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Design and Construction of Cost Effective Turbidimeter to be Used in Water Purification Plants in Sri Lanka

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ABSTRACT

The present research is designed to implement an automated system to monitor the turbidity level in water purification plants managed by the National Water Supply & Drainage Board (NWSDB), Sri Lanka. The system is able to measure the turbidity level in flowing water. This is in contrast to the current practice being adapted by the NWSDB in their plants in which the quality parameters are checked by manually before the distribution. The turbidimeter that has been designed and constructed for this purpose basically consists of an array of photodiodes to detect the light from reflected and scattered particles in water [1] that is being processed at the purification plant, and signal processing electronics. The automation is done using a PIC 16F877A microcontroller.

Turbidimeter has been calibrated by using a commercial turbidimeter. For this purpose, the turbidity of water in Nephlometric Turbidity Unit (NTU) values have been measured for different concentration levels. The accuracy of the instrument was checked with NTU versus Total Suspended Solids (TSS) curve, and the sensitivity has been improved by hardware design.

The relationship between NTU and TSS formula is used to deduce the corresponding value of NTU for the instrument. Results show that the characteristics of the constructed turbidimeter are in par with the commercial instrument.

1. INTRODUCTION

Turbidity is a measure of cloudiness of water which causes light to be scattered and absorbed rather than transmitted in straight lines. The cloudier the water, greater is the turbidity [2]. Turbidity in water is caused by suspended matter such as clay, silt, organic matter and by planktons and other micro-organisms that interfere with the passage of light through the liquid.

According to the Environmental Protection Agency, turbidity is the cloudy appearance of water caused by the presence of suspended and colloidal matter. In the waterworks field, a turbidity measurement is used to indicate the clarity of water. Technically, turbidity is an optical property of the water based on the amount of light reflected by suspended particles. Turbidity cannot be directly equated to suspended solids because white particles reflect more than dark-colored particles and many small particles will reflect more light than equivalent large particles.

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The monitoring of the purification level of drinking water in purification plants is an essential process, and it can be done either through continuous measurements or sampling of water at regular intervals. The turbidity level of drinking water in purification plants in Sri Lanka is measured manually at regular intervals. The standard set by the National Water Supply & drainage Board, Sri Lanka for turbidity of drinking water is that it should be below 2 NTU. The purpose of this study is to implement an automated system which is capable of measuring the turbidity levels below this value.

2. CONSTRUCTION OF THE DETECTOR ARRAY

Most commercial turbidimeters are designed for measuring low turbidities that give comparatively good indications of the intensity of light scattered in one particular direction, predominantly at right angles to the incident light. Turbidimeters with scattered light detectors located at 90^0 to the incident beam are called nephelometers. Fig. 1 shows basic components used in the present detector system.

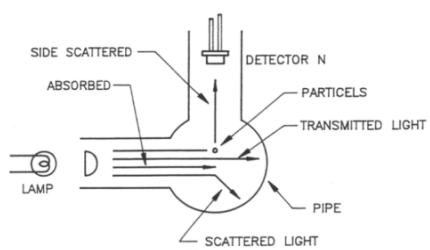

Fig. 1: Schematic view of a single cell of the detector array showing 90^0 scattering

3. LIGHT SOURCE

A diode laser source of high directivity and relatively high light intensity is used to improve Noise to Signal Ratio (NSR). The semiconductor laser produces red light (670 nm) and has low power consumption [3]. Maximum efficiency of the system is obtained when the source and detector are well-matched and their spectral curves have maximum overlap. The red laser pointer with 650nm range is allowed to use within the wide photodiode sensitive region. The wavelength of laser is around 650 nm and it can be detected by photo diodes. Selected light source and detectors are compatible for designing a turbidimeter.

Proceedings of the Technical Sessions, 28 (2012) 65-70
Institute of Physics – Sri Lanka

4. CONSTRUCTION OF THE SYSTEM

One of the designing objectives of this turbidimeter is to measure the turbidity level of continuous water flow which is to be achieved by a constant head. Collimated red laser beam is used as the light source [1]. Monochromatic light source is preferred in this design over an incandescent lamp to avoid limitations caused by the latter [4]. Photodiodes are housed in a cylindrical enclosure to avoid exposing them to ambient radiations (See Fig. 2). Water outlet and laser beam are located in same straight line and a long tube is connected with outlet to pass light beam with multiple reflections to avoid backward reflections of laser light in to the sensor array. Sensor outputs are added and amplified by an amplifier circuit made of 741 IC. The amplified signal is then fed into the analog pin of the PIC which is available at the base station.

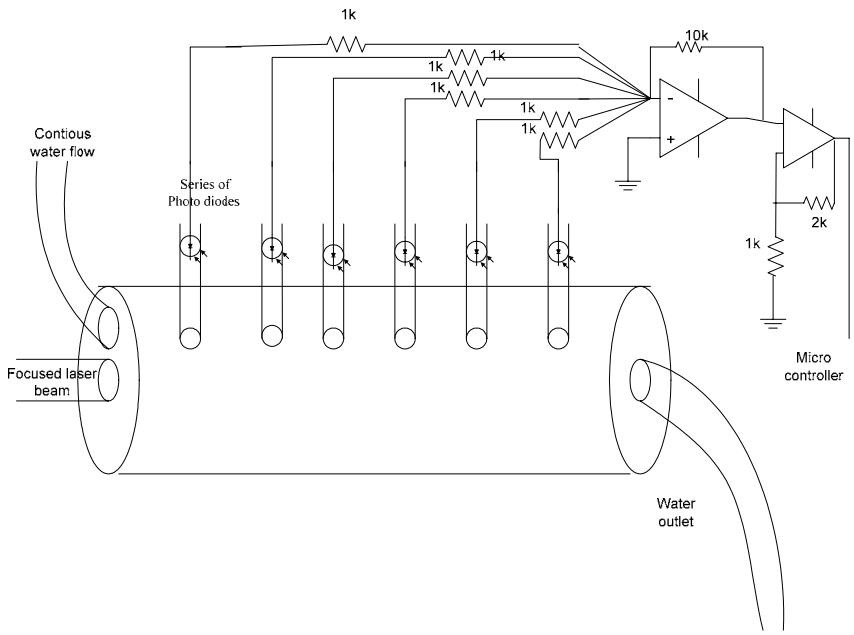

Fig. 2: Experimental apparatus for turbidity detection

4.1 Nephelometry

There are various parameters which can be associated with water quality. One of the common variables often measured and correlated to water quality is the Total Suspended Solids (TSS) capacity per unit liter of pure water (mg/l). On the other hand, water quality can also be represented in its appearance, which relates to its clarity and it is specifically defined as turbidity with the standard unit of measurement in NTU [4]. Through the experiments, it is found that turbidity has a strong relationship with TSS [4], as stated by equation 1,

$$\mathrm{NTU} = a\,(\mathrm{TSS})^{b} \qquad (1)$$

Where *a* and *b* are regression- estimated coefficients and b is approximately equal to one for all particles.

Proceedings of the Technical Sessions, 28 (2012) 65-70
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4. 2 Relationship between turbidity and TSS

Relationship between NTU and TSS has been obtained experimentally for the present system. For this purpose, water samples with different TSS were prepared to calibrate the instrument. For each and every sample NTU was measured by means of the constructed turbidity meter and the corresponding TSS was calculated by using the following standard method.

4. 2.1 Determination of total suspended solids (TSS)

The weight of a filter disk was recorded to nearest 0.001g (B). Accurately measured 50 ml sample was taken. Filter disk was placed on a clean watch glass and the watch glass and disk were then placed in a drying oven at 103 ^{0}C for one hour. Watch glass and disk were subsequently removed and placed in desiccators and allowed to cool to room temperature. Carefully removed filter from the watch glass was placed in an analytical balance to measure its weight to nearest 0.001g (A). Then,

$$\text{TSS (mg/l)} = (A - B) \times \text{dilution factor} \qquad (2)$$

Where, A = total weight of the filter disc with solids
B = initial weight of the filter disk

5. RESULTS AND DISCUSSION

Fig. 3 shows the graph of Turbidity in NTU units versus Total Suspended Solids (TSS). A least square analysis is done to show correlation between NTU and TSS. A least square value of 0.9 or greater indicates workable linear relationship.

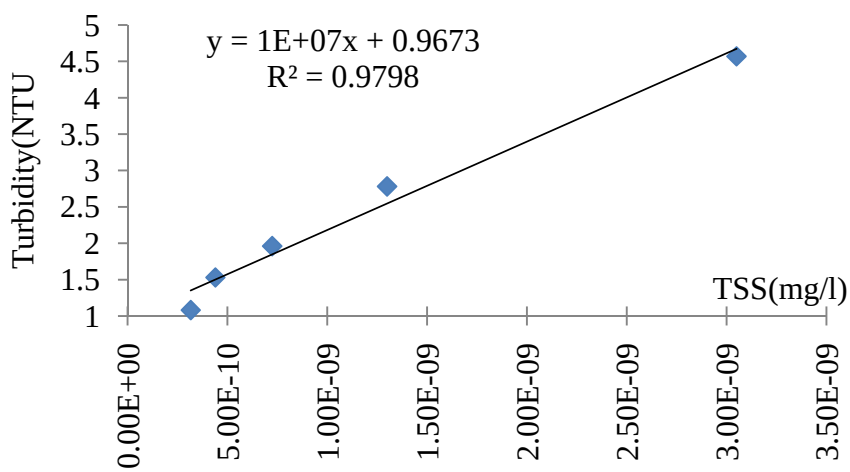

Fig. 3: Turbidity (NTU) Vs. TSS for drinking water

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For the drinking water, NTU value for low turbidity is very important. There is good agreements of linearity between NTU and TSS as depicted by the curve of the form Y = 1E+07x+3E+0.9673 with R^2 = 0.9798.

5. 1 Calibration of the turbitimeter

First a commercial standard turbidimeter has been used to measure NTU values and to plot the graph between NTU versus TSS for water in the purification plant. The curve is shown in Fig. 5 ('Experimental') and the corresponding relationship is given by, Y = 0.988X + 0.462, R^2 = 0.958. The equation between NTU and TSS is then used to deduce the value of experimental NTU to check the accuracy of the instrument. Extrapolated values for instrument are taken to compare the graph of experiment.

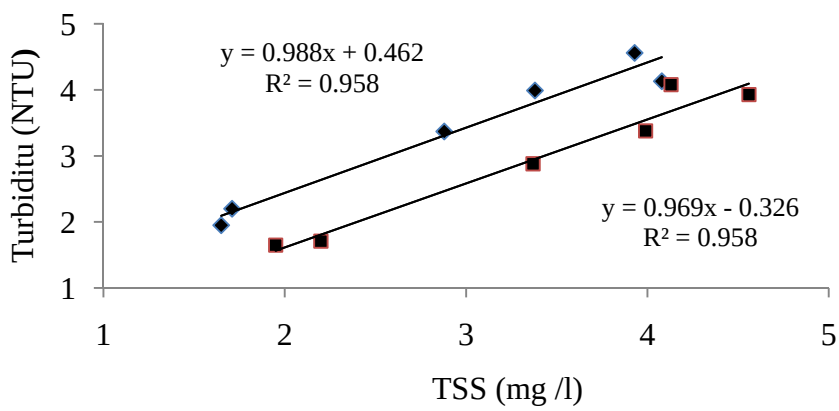

Fig. 4: the graph of turbidity Vs. Total suspended solids comparison with, ◇ -experimental graph and □ - extrapolated graph.

6. CONCLUSION

It is clear from Fig. 4 that two curves have almost same gradient but with a different intercept. The different intercepts for same sample may have caused by the ambient light. Ambient light factor can be removed by subtracting the difference between two intercepts to check the accuracy of the instrument.

Proceedings of the Technical Sessions, 28 (2012) 65-70
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