Trace Elements in Terrestrial Environments

Second Edition

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Domy C. Adriano

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Biogeochemistry, Bioavailability, and Risks of Metals

Second Edition

With 150 Illustrations

Springer

Domy C. Adriano
Savannah River Ecology Laboratory
University of Georgia
Aitken, SC 29802
USA

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To my wife, Zena Gaviola Adriano, for her incredible understanding and patience throughout my professional career

and

To hundreds of loyal supporters and participants in the highly successful biennial series "International Conference on the Biogeochemistry of Trace Elements"

Preface

Knowledge is not to be sought for the pleasures of the mind, or for contention, or for superiority to others, or for profit, or fame, or power, or any of these inferior things, but for the benefit and use of life.

—Sir Francis Bacon

Based on citations in the literature, it is evident the first edition, entitled *Trace Elements in the Terrestrial Environment* (1986), met its primary objective, which was to provide students and professionals with a comprehensive book in many important aspects of trace elements in the environment. Indeed the extent of its use has exceeded my expectations. As a result of its usefulness and encouragement by colleagues in the field, I was compelled to write this edition following a similar format, but including new chapters on biogeochemistry, bioavailability, environmental pollution and regulation, ecological and human health effects, and risk and risk management and expanding the coverage to include freshwater systems and groundwater where appropriate. In addition to plants, which was the main biota of emphasis in the earlier edition, fish and wildlife and invertebrates (both terrestrial and aquatic) are discussed as necessary. The ecological and human health effects of major environmental contaminants, such as As, Cd, Cr, Pb, and Hg are also highlighted, along with relevant information on potential risks to the ecology and human health.

As in the first edition, the chapters are organized by element, which are grouped into "the big five" environmental metals, the essential elements (e.g. the traditional plant micronutrients, Zn, Cu, Mn, Mo, and B and now Ni, and Se, which is essential in animal and human nutrition), and other trace elements. It was challenging to find a solution to the daunting task of discussing emerging paradigms on bioavailability and how bioavailability can be influenced by the source term, chemical speciation, and the "driving"

factors (i.e., pH, CEC, redox potential, and so on) that in turn can influence risk. Most challenging, however, were the areas of freshwater systems, with their attendant fishery and wildlife as well as human health effects of metals.

While the earlier edition was sparked by my mentors, especially Professor Al Page (University of California, Riverside, CA), but also Professor Parker Pratt (University of California, Riverside) and Dr. Larry Murphy (Kansas State University, Manhattan, KS), this edition is the result of encouragement by younger colleagues, foremost Professor Dr. Walter Wenzel (Universität für Bodenkultur, Vienna, Austria), Professor Dr. Jaco Vangronsveld (Limburgs Universitair Centrum, Diepenbeek, Belgium), and Dr. Ravi Naidu (CSIRO, Adelaide, Australia).

I trust that this book will enhance our understanding of the diverse roles, beneficial or detrimental, of trace metals in our society and environment.

Domy C. Adriano
Athens, Georgia
Aiken, South Carolina

Acknowledgments

An undertaking of this magnitude could have been painful without the support of the following people: my wife, Zena, for her continuous encouragement and sustainable patience; Dr. Mike Smith, our former director for allowing me to take my sabbatical leave in 1998–1999; Mr. Wouter Geebelen of Limburgs University (Belgium) for the artwork; Ms. Marie Heap and Ms. Pat Davis from SREL and Ms. Ilse Plesser of Limburgs University (Belgium) for typing parts of the manuscript; Mr. Brad Reinhart (SREL) for proofreading parts of the text; and Mrs. Jean Mobley, our librarian for ordering articles and books.

Although the majority of the chapters were not sent for external review before submission, the new chapter on bioabilability was reviewed by Drs. Tracy Punshon and Barbara Taylor (SREL) and the chapter on biogeochemistry was reviewed by Drs. Dan Kaplan (Savannah River Technology Center) and Vijay Vulava (SREL).

Hundreds of scientific articles were used to research the book, some of the most relevant were provided by the following colleagues in the United States, Europe, and Australia: Dr. Rufus Chaney (U.S. Department of Agriculture); Prof. Gary Pierzynski (Kansas State University); Dr. Bud Norvell (Cornell University); Dr. Bill Berti (DuPont Co); Prof. Bob Taylor (Alabama A&M University); Professor Andrew Chang (University of California, Riverside); Dr. Steve McGrath (Rothamsted Experiment Station, England); Professor Dr. Walter Wenzel (Universität für Bodenkultur, Vienna, Austria); Professor Dr. Jaco Vangronsveld (Limburgs Universitair Centrum, Belgium); Professor Bal Ram Singh (Agricultural University of Norway); Dr. Michel Mench (INRA, Bordeaux, France); Professor Dr. Alina Kabata-Pendias (IUNG, Pulawy, Poland); Professor Dr. Nicola Senesi (Universitá di Bari, Italy); and Drs. Ravi Naidu and Mike McLaughlin (CSIRO, Adelaide).

My sabbatical in 1998–1999 provided the venue conducive to this type of writing. Professors Wenzel and Vangronsveld not only provided me with the supplies and tools to be functional but they also served as a "sounding board" to discuss some of the emerging paradigms in trace metal research.

Often, I would walk with Dr. Wenzel at the Turkenshanz Park (my favorite park) by the University in Vienna to discuss "mind-boggling" things. To them, I am most grateful for such stimulating exchanges of ideas.

A special debt of gratitude goes to Dr. Laura Janecek and Mr. David Scott (SREL), an award-winning photographer, for their design and photography that is used on the cover of this book; also to Kathy Jackson and Barbara Chernow of Chernow Editorial Services in New York for their skillful editorial assistance throughout the production of the book.

Finally, my tenure at SREL, world renowned for its ecological research, enabled me to broaden and sharpen my vision on trace elements well into the twenty-first century. To my SREL colleagues, I am forever indebted for the inspiration to wander into the fields of ecology, environmental biology, risk assessment, and aquatic chemistry.

Domy C. Adriano
Athens, Georgia
Aiken, South Carolina

Contents