INTERNATIONAL STANDARD

ISO 7027

Third edition
1999-12-15

Water quality — Determination of turbidity

Qualité de l'eau — Détermination de la turbidité

Reference number
ISO 7027:1999(E)

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Printed in Switzerland

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 7027 was prepared by Technical Committee ISO/TC 147, *Water quality*, Subcommittee SC 2, *Physical, chemical, biochemical methods*.

This third edition cancels and replaces the second edition (ISO 7027:1990), which has been technically revised.

Annex A of this International Standard is for information only.

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

Water quality — Determination of turbidity

1 Scope

This International Standard specifies four methods for the determination of turbidity of water.

Two semiquantitative methods, employed for example in field work, are specified:

a) measurement of turbidity using the transparency testing tube (applicable to pure and lightly polluted water);

b) measurement of turbidity using the transparency testing disk (especially applicable to surface water).

Two quantitative methods, using optical turbidimeters, are specified:

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

Turbidity measured by this method is expressed in formazin nephelometric units (FNU); results typically range between 0 FNU and 40 FNU. Depending on the instrument design, it may also be applicable to waters of higher turbidity.

d) measurement of the attenuation of a radiant flux, more applicable to highly turbid waters (for example waste or polluted waters).

Turbidity measured by this method is expressed in formazin attenuation units (FAU); results typically range between 40 FAU and 4000 FAU.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 3864:1984, *Safety colours and safety signs.*

ISO 5667-3:1994, *Water quality — Sampling — Part 3: Guidance on the preservation and handling of samples.*

CIE Publication No. 17:1987, *International Lighting Vocabulary.*

3 Terms and definitions

For the purposes of this International Standard, 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 cool, 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 Semiquantitative methods of turbidity measurement

5.1 Measurement using the transparency testing tube

5.1.1 Apparatus

5.1.1.1 **Transparency testing tube**, consisting of a colourless glass tube 600 mm ± 10 mm long and of internal diameter 25 mm ± 1 mm, graduated in divisions of 10 mm.

5.1.1.2 **Shield**, close-fitting, to protect the transparency testing tube from lateral light.

5.1.1.3 **Print sample** to place under the tube (5.1.1.1), consisting of black print on a white background (height of characters 3,5 mm; line width 0,35 mm) or a **test mark** (for example, a black cross on white paper), provided with the apparatus.

5.1.1.4 **Constant light source**, 3 W low voltage tungsten lamp, to illuminate the print sample or test mark (5.1.1.3).

5.1.2 Procedure

It is absolutely essential that tests conducted according to this International Standard be carried out by suitably qualified staff.

Thoroughly mix the sample and transfer it to the transparency testing tube (5.1.1.1). Steadily lower the sample level until the print sample or test mark (5.1.1.3) is clearly recognizable as viewed from above. Read the liquid height from the graduations on the tube.

5.1.3 Expression of results

Report the measured liquid height, to the nearest 10 mm, together with the apparatus used (name of the manufacturer).

5.2 Measurement using the transparency testing disk

NOTE This method is intended primarily for testing bodies of water *in situ.*

5.2.1 Apparatus

5.2.1.1 **Transparency testing disk** made of cast bronze and coated with white (see ISO 3864) plastics, attached to a chain or rod.

NOTE A typical design comprises a disk of diameter 200 mm with six holes, each of diameter 55 mm, on a circle of diameter 120 mm.

5.2.2 Procedure

It is absolutely essential that tests conducted according to this standard be carried out by suitably qualified staff.

Lower the disk, on its chain or rod, into the water until the disk is barely visible when viewed from above. Measure the length of immersed chain or rod. Repeat the test several times.

Ensure that no interference arises from reflection at the water surface.

5.2.3 Expression of results

Report the depth of immersion.

For values less than 1 m, report the result to the nearest 10 mm. For values greater than 1 m, report the result to the nearest 0,1 m.

6 Quantitative methods of turbidity measurement using optical turbidimeters

6.1 General principles

It is absolutely essential that tests conducted according to this International Standard be carried out by suitably qualified staff.

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 $\alpha(\lambda)$:

$$\mu(\lambda) = s(\lambda) + \alpha(\lambda) \quad (1)$$

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).

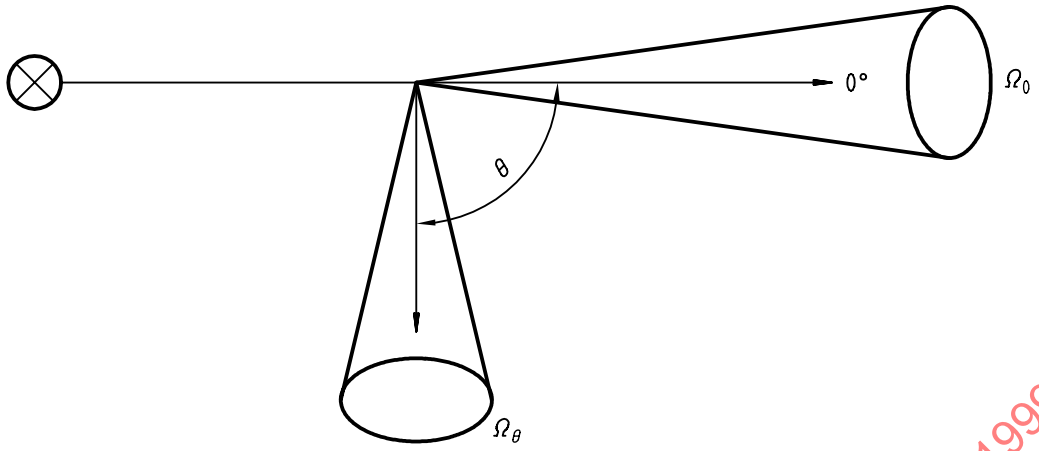

Figure 1

Application to 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 International Standard 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.

6.2 Reagents

Use only reagents of recognized analytical grade and store in hard glass bottles all reagents prepared in accordance with this International Standard.

6.2.1 Water, for the preparation of the formazine calibration suspensions.

Soak a membrane filter of pore size 0,1 µm (of the type used for bacteriological studies) 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 formazine suspensions.

6.2.2 Formazine ($C_2H_4N_2$) **stock I suspension** (4 000 FAU)

Dissolve 5,0 g of hexamethylenetetramine ($C_6H_{12}N_4$) in approximately 40 ml of water (6.2.1).

Dissolve 0,5 g of hydrazine sulfate ($N_2H_6SO_4$) in approximately 40 ml of water (6.2.1).

WARNING — Hydrazine sulfate is poisonous and may be carcinogenic.

Quantitatively pour the two solutions into a 100,0 ml volumetric flask, dilute to the mark with water (6.2.1) and mix well. Leave for 24 h at 25 °C ± 3 °C.

This suspension is stable for about four weeks if stored at a temperature of 25 °C ± 3 °C in the dark.

6.2.3 Formazine ($C_2H_4N_2$) **stock II suspension** (400 FAU)

Pipette 10,00 ml of the stock I formazine suspension (6.2.2) into a 100,0 ml volumetric flask and dilute to the mark with water (6.2.1).

This suspension is stable for about 4 weeks if stored at a temperature of 25 °C ± 3 °C in the dark.

6.2.4 **Diffuse-radiation calibration suspensions** (0 FNU to 40 FNU)

Dilute the formazine stock II suspension (6.2.3) with water (6.2.1) using pipettes and volumetric flasks to obtain calibration suspensions with turbidities (FNU) in the range of interest for diffused radiation measurements (see 6.3.2). These suspensions are stable for one day.

Alternatively, use proven commercially available standards[1)], such as styrene divinylbenzene bead suspensions, subject to them being verified as being equivalent to freshly prepared formazine suspensions. These standards are indicated to be stable for a period of one year. Verification of proven commercial standards against formazine shall be performed once every six months. Criteria for acceptable verification shall be based on parallel triplicate testing of the proven secondary standards at five suspension levels. The objective of the verification is to prove that the measured average bias and precision of the secondary standard is no greater than the proven average bias and precision of the secondary standard as determined by interlaboratory studies (see annex A).

Commercial standards with designated FNU values do not necessarily result in equivalent FAU values when measured against formazine in the attenuated mode; their use therefore shall be confined to the diffuse method only.

6.2.5 **Attenuated radiation calibration suspensions** (40 FAU to 4 000 FAU)

Dilute the formazine stock I suspension (see 6.2.2) with water (see 6.2.1) using pipettes and volumetric flasks to obtain calibration suspensions with turbidities (FAU) in the range of interest for attenuated radiation measurements (see 6.4.2). 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.

6.3 Measurement of diffuse radiation

6.3.1 Apparatus

6.3.1.1 **Turbidimeter** complying with the following requirements:

a) the wavelength, λ, of the incident radiation[2)] shall be 860 nm [3)];

With some apparatus, the influence of stray light or the noise level (background radiation) is such that it is impossible to measure very small degrees of turbidity, and it is preferable to operate at a wavelength of 550 nm with a bandwidth of 30 nm. In such cases, the water sample shall be colourless. Results obtained at different wavelengths cannot be compared with those obtained at a wavelength of 860 nm.

b) the spectral bandwidth, $\Delta\lambda$, of the incident radiation shall be less than or equal to 60 nm;

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

1) AMCO AEPA-1® Standards available from Advanced Polymer Systems, 123 Saginaw Drive, Redwood City, CA 94063, USA were evaluated in an international collaborative trial. The results and details of the trial are supplied in annex A. This information is given for the convenience of users of this International Standard and does not constitute an endorsement by ISO of these products.

2) Tungsten lamps fitted with monochromators and filters, diodes and lasers may be used as sources of monochromatic radiation. However, some older apparatus fitted with tungsten lamps, but without monochromators or filters, are still in use (polychromatic sources) and, while the reproducibility of such apparatus may be less than that of apparatus providing monochromatic radiation, they can be used for the daily control and monitoring of turbidity at waterworks and treatment plants. Results cannot, however, be compared when using different apparatus.

3) Measurements at 860 nm show a lower intensity of diffuse radiation in comparison with measurements at lower wavelengths.

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

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

6.3.2 Calibration

Set up the instrument in accordance with the manufacturer's calibration instructions.

After instrument set-up, perform a method calibration using the dilution water (6.2.1) as a blank and at least five formazine standard calibration suspensions (6.2.4) of turbidity equally spaced over the range of interest. In the absence of a precalibrated scale or where a precalibrated scale is shown to differ from the calibration values, prepare a calibration curve.

6.3.3 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 6.3.2).

6.3.4 Expression of results

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

a) if the turbidity is less than 0,99 FNU, to the nearest 0,01 FNU;

b) if the turbidity is between 1,0 FNU and 9,9 FNU, to the nearest 0,1 FNU;

c) if the turbidity is between 10 FNU and 40 FNU, to the nearest 1 FNU.

6.3.5 Test report

The test report shall include the following information:

a) a reference to this International Standard;

b) the result, expressed in accordance with 6.3.4;

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

6.4 Measurement of attenuated radiation

6.4.1 Apparatus

6.4.1.1 Turbidimeter complying with the following requirements:

a) the wavelength, λ, of the incident radiation[2] shall be 860 nm[3];

b) the spectral bandwidth, $\Delta\lambda$, of the incident radiation shall be less than or equal to 60 nm;

c) there shall be no divergence from parallelism of the incident radiation and any convergence shall not exceed 2,5°;

d) 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°;

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

6.4.2 Calibration

Set up the instrument in accordance with the manufacturer's calibration instructions.

After instrument set-up, perform a method calibration using the dilution water (6.2.1) as a blank and at least five formazine standard calibration suspensions (6.2.5) of turbidity equally spaced over the range of interest. In the absence of a precalibrated scale or where a precalibrated scale is shown to differ from the calibration values, prepare a calibration curve.

6.4.3 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 (6.4.2).

6.4.4 Expression of results

Report the results, in formazine 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 greater than 100 FAU, to the nearest 10 FAU.

6.4.5 Test report

The test report shall include the following information:

a) a reference to this International Standard;

b) the result, expressed in accordance with 6.4.4;

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 formazine in turbidity measurements

A.1 General

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

The study was designed so that formazine and the synthetic polymer, AMCO AEPA-1®, could be evaluated simultaneously and under repeatability conditions. Five concentration levels were designated for the formazine and the synthetic polymer. Concentrates of the formazine 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.

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

Table A.1 — Results of an interlaboratory trial

	Formazine					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
Repeatability	0,008	0,067	0,056	0,094	0,21	0,007	0,038	0,043	0,237	0,226
Standard deviation of repeatability (s_r)	$s_r = 0{,}006\ x + 0{,}018$					$s_r = 0{,}007\ x + 0{,}024$				
Reproducibility	0,065	0,224	0,445	0,866	1,613	0,065	0,264	0,500	0,939	2,630
Standard deviation of reproducibility (s_R)	$s_R = 0{,}047\ x + 0{,}057$					$s_R = 0{,}071\ x - 0{,}067$				
Bias	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 formazine standards. The polymer was found to be stable 18 months after manufacture at turbidity levels between 0,8 FNU and 40 FNU.