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Light Sources for Regulatory Turbidity Measurement Compliance

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Introduction:

The Lovibond® PTV Series of Process Turbidimeters offer three different incident light sources:

	Light Source	Spectral Output	Compliance
PTV 1000 WL	White LED	400 to 700 nm	EPA
PTV 1000 IR	Infrared LED	860 nm	ISO 7027
PTV 2000	Red LED	660 nm	EPA

These different light sources were needed to meet regulatory requirements, which differ across the world.

The PTV 1000 WL and the PTV 2000 versions are approved by the USEPA under the Safe Drinking Water Act[1] and are applicable for use in reporting filter effluent and combined filter effluent turbidities from drinking water plants[2]. The PTV 1000 IR version complies with the ISO 7027 design criteria for turbidity measurement below 40 FNU[3].

With respect to these three versions of turbidimeters, it is only the light source that differs. All other instrument components are the same. Although these three light sources are regulatory approved, they are expected to deliver slightly different results. These differences and their causes will be discussed.

This discussion focus is on the regulated part of drinking water turbidity. When used in this application, the turbidity will be below 0.3 NTU, and for many plants the target turbidity will be below 0.1 NTU. As measurements approach these levels, these different light sources will lead somewhat different readings relative to each other. However, the impact from the regulatory perspective will be minimal. The driving factors that impact the differences between these three light sources are: effective light scatter, stray light, and color.

Discussion:

Light Scatter

Turbidity is simply based on the scatter of an incident light beam by materials that are contained within a fluid matrix. There are two basic types of light scatter to consider. Mie scatter is caused by the scatter of light off particles that are at least as big, or bigger, as the wavelength(s) that make up the incident light beam. The scattering is non-uniform around the particle and is disproportionally in the forward direction (versus the 90° direction). Since the PTV Series light sources are within the wavelength range from approximately 400-900 nm, this means that particles that are 0.4 µm and larger have Mie scattering. Mie scattering is not highly dependent on wavelength. In turbidity, particles that are larger than about 0.50 of a micron generate this non-symmetrical scatter pattern (see Figure 1).

Light Scatter, Continued

Smaller particles whose size is approximately 0.10 the wavelength of the incident light will scatter more symmetrically. This is known as Rayleigh scattering. It is Rayleigh scattering that occurs when light scatters off the air molecules in our atmosphere that causes the sky to appear blue. Rayleigh scattering is more dependent on wavelength. A general rule with Rayleigh scattering is that shorter wavelengths are more effectively scattered relative to longer wavelengths of light. This means that a turbidimeter with a longer wavelength of incident light will read slightly lower (because it is less sensitive) than a turbidimeter with a shorter wavelength of incident light.

Note: 1000 nm (nanometers) = 1.000 µm (micron). The wavelengths of incident light used in the PTV Series turbidimeters range between 400-900 nm (0.4-0.9 microns). There are 1000 microns in a millimeter and 1 million microns in a meter.

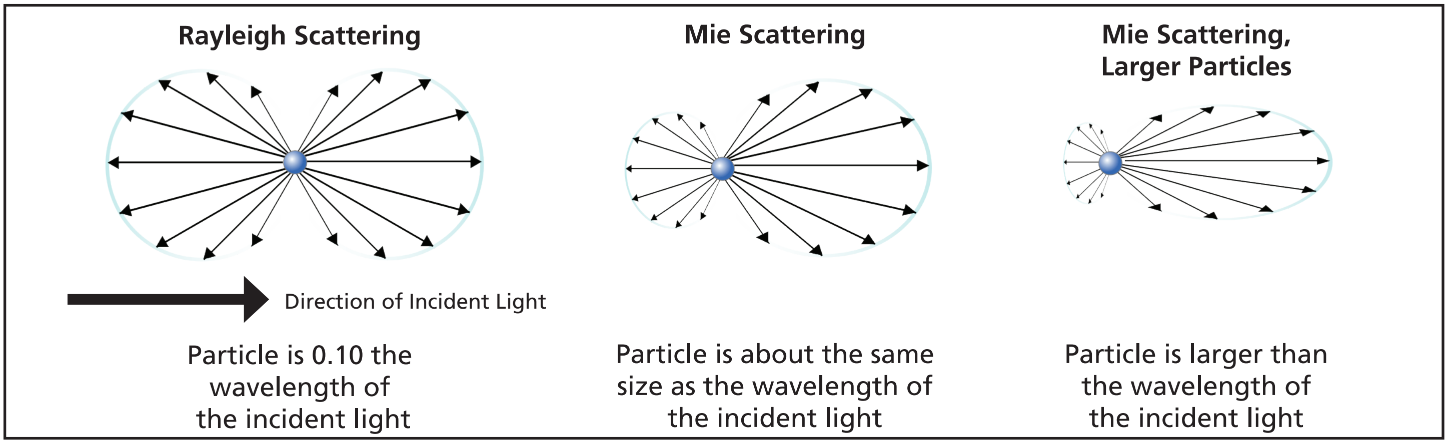

Figure 1 - Scatter profiles of a particle when impinged by incident light of a defined wavelength[4]. It is important to note that a real water sample will have a wide spectrum of particle sizes which results in a combination of Rayleigh and Mie scattering.

So what does all this light scatter mean? When looking at real-world samples, they are composed of particles that are a mix in sizes. This size mixture will generate light scatter in all directions including the regulatory scatter angle of 90° (for turbidimeter compliance). The detection angle of 90° is sensitive to scatter from both Mie and Rayleigh particle scatter for turbidimeters that use light in the 400-900 nm range.

The detector view area for the PTV Series Turbidimeters does capture some light scatter that is pushed in the forward direction and some backscatter up to about ±15° from 90°. This broad detection view angle helps to normalize the effects of the different wavelengths of light.

When a calibration is performed, any differences in light scatter between instrument types are further normalized by the calibration standard. The important characteristic of the turbidity calibrant is that it is composed of particles that cause both Mie and Rayleigh scatter. Formazin turbidity standards (or stabilized versions of formazin) contain a broad range of particles that cover both Mie and Rayleigh scatter principles and help to normalize the detector response regardless of the wavelength of incident light used. Thus, the detector angle, detector view area, and the use of a turbidity calibrant that causes both Mie and Rayleigh scatter will normalize the effects of light scatter from these different light sources on the Lovibond PTV Series turbidimeters.

Color

Color in samples can be caused by dissolved materials or by particles if they are capable of absorbing light. If the incident light beam contains wavelengths that are absorbed by these components in a sample, the quantity of light available to be scattered decreases. This will cause a negative interference in the turbidity response. The probability of a color interference occurrence will be greater with the PTV 1000 WL version versus either the PTV 2000 or PTV 1000 IR version. Water that is high in tannic or humic acids (which cause a transparent brown or tea color) is an example where this would cause a negative interference with a PTV 1000 WL instrument. The PTV 1000 IR light source is virtually immune to color absorbance in the visible spectrum and a good selection if color is present in water samples. Note that all versions of the PTV Series of process turbidimeters were designed to be immune to color interference up to 50 Platinum-Cobalt color units (CU)[5]. With respect to filter effluent water from drinking water plants, color is typically below 20 CU, so color is typically not a problem.

The PTV 1000 WL instrument can be the most sensitive to color because it uses the broadest spectral output of the PTV Series turbidimeters. The PTV 1000 IR and PTV 2000 instruments use a narrow bandwidth and will be less impacted by color in samples. However, this broad-band white light source may also serve the purpose of helping to detect dissolved materials in a sample. Some dissolved materials will exhibit a fluorescence effect and the PTV 1000 WL instrument exhibits a broad spectrum of light that is available to fluoresce. Thus, if a PTV 1000 WL instrument reads unexpectedly high on a highly filtered sample, the higher reading may be due to the fluorescence of a dissolved compound in the sample[6].

Stray Light

Stray Light is defined as light that reaches the scattered light detector in a turbidimeter that is not caused by particle scattering in the sample. Stray light is a positive interference[7]. This can be caused by internal reflections of incident light after it passes through the view volume of the turbidimeter's sample chamber. Light that is not columnated (it diverges) after it leaves its source can often miss an internal light trap (if designed into in a turbidimeter) and eventually reflect back into the detector. Light that is polychromatic (has many different wavelengths) will more readily diverge from parallelism than will a light source that is monochromatic (typically is composed of one wavelength). Thus, a white light source will have more stray light than a single wavelength light source.

Stray light is very difficult to quantify because there is always some true light scatter in the purist of samples. What can be performed is to compare measurements between technologies on a sample stream of essentially particle free water. Particle free water can be prepared through the filtration of tap water that is passed through a series of sub-micron filters to remove virtually all the insoluble and some soluble materials. When we compare the different turbidimeters on this very pure water, the WL version will deliver the highest baseline, followed by the PTV 2000 version, and the PTV 1000 IR version will deliver the lowest turbidity, respectively. When these three Lovibond® turbidimeters are calibrated using the same 5.0 NTU formazin standard and then measure particle free water, the PTV 1000 WL version will read between 0.02 and 0.03 NTU, the PTV 2000 version will read between 0.012 and 0.017 NTU, and the PTV 1000 IR version will read between 0.006 and 0.011 NTU.

The impact of Rayleigh scattering may be the contributing reason why the PTV 1000 IR instrument reads slightly lower than the PTV 2000 (0.009 NTU versus 0.013 NTU respectively). Even though the water is filtered through a very small pore-sized membrane, on the order of nanometers in size, may be present. In such a case, the longer wavelength instrument would be slightly less sensitive to this turbidity than the shorter wavelength instrument, thus contributing to the difference in the reading. Figure 2 provides a graphical comparison of these three turbidimeters that were set to measure the highly filtered tap water.

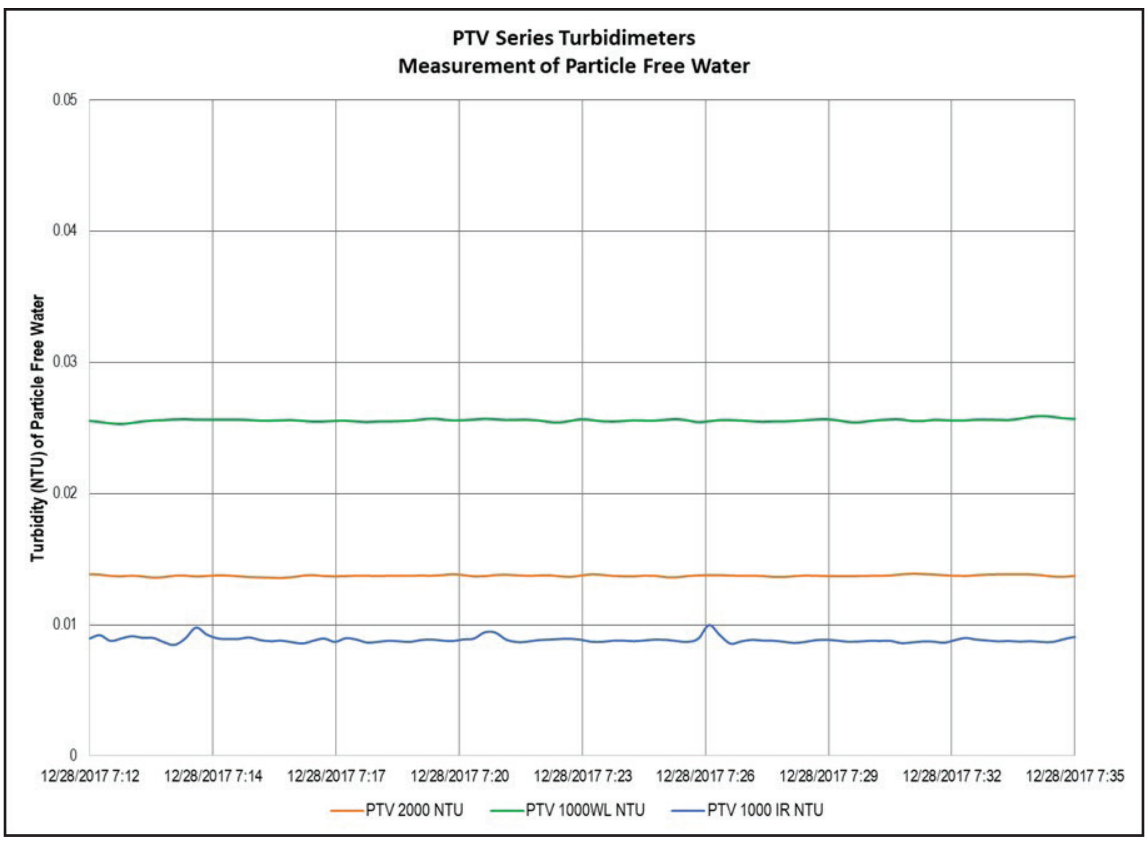

Figure 2 -The comparison of PTV turbidimeter response to particle free tap water. Stray light is the major contributor to these differences in reading. Note the scale is from 0.00 to 0.05 NTU.

Data and Recommendations:

The Lovibond® PTV Series of Turbidimeters will respond to turbidity events regardless of light source, but there are subtle differences between these types. Table 1 provides a summary of the different instruments and where selection of a particular type may prove to be beneficial for detection of turbidity events in a process application.

Table 1 – Selection Guide for the Different Versions of PTV 1000 and PTV 2000 Turbidimeters
Ability of the technology to meet the requirement (WL = PTV 1000 WL, IR = PTV 1000 IR, RED = PTV 2000)

Requirement	Good	Better	Best
EPA Approved	N/A	N/A	WL, RED
ISO Approved	N/A	N/A	IR
Color Removal	WL	RED	IR
Lowest Stray Light (Lower baseline)	WL	RED	IR
Detection of Dissolved Materials	IR	RED	WL
Detection of sub-micron particles(membrane performance)	IR	WL	RED
Conventional filtration performance	IR		WL,RED
Filtration Optimization	WL	IR	RED

Conclusions:

When measuring very low turbidity levels, the selection of the turbidimeter can have an impact on the reporting results. Aside from regulatory design requirements, the spectral output of the turbidimeters can impact the measurement floor of the instrument. It is important to understand the intended application and its respective measurement goals prior to selection of the turbidimeter. Regardless of the application, the Lovibond PTV offering will provide the type of instrument that will allow the user to accurately monitor the turbidity of their process.

References:

1. Federal Register, Section 40 CFR 141.74(a)(1), Vol 82 No. 143, published on Thursday, July 27, 2017.
2. Federal Register, Rules and Regulations, Vol. 82, No. 143, pp 34864-34865, Thursday, July 27, 2017
3. International Standardization Organization (2016), "ISO 7027-1:2016 Water quality — Determination of turbidity — Part 1: Quantitative methods," International Standardization Organization, Geneva, Switzerland.
4. Sharayanan. "File:Mie Scattering.svg." Wikimedia Commons, Sharayanan, 30 Apr. 2007, commons.wikimedia.org/wiki/File:Mie_scattering.svg#.
5. APHA Color, https://en.wikipedia.org/wiki/APHA_color
6. Hohman, Becky (2017), "LED Light Sources: A Major advance is Fluorescence Microscopy," Microscopy and Analysis, https://microscopy-analysis.com/editorials/editorial-listings/led-light-sources-major-advance-fluorescence-microscopy.
7. American Society for the Testing of Materials (2014), "ASTM D6698 Standard Test Method for the On-Line Measurement of Turbidity Below 5 NTU in Water," ASTM International, West Conshohocken, PA.

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