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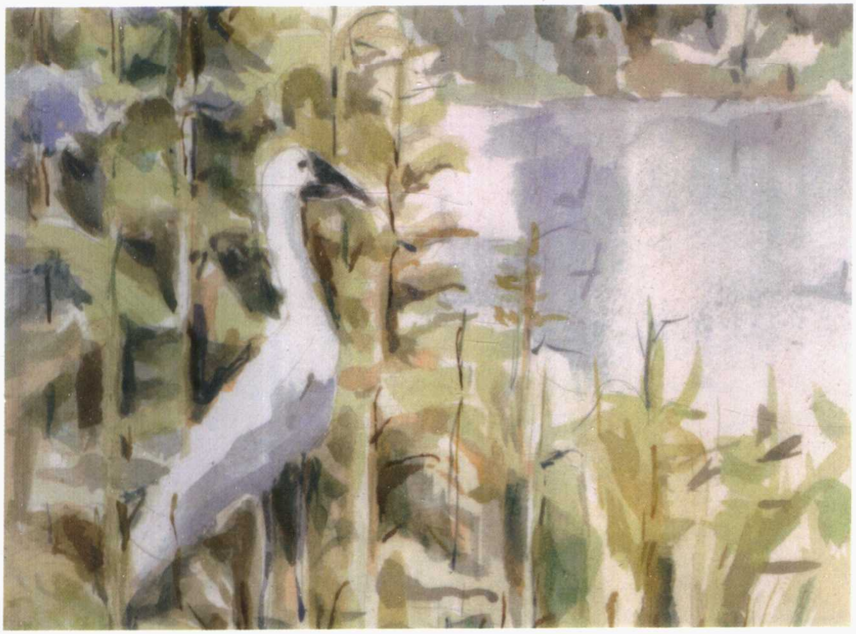
大学环境教育丛书
影印版

Mackenzie L. Davis   Susan J. Masten

Principles of Environmental Engineering and Science

环境科学与工程原理



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出版前言

在21世纪之初，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，我们精选了国外一些优秀的环境类教材，加以影印或翻译，组成大学环境教育丛书。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，也反映了作者不同的学术观点。

我们希望这套丛书的出版能对高等院校师生和广大科技人员有所帮助，并为我国的环境教育事业作出贡献。

清华大学出版社
2004年10月

Preface

Principles of Environmental Engineering and Science is geared toward students taking an introductory, sophomore-level engineering course. The book's material is also applicable for students enrolled in upper level biology, chemistry, resource development, fisheries and wildlife, microbiology, and soil sciences courses. These students should already understand such calculus topics as differentiation, integrations, and differential equations (at an introductory level).

Principles of *Principles*

Many of you are familiar with *Introduction to Environmental Engineering* by Mackenzie Davis and David Cornwell. Although some of the content of that text is similar to *Principles of Environmental Engineering and Science,* they are two separate books with very different objectives. *Principles* places more emphasis on scientific principles, ethics, and safety, and focuses less on engineering design. This book exposes students to a broader range of environmental topics through separate chapters on ecosystems, geological and soil resources, and agricultural effects.

True to its emphasis on an inclusive introduction to environmental topics, the first five chapters of *Principles* present the background of the discipline from which the following chapters spring. For example, Chapter 2 reviews chemistry topics essential for grasping the fundamentals of environmental engineering.

Another hallmark feature of *Principles* is its integration of mass balance. Chapter 3 introduces the concept of mass balance as a tool for problem solving and shows how it is applied in hydrology conservative systems. From this point on, mass balance explains many key environmental engineering concepts. For example, this approach illustrates conservation of soil and geological resources in Chapter 7 and develops the DO sag curve in Chapter 8 (water quality). The design equations for a completely mixed activated sludge system and a sludge mass balance are developed in Chapter 10. Mass balance accounts for the production of sulfur dioxide from the combustion of coal in Chapter 11. Finally, in Chapter 13, mass balance is used for waste auditing.

Supplements

Principles offers a Website stocked with tools for both students and instructors at:

www.mhhe.com/davismasten

Students find animations that put relevant chemistry and geology topics in motion, a glossary of key terms, links to plant tours and other environmental engineering resources, and information on Chem Skill Builder, a chemistry problem-solving application with more than 1500 algorithmically generated questions.

At the *Principles* Website, instructors will find a bank of book images, lecture slides, information on Chem Skill Builder, and the *Instructor's Solutions Manual,* featuring sample course outlines and sample exams. Instructors can access these tools by contacting their local McGraw-Hill sales representative for password information.

Acknowledgments

As with any other text, the number of individuals who have made it possible far exceeds those whose names grace the cover. At the hazard of leaving someone out, we would like to explicitly thank the following individuals for their contribution.

The following students helped to solve problems, proofread text, prepare illustrations, raise embarrassing questions, and generally make sure that other students could understand it: Shelley Agarwal, Stephanie Albert, Deb Allen, Mark Bishop, Aimee Bolen, Kristen Brandt, Jeff Brown, Amber Buhl, Nicole Chernoby, Rebecca Cline, Linda Clowater, Shauna Cohen, John Cooley, Ted Coyer, Marcia Curran, Talia Dodak, Kimberly Doherty, Bobbie Dougherty, Lisa Egleston, Karen Ellis, Craig Fricke, Elizabeth Fry, Beverly Hinds, Edith Hooten, Brad Hoos, Kathy Hulley, Lisa Huntington, Angela Ilieff, Alison Leach, Gary Lefko, Lynelle Marolf, Lisa McClanahan, Tim McNamara, Becky Mursch, Cheryl Oliver, Kyle Paulson, Marisa Patterson, Lynnette Payne, Jim Peters, Kristie Piner, Christine Pomeroy, Susan Quiring, Erica Rayner, Bob Reynolds, Laurene Rhyne, Sandra Risley, Lee Sawatzki, Stephanie Smith, Mary Stewart, Rick Wirsing, Ya-yun Wu. To them a hearty thank you!

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We would also like to thank the following reviewers for their many helpful comments and suggestions: David Bagley, U of Toronto; Theodore Cleveland, U of Houston; Benoit Cushman-Roisin, Dartmouth College; Brian Dempsey, Penn State U; Andrew Dzuril, Florida State U; Subhasis Ghoshal, McGill U; Mark Hernandez, U of Colorado; Howard Liljestrand, U of Texas, Austin; Taha Marhaba, NJIT; Thomas Overcamp, Clemson U; Michael Penn, U of Wisconsin, Platteville; Kelly Rusch, Louisiana State U; Richard Schuhmann, Penn State U.; Daniel Smith, U of South Florida; Helena Solo-Gabriele, U of Miami; and Scott Wells, Portland State U.

We give special thanks to Simon Davies for his contribution of Chapter 14. His efforts are sincerely appreciated. And last, but certainly not least, we wish to thank our families who have put up with us during the writing of this book, especially Rebecca and Jeffrey Masten-Davies, who gave up several Christmas vacations plus many other days during the year while their mom spent uncountable hours working on this book.

A special thanks to Macks' wife, Elaine, for putting up with the nonsense of book writing.

Mackenzie L. Davis Susan J. Masten

About the Authors

Mackenzie L. Davis is an Emeritus Professor of Environmental Engineering at Michigan State University. He received all his degrees from the University of Illinois. From 1968 to 1971 he served as a Captain in the U.S. Army Medical Services Corps. During his military service he conducted air pollution surveys at Army ammunition plants. From 1971 to 1973 he was branch chief of the Environmental Engineering Branch at the U.S. Army Construction Engineering Research Laboratory. His responsibilities included supervision of research on air, noise, and water pollution control and solid waste management for Army facilities. In 1973 he joined the faculty at Michigan State University. He has taught and conducted research in the areas of air pollution control and hazardous waste management.

In 1987 and 1989–1992, under an intergovernmental personnel assignment with the Office of Solid Waste of the U.S. Environmental Protection Agency, Dr. Davis performed technology assessments of treatment methods used to demonstrate the regulatory requirements for the land disposal restrictions ("land ban") promulgated under the Hazardous and Solid Waste Amendments.

Dr. Davis is a member of the following professional organizations: American Chemical Society; American Institute of Chemical Engineers; American Society for Engineering Education; American Meteorological Society; American Society of Civil Engineers; American Water Works Association; Air & Waste Management Association; Association of Environmental Engineering & Science Professors; and the Water Environment Federation.

His honors and awards include the State-of-the-Art award from the A.S.C.E., chapter honor member of Chi Epsilon, Sigma Xi, and election as a Diplomate in the American Academy of Environmental Engineers with certification in hazardous waste management. He has received teaching awards from the American Society of Civil Engineers Student Chapter, Michigan State University College of Engineering, North Central Section of the American Society for Engineering Education, Great Lakes Region of Chi Epsilon, and the AMOCO Corporation. He is a registered professional engineer in Illinois and Michigan.

In 2003, Dr. Davis retired from Michigan State University.

Susan J. Masten is a Professor in the Department of Civil and Environmental Engineering at Michigan State University. She received her Ph.D. in environmental engineering from Harvard University in 1986. She worked for several years in environmental research before joining the MSU faculty in 1989, including at the US Environmental Protection Agency Kerr Laboratory, in Ada, Oklahoma. Professor Masten's research involves the use of chemical oxidants for the remediation of soils, water, and wastewater. Her research is presently focused on the use of ozone for reducing the concentration of disinfection by-products in drinking water, controlling fouling in membranes, and reducing the toxicity of ozonation by-products formed from the ozonation of polycyclic aromatic hydrocarbons and pesticides. She also has research projects involving the use of ozone for the reduction of odor in swine manure slurry and the elimination of chlorinated hydrocarbons and semivolatile organic chemicals from soils using in-situ ozone stripping and ozone sparging.

Dr. Masten is a member of the following professional organizations: American Chemical Society, International Ozone Association, American Water Works Association and the American Society for Engineering Education. She has been on the Executive Committee of the MSU Chapter of the American Chemical Society since 1995.

Professor Masten was a Lilly Teaching Fellow during the 1994–1995 academic year. She is also the recipient of the Withrow Distinguished Scholar Award, College of Engineering, MSU, March 1995, and the Teacher-Scholar Award, Michigan State University, February 1996. Dr. Masten was also a member of the Faculty Writing Project, Michigan State University, May 1996. In 2001, she was awarded the Association of Environmental Engineering and Science Professors/Wiley Interscience Outstanding Educator Award.

Dr. Masten is a registered professional engineer in the state of Michigan.

About the Cover Artist

Barbara Masten Cobb, sister of Susan Masten, attended art school before completing an associate degree in nursing in 1983. Barbara is employed as the lead floor nurse in a New Jersey nursing home but in her spare time, she is able to continue her beloved career in art.

Contents

1 Introduction

1-1 WHAT IS ENVIRONMENTAL SCIENCE?

Natural Science

In the broadest sense, science is systematized knowledge derived from and tested by recognition and formulation of a problem, collection of data through observation, and experimentation. We differentiate between social science and natural science in that the former deals with the study of people and how they live together as families, tribes, communities, races, and nations, and the latter deals with the study of nature and the physical world. Natural science includes such diverse disciplines as biology, chemistry, geology, physics, and environmental science.

Environmental Science

Whereas the disciplines of biology, chemistry, and physics (and their subdisciplines of microbiology, organic chemistry, nuclear physics, etc.) are focused on a particular aspect of natural science, environmental science in its broadest sense encompasses all the fields of natural science. The historical focus of study for environmental scientists has been, of course, the natural environment. By this, we mean the atmosphere, the land, the water and their inhabitants as differentiated from the built environment. Modern environmental science has also found applications to the built environment or, perhaps more correctly, to the effusions from the built environment.

Quantitative Environmental Science

Science or, perhaps more correctly, the **scientific method,** deals with data, that is, with recorded observations. The data are, of course, a sample of the universe of possibilities. They may be representative or they may be skewed. Even if they are representative they will contain some random variation that cannot be explained with current knowledge. Care and impartiality in gathering and recording data, as well as independent verification, are the cornerstones of science.

When the collection and organization of data reveal certain regularities, it may be possible to formulate a generalization or **hypothesis.** This is merely a statement that under certain circumstances certain phenomena can generally be observed. Many generalizations are statistical in that they apply accurately to large assemblages but are no more than probabilities when applied to smaller sets or individuals.

In a scientific approach, the hypothesis is tested, revised, and tested again until it is proven acceptable.

If we can use certain assumptions to tie together a set of generalizations, we formulate a theory. For example, theories that have gained acceptance over a long time are known as **laws.** Some examples are the laws of motion, which describe the behavior of moving bodies, and the gas laws, which describe the behavior of gases. The development of a **theory** is an important accomplishment because it yields a tremendous consolidation of knowledge. Furthermore, a theory gives us a powerful new tool in the acquisition of knowledge for it shows us where to look for new generalizations. "Thus, the accumulation of data becomes less of a magpie collection of facts and more of a systematized hunt for needed information. It is the existence of classification and generalization, and above all theory that makes science an organized body of knowledge."[1]

Logic is a part of all theories. The two types of logic are qualitative and quantitative logic. Qualitative logic is descriptive. For example we can qualitatively state that when the amount of wastewater entering a certain river is too high, the fish die. With qualitative logic we cannot identify what "too high" means—we need quantitative logic to do that.

When the data and generalizations are quantitative, we need mathematics to provide a theory that shows the quantitative relationships. For example, a quantitative statement about the river might state that "When the mass of organic matter entering a certain river equals x kilograms per day, the amount of oxygen in the stream is y."

Perhaps more importantly, quantitative logic enables us to explore 'What if?' questions about relationships. For example, "If we reduce the amount of organic matter entering the stream,