ESSENTIALS of Industrial Hygiene

THOMAS P. FULLER
SCD, CIH, MSPH, MBA
## Contents

Preface .................................................. v

1 Introduction to Industrial Hygiene ................................. 1

2 The Occupational Safety and Health Act and Industrial Hygiene .... 23

3 Management Systems ........................................... 45

4 Basic Concepts in Industrial Toxicology .......................... 65

5 Occupational Exposure Limits and Assessment of Workplace Chemical Risks ............ 95

6 Gases and Vapors ............................................. 113

7 Aerosols .................................................... 137

8 Ventilation .................................................. 159

9 Respiratory Protection .......................................... 191

10 Dermal Hazards ............................................. 213

11 Noise ......................................................... 237

12 Radiation ................................................... 259

13 Thermal Stressors ............................................ 293

14 Ergonomics .................................................. 319

15 Biological Hazards ........................................... 349

Index ..................................................................... 373
PREFACE

The study of industrial hygiene is based upon several core sciences including chemistry, physics, physiology, anatomy, and biology. In the past several decades, undergraduates with science and math backgrounds have pursued advanced degrees in industrial hygiene that build on their education and experiences. Most industrial hygiene textbooks are thus written at the advanced reading and technical levels of postgraduates and working professionals.

With the growing recognition of the need for additional safety professionals in the United States and around the world, an increasing number of undergraduate programs in safety and occupational health are being developed. A course in industrial hygiene is fundamental to an undergraduate degree in these programs. The clear and concise delivery of the material makes Essentials of Industrial Hygiene a useful resource for new safety professionals as well as for those students taking an introductory course on the subject. Professionals with years of experience may also find the book a quick and easy reference to have at the ready.

Graduates of safety or occupational health degree programs may begin their careers in a broad array of industries. In manufacturing, energy, health care, and agriculture, young professionals need a sound industrial hygiene foundation in order to effectively and accurately evaluate working conditions and protect employees from chemical and physical hazards. The textbook used in such a program must address all of the key subject areas in sufficient detail to ensure that readers can understand and apply fundamental principles, but not provide so much information that it distracts and overwhelms them.

Decades of working experience in industrial hygiene have provided the authors of this textbook with a clear understanding of what levels of proficiency early industrial hygiene professionals should have when they enter the field. The authors also have years of undergraduate teaching experience, which allows them a precise understanding of the reading skills, capabilities, and interests of today’s occupational health students. In addition, this book presents the core body of knowledge that those graduating with advanced degrees in related fields such as public health, ergonomics, epidemiology, and environmental health should understand.

Each chapter contains learning objectives, examples, and hypothetical case studies, providing instructors with a straightforward basis for lecture material. Sample homework problems appear at the end of each chapter to help streamline courses using the text. Faculty can access supplemental materials that accompany the text on the National Safety Council’s Faculty Portal (www.nsc.org/facultyportal). The goals are laid out, the path is clear, and the reward is a solid foundation in industrial hygiene.
Because this is the first edition of this book, comments, criticisms, and suggestions for improvement are encouraged and will be actively considered for subsequent revisions. Please send your comments and suggestions to the National Safety Council, 1121 Spring Lake Drive, Itasca, IL 60143, attn. Deborah Meyer or deborah.meyer@nsc.org.

The ever-expanding need for occupational safety and health professionals in the United States and abroad ensures a need for well-educated and competent graduates with a solid understanding of the industrial hygiene field. In a realistic, efficient, and timely manner, this book is a way to increase the number of such graduates and provide them with a valuable resource they can continue to use once in the field.

**CONTRIBUTING AUTHORS**

The National Safety Council very much appreciates the dedication and expertise of the following authors who contributed to this textbook.

**Dr. Thomas P. Fuller** is Associate Professor of Safety at Illinois State University. He is a Certified Industrial Hygienist with more than 34 years of experience in occupational safety and industrial hygiene. He also has experience in health care, nuclear power plants, labor organizations, biopharmaceutical labs, manufacturing, and universities. He earned his doctorate from the University of Massachusetts Lowell, a Master of Science in Public Health from the University of North Carolina, and a Master of Business Administration from Suffolk University. Dr. Fuller is a Contributing Editor for the *American Journal of Nursing*, and is on the Editorial Advisory Board of the National Safety Council. Dr. Fuller is a past President of the Board of Directors of the *Journal of Occupational and Environmental Health*. E-mail: tfulle2@ilstu.edu.

**Dr. Farhang Akbar** (Chapter 13) is a professor in the Department of Public Health and Preventive Medicine at the University of Toledo. He is an environmental engineer and occupational health and safety scientist. His areas of expertise include exposure assessment regarding physical agents, hazardous chemicals, and mechanical agents; health and safety programs, auditing, and regulations; safety management; and hazard control methods. His current research activities are focused on exposure to nonionizing radiation; human chemical exposure assessment and biological changes; and exposure modeling. E-mail: farhang.akbar@utoledo.edu.
Dr. Sergio Caporali Filho (Chapter 7) has more than 21 years of manufacturing, industrial hygiene, safety, and ergonomics experience in the field. He has been a Certified Safety Professional since 2005 and a Certified Industrial Hygienist since 2011. Dr. Caporali Filho earned his BSc in Industrial Engineering from the University of Lima in 2004, his ME in Manufacturing Systems Engineering from the University of Puerto Rico at Mayaguez in 1998, his MSc in Occupational Hygiene and Occupational Safety in 2001, and his Ph.D. in Industrial Engineering–Ergonomics in 2002. He currently holds a professor and industrial hygiene program coordinator position at the Graduate School of Public Health in the University of Puerto Rico’s Medical Sciences Campus, and coordinates the occupational hazards control courses as well as the industrial hygiene and sampling courses at UPR’s IH graduate program. Dr. Caporali Filho’s most recent research interests are assessing hearing protection performance in real-world applications and welding fume control effectiveness through the correct use of Local Exhaust Ventilation. E-mail: sergio.caporali@upr.edu.

Dr. Andrew Maier (Chapters 4 and 5) is an Associate Professor of Environmental and Industrial Hygiene at the University of Cincinnati. He serves as a Science Fellow at the National Institute for Occupational Safety and Health. He is board certified in industrial hygiene and toxicology and maintains an active research program and field practice in occupational risk assessment methods. E-mail: maierma@ucmail.uc.edu.

Dr. Margaret Levin Phillips, CIH, (Chapter 12) is an Associate Professor of Occupational and Environmental Health at the University of Oklahoma Health Sciences Center and a member of the American Industrial Hygiene Association’s Nonionizing Radiation Committee. Prior to joining the faculty of the University of Oklahoma, Dr. Phillips worked as a field industrial hygienist in the private sector. She received her doctorate in Physical Chemistry from the University of Illinois and her Master of Health Science degree in Industrial Hygiene from the Johns Hopkins University School of Hygiene and Public Health. E-mail: margaret-phillips@ouhsc.edu.

Paul Ronczkowski (Chapter 9) teaches several courses in the Safety program at Illinois State University, including Agricultural Safety and Health, Accident/Incident Investigation, Construction Safety, Safety Fire Protection and Prevention, and General Industry Standards. He also coordinates the professional practice (internship) program. Mr. Ronczkowski has close to 20 years of college teaching experience in safety and health and 35 years of experience in the safety
and health profession in various industries, including production agriculture, construction, safety consulting, insurance (loss control), and the Veterans Affairs Medical Center. He has also published articles on student professional practice (internship) experiences. In addition to his teaching responsibilities, he is the student advisor and liaison for the student section of the American Society of Safety Engineers and the Central Illinois Chapter of the American Society of Safety Engineers. E-mail: pjroncz@ilstu.edu.

ACKNOWLEDGMENTS

The National Safety Council and author also want to thank the following for their contributions: Leo J. DeBobes, Dr. Katy Ellis, Dr. Janvier Gasana, Dr. David Christian Grieshaber, Philip E. Hagan, Dr. Michelle Homan, Michael Husarek, Dr. Farman A. Moayed, Jil Niland, and Dr. Allen Sullivan.