Paper ID: RT-70

A proposal for an autonomous robotic model ship for continuous measurement of turbidity using wireless network system and GPS

Maqsood Mansur[1], Preetom Kumar Sarker[2], Md. Safwan Ahsanullah[1], Md. Kamruzzaman Prodan[3], Kaustuv Brohmachary[1], Sakib Noor[1] and Doyal Kumar Sarker[1]
[1]Department of Naval Architecture and Marine Engineering, Bangladesh University of Engineering and Technology, Dhaka-1000, Bangladesh
[2]Department of Civil Engineering, Bangladesh University of Engineering and Technology, Dhaka-1000, Bangladesh
[3]Department of Electrical and Electronic Engineering, Bangladesh University of Engineering and Technology, Dhaka-1000, Bangladesh
E-mail: maqsoodmansur@outlook.com, 211bondhonpksb@gmail.com, safwanahsanullah@gmail.com, kamruzzaman.2301@gmail.com, kaustuv036@gmail.com, sakib9493@gmail.com, doyalkumar94@gmail.com

Abstract

Turbidity is a measure of haziness of water body. The measurement of turbidity is an important test to determine water quality. We propose a schematic for an autonomous vessel that will measure turbidity at prescribed locations using wireless networking and GPS tracking systems, thereby, presenting opportunity for continuous measurement of turbidity in real time with minimum human supervision. An autonomous model ship should be designed and fitted with wireless network system and GPS. A simple turbidimeter with necessary modifications should be mounted inside this vessel with provisions for collecting water samples directly from the water body using pumps and other necessary accessories. The vessel will be provided with preloaded sets of co-ordinates of locations where water quality test should be carried out. Using GPS the vessel will collect sample from each prescribed location. At regular intervals the turbidity test will be carried out and the results will be sent back.

Keywords: turbidity, autonomous robotic model ship, wireless network system, GPS, real-time data.

1. Introduction

Turbidity refers to the cloudiness of a fluid medium and is quantified by the intensity of light scattered by particles suspended in the medium [1]. For the purposes of water quality monitoring, the American Water Works Association defines turbidity as a nonspecific measure of the amount of particulate material in water including clay, silt, finely divided organic, and inorganic matter [2]. The suspended colloid-sized particles (with diameters roughly between one nanometer and one micrometer) are chiefly responsible for turbidity in water. The particles may have high specific surface area. The term suspended solids refers to particles that typically range from 10 to 100 microns in diameter. These particles often represent the majority of chemical contamination in a water supply as they can adsorb water quality contaminants such as heavy metals or pesticides [3]. Apparently such particles provide microscopic refuges for pathogens, absorb and scatter ultraviolet light (rendering UV light less effective as a disinfectant), and often have a high fraction of natural organic matter, which can consume the oxidizing power of chemical disinfectants such as chlorine and ozone and may form toxic by-products in the process [4].The effectiveness of disinfection processes for drinking water treatment can be significantly impaired by these particles causing turbidity. Moreover, the suspended particles absorb heat from sunlight, thus warming the turbid waters, as a result of which the concentration of oxygen in the water gets reduced. The suspended particles scatter the light, decreasing the photosynthetic activity of plants and algae and reducing the concentration further. Turbidity is therefore recognized, both in the engineering literature and in regulations set by the Environmental Protection Agency (EPA), as an important indicator of the cleanliness, drinkability and usability of water [5–7]. According to Bangladesh Environment Conservation Rules (1997), acceptable turbidity for drinking water is considered to be 10 NTU (Nephelometric Turbidity Unit).

Turbidity measurement is a qualitative parameter for water but its traceability to a primary standard allows the measurement to be applied as a quantitative measurement. When used as a quantitative measurement, turbidity is typically reported generically in turbidity units (TU’s). The primary standard for this parameter is a polymer compound known as formazin and this standard provides the traceable means for all other turbidity standards and is used to calibrate all types of turbidity meters. The developed polymer was matched to a gravimetric mass of kaolin clay and 1 TU approximately equals 1 mg/l Kaolin, when the clay is milled to a defined particle distribution. Formazin has been used as the traceable primary standard for turbidity for a considerable period. This means that a TU is equivalent to a nephelometric turbidity unit (NTU), which are equivalent to all other turbidity units in which the calibration standard was formazin (or an alternative calibration standard that was traced to match formazine). Thus, all turbidity meter measurement units will have the same magnitude relative to this traceable primary standard [8, 9]. The traceability of turbidity measurement to a common primary standard has allowed the application of this parameter to be used as a regulatory compliance tool for insuring a level of quality for water as it is applied to various uses. Turbidity is also used in environmental monitoring to assess the health of water- based ecosystems such as in, rivers, lakes, and streams.

In this study, we reviewed recent ongoing researches and various proposed models and proposed a self-operating robotic model ship for continuous measurement of turbidity using wireless network system and GPS. This proposal is expected to achieve advantages over the existing models in autonomy, finance, sustainability, ease of operation, requirement of less man-power and time consumption.

2. Basic principles of turbidity measurement

When light is shined through the sample, some of it will reflect off of the suspended particles and some of the light will exit at a right angle to the direction of entry into the sample. Most turbidimeters contain: (1) a light source that is directed through a liquid sample; (2) a chamber to hold the liquid sample; and (3) one or more photodetectors placed around the chamber. Three archetypal turbidimeter design patterns are diagrammed in Figure 1. A single-beam turbidimeter only measures scattered light, while ratio and modulated four-beam turbidimeters also measure transmitted light (the latter alternating between two light sources). Since the intensity of scattered light varies non-linearly with turbidity, single-beam turbidimeter designs have upper detection limits that are inherently lower than those of ratio or modulated four-beam turbidimeter designs, That is, in very clear water an increase in turbidity will result in more light scattering, but for sufficiently turbid water the addition of more colloidal particles may increase multiple scattering such that a scattered-light photodetector may report an apparent decrease in turbidity. Ratio and modulated four-beam turbidimeters normalize readings of scattered light using readings of transmitted light; series of these normalized values can remain linear even at very high turbidities. [7]

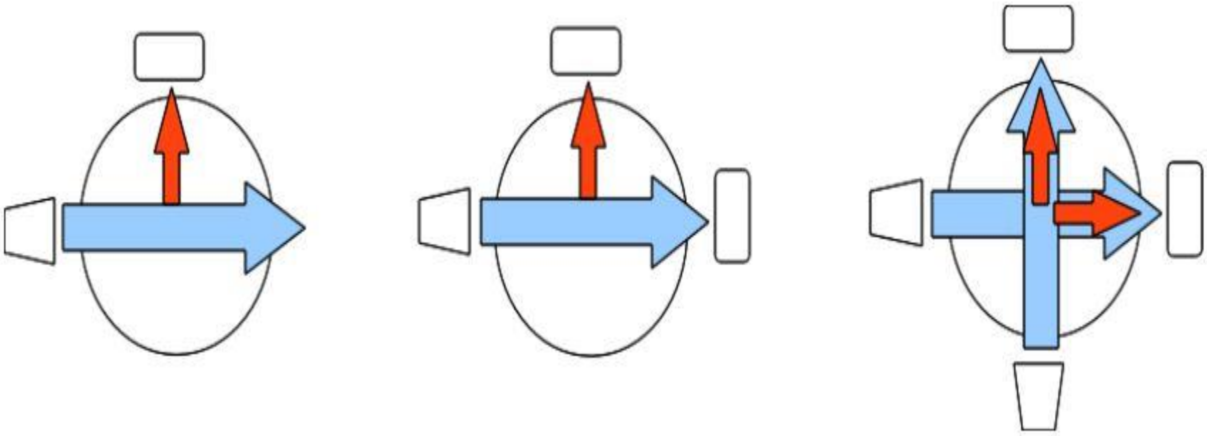

Fig 1. Common turbidimeter design patterns [10]

3. Review of previous works

Swapna et al. (2016) [11] used 5V supply to Arduino, kaoline powder solution as standard solution, temperature and flow sensor, and 470 nm blue LED as source. In that study two sensors in two directions were taken. Voltage ratio was used in this study. Table 1 briefly summarizes the findings from this study.

Table 1. Voltages, Ratios and Calculated Turbidity values [11]

Samples	Voltage Ratio	Calculated NTU	Measured Flow rate
1	0.17	80.96	64
2	0.20	92.96	80
3	0.25	122.88	88
4	0.38	180	96
5	0.40	219	98
6	0.53	365	112
7	0.61	529	120
8	0.64	621	128
9	0.77	660	136
10	0.84	780	136

However, Kelley et al. (2014) [10] took 860 nm infrared LED as source. Sample solution was prepared by diluting hydrophilic cutting oil with distilled water and standardized with standard formazine. Various measurements obtained in this arrangement are tabulated in Table 2.

Table 2. Mean, standard deviation (SD), and root-mean-square error (RMSE) of commercial and open-source turbidimeter readings of five non-formazine turbidity standards [10]

Turbidity Standard (NTU)	Measure	Turbidimeter (NTU) Commercial	Interpolated Open Turbidimeter (NTU) –Source
1,000	MEAN	992	968
	SD	0.68	1.05
	RMSE	7.60	31.5
100	MEAN	92.6	90.4
	SD	0.22	0.07
	RMSE	7.41	9.54
10	MEAN	8.90	9.68
	SD	0.01	0.00
	RMSE	1.10	0.33
1	MEAN	0.98	0.93
	SD	0.02	0.03
	RMSE	0.03	0.08
0.02	MEAN	0.01	0.00
	SD	0.00	0.00
	RMSE	0.01	0.02

4. Proposed Model

In the present study, we bring forth a new set-up for measuring turbidity. The arrangement consists of three units namely, turbidity measuring unit, signal I/O unit and propelling unit. The turbidity measuring unit comprises of a pump that collects sample water, an emitter and two receivers-one at 90^0 and another one at 180^0 that will receive the scattered light rays. The signal I/O unit sends the obtained measurements to the user using a Wi-Fi module and also receives the incoming GPS co-ordinates (sent by the user) of the locations where tests are desired to be carried out. The two units are mounted on a self-operating vessel (propelling unit) that reaches the test locations following the provided co-ordinates using a GPS tracking device. All these units are controlled by a microprocessor which is powered by a DC voltage source.

Figure 2 shows the schematic data-flow diagram of the proposed set-up.

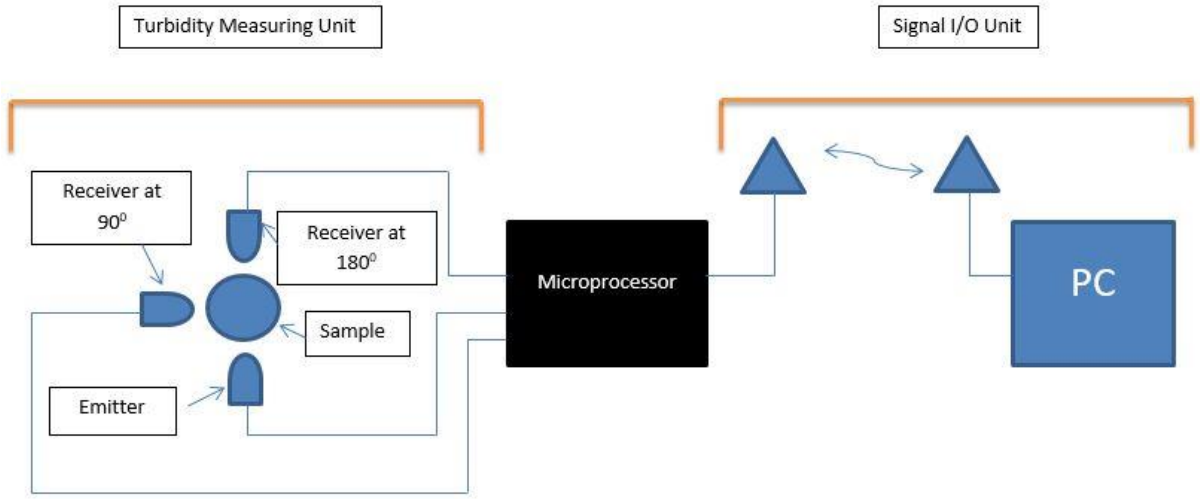

Fig 2. Data-flow diagram

5. Discussion

In traditional arrangements, a user must collect the sample physically from the desired location. However, our proposed model negates the necessity of the physical presence of user at the test location, rather sends the data to the user from far-flung locations. Moreover, it is expected to provide the user with continuous real-time data. The implementation of the proposed model is expected to have a very simplified fabrication procedure.

6. Conclusion

The principal focus of the study is to introduce the schematic of an autonomous turbidity measuring unit. We reviewed some of the existing models and explained how our proposed model offered certain advantages over them. The idea that is being presented here is still at a rudimentary stage which has ample scope of modifications and improvements. If provided with necessary facilities and funding, proper execution of the idea is possible.

7. References

[1] Standard Methods for the Examination of Water and Wastewater, *American Public Health Association: Washington DC, USA*, 9th edition, 1995.

[2] R. D. Letterman, Water Quality and Treatment: A Handbook of Community Water Supplies, *American Water Works Association: Denver, CO, USA*, 1999.

[3] C.R. O'Melia, "ES&T Features: Aquasols: The Behavior of Small Particles in Aquatic System", *Environ.Sci.Technol*. 14, 1052–1060, 1980.

[4] S. D. Richardson,M. J. Plewa, E. D. Wagner, R. Schoeny, D. M. DeMarini, "Occurrence, Genotoxicity, and Carcinogenicity of Regulated and Emerging Disinfection By-Products in Drinking Water: A Review and Roadmap for Research", *Mutat. Res. Rev. Mutat. Res*., 636, 178–242, 2007.

[5] M.W. LeChevallier, T.M. Evans, R.J. Seidler, "Effect of Turbidity on Chlorination Efficiency and Bacterial Persistence in Drinking Water", *J. Appl. Environ. Microbiol*. 42,159–167, 1981.

[6] M.W. LeChevallier, W.D. Norton, R.G. Lee, "Giardia and Cryptosporidium spp. in Filtered Drinking Water Supplies", *J. Appl. Environ. Microbiol*. 57, 2617–2621, 1991.

[7] Environmental Protection Agency. *EPA Guidance Manual*; Environmental Protection Agency: Washington, DC, USA, 1999; Turbidity Provisions April 1999, Chapter 7-1.

[8] Theofanis P. Lambrou, Christos C. Anastasiou, Christos G. Panayiotou, and Marios M. Polycarpou "A Low Cost Sensor Network for Real Time Monitoring and Contamination Detectioning Drinking Water Distribution Systems", *IEEE sensors journal*, Vol.14, No.8, 2014.

[9] Thermofisher scientic "Determintion of turbidity in wastewater by nephelometry" Thermo Scientific Orion Method AQ4500 Revision 5, December 2009.

[10] Christopher D. Kelley, Alexander Krolick, Logan Brunner, Alison Burklund, Daniel Kahn, William P. Ball and Monroe Weber-Shirk, “An Affordable Open-Source Turbidimeter”, *Sensors,* 14, 7142-7155, 2014.

[11] Swapna Bhavsar and Pramod Kanjalkar, “A Low Cost Flow Compensated Turbidity Sensor”, *Journal of Environmental Engineering and Studies,* Volume 1, Issue 3, 2016.