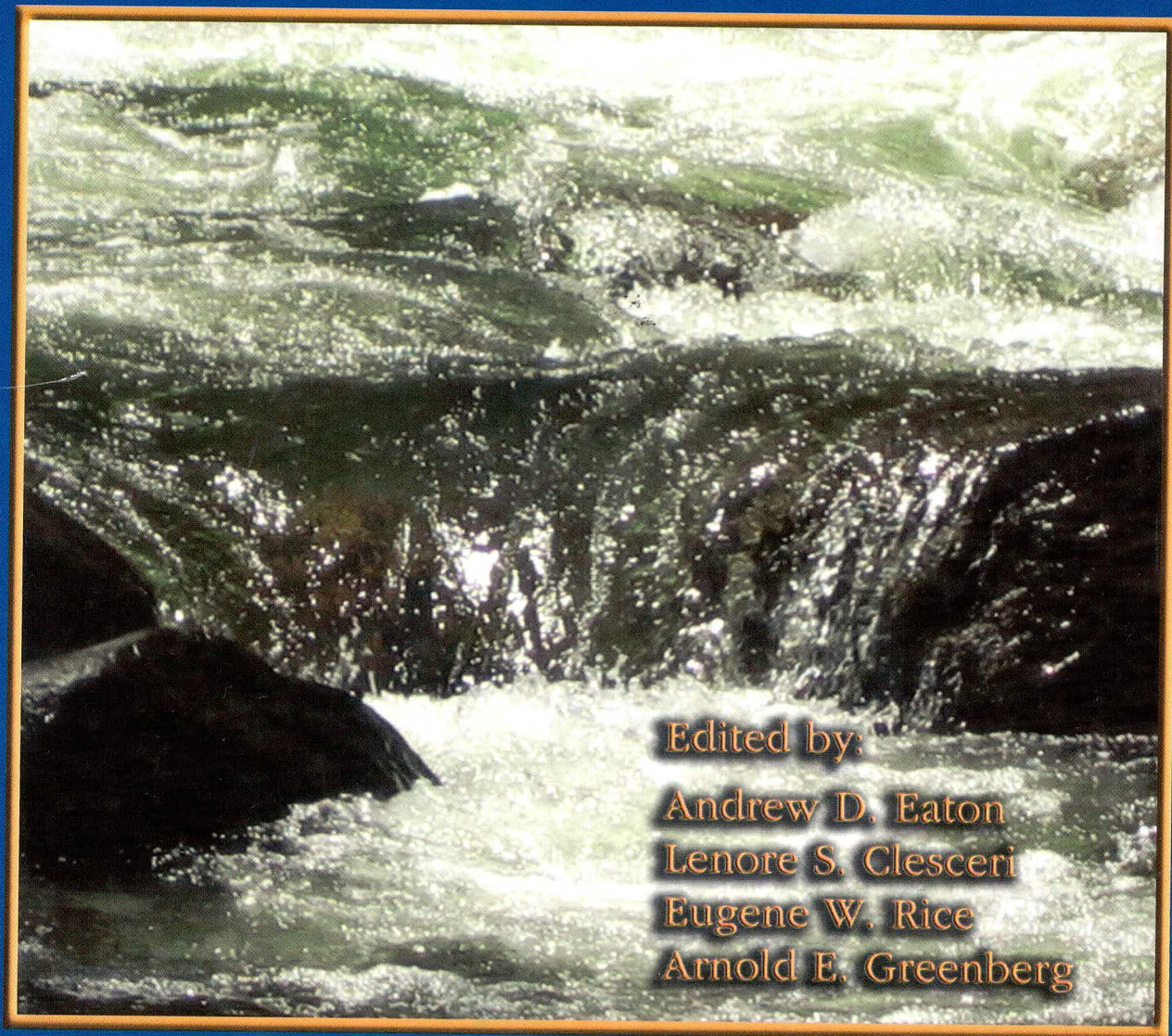


21st Edition

STANDARD METHODS

FOR THE EXAMINATION OF WATER & WASTEWATER



Edited by:

Andrew D. Eaton

Lenore S. Clesceri

Eugene W. Rice

Arnold E. Greenberg

2005

Centennial Edition

Preparation of Common Types of Desk Reagents Specified in *Standard Methods*

Acid Solutions

Prepare the following reagents by cautiously adding required amount of concentrated acids, with mixing, to designated volume of proper type of distilled water. Dilute to 1000 mL and mix thoroughly.

See Table A for preparation of HCl, H₂SO₄, and HNO₃ solutions.

Alkaline Solutions

a. Stock sodium hydroxide, NaOH, 15N (for preparing 6*N*, 1*N*, and 0.1*N* solutions): Cautiously dissolve 625 g solid NaOH in 800 mL distilled water to form 1 L of solution. Remove sodium carbonate precipitate by keeping solution at the boiling point for a few hours in a hot water bath or by letting particles settle for at least 48 h in an alkali-resistant container (wax-lined or polyethylene) protected from atmospheric CO₂ with a soda lime tube. Use the supernate for preparing dilute solutions listed in Table B.

Alternatively prepare dilute solutions by dissolving the weight of solid NaOH indicated in Table B in CO₂-free distilled water and diluting to 1000 mL.

Store NaOH solutions in polyethylene (rigid, heavy-type) bottles with polyethylene screw caps, paraffin-coated bottles with rubber or neoprene stoppers, or borosilicate-glass bottles with rubber or neoprene stoppers. Check solutions periodically. Protect them by attaching a tube of CO₂-absorbing granular material such as soda lime or a commercially available CO₂-removing agent.* Use at least 70 cm of rubber tubing to minimize vapor diffusion from bottle. Replace absorption tube before it becomes exhausted. Withdraw solution by a siphon to avoid opening bottle.

* Ascarite II®, Arthur H. Thomas Co.; or equivalent.

TABLE B. PREPARATION OF UNIFORM SODIUM HYDROXIDE SOLUTIONS

Normality of NaOH Solution	Required Weight of NaOH to Prepare 1000 mL of Solution g	Required Volume of 15 <i>N</i> NaOH to Prepare 1000 mL of Solution mL
6	240	400
1	40	67
0.1	4	6.7

b. Ammonium hydroxide solutions, NH₄OH: Prepare 5*N*, 3*N* and 0.2*N* NH₄OH solutions by diluting 333 mL, 200 mL, and 13 mL, respectively, of the concentrated reagent (sp gr 0.90, 29.0% 15*N*) to 1000 mL with distilled water.

Indicator Solutions

a. Phenolphthalein indicator solution: Use either the aqueous (1) or alcoholic (2) solution.

1) Dissolve 5 g phenolphthalein disodium salt in distilled water and dilute to 1 L.

2) Dissolve 5 g phenolphthalein in 500 mL 95% ethyl or isopropyl alcohol and add 500 mL distilled water

If necessary, add 0.02*N* NaOH dropwise until a faint pink color appears in solution 1) or 2).

b. Methyl orange indicator solution: Dissolve 500 mg methyl orange powder in distilled water and dilute to 1 L.

TABLE A: PREPARATION OF UNIFORM ACID SOLUTIONS*

Desired Component	Hydrochloric Acid (HCl)	Sulfuric Acid (H ₂ SO ₄)	Nitric Acid (HNO ₃)
Specific gravity (20/4°C) of ACS-grade conc acid	1.174–1.189	1.834–1.836	1.409–1.418
Percent of active ingredient in conc reagent	36–37	96–98	69–70
Normality of conc reagent	11–12	36	15–16
Volume (mL) of conc reagent to prepare 1 L of:			
18 <i>N</i> solution	—	500 (1 + 1)†	—
6 <i>N</i> solution	500 (1 + 1)†	167 (1 + 5)†	380
1 <i>N</i> solution	83 (1 + 11)†	28	64
0.1 <i>N</i> solution	8.3	2.8	6.4
Volume (mL) of 6 <i>N</i> reagent to prepare 1 L of:			
0.1 <i>N</i> solution	17	17	17
Volume (mL) of 1 <i>N</i> reagent to prepare 1 L of:			
0.02 <i>N</i> solution	161	161	20

*All values approximate.

†The *a* + *b* system of specifying concentrated reagent are diluted

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Standard methods for the examination of water and wastewater / edited by Andrew D. Eaton (et al.).

means that *a* volumes of the

Standard Atomic Weights, 2001

[Scaled to $A_r(^{12}\text{C}) = 12$]

The atomic weights of many elements are not invariant but depend on the origin and treatment of the material. The standard values of $A_r(E)$ and the uncertainties (in parentheses, following the last significant figure to which they are attributed) apply to elements of natural terrestrial origin. The footnotes to this table elaborate the types of variation that may occur for individual elements and that may be larger than the listed uncertainties of values of $A_r(E)$. Names of elements with atomic number 110 to 116 are provisional.

Name	Symbol	Atomic Number	Atomic Weight	Footnotes	Name	Symbol	Atomic Number	Atomic Weight	Footnotes
Actinium*	Ac	89			Molybdenum	Mo	42	95.94(2)	g
Aluminium	Al	13	26.981 538(2)		Neodymium	Nd	60	144.24(3)	g
Americium*	Am	95			Neon	Ne	10	20.1797(6)	g, m
Antimony	Sb	51	121.760(1)	g	Neptunium*	Np	93		
Argon	Ar	18	39.948(1)	g, r	Nickel	Ni	28	58.6934(2)	
Arsenic	As	33	74.921 60(2)		Niobium	Nb	41	92.906 38(2)	
Astatine*	At	85			Nitrogen	N	7	14.0067(2)	g, r
Barium	Ba	56	137.327(7)		Nobelium*	No	102		
Berkelium*	Bk	97			Osmium	Os	76	190.23(3)	g
Beryllium	Be	4	9.012 182(3)		Oxygen	O	8	15.9994(3)	g, r
Bismuth	Bi	83	208.980 38(2)		Palladium	Pd	46	106.42(1)	g
Bohrium*	Bh	107			Phosphorus	P	15	30.973 761(2)	
Boron	B	5	10.811(7)	g, m, r	Platinum	Pt	78	195.078(2)	
Bromine	Br	35	79.904(1)		Plutonium*	Pu	94		
Cadmium	Cd	48	112.411(8)	g	Polonium	Po	84		
Calcium	Ca	20	40.078(4)	g	Potassium	K	19	39.0983(1)	g
Californium*	Cf	98			Praseodymium	Pr	59	140.907 65(2)	
Carbon	C	6	12.0107(8)	g, r	Promethium*	Pm	61		
Cerium	Ce	58	140.116(1)	g	Protactinium*	Pa	91	231.035 88(2)	
Cesium	Cs	55	132.905 45(2)		Radium*	Ra	88		
Chlorine	Cl	17	35.453(2)	g, m, r	Radon*	Rn	86		
Chromium	Cr	24	51.9961(6)		Rhenium	Re	75	186.207(1)	
Cobalt	Co	27	58.933 200(9)		Rhodium	Rh	45	102.905 50(2)	
Copper	Cu	29	63.546(3)	r	Rubidium	Rb	37	85.4678(3)	g
Curium*	Cm	96			Ruthenium	Ru	44	101.07(2)	g
Dubnium*	Db	105			Rutherfordium*	Rf	104		
Dysprosium	Dy	66	162.500(1)	g	Samarium	Sm	62	150.36(3)	g
Einsteinium*	Es	99			Scandium	Sc	21	44.955 910(8)	
Erbium	Er	68	167.259(3)	g	Seaborgium*	Sg	106		
Europium	Eu	63	151.964(1)	g	Selenium	Se	34	78.96(3)	r
Fermium*	Fm	100			Silicon	Si	14	28.0855(3)	r
Fluorine	F	9	18.998 4032(5)		Silver	Ag	47	107.8682(2)	g
Francium*	Fr	87			Sodium	Na	11	22.989 770(2)	
Gadolinium	Gd	64	157.25(3)	g	Strontium	Sr	38	87.62(1)	g, r
Gallium	Ga	31	69.723(1)		Sulfur	S	16	32.065(5)	g, r
Germanium	Ge	32	72.64(1)		Tantalum	Ta	73	180.9479(1)	
Gold	Au	79	196.966 55(2)		Technetium*	Tc	43		
Hafnium	Hf	72	178.49(2)		Tellurium	Te	52	127.60(3)	g
Hassium*	Hs	108			Terbium	Tb	65	158.925 34(2)	
Helium	He	2	4.002 602(2)	g, r	Thallium	Tl	81	204.3833(2)	
Holmium	Ho	67	164.930 32(2)		Thorium*	Th	90	232.0381(1)	g
Hydrogen	H	1	1.007 94(7)	g, m, r	Thulium	Tm	69	168.934 21(2)	
Indium	In	49	114.818(3)		Tin	Sn	50	118.710(7)	g
Iodine	I	53	126.904 47(3)		Titanium	Ti	22	47.867(1)	
Iridium	Ir	77	192.217(3)		Tungsten	W	74	183.84(1)	
Iron	Fe	26	55.845(2)		Ununbium*	Uub	112		
Krypton	Kr	36	83.798(2)	g, m	Ununhexium*	Uuh	116		
Lanthanum	La	57	138.9055(2)	g	Ununnilium*	Uun	110		
Lawrencium*	Lr	103			Ununquadium*	Uuq	114		
Lead	Pb	82	207.2(1)	g, r	Ununonium*	Uuo	111		
Lithium	Li	3	[6.941(2)] [†]	g, m, r	Uranium*	U	92	238.02891(3)	g, m
Lutetium	Lu	71	174.967(1)	g	Vanadium	V	23	50.9415(1)	
Magnesium	Mg	12	24.3050(6)		Xenon	Xe	54	131.293(6)	g, m
Manganese	Mn	25	54.938 049(9)		Ytterbium	Yb	70	173.04(3)	g
Meitnerium*	Mt	109			Yttrium	Y	39	88.905 85(2)	
Mendelevium*	Md	101			Zinc	Zn	30	65.409(4)	
Mercury	Hg	80	200.59(2)		Zirconium	Zr	40	91.224(2)	g

* Element has no stable nuclides.

† Commercially available Li materials have atomic weights that range between 6.94 and 6.99; if a more accurate value is required, it must be determined for the specific material.

g geological specimens are known in which the element has an isotopic composition outside the limits for normal material. The difference between the atomic weight of the element in such specimens and that given in the Table may exceed the stated uncertainty.

m modified isotopic compositions may be found in commercially available material because it has been subjected to an undisclosed or inadvertent isotopic fractionation. Substantial deviations in atomic weight of the element from that given in the Table can occur.

r range in isotopic composition of normal terrestrial material prevents a more precise $A_r(E)$ being given; the tabulated $A_r(E)$ value should be applicable to any normal material.

Source: INTERNATIONAL UNION OF PURE AND APPLIED CHEMISTRY, 2003. Atomic weights of the elements, 2001. *Pure Appl. Chem.* 75:1107.

STANDARD METHODS

FOR THE EXAMINATION OF WATER & WASTEWATER



21st Edition

2005

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American Water Works Association
Water Environment Federation*

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Centennial Edition

PREFACE TO THE TWENTY-FIRST EDITION

The Twentieth and Earlier Editions

The first edition of *Standard Methods* was published in 1905. Each subsequent edition presented significant improvements of methodology and enlarged its scope to include techniques suitable for examination of many types of samples encountered in the assessment and control of water quality and water pollution.

A brief history of *Standard Methods* is of interest because of its contemporary relevance. A movement for "securing the adoption of more uniform and efficient methods of water analysis" led in the 1880s to the organization of a special committee of the Chemical Section of American Association for the Advancement of Science. A report of this committee, published in 1889, was entitled: A Method, in Part, for the Sanitary Examination of Water, and for the Statement of Results, Offered for General Adoption.* Five topics were covered: (1) "free" and "albuminoid" ammonia; (2) oxygen-consuming capacity; (3) total nitrogen as nitrates and nitrites; (4) nitrogen as nitrites; and (5) statement of results.

In 1895, members of the American Public Health Association, recognizing the need for standard methods in the bacteriological examination of water, sponsored a convention of bacteriologists to discuss the problem. As a result, an APHA committee was appointed "to draw up procedures for the study of bacteria in a uniform manner and with special references to the differentiation of species." Submitted in 1897,† the procedures found wide acceptance.

In 1899, APHA appointed a Committee on Standard Methods of Water Analysis, charged with the extension of standard procedures to all methods involved in the analysis of water. The committee report, published in 1905, constituted the first edition of *Standard Methods* (then entitled *Standard Methods of Water Analysis*). Physical, chemical, microscopic, and bacteriological methods of water examination were included. In its letter of transmittal, the Committee stated:

The methods of analysis presented in this report as "Standard Methods" are believed to represent the best current practice of American water analysts, and to be generally applicable in connection with the ordinary problems of water purification, sewage disposal and sanitary investigations. Analysts working on widely different problems manifestly cannot use methods which are identical, and special problems obviously require the methods best adapted to them; but, while recognizing these facts, it yet remains true that sound progress in analytical work will advance in proportion to the general adoption of methods which are reliable, uniform and adequate.

It is said by some that standard methods within the field of applied science tend to stifle investigations and that they retard true progress. If such standards are used in the proper spirit, this ought not to be so. The Committee strongly desires that every effort shall be continued to improve the techniques of water analysis and especially to compare current methods with those herein recommended, where different, so that the results obtained may be still more accurate and reliable than they are at present.

Revised and enlarged editions were published by APHA under the title *Standard Methods of Water Analysis* in 1912 (Second Edition), 1917 (Third), 1920 (Fourth), and 1923 (Fifth). In 1925, the American Water Works Association joined APHA in publishing the Sixth Edition, which had the broader title, *Standard Methods of the Examination of Water and Sewage*. Joint publication was continued in the Seventh Edition, dated 1933.

In 1935, the Federation of Sewage Works Associations (now the Water Environment Federation) issued a committee report, "Standard Methods of Sewage Analysis."‡ With minor modifications, these methods were incorporated into the Eighth Edition (1936) of *Standard Methods*, which was thus the first to provide methods for the examination of "sewages, effluents, industrial wastes, grossly polluted waters, sludges, and muds." The Ninth Edition, appearing in 1946, likewise contained these methods, and in the following year the Federation became a full-fledged publishing partner. Since 1947, the work of the *Standard Methods* committees of the three associations—APHA, AWWA, and WEF—has been coordinated by a Joint Editorial Board, on which all three are represented.

The Tenth Edition (1955) included methods specific for examination of industrial wastewaters; this was reflected by a new title: *Standard Methods for the Examination of Water, Sewage and Industrial Wastes*. To describe more accurately and concisely the contents of the Eleventh Edition (1960), the title was shortened to *Standard Methods for the Examination of Water and Wastewater*. It remained unchanged in subsequent editions.

In the Fourteenth Edition, the separation of test methods for water from those for wastewater was discontinued. All methods for a given component or characteristic appeared in a single section. With minor differences, the organization of the Fourteenth Edition was retained for the Fifteenth and Sixteenth (1985) Editions. Two major policy decisions of the Joint Editorial Board were implemented for the Sixteenth Edition. First, the International System of Units (SI) was adopted except where prevailing field systems or practices require English units. Second, the use of trade names or proprietary materials was eliminated insofar as possible, to avoid potential claims regarding restraint of trade or commercial favoritism.

The organization of the Seventeenth Edition (1989) reflected a commitment to develop and retain a permanent numbering system. New numbers were assigned to all sections, and unused numbers were reserved for future use. All part numbers were expanded to multiples of 1000 instead of 100. The parts retained their identity from the previous edition, with the exception of Part 6000, which was reallocated from automated methods to methods for the measurement of specific organic compounds. The more general procedures for organics remained in Part 5000.

The Seventeenth Edition also underwent a major revision in the introductory Part 1000. Sections dealing with statistical analysis, data quality, and methods development were greatly expanded.

* *J. Anal. Chem.* 3:398 (1889).

† *Proc. Amer. Pub. Health Assoc.* 23:56 (1897).

‡ *Sewage Works J.* 7:444 (1935).

The section on reagent water was updated to include a classification scheme for various types of reagent water. At the beginning of each of the subsequent parts of the manual, sections were included that discussed quality assurance and other matters of general application within the specific subject area, to minimize repetition in the succeeding text.

The Eighteenth Edition (1992) underwent only minor revisions in format adopted in the Seventeenth Edition. New methods were added in each part.

In the Nineteenth Edition (1995), sections on laboratory safety and waste management were added to Part 1000. Substantial changes occurred throughout, adding new methodology and revisions to many of the sections.

In the Twentieth Edition (1998), there were continued updates to Part 1000. Substantial changes were made in introductory and quality control sections in various parts (notably 3000 and 9000). New methods appeared in Parts 3000, 6000, and 8000. Most other sections were revised.

The Twenty-First Edition

The Twenty-First Edition has continued the trend to revise methods as issues are identified and contains further refined quality assurance requirements in a number of Parts and new data on precision and bias. New methods have been added in Parts 2000, 4000, 5000, 6000, 7000, 8000, and 9000, and numerous methods have been revised. Details of these changes appear on the reverse of the title page for each part.

The methods in this book, with the exception of the supplemental methods on pages S-1 through S-16, appeared initially in *Standard Methods Online* (www.StandardMethods.org), the website inaugurated in early 2004. Existing methods and methods approved subsequently are available from this source, so that *Standard Methods* users will always have access to the most current methods.

Selection and Approval of Methods

For each new edition both the technical criteria for selection of methods and the formal procedures for their approval and inclusion are reviewed critically. In regard to the approval procedures, it is considered particularly important to assure that the methods presented have been reviewed and are supported by the largest number of qualified people, so that they may represent a true consensus of expert opinion.

For the Fourteenth Edition a Joint Task Group was established for each section. This scheme has continued for each subsequent edition. Appointment of an individual to a Joint Task Group generally was based on the expressed interest or recognized expertise of the individual. The effort in every case was to assemble a group having maximum available expertise in the test methods of concern.

Each Joint Task Group was charged with reviewing the pertinent methods in the Twentieth Edition along with other methods from the literature, recommending the methods to be included in the Twenty-First Edition, and presenting those methods in the form of a proposed section manuscript. Subsequently, each section manuscript (except for Part 1000) was ratified by vote of those members of the Standard Methods Committee who asked to review sections in that part. Every negative vote and every comment

submitted in the balloting was reviewed by the Joint Editorial Board. Relevant suggestions were referred appropriately for resolution. When negative votes on the first ballot could not be resolved by the Joint Task Group or the Joint Editorial Board, the section was reballoted among all who voted affirmatively or negatively on the original ballot. Only a few issues could not be resolved in this manner and the Joint Editorial Board made the final decision.

The general and quality assurance information presented in Part 1000 were treated somewhat differently. Again, Joint Task Groups were formed, given a charge, and allowed to produce a consensus draft. This draft was reviewed by the Joint Editorial Board Liaison and subsequently by the Joint Editorial Board. The draft sections were sent to the Standard Methods Committee and comments resulting from this review were used to develop the final draft.

The methods presented here, as in previous editions, are believed to be the best available and generally accepted procedures for the analysis of water, wastewaters, and related materials. They represent the recommendations of specialists, ratified by a large number of analysts and others of more general expertise, and as such are truly consensus standards, offering a valid and recognized basis for control and evaluation.

The technical criteria for selection of methods were applied by the Joint Task Groups and by the individuals reviewing their recommendations, with the Joint Editorial Board providing only general guidelines. In addition to the classical concepts of precision, bias, and minimum detectable concentration, selection of a method also must recognize such considerations as the time required to obtain a result, needs for specialized equipment and for special training of the analyst, and other factors related to the cost of the analysis and the feasibility of its widespread use.

Status of Methods

All methods in the Twenty-First Edition are dated to assist users in identifying those methods that have been changed significantly between editions. The year the section was approved by the Standard Methods Committee is indicated in a footnote at the beginning of each section. Sections or methods that appeared in the Twentieth Edition that are unchanged, or changed only editorially in the Twenty-First Edition, show an approval date of 1997. Sections or methods that were changed significantly, or that were reaffirmed by general balloting of the Standard Methods Committee, are dated 1998 or later. If an individual method within a section was revised, that method carries an approval date different from that of the rest of the section. In the Twenty-First Edition, the Joint Task Groups that were active since the last full edition are listed at the beginning of each part, along with the more detailed summary of changes in that part.

Methods in the Twenty-First Edition are divided into two fundamental classes: PROPOSED and STANDARD. Regardless of assigned class, all methods must be approved by the Standard Methods Committee. The classes are described as follows:

1. PROPOSED—A PROPOSED method must undergo development and validation that meets the requirements set forth in Section 1040A of *Standard Methods*.
2. STANDARD—A procedure qualifies as a STANDARD method in one of two ways: a) The procedure has undergone development and validation and collaborative testing that

meet the requirements set forth in Sections 1040B and C of *Standard Methods*, respectively, and it is "WIDELY USED" by the members of the Standard Methods Committee; or b) The procedure is "WIDELY USED" by the members of the Standard Methods Committee and it has appeared in *Standard Methods* for at least five years.

The Joint Editorial Board assigns method classifications. The Board evaluates the results of the survey on method use by the Standard Methods Committee that is conducted at the time of general balloting of the method and considers recommendations offered by Joint Task Groups and the Part Coordinator.

Methods categorized as "PROPOSED" are so designated in their titles; methods with no designation are "STANDARD."

Technical progress makes advisable the establishment of a program to keep *Standard Methods* abreast of advances in research and general practice. The Joint Editorial Board has developed the following procedure for effecting changes in methods:

1. Any method given proposed status currently may be elevated by action of the Joint Editorial Board, on the basis of adequate published data supporting such a change as submitted to the Board by the appropriate Joint Task Group. Notification of such a change in status shall be accomplished by publication in the official journals of the three associations sponsoring *Standard Methods* and notification on the *Standard Methods Online* website.
2. No method may be abandoned or reduced to a lower status without notification on the *Standard Methods Online* website.
3. A new method may be adopted as proposed or standard by the Joint Editorial Board at any time, such action being based on the usual consensus procedure. Such methods will be added to *Standard Methods Online*.

Reader comments and questions concerning this manual should be addressed to: Standard Methods Manager, American Water Works Association, 6666 West Quincy Avenue, Denver, CO 80235.

Acknowledgments

For the work in preparing and revising the methods in the Twenty-First Edition, the Joint Editorial Board gives full credit to the Standard Methods Committees of the American Water Works Association and of the Water Environment Federation and to the Committee on Laboratory Standards and Practices of the American Public Health Association. Full credit also is given to those individuals who were not members of the sponsoring societies. A list of all committee members follows these pages. Herbert J. Brass, U.S. Environmental Protection Agency, served as a liaison from EPA to the Joint Editorial Board; thanks are due for his interest and help.

The Joint Editorial Board expresses its appreciation to Mohammad N. Akhter, M.D., former Executive Director, and Georges C. Benjamin, M.D., F.A.C.P., current Executive Director, American Public Health Association, to Jack W. Hoffbuhr, Executive Director, American Water Works Association, to Quincalee Brown, former Executive Director, and William J. Bertera, current Executive Director, Water Environment Federation, for their cooperation and advice in the development of this publication. Steven J. Posavec, Standard Methods Manager and Joint Editorial Board Secretary, provided a variety of important services that are vital to the preparation of a volume of this type. Ellen Meyer, Director of Publications, American Public Health Association, functioned as publisher. Terence Mulligan, also with APHA, served as production manager. Special recognition for her valuable services is due to Mary Ann H. Franson, Managing Editor, who discharged most efficiently the extensive and detailed responsibilities on which this publication depends.

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At several places in this text, a manufacturer's name or trade name of a product, chemical, or chemical compound is referenced. The use of such a name is intended only to be a shorthand reference for the functional characteristics of the manufacturer's item. These references are not intended to be an endorsement of any item by the co-publishers, and materials or reagents with equivalent characteristics may be used.

JOINT EDITORIAL BOARD

Arnold E. "Archie" Greenberg
1926 – 2001



The sponsoring societies, volunteers, and staff of *Standard Methods for the Examination of Water and Wastewater* dedicate the Twenty-First Edition to the revered memory of Arnold E. "Archie" Greenberg.

For more than four decades, Mr. Greenberg volunteered scientific expertise and untold hours for the benefit of *Standard Methods*. A member of the American Public Health Association since 1949, he began his involvement in *Standard Methods* in the 1950s, was appointed to the Joint Editorial Board in 1971, and was its Chair for the Fifteenth, Sixteenth, and Eighteenth Editions. Through a period of rapid expansion and change, he significantly influenced the development of the book, especially the parts dealing with microbiological, biological, and radioactivity analyses.

Mr. Greenberg received a BS from City College of New York in 1947, MS in bacteriology from the University of Wisconsin in 1948, and SM in sanitary engineering from the Massachusetts Institute of Technology in 1950.

Beginning in 1955, Mr. Greenberg guided laboratory operations for the California Department of Health Services, serving as Chief of the Sanitation and Radiation Laboratory, Chief of the Bioenvironmental Laboratories Section, and Assistant Chief of the Laboratory Services Branch of the Department. In 1982, he became Manager of the Laboratory Services Division for the East Bay Municipal Utilities District in Oakland. He retired in 1992.

Mr. Greenberg was an Honorary Member of the American Water Works Association and received the American Public Health Association Award for Excellence in 1993. To quote the APHA citation: "As an APHA volunteer and as an individual who has dedicated his professional life to the use of science to the public benefit, Archie, who has sought so little while giving so much, has exemplified the spirit to which all of us aspire." From 1977 to 1983, he chaired APHA's Committee on Laboratory Standards and Practices. He was also one of the editors of the APHA book *Laboratory Procedures for the Examination of Seawater and Shellfish*.

Rich in wisdom, astute in counsel, unstinting in kindness and helpfulness, Mr. Greenberg embodied the spirit of volunteer service and always upheld the highest standards of scientific excellence. He is greatly missed by the *Standard Methods* community.

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