INTERNATIONAL STANDARD

ISO 7027-1

First edition
2016-06-15

Water quality — Determination of turbidity —

Part 1: Quantitative methods

Qualité de l'eau — Détermination de la turbidité —

Partie 1: Méthodes quantitatives

Reference number
ISO 7027-1:2016(E)

COPYRIGHT PROTECTED DOCUMENT

ISO copyright office
Ch. de Blandonnet 8 • CP 401
CH-1214 Vernier, Geneva, Switzerland
Tel. +41 22 749 01 11
Fax +41 22 749 09 47
copyright@iso.org
www.iso.org

Contents

Page

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 147, *Water quality*, Subcommittee SC 2, *Physical, chemical and biochemical methods*.

This first edition of ISO 7027-1, together with ISO 7027-2, cancels and replaces ISO 7027:1999, which has been technically revised.

ISO 7027 consists of the following parts, under the general title *Water quality — Determination of turbidity*:

— *Part 1: Quantitative methods*

The following part is under preparation:

— *Part 2: Semi-quantitative methods*

Introduction

Measurements of turbidity can be affected by the presence of dissolved light-absorbing substances (substances imparting colour). Such effects can be minimized, however, by performing measurements at wavelengths greater than 800 nm. Only carbon black and a blue colour, which can be found in certain polluted waters, slightly affects measurements of turbidity in this region of the spectrum. Air bubbles can also interfere with measurements, but such interference can be minimized by careful handling of the samples.

It is to be investigated whether and to what extent, particular problems will require the specification of additional marginal conditions.

Water quality — Determination of turbidity —

Part 1: Quantitative methods

WARNING — Persons using this International Standard should be familiar with normal laboratory practice. This International Standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user to establish appropriate safety and health practices and to ensure compliance with any national regulatory conditions.

IMPORTANT — It is absolutely essential that tests conducted in accordance with this International Standard be carried out by suitably qualified staff.

1 Scope

This part of ISO 7027 specifies two quantitative methods using optical turbidimeters or nephelometers for the determination of turbidity of water:

a) nephelometry, procedure for measurement of diffuse radiation, applicable to water of low turbidity (for example drinking water);

b) turbidimetry, procedure for measurement of the attenuation of a radiant flux, more applicable to highly turbid waters (for example waste waters or other cloudy waters).

Turbidities measured according to the first method are presented as nephelometric turbidity units (NTU). The results typically range between <0,05 NTU and 400 NTU. Depending on the instrument design, it can also be applicable to waters of higher turbidity. There is numerical equivalence of the units NTU and formazin nephelometric unit (FNU).

Turbidity measured by the second method is expressed in formazin attenuation units (FAU), results typically range between 40 FAU and 4 000 FAU.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

CIE Publication No. 17, *International Lighting Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in CIE Publication No. 17 and the following apply.

3.1
turbidity
reduction of transparency of a liquid caused by the presence of undissolved matter

4 Sampling and samples

Maintain all containers that come into contact with the sample in a scrupulously clean condition. Wash with hydrochloric acid or surfactant cleaning solution.

Collect samples in glass or plastics bottles and carry out the determinations, as soon as possible after collection. If storage is unavoidable, store the samples in a cool, dark room but for not longer than 24 h. If the samples have been stored under cool conditions, allow them to come to room temperature before measurement. Prevent contact between the sample and air and avoid unnecessary changes in the temperature of the sample.

5 Quantitative methods of turbidity measurement using optical nephelometers and turbidimeters

5.1 General principles

A water sample coloured by dissolved substances is a homogeneous system that only attenuates radiation passing through the sample. A water sample containing undissolved substances attenuates the incident radiation and in addition the insoluble particles which are present diffuse the radiation unequally in all directions. The forward diffusion of radiation by the particles affects the attenuation so that the common spectral attenuation coefficient $\mu(\lambda)$ is the sum of the spectral diffusion coefficient $s(\lambda)$ and the spectral absorption coefficient $\alpha(\lambda)$:

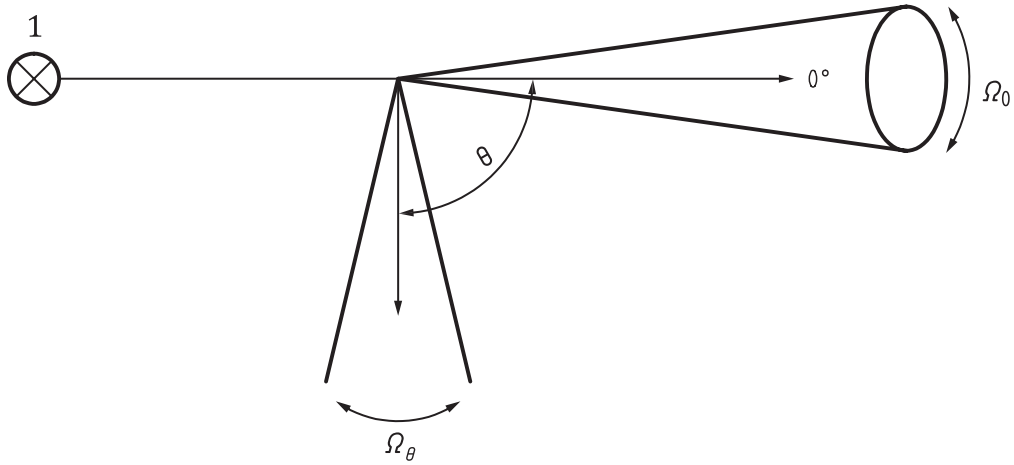
$$\mu(\lambda) = s(\lambda) + \alpha(\lambda) \tag{1}$$

To obtain the spectral diffusion coefficient $s(\lambda)$ alone, the spectral absorption coefficient $\alpha(\lambda)$ needs to be known. In order to determine the spectral absorption coefficient of the dissolved substance, the undissolved substances can, in some cases, be removed by filtration, but this may cause interferences. Therefore, it is necessary to report the results of the determination of turbidity in comparison to a calibration standard.

The intensity of the diffuse radiation depends upon the wavelength of the incident radiation, the measurement angle, and the shape, optical characteristics and particle size distribution of the particles suspended in the water.

In measurements of the attenuation of transmitted radiation, the measured value depends upon the aperture angle Ω_0 of the radiant efficiency arriving at the receiver.

When measuring the diffuse radiation, the measured values depend upon the angle θ and the aperture angle Ω_θ. The angle θ is that enclosed by the direction of the incident radiation and the direction of the measured diffuse radiation (see Figure 1).



Key

1 light source

Figure 1

Application of the measurement of the concentration of undissolved substances would be possible only if the parameters identified above were known. In general, this information is not available, so the mass concentration of the suspended particles cannot be calculated from the value of turbidity.

NOTE 1 Instrument-to-instrument comparisons are possible only if apparatus is used in accordance with this part of ISO 7027 and the same measuring principle is applied.

NOTE 2 The Jackson candle turbidimeter was originally the standard instrument for turbidity measurements. In general, Jackson turbidity units (JTU) cannot be related to other turbidity units.

5.2 Reagents

Use only reagents of recognized analytical grade. Reagents prepared in accordance with this part of ISO 7027 can be stored in hard glass, high-density polyethylene (HDPE) or low-density polyethylene (LDPE) bottles respectively.

5.2.1 **Water**, for the preparation of the formazin stock and reference suspensions.

Soak a membrane filter of pore size 0,45 µm for 1 h in 100 ml of distilled water. Filter 250 ml of distilled water through it and discard the water. Then pass a two-litre volume of distilled water twice through the membrane and reserve this water for the preparation of the formazin suspensions. Other particle free waters like reverse osmosis water can be used instead.

5.2.2 **Formazin $(C_2H_4N_2)_x$, stock suspension I (4 000 FNU)**.

Suspensions with 4 000 FNU (NTU) are commercially available. Their use is recommended. They are available from numerous sources. Possible health hazards arising from the toxicity and carcinogenicity of hydrazine sulfate used for preparing the standard on the bench can be avoided.

From some manufacturers, specific stabilized formazin suspensions are available.[1)]

These commercially available suspensions may be stable for up to one year if stored under cool temperatures and in the dark. The manufacturer's recommendations regarding preparation, usage, and storage have to be considered in this respect.

1) e.g. the StablCal™ Turbidity Standards series, available from HACH www.hach.com or T-CAL™, available from Tintometer GmbH. This information is given for the convenience of users of this part of ISO 7027 and does not constitute an endorsement by ISO of these products.

Alternatively, the standard can be prepared in the laboratory. In this case, all safety precautions have to be considered. The standard can be prepared as follows:

Dissolve 5,0 g of hexamethylenetetramine ($C_6H_{12}N_4$) in approximately 40 ml of water (5.2.1).

Dissolve 0,5 g of hydrazine sulfate ($N_2H_6SO_4$) in approximately 40 ml of water (5.2.1).

WARNING — Hydrazine sulfate is poisonous and may be carcinogenic.

Quantitatively pour the two solutions into a 100 ml volumetric flask, dilute to the mark with water (5.2.1) and mix well. Leave for 24 h at 25 °C ± 3 °C.

This suspension is stable for up to 6 months if stored in a tightly sealed container at a temperature of 25 °C ± 3 °C in the dark.

A numerical equivalence between NTU and FNU is true with respect to prepared formazin standards. The same stock solution can be used to prepare either NTU or FNU standards. The traceability of quantitative determination of turbidity should be ensured by calibration with the same calibration formazin suspension.

5.2.3 Formazin $(C_2H_4N_2)_x$, stock suspension II (400 FNU).

Pipette 10,00 ml of the stock I formazin suspension (5.2.2) into a 100 ml volumetric flask and dilute to the mark with water (5.2.1).

This suspension is stable for about four weeks if stored at a temperature of 5 °C ± 3 °C in the dark.

5.2.4 Diffuse-radiation reference suspensions (0 FNU to 40 FNU).

Dilute the formazin stock suspension II (5.2.3) with water (5.2.1) using pipettes and volumetric flasks to obtain calibration suspensions with turbidities (FNU) in the range of interest for diffused radiation measurements (see 5.3). These suspensions are stable for one day at room temperature.

Alternatively, proven reference materials, such as styrene divinylbenzene bead suspensions, may be used as secondary standards. Such materials are commercially available[2)] and indicated to be stable for a period of one year. Their equivalency to freshly prepared formazin suspensions shall be verified once every six months. Criteria for acceptable verification shall be based on parallel triplicate testing at five suspension levels. The objective of the verification is to demonstrate that the measured average bias and precision of the secondary standard is no greater than the average bias and precision determined by interlaboratory studies (see Annex A).

Commercial standards with designated FNU values do not necessarily result in equivalent NTU values when measured against formazin in the attenuated mode (5.2.5), their use therefore shall be confined to the diffuse method only.

5.2.5 Attenuated radiation reference suspensions (40 FAU to 4 000 FAU).

Dilute the formazin stock I suspension (see 5.2.2) with water (see 5.2.1) using pipettes and volumetric flasks to obtain calibration suspensions with turbidities (FAU) in the range of interest for attenuated radiation measurements (see 5.4). Suspensions in the range 40 FAU to 400 FAU are stable for about one week while those in the range 400 FAU to 4 000 FAU are stable for about four weeks if stored at a temperature of 25 °C ± 3 °C in the dark.

---

2) Suitable secondary standards on the basis of polymer bead suspensions are e.g. available from GFS Chemicals, Inc. Columbus, Ohio U.S.A., www.gfschemicals.com (e.g. AMCO CLEAR® TURBIDITY STANDARD). The product is equivalent to the AMCO AEPA-1® Standards mentioned in Annex A and in ISO 7027:1999. This information is given for the convenience of users of this part of ISO 7027 and does not constitute an endorsement by ISO of these products.

5.3 Measurement of diffuse radiation (nephelometry)

5.3.1 Apparatus

5.3.1.1 Nephelometer, complying with the following requirements:

a) the spectral bandwidth [full width at half maximum (FWHM)] of the incident radiation shall be contained in the range of 830 nm to 890 nm;

b) there shall be no divergence from parallelism of the incident radiation, and any convergence shall not exceed 1,5 °;

c) the measuring angle, θ, between the optical axis of the incident radiation and that of the diffused radiation shall be 90° ± 2,5°;

d) the aperture angle, Ω_θ, should be between 20° and 30° in the water sample.

5.3.2 Calibration

Set up and calibrate the instrument in accordance with the instrument manufacturer's instructions, paying attention to any regulations that apply to the installation location and instrument use.

For the measurement of very low turbidity, the results should be corrected for the stray light (background radiation) of the instrument.

5.3.3 Procedure

Perform a measurement, in accordance with the manufacturer's instructions, on a well-mixed sample. Read the turbidity value from the prepared calibration curve or directly from the instrument scale if the scale has been verified as calibrated (see 5.3.2).

Bubbles are an interference with low turbidity samples and shall be minimized. Refer to manufacturer recommendations on how to minimize bubble interference.

5.3.4 Expression of results

Report the results, in formazin nephelometric units, as follows:

a) if the turbidity is < 1 FNU, to the nearest 0,01 FNU;

b) if the turbidity is ≥ 1,0 FNU and < 10 FNU, to the nearest 0,1 FNU;

c) if the turbidity is ≥ 10 FNU and < 400 FNU, to the nearest 1 FNU.

5.3.5 Test report

This test report shall contain at least the following information:

a) the test method used, together with a reference to this part of ISO 7027, i.e. ISO 7027-1:2016;

b) the result, expressed in accordance with 5.3.4;

c) details of any circumstances that might have influenced the result.

5.4 Measurement of attenuated radiation (turbidimetry)

5.4.1 Apparatus

5.4.1.1 Turbidimeter, complying with the following requirements:

a) the spectral bandwidth [full width at half maximum (FWHM)] of the incident radiation shall be contained in the range of 830 nm to 890 nm;

b) the measuring angle (tolerance on deviation of the optical axis) of the incident radiation and that of the diffuse radiation shall be 0° ± 2,5°;

c) the aperture angle, Ω_0, should be between 10° and 20° in the water sample.

5.4.2 Calibration

Set up and calibrate the instrument in accordance with the instrument manufacturer's instructions, paying attention to any regulations that apply to the installation location, and instrument use.

For the measurement of very low turbidities, the results should be corrected for the stray light (background radiation) of the instrument.

5.4.3 Procedure

Perform a measurement, in accordance with the manufacturer's instructions, on a well-mixed sample. Read the turbidity value from the prepared calibration curve or directly from the instrument scale if the scale has been verified as calibrated (5.4.2).

5.4.4 Expression of results

Report the results, in formazin attenuation units, as follows:

a) if the turbidity is between 40 FAU and 99 FAU, to the nearest 1 FAU;

b) if the turbidity is equal or above 100 FAU, to the nearest 10 FAU.

5.4.5 Test report

This test report shall contain at least the following information:

a) the test method used, together with a reference to this part of ISO 7027, i.e. ISO 7027-1:2016;

b) the result, expressed in accordance with 5.4.4;

c) details of any circumstances that might have influenced the result.

Annex A
(informative)

Results of an interlaboratory collaborative trial to evaluate the suitability of a synthetic polymer for use as a secondary standard to formazin in turbidity measurements

A.1 General

An interlaboratory collaborative trial was conducted in 1996 among 33 participants. The objective of the trial was to evaluate the suitability of using a synthetic polymer as a secondary standard to formazin. The trial was conducted in accordance with the criteria given in ISO 5725-1 and ISO 5725-2.

The study was designed so that formazin and a synthetic polymer on the basis of a styrene divinylbenzene bead suspension, AMCO AEPA-l® could be evaluated simultaneously and under repeatability conditions. Five concentration levels were designated for the formazin and the synthetic polymer. Concentrates of the formazin suspensions were prepared and dispatched to participating laboratories with documented instruction on dilution prior to measurement. The synthetic polymer was dispatched at the designated concentration levels.

NOTE 1 The AMCO AEPA-1® standards were kindly supplied from Advanced Polymer Systems, Redwood City, USA.

NOTE 2 The AMCO AEPA-1® standards are equivalent to AMCO CLEAR® TURBIDITY STANDARDS provided by GFS Chemicals, Inc., Columbus, Ohio USA, www.gfschemicals.com. In 2003, GFS Chemicals, Inc. purchased this part of the product line from Advanced Polymer Systems in Redwood, California.

All suspensions were randomly coded. Participants were requested to test the suspensions in triplicate. The results of the trial are given in Table A.1.

Table A.1 — Results of an interlaboratory trial

	Formazin					AMCO AEPA-1 ®				
	Level					Level				
	1	2	3	4	5	1	2	3	4	5
Number of laboratories	26	27	31	31	31	32	32	32	32	32
Number of outliers	3	1	4	4	2	6	1	3	1	3
Theoretical values (FNU)	0,8	3,2	8,0	16,0	32,0	0,8	4,0	8,0	15,0	35,0
Mean value (FNU)	0,825	3,304	7,918	16,697	33,255	0,824	4,147	8,374	16,052	36,916
Standard deviation of repeatability (s_r) (FNU)	0,008	0,067	0,056	0,094	0,21	0,007	0,038	0,043	0,237	0,226
Standard deviation of reproducibility (s_R) (FNU)	0,065	0,224	0,445	0,866	1,613	0,065	0,264	0,500	0,939	2,630
Bias (FNU)	0,025	0,104	−0,082	0,697	1,255	0,024	0,147	0,374	1,052	1,916
Bias (%)	+3,1	+3,2	−1,0	+4,4	+3,9	+3,0	+3,7	+4,7	+7,0	+5,5
Significant at α = 5 %?	No	Yes	No	Yes	Yes	No	Yes	Yes	Yes	Yes

The trial proved the polymer to have a bias and precision which, overall, was not significantly different to that obtained with the use of formazin standards. The polymer was found to be stable 18 months after manufacture at turbidity levels between 0,8 FNU and 40 FNU.

A.2 Verification procedure for a proven secondary standard

— Prepare, in triplicate, five suspensions of turbidity levels within the range of interest.

— Randomize the suspensions in accordance with ISO 5725-1 and ISO 5725-2.

— Measure the turbidity levels on an instrument which has been calibrated in accordance with 5.3.2 of this part of ISO 7027.

— Collate the data and determine the mean and standard deviation of each suspension level.

— Determine percent bias from the expected value for each suspension level.

— Verify that the average percent bias of all levels does not exceed the average percent bias of the proven standard (4,8 %) and that the standard deviation obtained at each level does not exceed s_r calculated for each level.

Bibliography

[1] ISO 5725-1, *Accuracy (trueness and precision) of measurement methods and results — Part 1: General principles and definitions*

[2] ISO 5725-2, *Accuracy (trueness and precision) of measurement methods and results — Part 2: Basic method for the determination of repeatability and reproducibility of a standard measurement method*

[3] ISO 3864-1, *Graphical symbols — Safety colours and safety signs — Part 1: Design principles for safety signs and safety markings*

ICS 13.060.60

Price based on 9 pages