage. The sensor networks with the determination of converting the normal mode of energy to electrical source has become major concern over the energy consumption techniques. By energy harvesting sensor nodes have the potential to address the conflicting design goals of lifetime and performance. This paper presents the various techniques of energy efficient systems and the energy storage systems with the new methods of harvesting the energy sources upon the available energy alternatives. This paper also illustrates the methods of analysing the sensor networks with the determination of the operating nodes of available sensor networks. In [17] – [20], the paper presents a low cost and holistic approach to the water quality monitoring problem for drinking water distribution systems as well as for consumer sites. Our approach is based on the development of low cost sensor nodes for real time monitoring and assessment of water quality on the fly. To observe the contamination factor in water, sensor setup is installed in water tank. The parameters such as temperature, turbidity, ph value of water which is very important and even water level of tank is monitored and all these data is transmitted to control room through zigbee wireless communication to alert the authorized persons. Voice speaker has been added which gives voice announcements for different thresholds and also the data has been updated to GPRS webpage.

III. SYSTEM IMPLEMENTATION

A. *BLOCK DIAGRAM:*

As we all know the invention of latest technology cannot be activated without the source of power. In this fast moving world we deliberately need a proper power which will be apt for a particular requirement. All the electronic or electrical components needs power supply of AC or DC supply. The overall system architecture under discussion in presented in and is comprised of the following three subsystems: a central measurement node (PIC32 MCU based board) that collects water quality measurements from sensors, implements the algorithm to assess water quality and

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transmits data to other nodes, a control node (ARM/Linux based plat- form) 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 (PIC MCU based board) that receives information from the central measurement node through an interconnected ZIGBEE RF transceiver and provides local near-tap notifications to the user (water consumer) via several interfaced peripherals (LED, LCD, Buzzer).

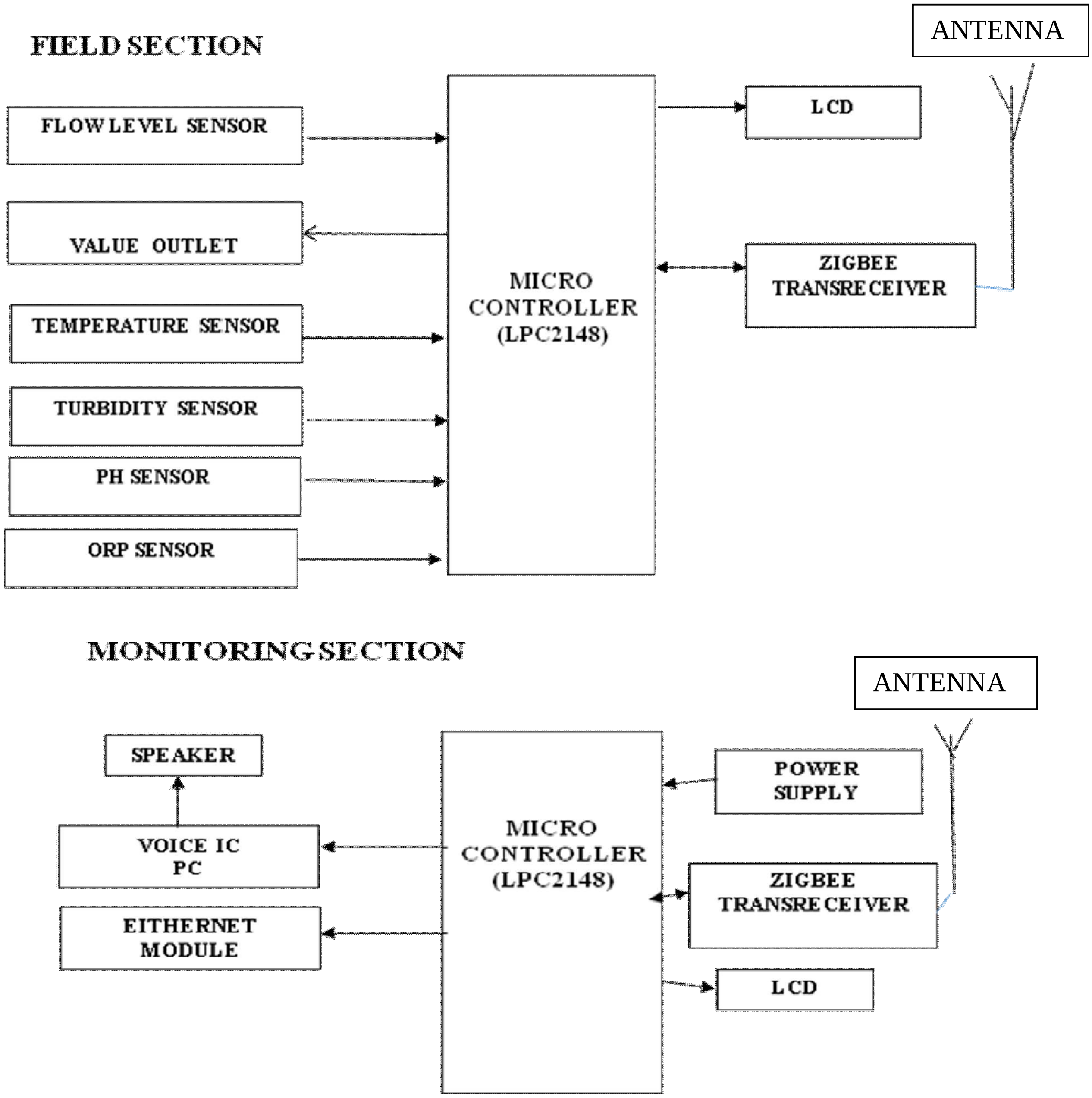

Fig.1. Block Diagram of the Proposed System

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B. ***BLOCK DIAGRAM DESCRIPTION:***

Block diagram of low cost sensor network for real time monitoring and contamination detection in drinking water distribution system consists of Water flow level sensor, Temperature sensor, Turbidity sensor, pH sensor, ORP sensor, Micro Controller, ZIGBEE, Voice Over pc and Ethernet module was shown in Fig 1.

C. ***WATER FLOW LEVEL SENSOR:***

The TurboFlow-226000 is a very simple to use, extremely high accuracy, and in-line flow meter. The TurboFlow-226000 Flow Meter can operate at pressure ranging from (0-200 psi) to 1,379 kpa. The output from the TurboFlow-226000 Flow Meter is in Hz from 0 - 345+ Hz. A pulse from the TurboFlow-226000 is a rising edge, followed by a falling edge was shown in Fig 2.

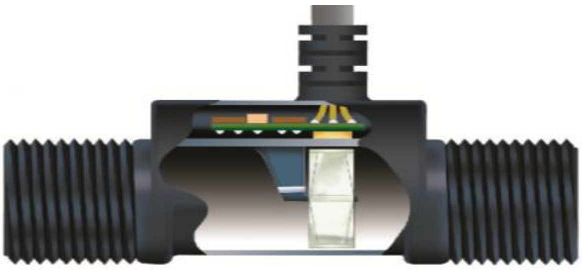

Fig.2. Water Flow Level Sensor

D. ***TURBIDITY SENSOR:***

Turbidity refers to how clear or how cloudy the water is; clear water has a low turbidity level and cloudy or murky water has a high turbidity level was shown in Fig 3. High levels of turbidity can be caused by suspended particles in the water such as soil, sediments, sewage, and plankton. Excess soil can enter a water body by erosion or runoff from nearby lands. Sediments can be stirred up by activity in the water, caused by organisms living in the water, humans, machinery, and powerful weather events. Turbidity is often measured to provide a quick estimate of the total suspended solids or sediments (TSS) concentration (in milligrams dry weight/L). If the turbidity level of the water is high, there will be many suspended particles in the water. These solid particles will block sunlight and can prevent aquatic plants from getting the sunlight they need for photosynthesis. The plants will produce less oxygen thereby decreasing the dissolved oxygen levels. The plants could die and decompose in the water, which will further reduce the dissolved oxygen levels.

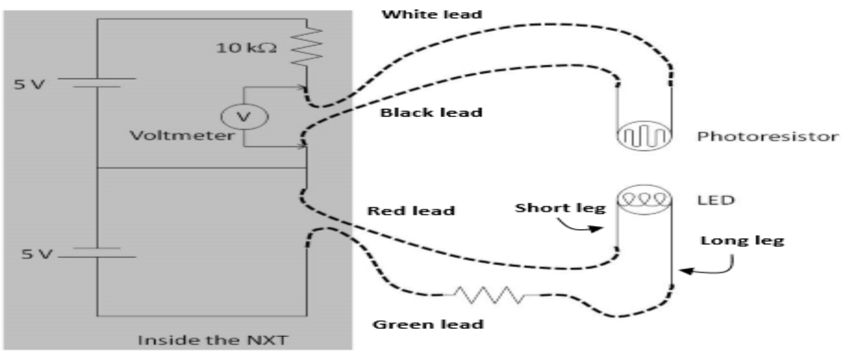

Fig.3. Turbidity Sensor

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IV. HARDWARE IMPLEMENTATION

E. *HARDWARE CIRCUIT DIAGRAM:*

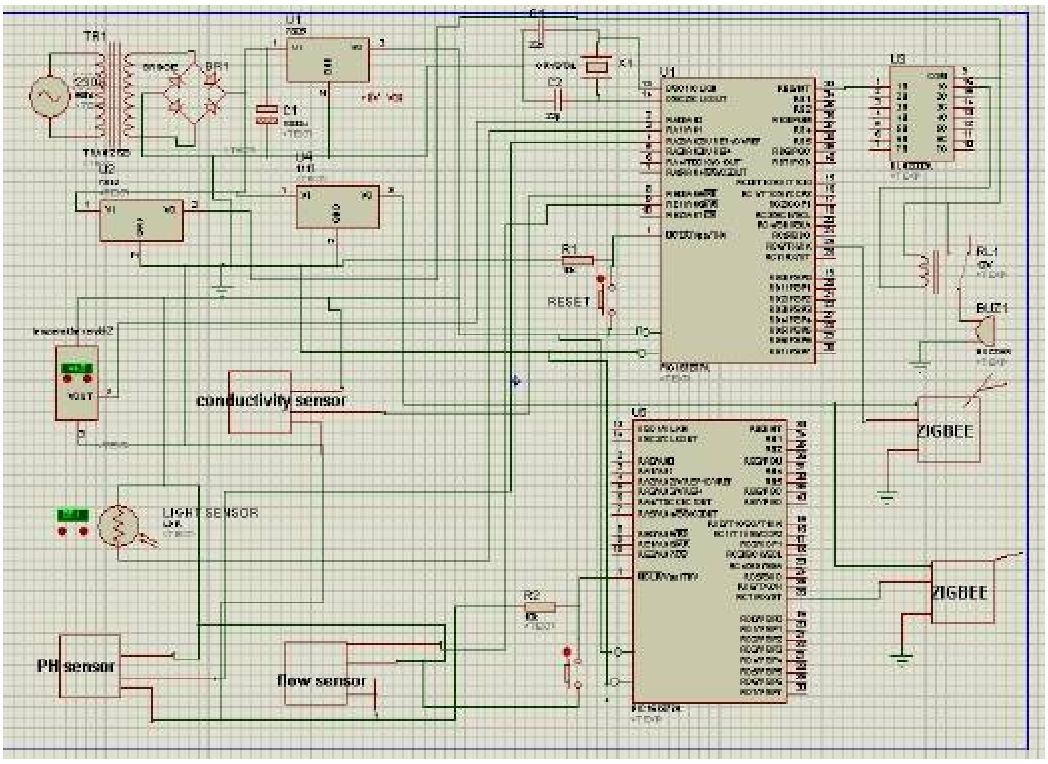

Fig.4. Hardware Circuit Diagram

The overall system architecture under discussion in pre- sented in Figure and is comprised of the following three subsystems: a central measurement node (PIC32 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 based plat- form) 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 ZigBee RF transceiver and provides local near-tap notifications to the user (water consumer) via several interfaced peripherals (LED, LCD, Buzzer) was shown in Fig 4. 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. The central measurement node is interfaced to multi-parameter sensor array comprised of Turbidity (TU), ORP, pH, Electrical Conductivity (EC) and Temperature (T) sensors. The in-pipe Turbidity sensor is constructed from scratch based on our previous work while the other sensor probes obtained from SensoreX Corp. The pH sensor embeds an RTD sensor which is used for temperature sensing and temperature compensation of pH and EC measurements. TU, ORP, pH and toroidal EC sensors have flat measuring surfaces for cost effective self-cleaning. Turbidity Sensor Development: Although there is plenty of turbidity measuring instruments available on the market at the moment, most of them are expensive and not directly compatible with in-pipe, in-line requirements as well as WSNs technology. Therefore, the goal is to develop a low cost, easy to use and accurate enough turbidity sensor for continuous in pipe turbidity monitoring in water distribution systems using commercial off-the self-components. An infrared (860nm) narrow beam LED emits light through an optical gap to the water sample and two IR photodiodes

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separated around 1cm from the emitter receive simultaneously the 90° scattered and 0° transmitted light. The photodiodes spectral sensitivity is selected to fit with that of the IR light source. The instrumentation and analog signal conditioning of the sensor is as follows: The IR emitter is pulsed at 1 kHz with a square wave signal and the photodiodes convert the light directly into electrical current, then a high-gain, low-noise CMOS (Complementary metal-oxide-semiconductor) transim- pedance amplifier with background light rejection is used to convert the each photocurrent to voltage output. The ac output of each transimpedance amplifier is then converted to a dc signal using a precision active peak detector. Finally the 90° scattered dc signal is further conditioned by an instrumentation amplifier for 0 NTU offset nulling and additional amplifica- tion. The conditioned voltage outputs are then sampled by a 10 bit A/D converter with reference voltage of 1.1V and the sensor output voltage V = V90° c.V0° is given as the signal ratio of the scattered V90° to the transmitted V0° voltage, c is calibration coefficient.

V. RESULTS AND DISCUSSION

F. *HARDWARE RESULTS:*

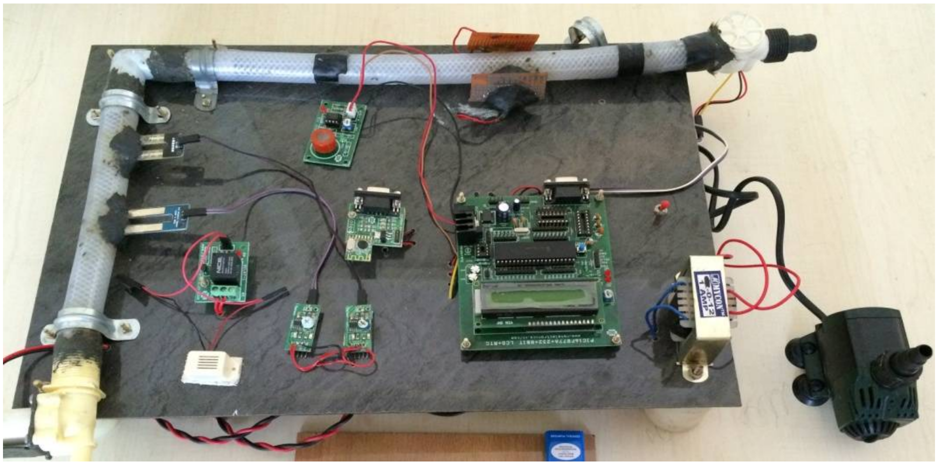

Fig.5. Hardware Result of the Proposed System

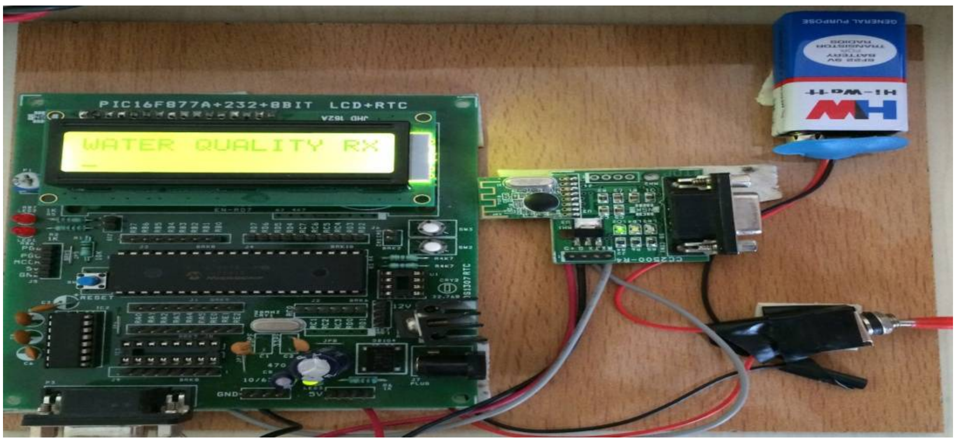

Fig.6. Hardware Result Notification using LCD Display

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G. *DISCUSSION:*

- The value of Ph sensor is 75
- The value of ORP sensor is low
- The value of Turbidity sensor is 0.53

These values are obtained from the hardware results which were shown in the Fig 5 and Fig 6 respectively.

VI. CONCLUSION AND FUTURE WORK

In this paper, the design and development of a low cost sensor node for real time monitoring of drinking water quality at consumer sites is presented. The various sensors are used in this system to check the quality of water without the contamination using the efficient knobs. 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. This efficient approach was most appropriate using embedded system technology with real time system for huge quantity of water resources available via companies and repellent authorities. In 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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BIOGRAPHY

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