Application of a colorimeter for turbidity measurement

Yizhang Wen, Yingtian Hu, and Xiaoping Wang*

State Key Laboratory of Modern Optical Instrumentation, Department of Optical Engineering, Zhejiang University, Hangzhou, China

E-mail address: xpwang@zju.edu.cn

Abstract. This paper describes a new turbidity transducer based on color measurement. The absorbance of solutions reflects the absorption and scattering of suspended particle for incident light which could determine the turbidity of solutions. The experimental results indicate that there are good linear relationships between chromaticity and turbidity. The new way is suitable for continuous monitoring of water turbidity in the wide range.

1. Introduction

Accurate determination of turbidity is of great importance for many aspects of water resource development and river basin management [1]. Turbidity is an important parameter in monitoring water pollution and water eutrophication because spread of protozoa can be greatly reduced when the turbidity is very low [2]. Regular monitoring of turbidity can help to detect trends that might indicate increasing waste discharge or excessive algal growth [3].

There are two main types of turbidity transducers. The first kind of common turbidity transducers measure light attenuation. The absorbance of solutions reflects the absorption and scattering of suspended particle for incident light which could determine the turbidity of solutions. The response of this kind of turbidimeters varied uniformly when the turbidity became very large. So turbidimeters using transmission method were suitable for solutions with large turbidity.

The other kind of nephelometric turbidity transducers measure scattered light at a certain angle to the incident beam [4]. The standardized method makes use of the Tyndall effect, measuring scattered light at an angle 90 deg relative to the incident light. However, there are variations regarding the used lamps and measurement angles in the turbidimeters [5]. Until recently most instruments for water turbidity measurement have been constructed to meet the requirements in the U.S. standard. Such turbidimeters measure the particle scattering of light from a tungsten lamp and the wavelength of the spectral peak response of the detection system should be between 400 and 600 nm. A revised procedure has been introduced by The International Organization for Standardization. This standard (ISO 7027) prescribes that particle light scattering should be measured in the near infrared (λ= 860 nm) and it sets stringent conditions to parallelism for the incident light. The use of near infrared light minimized interferences caused by the presence of dissolved light-absorbing substances. Since colored organic substances are often present in surface water and drinking water from surface sources, it should be assumed that instruments using the longer wavelength will produce better turbidity measurements.

Apart from the two basic methods mentioned above, there are many other improved ways for the turbidity measurement. Kontturi et al. [5] developed a new sensor which makes use of the total internal reflection of a laser beam at the liquid–prism interface, and the turbidity is assessed using the concept of laser speckle pattern. Good correlation between the standard deviation of dynamic speckle and turbidity value. Shenoy [6] developed Optical fibre probes in the measurement of scattered light, and describe the application of turbidity sensing. Wang et al. [2] developed an instrument for real-time measurement of low
turbidity by using time-correlated single photon counting technique.

In this paper, upon on the transmission method, we have developed a new system and algorithm realizing turbidity measurement based on chromaticity coordinates measurement. The mechanism underlying the turbidity measurement will be discussed, and supported by the experimental results. The proposed realtime turbidimeter in this paper can be used to continuously monitor the turbidity of water.

2. Experimental

2.1. Experimental setup

The visible spectral acquisition system consisted of a light source, a sample cell, and a spectrometer (Fig. 1). The pulsed xenon light source (PX-2, Ocean Optics, USA) produced visible light, which was collimated by a lens and then passed through the sample cell; the emergent light was collected into the spectrometer (USB2000+, Ocean Optics, USA) by the converging lens. The spectral data were shown in the computer.

![Experimental setup](image)

2.2. Measurement

In this study, turbidity solutions of 2, 5, 10, 20, 30, 40, and 50 NTU were prepared by diluting a 400 NTU formazine turbidity solution. The water used for all solutions consisted of deionized water supplied by a MilliQ water purification system (Millipore, Billerica, MA, USA). A series of experiments were carried out with the experimental setup shown in Fig. 1, and a 10 mm optical path was used during measurements.

3. Results and Discussions

3.1 The absorbance in the visible spectrum for different turbidity solutions

In theory, the absorbance was satisfied with Lambert Beer's law, the equation was shown as below:

\[
I = I_0 \times 10^{-kCL}
\]

(1)

where k is the absorption coefficient, C is the concentration of substance, L is the optical path, \(I_0\) and I are the original and emergent light intensity.

The absorbance of solutions reflects the absorption and scattering of suspended particle for incident light which could determine the turbidity of solutions. The light absorption experiments for different turbidity solutions were carried out to explore the absorption and scattering of suspended particle. As shown in the Fig. 2, the loss of light intensity became larger with the increase of turbidity in the visible region. Moreover, the change of absorbance is larger when the wavelength is shorter. Therefore, chromaticity coordinate of solutions could reflect the turbidity.
3.2 The color coordinates of different turbidity solutions

Color tristimulus values are used to indicate the visual feeling for water color, the computational formula are listed below:

\[ X = k \sum S(\lambda)10^{-A(\lambda)}x(\lambda)\Delta\lambda \]  \hspace{1cm} (2)

\[ Y = k \sum S(\lambda)10^{-A(\lambda)}y(\lambda)\Delta\lambda \]  \hspace{1cm} (3)

\[ Z = k \sum S(\lambda)10^{-A(\lambda)}z(\lambda)\Delta\lambda \]  \hspace{1cm} (4)

where \( x(\lambda), y(\lambda), z(\lambda) \) are visual matching function, \( S(\lambda) \) is spectral power distribution of lighting luminous, the D65 light source is used to represent \( S(\lambda) \), \( A(\lambda) \) is absorbance of testing solutions.
The color coordinates \(xyz\) are normalization of XYZ values, the XYZ values of different turbidity solutions are calculated using equation (2), (3) and (4). The black squares shown in the Fig. 3 represented the positions in the chromaticity diagram of 0, 2, 5, 10, 20, 30, 40, 50 NTU turbidity solutions from the bottom up. These points can be distinguished clearly, and the relationships between \(xyz\) values in chromaticity diagram and turbidity are shown in Fig. 4.

![Fig. 4 Relationships between \(xyz\) values in color diagram and turbidity](image)

As seen in the Fig. 4, there are good linear relationships between \(xyz\) values and turbidity. The \(z\) value is more sensitive with the increase of turbidity. In the meantime, the method can be applied up to 50 NTU, and it is reliable up to that range.

4. Conclusion

In this paper, a new color measurement-based turbidimeter had been developed for accurate measurement of the turbidity. The feasibility of this instrument was demonstrated by series of turbidity measurement experiments. The results showed the turbidity could be stably measured in the range of 0-50 NTU.

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