

Cost Effective Fluoride Level Detector for Well Water

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Abstract – Fluoride is a chemical that humans need at a specified level. The content of fluoride in water varies by region with dry zone generally having higher fluoride level than the average level in wet zone. The fluoride level in well-water will depend on the nature of the rock near the well and the presence of fluoride-bearing minerals. When fluoride levels are above the Maximum Contaminant Level (MCL), health department or local water systems authority must take steps to reduce the amount of fluoride.

Even though there is a requirement for the government to monitor private wells to assure acceptable water quality, such monitoring in practice does not take place due to logistics issues and the high cost of the monitoring devices. We propose a solution to this problem by introducing a cost effective system that can accurately measure the fluoride content in the water and send such measurement data to a central location for analysis purposes. The system comprises a monitoring device, a communication link and central server that logs data for analysis. The ability to remotely collect data from large number of places would allow a more detailed analysis into the variation of fluoride levels and its underlying causes. This instrument uses the similar analytical method uses in the laboratory where a LED and a photo diode light intensity sensor to determine the concentration of fluoride. A pre-calibrated graph of voltage vs. fluoride concentration is used to detect fluoride level of the water tested.

Keywords: Fluoride concentration, well water, remote data acquisition

1 INTRODUCTION

Fluoride is a natural substance that comes from the element fluorine, which is found naturally in rocks and soil. Water passing through the earth absorbs the naturally occurring fluoride and as a result, most water contains some amount of fluoride. Due to the above process, groundwater typically contains more fluoride than surface water. The content of fluoride varies by region with dry zone generally having higher fluoride levels in their water than that of wet zone. Due to the direct impact on human health, there is a need to monitor quality of well water (E.g. Fluoride level). Monitoring of Fluoride concentration in well water poses a challenge due to depth of the well and seasonal changes that occur. Fluoride occurs naturally in most groundwater and as per existing literature, their levels range from 0.1 to 15 parts per million (ppm) [Dissanayake, 2005]. The fluoride level in well-water depends on the nature of the rock near the well and the presence of fluoride-bearing minerals. According to the WHO standards consumption of

water with Fluoride concentration above 1.5 mg/l results in acute to chronic dental fluorosis where the tooth colour becomes brown from yellow. This WHO danger level of 1.5 mg/l is not suitable for Sri Lanka as the individual consumption of water in a tropical and humid environment is much higher than that in the more temperate lands. Researchers find this danger level is 0.6 mg /l in the dry zone of Sri Lanka (Dissanayake, 2005). In the context of Sri Lanka, the Maximum Contaminant Level (MCL) then becomes 0.6 mg/l.

Exposure to excessive consumption of fluoride over a lifetime may lead to increased likelihood of bone fractures in adults, and may result in effects on bone leading to pain and tenderness. Children aged 8 years and younger exposed to excessive amounts of fluoride have an increased chance of developing pits in the tooth enamel, along with a range of cosmetic effects to teeth. When Fluoride levels are above the MCL, health department or authorities managing local water systems must take steps to reduce the amount of fluoride so that it is below that level. Since Fluoride is present in virtually all waters at some level, it is necessary to have a mechanism to monitor the level, particularly in well water where higher Fluoride levels can have a severe impact on humans. Testing individual well water quality on a regular basis is important for maintaining a safe and reliable water source. Awareness of water quality allows overcoming specific problems of a water supply through appropriate interventions. This will help to ensure that the water source is being properly protected from potential contamination, and if not appropriate treatment or action can be taken place to avoid health risks. Lack of such mechanism is quite evident today due to higher cost of monitoring devices and also the logistics issues related to manual monitoring mechanism. Neither the government nor the people in affected zones can afford such costly monitoring systems. However, it is important to test the suitability of water quality for its intended use, whether it is livestock watering, or drinking water. Recent advances in electronic and communication through sensor technology have Catalyzed progress in remote monitoring capabilities for water quality. Real-time remote monitoring and sensing technologies becomes a progressively more important tool for evaluating water quality (Glasgow et al, 2004; Storey et al, 2011)

This study proposes a cost effective system that can accurately measure the Fluoride content in the water and send such measurement data to a central location for purpose of analysis. The system comprises a monitoring device, a communication link and central server that logs data for analysis. The ability to remotely collect data from large number of places would allow a more detailed analysis into the variation of fluoride levels and its underlying causes. This instrument uses the similar analytical method used in the laboratory where a LED and a photo diode light intensity sensor to determine the concentration of fluoride.

Various methods have been used for measuring the fluoride content of water samples. The most commonly used methods are Ion Specific Electrode (ISE) method and SPADNS reagent method (colorimetric method). In ISE method, the ion selective electrode incorporates a special ion-sensitive membrane which may be glass, a crystalline inorganic material or an organic ion-exchanger. The membrane interacts specifically with the ion of

choice, in this case fluoride, allowing the electrical potential of the half cell to be controlled predominantly by the F⁻ concentration. The potential of the ISE is measured against a suitable reference electrode using an electrometer or pH meter. In the SPADNS method, Fluoride reacts with a dark red Zirconium dye lake to form a colourless complex and another dye. The dye becomes progressively lighter as Fluoride concentration is getting high. This colour change is measured using a colorimeter, simple photometer or by comparing the colour intensity with the colour scale. The SPADNS method is used in this work due to its cost effectiveness and ease of implementation (Burton et al., 1992)

2 METHODOLOGY AND SYSTEM OPERATION

The proposed system complies mainly two sub systems namely Data Acquisition System (DAS) and remote device. Fig. 1 shows the functional block diagram of the proposed system.

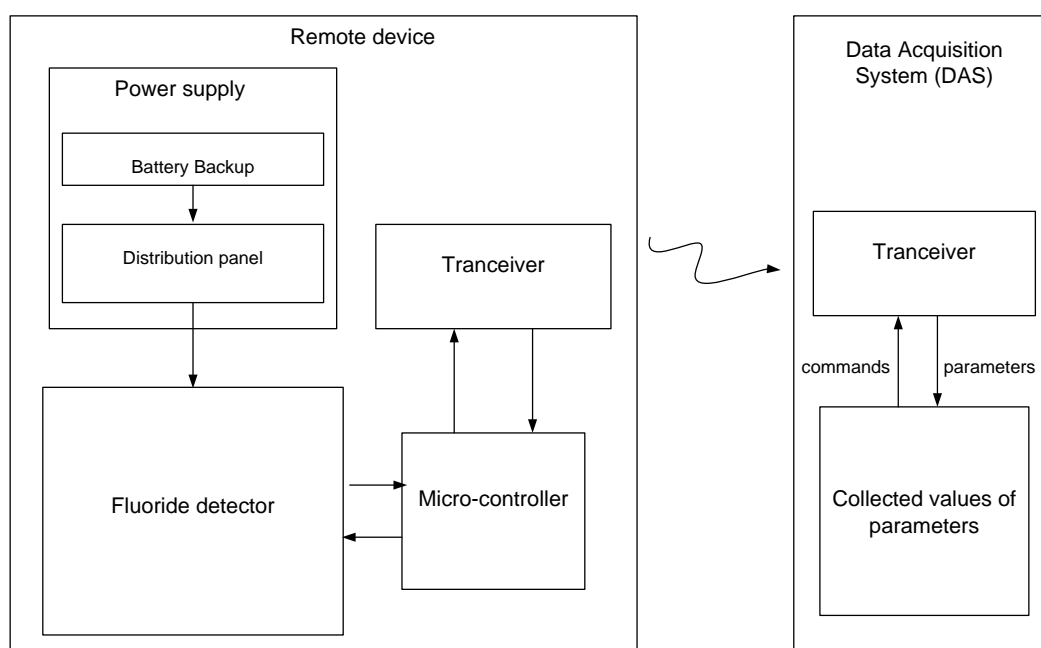


Fig. 1 Functional block diagram of the proposed system

2.1 Data Acquisition System (DAS)

DAS can be considered as the brain of the system. It consists of a PC and a transceiver through which the data of the remote device can be accessed. In this experimental prototype, Bluetooth technology is used for communication link, however it can be easily replaced with a GSM module for expanding the accessibility. DAS has a graphical user interface (GUI) to operate the system. Functions of this DAS are sending commands to the remote device, acquiring data from the remote device and analysis of the received data. When the user clicks on the start button, the program sends the command to the device via the transceiver and waits until it receives the digital signal from the sensing part of the device. These signals are compared with the data included in the system and corresponding values of the parameters are displayed on the GUI. All data can be represented in graphs, data sheets, and references and are saved for future references.

Remote Device

Remote device has 4 main parts, namely, power supply, microcontroller, Fluoride detector and the transceiver. Once the transceiver receives the command signal from the DAS microprocessor sends commands to the Fluoride detector. Once all the processing is completed, results are sent to the DAS via the transceiver. In order to save power, the remote device will go to sleep mode until the next command from DAS is received.

Fluoride detector

The block diagram of the Fluoride detector is shown in Fig. 3. It has four main parts in its operation, namely, Water Pump, Fluoride meter, Colorimeter and Washer. Fluoride detector begins its operation when a control signal is received from DAS. To carry out the Fluoride testing a 10 ml water sample is mixed with a 2 ml Fluoride reagent. A LED and a photo diode light intensity sensor are used to measure the output voltage of the resultant colour which changes with the concentration of fluoride. Using an early calibrated graph of voltage vs. fluoride concentration, the fluoride concentration present in water sample is detected.

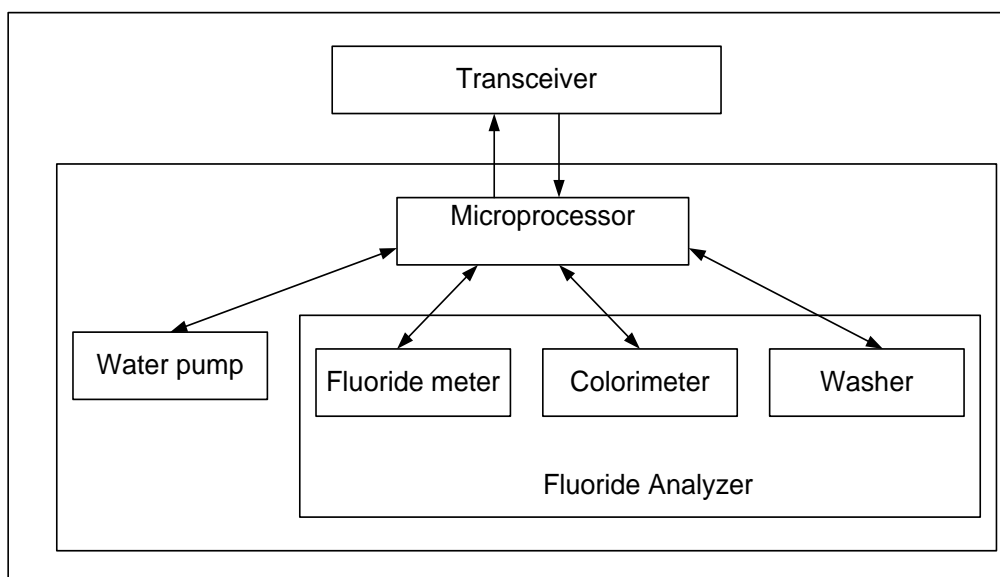


Fig. 2 Block diagram of the Fluoride detector

Automated Fluoride Detection process is as follows: 1. Washing of test tube prior to the collection of water sample. 2. Water sample is taken from the storage to a standard sized (10ml) test tube. 3. Addition of 2ml of fluoride reagent. 4. Passing of light through the solution and detect the output voltage of LDR according to the colour intensity. 5. Transmission of the value to the DAS. 6. Disposing of the resultant water to a safe place. 7. Washing of the test tube fully with the remaining water in the storage.

Light sensing device

Light sensing circuit consists of LED and Photo Diode (Fig. 3). After the reagent is added to the system this circuit is switched on by applying a pulse to the gate of MOSFET. The output intensity of LED will vary according to the colour of the solution. This colour

intensity can be identified by a photodiode and a voltage is produced by the circuit. The voltage is proportional to the fluoride concentration.

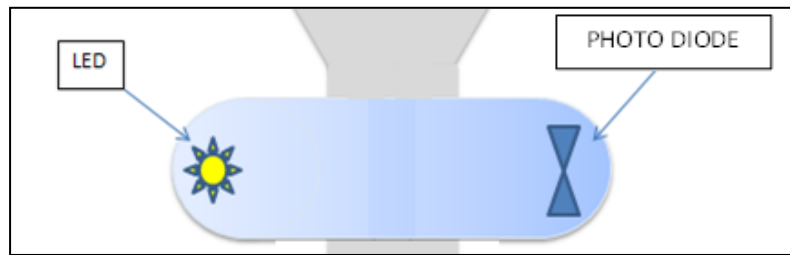


Fig. 3 LED and Photo Diode arrangement in the Light Sensor

Level detectors

A glass funnel is used as the sample collector. Level detector probes and light sensor arrangements are shown in Fig. 4. The outlet of the funnel is fixed with the solenoid valve. The light sensor is fixed to the outer surface. All level detectors are placed inside the funnel. To carry on the fluoride test it is required to mix 10ml of water and 2ml of fluoride reagent. To make sure the reagent is well mixed with water, level detectors are marked at 5ml, 7ml and 12ml levels. Water is filled up to 5ml level and then the reagent is filled up to 7ml level. Finally water is filled again up to 12ml level. These marked levels were detected using timer delays by the microcontroller.

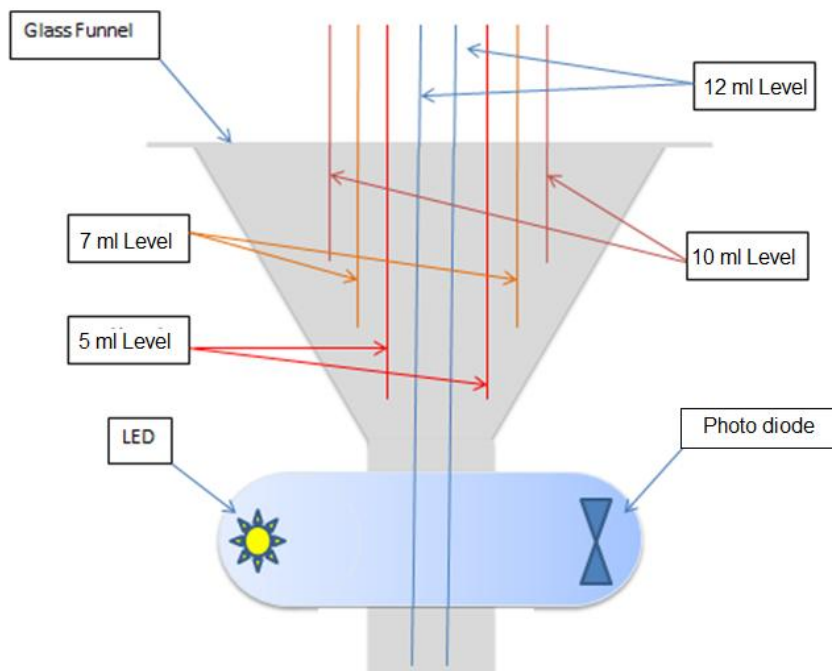


Fig. 4 Level detector probes and light sensor arrangements

Operation of Water Pump

The device can be mounted on the top of the well and it needs a pump to get water from the well or detector can be placed on top of the water level as a floating device. Since the resultant solution has to be safely disposed, the water pumping system is needed and the safest and maintainable way is to have the device fixed on the top of the well. Storage tank volume of the water pumping device is designed to store water to fulfill amount of water required to whole process. Solenoid valves are used to control the water flow and are in normally close position when no current is applied. A simple MOSFET biasing circuit is used to control the valves.

3 TESTING & RESULTS

The prototype was tested under the laboratory conditions. When the LED is switched on, the photodiode detects the intensity of the light and change its resistance resulting in a voltage change in the output of the circuit. To find the output voltage change according to the concentration of the Fluoride, known concentrated NaF solution was prepared. The output voltage vs. the concentration of the fluoride was tabulated in Table 1 while Fig 5 shows the graphical representation.

Table 1 Output voltages of Photodiode circuit for known concentrated NaF solution

Concentration (ppm)	Output Voltages (mV)
0.1	1630
0.2	1110
0.3	1000
0.4	900
0.5	800

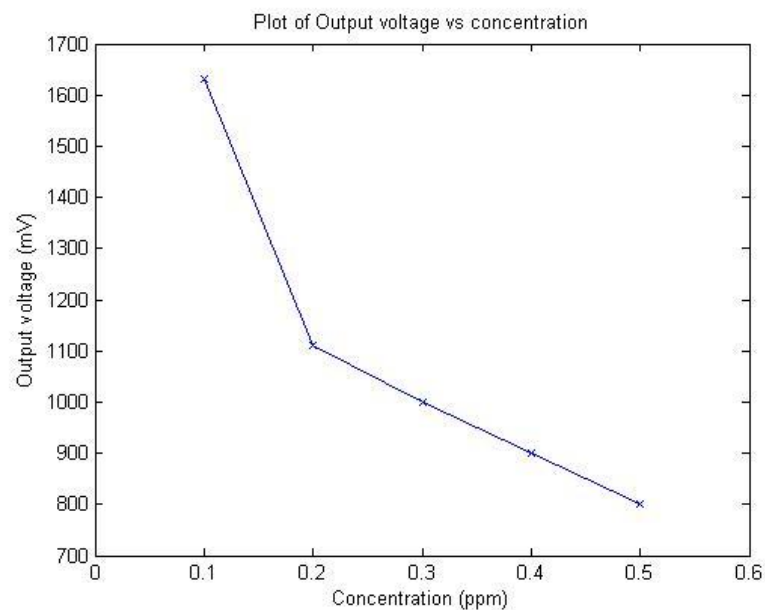


Fig.5 Variation of output voltage vs the known concentration of NaF

Based on the preliminary experiments conducted, the fluoride concentration vs voltage graph appears to be piece-wise linear. More experiments are required to determine the actual relationship between these two parameters.

4 CONCLUSIONS / RECOMMENDATIONS

The research objective of this work was to develop a cost effective mechanism for remote monitoring of Fluoride levels of well water. This paper explains the development of the cost effective fluoride detector with remote data acquisition device. However, more onsite investigations are required to establish the relationship between actual level of Fluoride and the sensor data. Calibration based on highly accurate values from advanced measuring equipment can lead to accurate values from this cost effective device. From a product perspective, only refill cost of reagent is required for the operation after the initial investment and also reuse of the reagent leads to a lower operational cost.

The main advantage of this device is the ability to reuse the hardware as the necessary cleaning happens automatically at regular intervals. A single test requires 2ml of fluoride reagent. Fluoride reagent storing tank can store up to 500ml of fluoride reagent solution. Therefore it is possible to use this detector up to 250 times without refilling the reagent. The solution was designed as an easy to use device from a user point of view. The operation does not require human intervention as this device automatically collects the water sample. Since the collection of sample is automated, the collecting procedure does not change from time to time and thus the standard is maintained. As this tester is attached to a fixed device (Data Acquisition and Measuring Device), testing can be carried out remotely. Time and cost spent for sample collection and analysing is greatly reduced by the remote accessing method and self-operated laboratory procedures. As this device is attached to Data Acquisition and measuring Device, there is no need for manual graph referring, calculation or observations to obtain the results.

Future work

For the trial, a glass funnel available in the market was used as the sample collector. This can be replaced by a good quality less absorption glass so that a higher accuracy can be obtained.

The device can be used to test additional parameters with minor modifications. Some heavy materials are capable of absorbing certain light wavelength (e.g. Fluoride can absorb 580nm yellow light). Hence a relevant wavelength emitting colour LED is required. A multi-colour LED can be used for this purpose. And additional storage of reagent for relevant parameter is required to be added. The same colour intensity sensing arrangement can be used to detect the colour level of the water.

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