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Estimation of nitrate in water samples using microcontroller

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Abstract

A simple and cost effective colorimetric spectrophotometer for determining nitrate levels in water samples has been developed. The system consists of an ultra blue LED as the light source, sample holder, a photo diode as the detector and micro controller for acquiring and processing the data. The system is working on the principle of Beer-Lambert's law. The hardware and software details of the proposed system are presented. The stability and performance of the developed system is investigated by obtaining the calibration curve for standard nitrate solutions. The nitrate levels in water samples were also measured by the system designed and compared with the values obtained by a conventional spectrophotometer.

Keywords : Beer-Lambert's law, microcontroller, nitrate, photodiode, ultra blue LED

INTRODUCTION

Nitrate is an important chemical that plays a vital role in agricultural environment. The main sources that contribute to nitrate content of natural waters are atmosphere, geological features, anthropogenic sources, atmospheric nitrogen fixation and soil nitrogen. Sources that cause excess nitrate in water include fertilizers, septic systems, wastewater treatment lagoons, animal wastes, industrial wastes and food processing wastes. Nitrate enters human body through drinking water, food and air. Ingested nitrates are converted into nitrites by microflora, which lead to methaemoglobinemia, increased free oxide radicals that predispose cells to irreversible damage and effects cancer, abortions, diarrhoea and deterioration of immune system of the body (Gupta *et al.,* 2008). A test for nitrates in water is highly recommended for households with infants, pregnant women, nursing mothers and elderly people (Campell *et al.,* 2000). Concern over nitrate contamination is growing, and a safe, accurate, and reliable nitrate concentration measurement device may play a role in improved monitoring and control of the release of nitrate into the environment. So, an attempt has been made to develop a low cost optoelectronics system that can be used for the estimation of nitrate in water samples, and this paper presents the design and development of an inexpensive and simplified spectrophotometer with ultra blue LED operating at 430 nm as a source and a photo detector as a detector. LEDs have been employed in a wide variety of chemical sensors for environmental monitoring due to their many advantageous characteristics. The advancement in LED source and photo detector technologies provides a solution to issues of compactness and they are low power and low cost detectors for incorporating into colorimetric analytical methods (Sequeira *et al.,* 2002). The developed system can be used in field applications to monitor nitrate in water samples. For use in field applications, the developed system is calibrated with standard solutions of Nitrate.

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DESCRIPTION OF THE EXPERIMENTAL SET UP

The block diagram of the experimental set up is shown in figure 1. The system hardware consists of an ultra blue LED, photo diode, signal conditioning circuit and ATmega8535microcontroller. Figure 2 shows the circuit diagram of the measurement system. The classic tungsten filament lamp which is the most commonly used light source for visible radiation is replaced with LED and it emits continuous radiation of 430 nm of wavelength. A photo diode used as a sensor detects the incident light and converts it into current. The photo detection assembly is well insulated from external light. A black casing ensures isolation from the ambient light. The output current of photodiode is suitably transduced to a voltage signal using signal conditioning circuit. The subsequent conditioning circuit is based on the gain offset amplifier, which adapts the voltage range to the analog to digital converter full scale value and an RC low pass filter reduces the noise from the photodiode and the power supply. The output signal is input to one of analog input of ATmega8535, an electronic gadget (embedded system) wth 8K bytes of In-System Programmable Flash with Read-While-Write capabilities, 512 bytes EEPROM, 512 bytes SRAM, 32 general purpose I/O lines, 32 general purpose working registers, three flexible Timer/Counters with

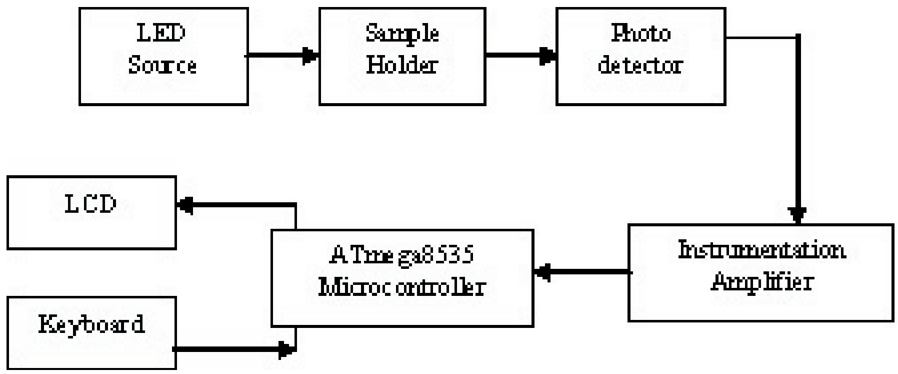

Figure 1. Block diagram of the instrument system

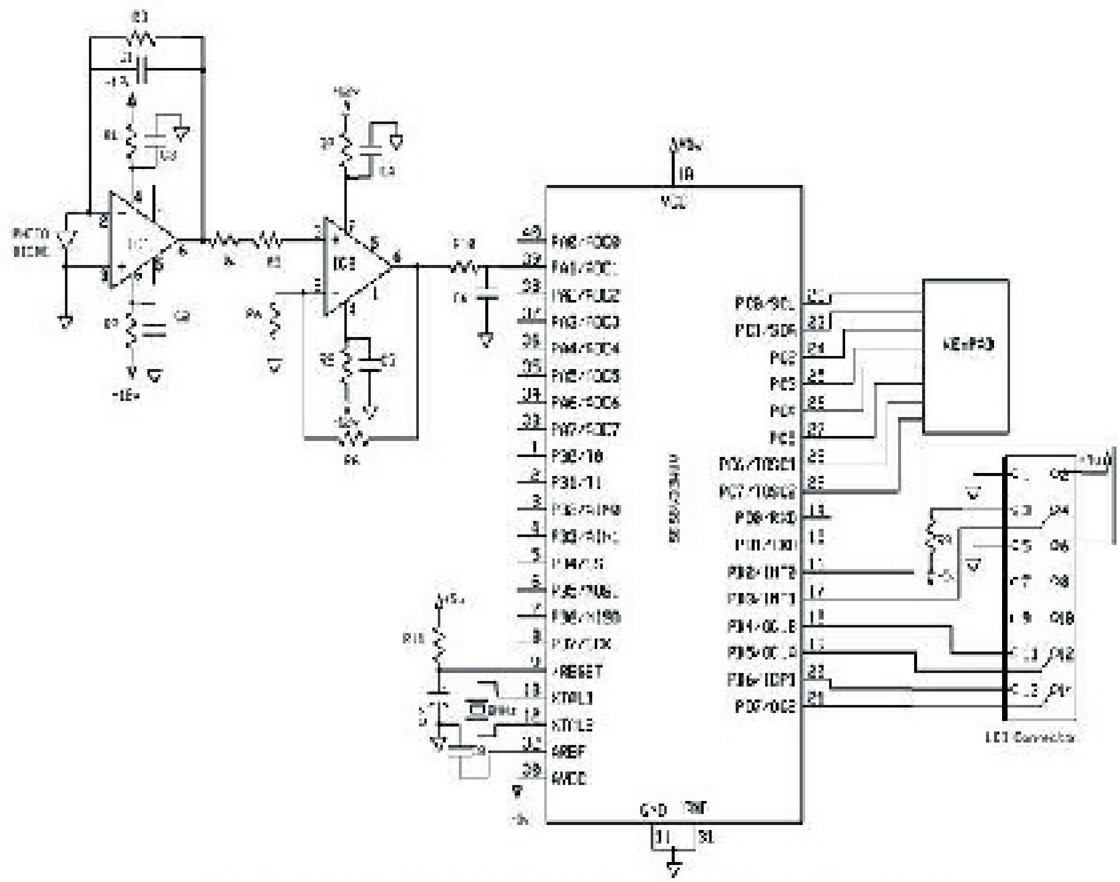

Figure 2. Circuit diagram of the measurement system

compare modes, internal and external interrupts, a serial programmable USART, a byte oriented Two-wire Serial Interface, an 8-channel, 10-bit ADC with optional differential input stage with programmable gain [ATMEL datasheet]. An LCD display is employed to display the user information, measured data and results. The keyboard enables the user to enter the experimental variables and modes of operation into the system.

MATERIAL AND METHODS

To test the efficacy of the device developed in measuring concentration of nitrate, water samples were collected at various places and stored in well-cleaned containers. The wavelength of LED is chosen to fit the absorption band of chemical reagents which develop colour by reaction with water samples. Nitrate reacts with phenol disulphonic acid and produces a nitro derivative which in alkaline solution develops yellow colour. Five ml of water sample was taken and to this 2 ml of phenol disulphonic acid solution was added and mixed well. Then 10 ml of KOH solution was added. To avoid turbidity 10 ml concentrated NH_4OH may be added instead of KOH. Blank solution is prepared in the same way using distilled water. Standard solution is prepared using KNO_3 solution. Chlorides and Nitrite are two main sources of interference and so the samples were pretreated as per Bear (1964) before taking measurements. By placing the blank, standard and sample solution in a sample holder, the voltages (V_{blank}), (V_{std}) and (V_{sample}) are measured by the microcontroller , respectively and the concentration of the sample was computed using the following relationship. Concentration of the sample (mg/dl) = Log10 (V_{blank}/ V_{std})/ Log_{10} (V_{blank}/V_{sample}) x Concentration of standard solution.

A software is developed in C language to initialize LCD display, read data from the keyboard, measure analog voltage, and measure the data for blank, standard and sample solutions, compute absorption and hence concentration, store the data and display the results. The software is an integral part of any microcontroller-based system and demands equal importance as that of hardware. The flow chart of the measurement system is shown in figure 3.

RESULTS AND DISCUSSION

The concentration of nitrate in water samples, which are collected at various places, was measured using the Instrumentation System developed. Table 1 and Table 2 compare the concentrations of nitrate in drinking water and drainage water samples, respectively, using the developed system and spectranic21 analyzer. It is found that the concentration measured using the developed instrument is close to the concentration measured by the commercial equipment. As such the developed system could be used for the assay of nitrate in water samples and has enough sensitivity compared to the conventional spectrophotometric method. The construction of such system depends upon the availability of a low cost and low power source and a simple compact optical system with effective background correction. From the analytical point of view, a colorimetric absorption spectrometer with an LED seems to be very attractive in the development of a small analyzer with simple components. Its advantages over conventional spectrometers with an incandescent bulb as the light source are easy operation, portability and simplicity of electronics and optical alignments on the contrary, the conventional stationary systems are relatively large, heavy and costlier.

Table 1. Comparison of concentration of nitrate in drinking water at various places obtained by the system developed and spectronic 21 analyzer

Samples	Concentration of Nitrate (mg/l)	
	Developed system	Spectronic21 analyzer
S1	0.615	0.581
S2	0.680	0.664
S3	0.784	0.748
S4	0.839	0.829
S5	1.450	1.333
S6	1.890	1.825

Table 2. Comparison of concentration of nitrate in drainage water at various places obtained by the system developed and spectronic 21 analyzer

Samples	Concentration of Nitrate (mg/l)	
	Developed system	Spectronic21 analyzer
S1	1.613	1.580
S2	2.115	2.004
S3	2.463	2.328
S4	2.566	2.503
S5	6.283	6.185

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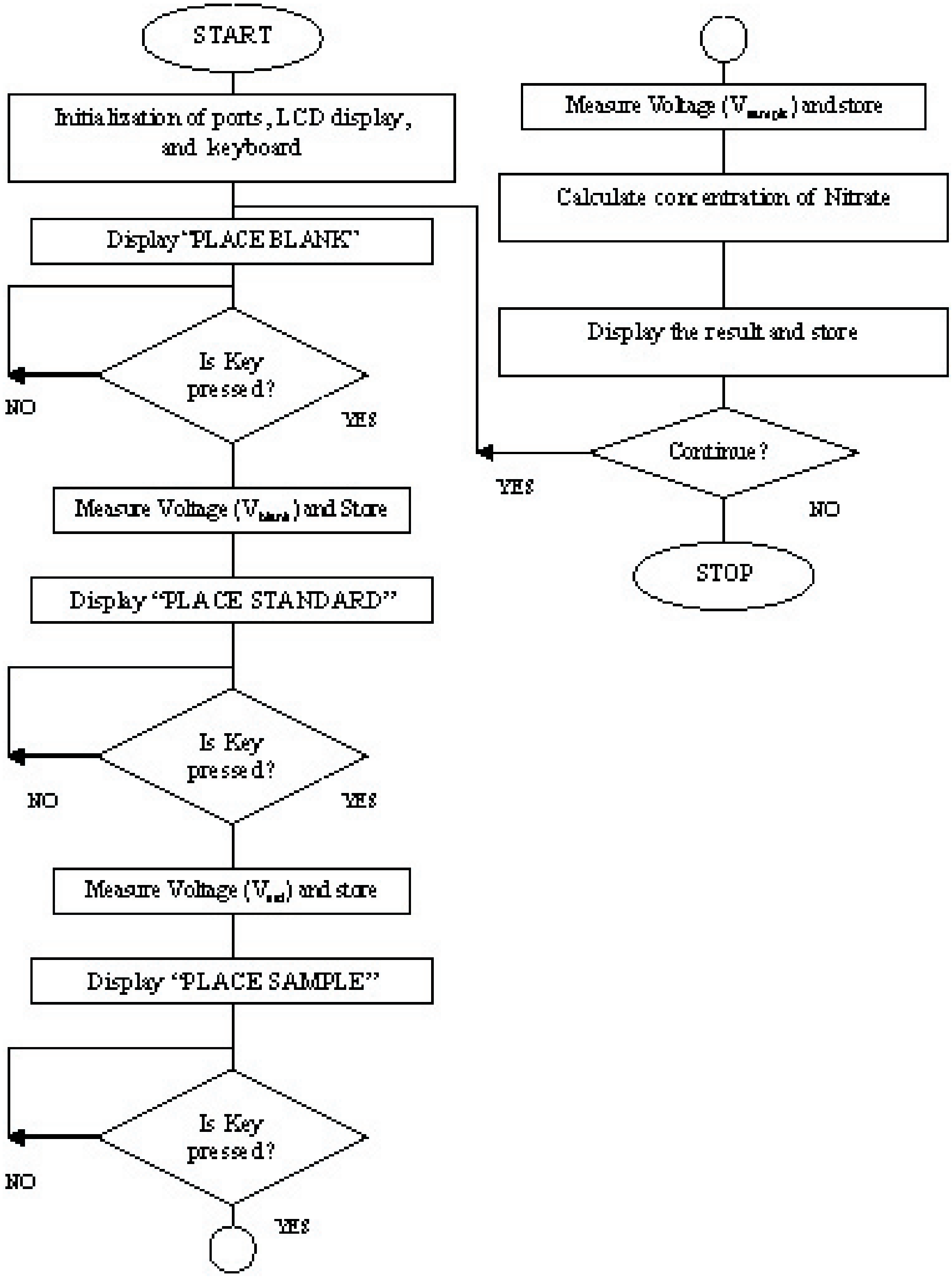

Figure 3. Flowchart for overall measurement system

encouragement.

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