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Standard Guide for The Use of Various Turbidimeter Technologies for Measurement of Turbidity in Water[1]

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ε^1 NOTE—Editorial corrections were made throughout in November 2016.

1. Scope

1.1 This guide covers the best practices for use of various turbidimeter designs for measurement of turbidity in waters including: drinking water, wastewater, industrial waters, and for regulatory and environmental monitoring. This guide covers both continuous and static measurements.

1.1.1 In principle there are three basic applications for on-line measurement set ups. The first is the bypass or slipstream technique; a portion of sample is transported from the process or sample stream and to the turbidimeter for analysis. It is then either transported back to the sample stream or to waste. The second is the in-line measurement; the sensor is submerged directly into the sample or process stream, which is typically contained in a pipe. The third is in-situ where the sensor is directly inserted into the sample stream. The in-situ principle is intended for the monitoring of water during any step within a processing train, including immediately before or after the process itself.

1.1.2 Static covers both benchtop and portable designs for the measurement of water samples that are captured into a cell and then measured.

1.2 Depending on the monitoring goals and desired data requirements, certain technologies will deliver more desirable results for a given application. This guide will help the user align a technology to a given application with respect to best practices for data collection.

1.3 Some designs are applicable for either a lower or upper measurement range. This guide will help provide guidance to the best-suited technologies based given range of turbidity.

1.4 Modern electronic turbidimeters are comprised of many parts that can cause them to produce different results on samples. The wavelength of incident light used, detector type, detector angle, number of detectors (and angles), and optical pathlength are all design criteria that may be different among instruments. When these sensors are all calibrated with the sample turbidity standards, they will all read the standards the same. However, samples comprise of completely different matrices and may measure quite differently among these different technologies.

1.4.1 This guide does not provide calibration information but rather will defer the user to the appropriate ASTM turbidity method and its calibration protocols. When calibrated on traceable primary turbidity standards, the assigned turbidity units such as those used in Table 1 are equivalent. For example, a 1 NTU formazin standard is also equivalent in measurement magnitude to a 1 FNU, a 1 FAU, and a 1 BU standard and so forth.

1.4.2 Improved traceability beyond the scope of this guide may be practiced and would include the listing of the make and model number of the instrument used to determine the turbidity values.

1.5 This guide does not purport to cover all available technologies for high-level turbidity measurement.

1.6 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.7 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

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limitations prior to use. Refer to the MSDSs for all chemicals used in this procedure.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D1129 Terminology Relating to Water

D3977 Test Methods for Determining Sediment Concentration in Water Samples

D6698 Test Method for On-Line Measurement of Turbidity Below 5 NTU in Water

D6855 Test Method for Determination of Turbidity Below 5 NTU in Static Mode

D7315 Test Method for Determination of Turbidity Above 1 Turbidity Unit (TU) in Static Mode

2.2 *Other References:*

USGS National Field Manual for the Collection of Water Quality Data[3]

Wagner's Field Manual Guidelines and Standard Procedures for Continuous Water-Quality Monitors: Station Operation, Record Computation, and Data Reporting[4]

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms used in this standard, refer to Terminology D1129.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *calibration drift, n*—the error that is the result of drift in the sensor reading from the last time the sensor was calibrated and is determined by the difference between cleaned-sensor readings in calibration standards and the true, temperature-compensated value of the calibration standards.

3.2.2 *calibration turbidity standard, n*—a turbidity standard that is traceable and equivalent to the reference turbidity standard to within statistical errors; calibration turbidity standards include commercially prepared 4000 NTU Formazin, stabilized formazin, and styrenedivinylbenzene (SDVB).

3.2.2.1 *Discussion*—These standards may be used to calibrate the instrument.

3.2.3 *calibration-verification standards, n*—defined standards used to verify the accuracy of a calibration in the measurement range of interest.

3.2.3.1 *Discussion*—These standards may not be used to perform calibrations, only calibration verifications. Included verification standards are opto-mechanical light-scatter devices, gel-like standards, or any other type of stable-liquid standard.

3.2.4 *continuous, adj*—the type of automated measurement at a defined-time interval, where no human interaction is required to collect and log measurements.

3.2.4.1 *Discussion*—Measurement intervals range from seconds to months, depending on monitoring goals of a given site.

3.2.5 *design, n*—a more detailed technology description that will encompass all of the elements making up a technology, plus any inherent criteria used to generate a specific turbidity value.

3.2.5.1 *Discussion*—The design will typically translate into a specific make or model of an instrument.

3.2.6 *detection angle, n*—the angle formed with its apex at the center of the analysis volume of the sample, and such that one vector coincides with the centerline of the incident light source's emitted radiation and the second vector projects to the center of the primary detector's view.

3.2.6.1 *Discussion*—This angle is used for the differentiation of turbidity-measurement technologies that are used in this guide.

3.2.6.2 *attenuation-detection angle, n*—the angle that is formed between the incident light source and the primary detector, and that is at exactly 0 degrees.

(1) Discussion—This is typically a transmission measurement.

3.2.6.3 *backscatter-detection angle, n*—the angle that is formed between the incident light source and the primary detector, and that is greater than 90 degrees and up to 180 degrees.

3.2.6.4 *nephelometric-detection angle, n*—the angle that is formed between the incident light source and the detector, and that is at 90 degrees.

3.2.6.5 *forward-scatter-detection angle, n*—the angle that is formed between the incident light source and the primary detector, and that is greater than 0 degrees but less than 90 degrees.

(1) Discussion—Most designs will have an angle between 135 degrees and 180 degrees.

3.2.6.6 *surface-scatter detection, n*—a turbidity measurement that is determined through the detection of light scatter caused by particles within a defined volume beneath the surface of a sample.

(1) Discussion—Both the light source and detector are positioned above the surface of the sample. The angle formed between the centerline of the light source and detector is typically at 90 degrees. Particles at the surface and in a volume below the surface of the sample contribute to the turbidity reading.

3.2.7 *fouling, v*—the measurement error that can result from a variety of sources and is determined by the difference between sensor measurements in the environment before and after the sensors are cleaned.

3.2.8 *in-situ nephelometer, n*—a turbidimeter that determines the turbidity of a sample using a sensor that is placed directly in the sample.

3.2.8.1 *Discussion*—This turbidimeter does not require transport of the sample to or from the sensor.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from United States Geological Survey (USGS), USGS Headquarters, 12201 Sunrise Valley Drive, Reston, VA 20192, http://www.usgs.gov/FieldManual/Chapters6/6.7.htm.

[4] Wagner, R. J., et al, *Guidelines and Standard Procedures for Continuous Water-Quality Monitors: Station Operation, Record Computation, and Data Reporting*, USGS Enterprise Publishing Network, 2005, available from: http://pubs.usgs.gov/tm/2006/tm1D3.

3.2.9 *metadata, n*—the ancillary descriptive information that describes instrument, sample, and ambient conditions under which data were collected.

3.2.9.1 *Discussion*—Metadata provide information about data sets. An example is the useful background information regarding the sampling site, instrument setup, and calibration and verification results for a given set of turbidity data (especially when data are critically reviewed or compared against another data set).

3.2.10 *nephelometric-turbidity measurement, n*—the measurement of light scatter from a sample in a direction that is at 90° with respect to the centerline of the incident-light path.

3.2.10.1 *Discussion*—Units are NTU (Nephelometric Turbidity Units). When ISO 7027 technology is employed units are FNU (Formazin Nephelometric Units).

3.2.11 *pathlength, n*—The greatest distance that the sum of the incident light and scattered light can travel within a sample volume (cell or view volume).

3.2.11.1 *Discussion*—The pathlength is typically measured along the centerline of the incident-light beam plus the scattered light. The pathlength includes only the distance the light and scattered light travel within the sample itself.

3.2.12 *ratio-turbidity measurement, n*—the measurement derived through the use of a nephelometric detector that serves as the primary detector, and one or more other detectors used to compensate for variation in incidentlight fluctuation, stray light, instrument noise, or sample color.

3.2.13 *reference-turbidity standard, n*—a standard that is synthesized reproducibly from traceable raw materials by the user.

3.2.13.1 *Discussion*—All other standards are traced back to this standard. The reference standard for turbidity is formazin.

3.2.14 *seasoning, v*—the process of conditioning labware with the standard that will be diluted to a lower value to reduce contamination and dilution errors.

3.2.15 *slipstream, n*—an on-line technique for analysis of a sample as it flows through a measurement chamber of an instrument.

3.2.15.1 *Discussion*—The sample is transported from the source into the instrument (for example, a turbidimeter), analyzed, and then transported to drain or back to the process stream. The term is synonymous with the terms "on-line instrument" or "continuous monitoring instrument."

3.2.16 *sonde, n*—a monitoring instrument that contains two or more measurement sensors that share common power, transmitting, and data logging.

3.2.16.1 *Discussion*—A sonde usually has one end that contains the measurement sensors, which are in close proximity to each other and together are submerged in a sample.

3.2.17 *stray light, n*—all light reaching the detector other than that contributed by the sample.

3.2.18 *technology, n*—a general classification of a turbidimeter design that incorporates the type and wavelength of the incident-light source, detection angles, and the number of detectors used to generate a turbidity measurement and its defined reporting unit.

3.2.18.1 *Discussion*—In ASTM turbidity test methods, the technology is based on type and number of light sources, and their respective wavelength, detector angle(s), and number of detectors used in the technology to generate the turbidity value.

3.2.19 *turbidimeter, n*—an instrument that measures light scatter caused by particulates within a sample and converts the measurement to a turbidity value.

3.2.19.1 *Discussion*—The detected light is quantitatively converted to a numeric value that is traced to a light-scatter standard. See Test Method D7315.

3.2.20 *turbidity, n*—an expression of the optical properties of a sample that causes light rays to be scattered and absorbed rather than transmitted in straight lines through the sample.

3.2.20.1 *Discussion*—Turbidity of water is caused by the presence of matter such as clay, silt, finely divided organic matter, plankton, other microscopic organisms, organic acids, and dyes.

4. Summary of Practice

4.1 This guide is to assist the user in meeting and understanding the following criteria with respect to turbidity measurements:

4.1.1 The selection of the appropriate technology for measurement of a given sample with implied characteristics.

4.1.2 Help in the selection of a measurement technology that will help meet the scope of requirements (goals) for use of the data.

4.1.3 Assist in the selection of a technology that is best suited to withstand the expected environmental and sample deviations over the course of data collection. Examples of deviations would be expected measurement range and interferences.

4.1.4 Understand both the general strengths and limitations for a given type (design) of technology in relation to overcoming known interferences in turbidity measurement.

4.1.5 Provide general procedures that can be used to determine whether a given technology is suitable for use in a given sample or a given application.

4.1.6 Understand the need for the user to include critical metadata related to turbidity measurement.

4.1.7 This guide will help the user select the appropriate technology for regulatory purposes.

5. Significance and Use

5.1 Turbidity is a measure of scattered light that results from the interaction between a beam of light and particulate material in a liquid sample. Particulate material is typically undesirable in water from a health perspective and its removal is often required when the water is intended for consumption. Thus, turbidity has been used as a key indicator for water quality to assess the health and quality of environmental water sources. Higher turbidity values are typically associated with poorer water quality.

5.1.1 Turbidity is also used in environmental monitoring to assess the health and stability of water-based ecosystems such as in lakes, rivers and streams. In general, the lower the turbidity, the healthier the ecosystem.