



## Standard Test Methods for Zinc in Water <sup>1</sup>

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*This standard has been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.*

### 1. Scope

1.1 These test methods cover the determination of zinc in water. Two test methods are given as follows:

		Sections
Test Method A—Atomic Absorption, Direct	0.05 to 2 mg/L	8-16
Test Method B—Atomic Absorption, Chelation-Extraction	20 to 200 $\mu$ g/L	17-25

1.2 Either dissolved or total recoverable zinc may be determined.

1.3 These test methods have been used successfully with reagent grade water. See the specific test method for applicability to other matrices. It is the user's responsibility to assure the validity of these test methods in other matrices.

1.4 *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.* For specific hazard statements, see Section 6 and Note 5, Note 8, and Note 13.

1.5 Two former colorimetric test methods were discontinued. Refer to Appendix X1 for historical information.

### 2. Referenced Documents

#### 2.1 ASTM Standards:

- D 858 Test Methods for Manganese in Water <sup>2</sup>
- D 1066 Practice for Sampling Steam <sup>2</sup>
- D 1068 Test Methods for Iron in Water <sup>2</sup>
- D 1129 Terminology Relating to Water <sup>2</sup>
- D 1192 Specification for Equipment for Sampling Water and Steam in Closed Conduits <sup>2</sup>
- D 1193 Specification for Reagent Water <sup>2</sup>
- D 1687 Test Methods for Chromium in Water <sup>2</sup>
- D 1688 Test Methods for Copper in Water <sup>2</sup>
- D 1886 Test Methods for Nickel in Water <sup>2</sup>
- D 2777 Practice for Determination of Precision and Bias of Applicable Methods of Committee D-19 on Water <sup>2</sup>

<sup>1</sup> These test methods are under the jurisdiction of ASTM Committee D-19 on Water and are the direct responsibility of Subcommittee D19.05 on Inorganic Constituents in Water.

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 11.01.

D 3370 Practices for Sampling Water from Closed Conduits <sup>2</sup>

D 3557 Test Methods for Cadmium in Water <sup>2</sup>

D 3558 Test Methods for Cobalt in Water <sup>2</sup>

D 3559 Test Methods for Lead in Water <sup>2</sup>

D 4841 Practice for Estimation of Holding Time for Water Samples Containing Organic and Inorganic Constituents <sup>2</sup>

### 3. Terminology

3.1 *Definitions:*—For definitions of terms used in these test methods, refer to Terminology D 1129.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *total recoverable zinc*—an arbitrary analytical term relating to the recoverable form of zinc that is determinable by the digestion method which is included in the Procedure.

### 4. Significance and Use

4.1 Zinc is an essential and beneficial element in body growth. Concentrations above 5 mg/L can cause a bitter astringent taste and opalescence in alkaline waters. The zinc concentration of U.S. drinking waters varies between 0.06 and 7.0 mg/L with a mean of 1.33 mg/L. Zinc most commonly enters the domestic water supply from deterioration of galvanized iron and dezincification of brass. Zinc in water also may result from industrial water pollution. <sup>3</sup>

### 5. Purity of Reagents

5.1 Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available. <sup>4</sup> Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

5.2 *Purity of Water*—Unless otherwise indicated, references

<sup>3</sup> "Standard Methods for the Examination of Water and Wastewater," 16th edition, 1985, APHA, AWWA-WPCF.

<sup>4</sup> *Reagent Chemicals, American Chemical Society Specifications*, American Chemical Society, Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see *Analar Standards for Laboratory Chemicals*, BDH Ltd., Poole, Dorset, U.K., and the *United States Pharmacopeia and National Formulary*, U.S. Pharmaceutical Convention, Inc. (USPC), Rockville, MD.

to water shall be understood to mean reagent water conforming to Specification D 1193, Type I. Other reagent water types may be used, provided it is first ascertained that the water is of sufficiently high purity to permit its use without adversely affecting the bias and precision of the test method. Type II water was specified at the time of round-robin testing of this test method.

## 6. Hazards

6.1 Although zinc is nontoxic to man, these test methods require the use of certain other toxic and hazardous reagents and materials. Each should be used with care and exerting proper precautions.

## 7. Sampling

7.1 Collect the sample in accordance with Practice D 1066, Specification D 1192, and Practices D 3370, as applicable.

7.2 Samples shall be preserved with nitric acid ( $\text{HNO}_3$ ) (sp gr 1.42) to a pH of 2 or less immediately at the time of collection, normally about 2 mL/L of  $\text{HNO}_3$ . If only dissolved zinc is to be determined, the sample, shall be filtered through a 0.45- $\mu\text{m}$  membrane filter before acidification. The holding time for samples may be calculated in accordance with Practice D 4841.

## TEST METHOD A—ATOMIC ABSORPTION, DIRECT

## 8. Scope

8.1 This test method covers the determination of dissolved and total recoverable zinc in most waters and wastewaters.

8.2 This test method is applicable in the range from 0.05 to 2.0 mg/L of zinc. The range may be extended to concentrations greater than 2.0 mg/L by dilution of the sample.

8.3 This test method has been used successfully with reagent grade water, river water, wastewater, ground water, tap water, lake water, refinery effluent. The information on precision and bias may not apply to other waters.

## 9. Summary of Test Method

9.1 Zinc is determined by atomic absorption spectrophotometry. Dissolved zinc is determined by aspirating a portion of the filtered and preserved sample directly with no pretreatment. Total recoverable zinc is determined by aspirating the sample following hydrochloric-nitric acid digestion and filtration. The same digestion procedure is used to determine total recoverable cadmium (Test Methods D 3557), chromium, (Test Methods D 1687), cobalt (Test Methods D 3558), copper (Test Methods D 1688), iron (Test Methods D 1068), lead (Test Methods D 3559), manganese (Test Methods D 858), and nickel (Test Methods D 1886).

## 10. Interferences

10.1 Sodium, potassium, sulfate, and chloride (9000 mg/L each), calcium and magnesium (4000 mg/L each), nitrate (2000 mg/L), and cadmium, lead, copper, nickel, cobalt, and chromium (10 mg/L each) do not interfere.

10.2 Background correction or a chelation-extraction procedure (see Test Method B) may be necessary to determine low levels of zinc in some waters.

NOTE 1—Instrument manufacturers' instructions for use of the specific correction technique should be followed.

## 11. Apparatus

11.1 *Atomic Absorption Spectrophotometer*, for use at 213.9 nm.

NOTE 2—The manufacturer's instructions should be followed for all instrumental parameters. Wavelengths other than 213.9 nm may be used if they have been determined to be equally suitable.

11.1.1 *Zinc Light Source*—Hollow-cathode lamps or electrodeless discharge lamps have been found satisfactory.

11.2 *Oxidant*—See 12.6.

11.3 *Fuel*—See 12.7.

11.4 *Pressure-Reducing Valves*—The supplies of fuel and oxidant shall be maintained at pressures somewhat higher than the controlled operating pressure of the instrument by suitable valves.

## 12. Reagents and Materials

12.1 *Hydrochloric Acid* (sp gr 1.19)—Concentrated hydrochloric acid (HCl).

NOTE 3—If the reagent blank concentration is greater than the method detection limit, distill the HCl or use a spectrograde acid. **Caution**—When HCl is distilled an azeotropic mixture is obtained (approximately 6 N HCl). Therefore, whenever concentrated HCl is specified in the preparation of a reagent or in the procedure, use double the amount specified if a distilled acid is used.

12.2 *Nitric Acid* (sp gr 1.42)—Concentrated nitric acid ( $\text{HNO}_3$ ).

NOTE 4—If the reagent blank concentration is greater than the method detection limit, distill the  $\text{HNO}_3$  or use a trace metal grade acid.

12.3 *Nitric Acid* (1 +499)—Add 1 volume of  $\text{HNO}_3$ (sp gr 1.42) to 499 volumes of water.

12.4 *Zinc Solution, Stock* (1 mL = 1.0 mg Zn)—Dissolve 1.245 g of zinc oxide (ZnO) in a mixture of 10 mL of  $\text{HNO}_3$ (sp gr 1.42) and 10 mL of water. Dilute to 1 L with water.

12.5 *Zinc Solution, Standard* (1 mL = 0.1 mg Zn)—Dilute 100.0 mL of the zinc stock solution and 1 mL of  $\text{HNO}_3$ (sp gr 1.42) to 1 L with water.

12.6 *Oxidant*:

12.6.1 *Air*, which has been passed through a suitable filter to remove oil, water, and other foreign substances, is the usual oxidant.

12.7 *Fuel*:

12.7.1 *Acetylene*—Standard, commercially available acetylene is the usual fuel. Acetone, always present in acetylene cylinders, can affect analytical results. The cylinder should be replaced at 50 psig (345 kPa).

NOTE 5—**Warning**: "Purified" grade acetylene containing a special proprietary solvent rather than acetone should not be used with poly(vinyl chloride) tubing as weakening of the tubing walls can cause a potentially hazardous situation.

## 13. Standardization

13.1 Prepare 100 mL each of a blank and at least four standard solutions to bracket the expected zinc concentration range of the samples to be analyzed by diluting the standard zinc solution (12.5) with  $\text{HNO}_3$ (1 +499). Prepare the standards

each time the test is to be performed and select so as to give zero, middle, and maximum points for an analytical curve.

13.2 When determining total recoverable zinc, add 0.5 mL of HNO<sub>3</sub> (sp gr 1.42) to each blank and standard solution and proceed as directed in 14.2-14.4. After the digestion of the blank and standard solutions has been completed in 14.4, return to 13.3 to complete the standardization for total recoverable determinations. To determine dissolved zinc, proceed with 13.3.

13.3 Aspirate the blank and standards, and record the absorbance of each at 213.9 nm. Aspirate HNO<sub>3</sub> (1 + 499) between each standard.

13.4 Prepare an analytical curve by plotting the absorbance versus concentration for each standard on linear graph paper. Alternatively, read directly in concentration if the capability is provided with the instrument.

#### 14. Procedure

14.1 Measure 100.0 mL of a well-mixed acidified sample into a 125-mL beaker or flask.

NOTE 6—If only dissolved zinc is to be determined, start with 14.5.

14.2 Add 5 mL of HCl (sp gr 1.19) to each sample.

14.3 Heat the samples on a steam bath or hotplate in a well-ventilated hood until the volume has been reduced to 15 to 20 mL, making certain that the samples do not boil.

NOTE 7—For samples with appreciable amounts of suspended matter or dissolved solids, the amount of reduction in the volume is left to the discretion of the analyst.

14.4 Cool and filter the samples through a suitable filter, such as fine-textured, acid-washed, ashless paper, into 100-mL volumetric flasks. Wash the filter paper two or three times with water and adjust to volume.

14.5 Aspirate each filtered and acidified sample and standard and determine its absorbance or concentration at 213.9 nm. Atomize HNO<sub>3</sub> (1 + 499) between each sample and standard.

#### 15. Calculation

15.1 Calculate the concentration of zinc in each sample, in milligrams per litre, using the analytical curve prepared in 13.4 or read directly in concentration.

#### 16. Precision and Bias<sup>5</sup>

16.1 The overall precision and bias of this test method, within its designated range, is shown in Table 1.

16.2 These collaborative test data were obtained from eleven laboratories on reagent grade, river, lake, ground and effluent waters. For other waters these data may not apply.

#### TEST METHOD B—ATOMIC ABSORPTION, CHELATION-EXTRACTION

#### 17. Scope

17.1 This test method covers the determination of dissolved and total recoverable zinc in most waters and brines.

**TABLE 1 Determination of Precision and Bias for Zinc by Atomic Absorption, Direct**

Amount Added, mg/L	Amount Found, mg/L	$S_T$ , mg/L	$S_O$ , mg/L	%, Bias	Statistically Significant, 95 % Level
Reagent Water					
0.16	0.172	0.052	0.038	+ 7.5	No
0.80	0.798	0.068	0.034	-0.2	No
1.50	1.459	0.107	0.041	-2.7	Yes
Water of Choice					
0.16	0.172	0.041	0.033	+ 7.5	Yes
0.80	0.796	0.081	0.047	-0.5	No
1.50	1.446	0.098	0.060	-3.6	Yes

17.2 This test method is applicable in the range from 20 to 200 µg/L of zinc.

17.3 This test method has been used successfully with reagent grade water, river water, wastewater, ground water, tap water, lake water, refinery effluent. The information on precision and bias may not apply to other waters.

#### 18. Summary of Test Method

18.1 Zinc is determined by atomic absorption spectrophotometry. The element, either dissolved or total recoverable, is chelated with pyrrolidine dithiocarbamic acid and extracted with chloroform. The extract is evaporated to dryness, treated with hot nitric acid to destroy organic matter, dissolved in hydrochloric acid, and diluted to a specified volume with water. The resulting solution is then aspirated into the air-acetylene flame of the spectrophotometer. The digestion procedure summarized in 9.1 is used when determining total recoverable zinc. The same chelation-extraction procedure is used to determine total recoverable cadmium (Test Methods D 3557), cobalt (Test Methods D 3558), copper (Test Methods D 1688), iron (Test Methods D 1068), lead (Test Methods D 3559), and nickel (Test Methods D 1886).

#### 19. Interferences

19.1 See Section 10.

#### 20. Apparatus

20.1 Apparatus described in Section 11 are required.

#### 21. Reagents and Materials

21.1 *Bromphenol Blue Indicator Solution* (1 g/L)—Dissolve 0.1 g of bromphenol blue in 100 mL of 50 % ethanol or isopropanol.

21.2 *Chloroform* (CHCl<sub>3</sub>).

21.3 *Hydrochloric Acid* (sp gr 1.19)—Concentrated hydrochloric acid (HCl) (see Note 2).

21.4 *Hydrochloric Acid* (1 + 2)—Add 1 volume of hydrochloric acid (HCl), sp gr 1.19, to 2 volumes of water.

21.5 *Hydrochloric Acid* (1 + 49)—Add 1 volume of hydrochloric acid (HCl) sp gr 1.19, to 49 volumes of water.

21.6 *Nitric Acid* (sp gr 1.42)—Concentrated nitric acid (HNO<sub>3</sub>) (see Note 4).

21.7 *Pyrrolidine Dithiocarbamic Acid-Chloroform Reagent*—Add 36 mL of pyrrolidine to 1 L of CHCl<sub>3</sub>. Cool the solution and add 30 mL of CS<sub>2</sub> in small portions, swirling

<sup>5</sup> Supporting data are available from ASTM Headquarters. Request RR: D19-1039.

between additions. Dilute to 2 L with  $\text{CHCl}_3$ . The reagent can be used for several months if stored in a cool, dark place.

**NOTE 8—Warning:** All components of this reagent are highly toxic. Carbon disulfide is also highly flammable. Prepare and use in a well-ventilated hood. Avoid inhalation and direct contact.

21.8 *Sodium Hydroxide Solution* (100 g/L)—Dissolve 100 g of sodium hydroxide (NaOH) in water and dilute to 1 L.

21.9 *Zinc Solution, Stock* (1.0 mL = 1.0 mg Zn)—See 12.4.

21.10 *Zinc Solution, Intermediate* (1.0 mL = 0.1 mg Zn)—See 12.5.

21.11 *Zinc Solution, Standard* (1.0 mL = 1.0  $\mu\text{g}$  Zn)—Immediately before use, dilute 10.0 mL of zinc intermediate standard solution and 1 mL of  $\text{HNO}_3$  (sp gr 1.42) to 1 L with water. This standard is used to prepare working standards at the time of analysis.

21.12 *Oxidant*—See 12.6.

21.13 *Fuel*—See 12.7.

## 22. Standardization

22.1 Prepare a blank and sufficient standards containing from 0.0 to 20.0  $\mu\text{g}$  of zinc by diluting 0.0 to 20.0-mL portions of zinc standard solution (21.11) to 100 mL with water.

22.2 When determining total recoverable zinc use 125-mL beakers or flasks, add 0.5 mL of  $\text{HNO}_3$  (sp gr 1.42) and proceed as directed in 23.2-23.15). When determining dissolved zinc use 250-mL separatory funnels and proceed as directed in 23.5-23.15.

22.3 Construct an analytical curve by plotting the absorbances of standards versus micrograms of zinc on linear graph paper. Alternatively, read directly in concentration if this capability is provided with the instrument.

## 23. Procedure

23.1 Measure a volume of a well-mixed acidified sample containing less than 20.0  $\mu\text{g}$  of zinc (100-mL maximum) into a 125-mL beaker or flask and adjust the volume to 100 mL with water.

**NOTE 9**—If only dissolved zinc is to be determined, measure a volume of filtered and acidified sample containing less than 20.0  $\mu\text{g}$  of nickel (100-mL maximum) into a 250-mL separatory funnel, and start with 23.5).

23.2 Add 5 mL of HCl (sp gr 1.19) to each sample.

23.3 Heat the samples on a steam bath or hotplate in a well-ventilated hood until the volume has been reduced to 15 to 20 mL, making certain that the samples do not boil.

**NOTE 10**—For brines and samples with appreciable amounts of suspended matter or dissolved solids, the amount of reduction in volume is left to the discretion of the analyst.

23.4 Cool and filter the samples through a suitable filter, such as fine-textured, acid-washed, ashless paper, into 250-mL separatory funnels. Wash the filter paper two or three times with water and adjust the volume to approximately 100 mL.

23.5 Add 2 drops of bromphenol blue indicator solution and mix.

23.6 Adjust the pH by addition of NaOH (100 g/L) solution until a blue color persists. Add HCl (1 +49) by drops until the blue color just disappears; then add 2.5 mL of HCl (1 +49) in excess. The pH at this point should be 2.3.

**NOTE 11**—The pH adjustment in 23.6 may be made with a pH meter instead of using indicator.

23.7 Add 10 mL of pyrrolidine dithiocarbamic acid-chloroform reagent and shake vigorously for 2 min. **Warning**—See Note 8.

23.8 Plug the tip of the separatory funnel with cotton, allow the phases to separate, and drain the  $\text{CHCl}_3$  phase into a 100-mL beaker.

23.9 Repeat the extraction with 10 mL of  $\text{CHCl}_3$  and drain the  $\text{CHCl}_3$  layer into the same beaker.

**NOTE 12**—If color still remains in the  $\text{CHCl}_3$  extract, reextract the aqueous phase until the  $\text{CHCl}_3$  layer is colorless.

23.10 Place the beaker on a hotplate set at a low heat or on a steam bath, and evaporate to near dryness. Remove beaker from heat and allow residual solvent to evaporate without further heating.

**NOTE 13—Precaution:** Perform in a well-ventilated hood.

23.11 Hold the beaker at a 45° angle, and slowly add dropwise 2 mL of  $\text{HNO}_3$  (sp gr 1.42), rotating the beaker to effect thorough contact of the acid with the residue.

23.11.1 If acid is added to the beaker in a vertical position, a violent reaction will occur accompanied by high heat and spattering.

23.12 Place the beaker on a hotplate set at low heat or on a steam bath, and evaporate to near dryness. Remove beaker from heat and allow residual solvent to evaporate without further heating.

23.13 Add 2 mL of HCl (1 +2) to the beaker, and heat, while swirling for 1 min.

23.14 Cool and quantitatively transfer the solution to a 10-mL volumetric flask and adjust to volume with water.

23.15 Aspirate each sample and record the scale reading or concentration at 213.9 nm.

## 24. Calculation

24.1 Determine the weight of zinc in each sample by referring to the analytical curve. Calculate the concentration of zinc in micrograms per litre using Eq. 1:

$$\text{Zinc, } \mu\text{g/L} = 1000 / A \times B \quad (1)$$

where:

$A$  = volume of original sample, mL and

$B$  = weight of zinc in sample,  $\mu\text{g}$ .

## 25. Precision and Bias

25.1 These collaborative test data were obtained from six laboratories on reagent grade, river, and potable waters. A synthetic brine was also analyzed. This data may not apply for other waters. Precision and bias data are shown in Table 2.

## 26. Keywords

26.1 atomic absorption; chelation; flame; water; zinc

**TABLE 2 Determination of Precision and Bias for Zinc by Atomic Absorption, Chelation-Extraction**

Amount Added, $\mu\text{g/L}$	Amount Found, $\mu\text{g/L}$	$S_{\overline{T}}$ , $\mu\text{g/L}$	$S_{\overline{O}}$ , $\mu\text{g/L}$	%, Bias	Statistically Significant, 95 % Level
Reagent Water					
10	24.1	16.2	6.0	+ 141.0	Yes
70	78.1	19.2	11.0	+ 11.6	No
160	171.8	24.2	13.5	+ 7.4	No
Water of Choice					
10	17.2	11.7	5.9	+ 72.0	Yes
70	82.3	26.8	12.5	+ 17.5	No
160	165.2	28.7	10.2	+ 3.3	No

## APPENDIX

### (Nonmandatory Information)

#### X1. RATIONALE FOR DISCONTINUATION OF TEST METHODS

##### X1.1 Colorimetric with Zincon (High and Low Ranges):

X1.1.1 These test methods were discontinued in 1988. They were last published in the 1988 *Annual Book of ASTM Standards*, Vol 11.01.

X1.1.2 These test methods cover the determination of zinc in water for samples containing 0.02 to 5.0 mg/L (high range) and 0.002 to 0.25 mg/L (low range) of zinc. Relevant data has been filed at ASTM Headquarters as Research Report RR:D-19-160.

X1.1.3 The chemistry of both test methods is the same; they differ only with respect to sample size and reagent concentration of the treated aliquot.

(a) Zinc forms a blue-colored complex with 2-carboxy-2'-hydroxy-5'-sulfoformazyl benzene (zircon) in a solution buffered to a pH of 9.0.

(b) The blue-colored zinc-zircon complex is masked at the low zinc concentration range of the test methods by the intense brick-red color of the zincon indicator solution. The color obeys Beer's law up to a concentration of 5 mg/L of zinc.

X1.1.4 These test methods were discontinued because there were insufficient laboratories interested in participating in a collaborative study to obtain the necessary precision and bias data as required by Practice D 2777.

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