大学环境教育丛书

影印版

Metcalf & Eddy, Inc.

Wastewater Engineering

Treatment and Reuse

(Fourth Edition)

废水工程

处理与回用

（第4版）

I

Mc Graw Hill

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废水工程 处理与回用 （第4版）

本书为市政与环境工程专业废水处理方面的一本经典的、权威的教科书，并且是该专业人士的必备工具书。本书前3版分别于1972，1979，1991年出版。

本书主要内容包括：废水组分的确定，处理工艺的分析与选择，物理单元过程，化学单元过程，生物处理原理，悬浮生长和附着生长生物处理工艺，废水高级处理，消毒工艺，废水回用，生物固体的处理、处置及再利用，水处理厂运行的有关问题等。

在前3版内容的基础上，本书介绍了近十年来废水处理技术和法规方面的变化，并提供了该领域最新技术现状的信息，结合物理、化学和生物处理工艺阐述了废水处理的理论和设计问题，并扩充了废水生物处理的理论和设计部分。本书还对数据表进行了全面更新，并加入了新的设计实例，反映了工艺设计中的技术变化。

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出版前言

在跨入21世纪之际，面临不断恶化的生存环境，人类清醒地认识到要走可持续发展之路。而发展环境教育是解决环境问题和实施可持续发展战略的根本。高等学校的环境教育，是提高新世纪建设者的环境意识，并向社会输送环境保护专门人才的重要途径。为了反映国外环境类教材的最新内容和编写风格，同时也为了提高学生阅读专业文献和获取信息的能力，我们精选了一些国外优秀的环境类教材，组成大学环境教育丛书（影印版），本书即为其中的一册。所选教材均在国外被广泛采用，多数已再版，书中不仅介绍了有关概念、原理及技术方法，给出了丰富的数据，还反映了作者不同的学术观点。

我们希望这套丛书能对高等院校师生和广大科技人员有所帮助，同时对我国环境教育的发展作出贡献。

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2002年8月

About the Authors

George Tchobanoglous is a professor emeritus of environmental engineering in the Department of Civil and Environmental Engineering at the University of California at Davis. He received a B.S. degree in civil engineering from the University of the Pacific, an M.S. degree in sanitary engineering from the University of California at Berkeley, and a Ph.D. in environmental engineering from Stanford University. His principal research interests are in the areas of wastewater treatment, wastewater filtration, UV disinfection, aquatic wastewater management systems, solid waste management, and wastewater management for small systems. He has authored or coauthored over 350 technical publications, including 12 textbooks and two reference works. The textbooks are used in more than 200 colleges and universities throughout the United States. The textbooks and reference books are also used extensively by practicing engineers both in the United States and abroad. Professor Tchobanoglous serves nationally and internationally as consultant to both governmental agencies and private concerns. An active member of numerous professional societies, he is a past president of the Association of Environmental Engineering and Science Professors. He is a registered civil engineer in California.

Franklin L. Burton spent 30 years with Metcalf & Eddy serving as vice president and chief engineer in their western regional office in Palo Alto, CA. He received a B.S. degree in mechanical engineering from Lehigh University and an M.S. degree in civil engineering from the University of Michigan. He has been involved in the planning, design, and technical review of over 50 wastewater treatment plants. He was the coauthor of the third edition of this textbook. He retired from Metcalf & Eddy in 1986 and is in private practice in Los Altos, CA, specializing in treatment technology evaluation, energy management, facilities design review, and value engineering. He is a registered civil and mechanical engineer in California and is a life member of the American Society of Civil Engineers, Water Environment Federation, and the American Water Works Association.

H. David Stensel is a professor of civil and environmental engineering at the University of Washington, Seattle, WA. Prior to his academic positions, he spent 10 years in practice developing and applying industrial and municipal wastewater treatment processes. He received a B.S. degree in civil engineering from Union College, Schenectady, NY, and M.E. and Ph.D. degrees in environmental engineering from Cornell University. His principal research interests are in the areas of wastewater treatment, biological nutrient removal, sludge processing methods, biodegradation of hazardous substances, and stormwater treatment. He has authored or coauthored over 100 technical publications and a textbook on biological nutrient removal. He has received the ASCE Rudolf Hering Medal and twice received the Water Environment Federation Harrison

Prescott Eddy Medal for his research contributions. He is a member of numerous professional societies, and has served as chair of the ASCE Environmental Engineering Division, treasurer of the American Association of Environmental Engineering Professors, and associate editor of the *Water Environment Federation Research Journal.* He is a registered professional engineer and a diplomate in the American Academy of Environmental Engineers.

Preface

During the past 12 years since the publication of the third edition of this textbook, the number of new developments and changes that have occurred in the field of wastewater engineering has been dramatic, especially with respect to

(1) the characterization of the constituents found in wastewater, both in terms of the range of constituents and the detection limits;
(2) a greater fundamental understanding of the mechanisms of biological wastewater treatment;
(3) the application of advanced treatment methods for the removal of specific constituents;
(4) the increased emphasis on the management of the biosolids resulting from the treatment of wastewater; and
(5) the issuance of more comprehensive and restrictive permit requirements for the discharge and reuse of treated wastewater.

The fourth edition of this textbook has been prepared to address the significant new developments and changes that have occurred in the field and to correct other issues with the third edition to make the fourth edition more user friendly. For example, the theory and practice chapters, separated in the third edition, are now combined in the fourth edition to provide subject continuity and eliminate redundancy. Because of the importance of biological wastewater treatment, four separate chapters have been devoted to this subject. The chapter on advanced wastewater treatment has been expanded to include processes that are increasingly required to meet more stringent discharge requirements. A new chapter on disinfection has been added to deal with recent developments in the field. The chapter on reclamation and reuse has been revised completely and much new material has been added. Because of the importance of biosolids management, an entire chapter is devoted to this subject. The issues of process design and performance to meet more stringent permit requirements, including the upgrading of existing treatment plants, are considered in Chapter 15.

IMPORTANT FEATURES OF THIS BOOK

Following the practice in the third edition, more than 100 new example problems have been worked out in detail to enhance the readers' understanding of the basic concepts presented in the text. Wherever possible, spreadsheet solutions are presented. To aid in the planning, analysis, and design of wastewater management systems, design data and information are summarized and presented in more than 300 tables, most of which are new. To illustrate the principles and facilities involved in the field of wastewater management, over 570 illustrations, graphs, diagrams, and photographs are included. To help the readers of this textbook hone their analytical skills and mastery of the material,

problems and discussion topics are included at the end of each chapter. Selected references are also provided for each chapter.

The International System (SI) of Units is used in the fourth edition. The use of SI units is consistent with teaching practice in most U.S. universities and in many countries throughout the world. In general, dual sets of units (i.e., SI and U.S. customary) have been used for the data tables. Where the use of double units was not possible, conversion factors are included as a footnote to the table.

To further increase the utility of this textbook, several appendixes have been included. Conversion factors from International System (SI) of Units to U.S. Customary Units and the reverse are presented in Appendixes A–1 and A–2, respectively. Conversion factors commonly used for the analysis and design of wastewater management systems are presented in Appendix A–3. Abbreviations for SI and U.S. Customary units are presented in Appendixes A–4 and A–5, respectively. Physical characteristics of air and selected gases and water are presented in Appendixes B and C, respectively. Dissolved oxygen concentrations in water as a function of temperature are presented in Appendix D. Tables of most probable numbers (MPN) are presented in Appendix E, carbonate equilibrium is considered in Appendix F, and Moody diagrams for the analysis of flow in pipes are presented in Appendix G.

USE OF THIS BOOK

Enough material is presented in this textbook to support a variety of courses for one or two semesters or three quarters at either the undergraduate or graduate level. The specific topics to be covered will depend on the time available and the course objectives. Suggested course outlines follow.

For a one-semester introductory course on wastewater treatment, the following material is suggested:

Topic	Chapter	Sections
Introduction to wastewater treatment	1	All
Wastewater characteristics	2	All
Wastewater flowrates and constituent loadings	3	All
Introduction to process analysis	4	All
Physical unit operations	5	5–1 to 5–8
Chemical unit operations	6	6–1, 6–2,
Introduction to biological treatment of wastewater	7	All
Disinfection	12	12–1 to 12–5, 12–9
Water reuse	13	13–1 to 13–2
Biosolids management	14	All
Introduction to treatment plant performance	15	15–1 to 15–3

For a two-semester course on wastewater treatment, the following material is suggested:

Topic	Chapter	Sections
Introduction to wastewater treatment	1	All
Wastewater characteristics	2	All
Wastewater flowrates and constituent loadings	3	All
Introduction to process analysis	4	All
Introduction to treatment plant performance	15	15–1 to 15–3
Physical unit operations	5	All
Chemical unit operations	6	All
Introduction to biological treatment of wastewater	7	All
Suspended growth biological treatment processes	8	All
Attached growth and combined biological treatment processes	9	9–1 to 9–5
Anaerobic suspended and attached growth treatment processes	10	10–1, 10–2, 10–4
Disinfection	12	All
Water reuse	13	All
Biosolids management	14	All
Process control and upgrading treatment plant performance	15	15–3 to 15–7

For a one-semester course on biological wastewater treatment, the following material is suggested:

Topic	Chapter	Sections
Introduction to wastewater treatment	1	All
Wastewater characteristics	2	All
Introduction to process analysis	4	All
Introduction to treatment plant performance	15	15–1 to 15–3
Introduction to biological treatment of wastewater	7	All
Suspended growth biological treatment processes	8	All
Attached growth and combined biological treatment processes	9	All
Anaerobic suspended and attached growth treatment processes	10	All
Anaerobic and aerobic digestion and composting	14	14–9 to 14–11

For a one-semester course on wastewater reclamation and reuse, the following material is suggested:

Topic	Chapter	Sections
Introduction to wastewater treatment	1	All
Wastewater characteristics	2	All
Introduction to water reclamation and reuse	13	13–1
Introduction to risk assessment	13	13–3
Introduction to treatment plant performance	15	15–1 to 15–3
Advanced wastewater treatment (optional)	11	11–6
Disinfection	12	12–1 to 12–5, 12–7 to 12–9
Water reclamation technologies	13	13–4
Storage of reclaimed water	13	13–5
Reuse of reclaimed water	13	13–6 to 13–9
Planning consideration for reclamation and reuse	13	10

For a one-semester course on physical and chemical unit operations and processes, the following material is suggested. It should be noted that material listed below could be supplemented with additional examples from water treatment.

Topic	Chapter	Sections
Introduction to process analysis	4, 15	All
Introduction to treatment plant performance	15	15–1 to 15–3
Introduction to physical unit operations		
Mixing and flocculation	5	5–4
Sedimentation	5	5–5, 5–7, 5–8
Gas transfer	5	5–11 to 5–12
Filtration (conventional depth filtration)	11	11–3, 11–4
Membrane filtration	11	11–6
Adsorption	11	11–7
Gas stripping	5, 11	5–13, 11–8
UV disinfection	12	12–9
Introduction to chemical unit processes		6–2
Coagulation	6	6–2
Chemical precipitation	6	6–3 to 6–5
Ion exchange	11	11–9
Water stabilization	6	6–7
Chemical oxidation (conventional)	6	6–6
Advanced oxidation processes	11	11–9