Second Edition

Natural Wastewater Treatment Systems

Ronald W. Crites
E. Joe Middlebrooks
Robert K. Bastian
Sherwood C. Reed

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Dedication

We dedicate this book to the memory of Sherwood C. "Woody" Reed. Woody was the inspiration for this book and spent his wastewater engineering career planning, designing, evaluating, reviewing, teaching, and advancing the technology and understanding of natural wastewater treatment systems. Woody was the senior author of Natural Systems for Waste Management and Treatment, *published in 1988, which introduced a rational basis for design of free water surface and subsurface flow constructed wetlands, reed beds for sludge treatment, and freezing for sludge dewatering. Woody passed away in 2003.*

Preface

Natural systems for the treatment and management of municipal and industrial wastewaters and residuals feature processes that use minimal energy and minimal or no chemicals, and they produce relatively lower amounts of residual solids. This book is intended for the practicing engineers and scientists who are involved in the planning, design, construction, evaluation, and operation of wastewater management facilities. The second edition incorporates current design and regulatory and operational developments in the natural wastewater treatment field. Detailed design examples and analyses along with significant operational data are presented in each chapter.

The focus of the text is on wastewater management processes that provide passive treatment with a minimum of mechanical elements. Use of these natural systems often results in sustainable systems because of the low operating requirements and a minimum of biosolids production. Natural systems such as wetlands, sprinkler or drip irrigation, and groundwater recharge also result in water recycling and reuse.

The book is organized into ten chapters. The first three chapters introduce the planning procedures and treatment mechanisms responsible for treatment in ponds, wetlands, land applications, and soil absorption systems. Design criteria and methods of pond treatment and pond effluent upgrading are presented in Chapter 4 and Chapter 5. Constructed wetlands design procedures, process applications, and treatment performance data are described in Chapter 6 and Chapter 7. Land treatment concepts and design equations are described in Chapter 8. Residuals and biosolids management are presented in Chapter 9. A discussion of on-site wastewater management, including nitrogen removal pretreatment methods, is presented in Chapter 10. In all chapters, U.S. customary and metric units are used.

Authors

Ronald W. Crites is a senior associate with Brown and Caldwell in Davis, California. As the Natural Systems Service Leader, he consults on land treatment, water recycling and reuse, constructed wetlands, biosolids land application, decentralized wastewater treatment, and industrial wastewater land application systems. He received his BS in civil engineering from California State University in Chico and his MS and engineer's degree in sanitary engineering from Stanford University. He has 44 years of experience in wastewater treatment and reuse experience. He has authored or coauthored over 200 technical publications, including seven textbooks. He is a registered civil engineer in California, Hawaii, and Oregon.

E. Joe Middlebrooks is a consulting environmental engineer based in Superior, Colorado. His 45 years as an engineering college professor as well as administrative positions including dean of Engineering at Utah State University provided a platform for his extensive research and contributions to the environment engineering field. With a focus on domestic and industrial wastewater treatment, he has designed and evaluated numerous waste treatment systems including nutrient removal in activated sludge systems. He has served as an expert witness in many legal cases involving wastewater treatment and operation. He has been a consultant to international agencies and countries throughout the world regarding water issues with implications across international borders. He received his BS and MS in civil engineering from the University of Florida and his PhD in civil engineering (environmental engineering) from Mississippi State University, followed by postdoctoral studies at the University of California at Berkeley. He has authored or coauthored 14 books and over 300 articles and reports. He is a registered professional engineer in Arizona, Mississippi, Colorado, Utah, and Washington, and he is a Board Certified Environmental Engineer by the American Academy of Environmental Engineers. He has served as president of the American Academy of Environmental Engineers, and he has been active in many professional organizations. He has received numerous awards including the Harrison Prescott Eddy Medal from the Water Environment Federation and is an internationally known expert in wastewater treatment pond systems.

Robert K. Bastian is a senior environmental scientist in the Office of Wastewater Management at the U.S. Environmental Protection Agency in Washington, DC, where he has worked on a wide range of wastewater and biosolids management issues associated with municipal wastewater treatment plants. He has extensive experience dealing with natural systems for wastewater treatment, wastewater and biosolids reuse practices, and has coordinated the development of numerous Agency policy and guidance documents, technology assessments, planning and design guidance documents, demonstration projects, and special studies related to treatment technologies and management practices involving natural systems. He received his

BS and MS in biology, earth sciences, and mathematics from Bowling Green State University in Ohio and served as an officer in the U.S. Army Corps of Engineers before joining EPA in 1975.

Sherwood C. Reed (1932–2003) was an environmental engineer who was a leader in the planning and design of constructed wetlands and land treatment systems. He was the principal of Environmental Engineering Consultants (E.E.C.). He was a graduate of the University of Virginia (BSCE, 1959) and the University of Alaska (MS, 1968) and had a distinguished career with the U.S. Army Corps of Engineers, during which he spent most of his time at the Cold Regions Research and Engineering Laboratory (CRREL) in Hanover, New Hampshire, where he retired after an extended period of service from 1962 to 1989. His peers voted him into the CRREL Hall of Fame in 1991. After his retirement, he continued to teach, write, and accept both private and public sector consulting assignments. He was the author of four textbooks and over 100 technical articles.

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