DADE W. MOELLER

ENVIRONMENTAL HEALTH

REVISED EDITION

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To Betty Jean, who for almost fifty years has been the joy of my life, and to Rad, Mark, Kehne, Matt, and Anne, who never cease to make us proud

PREFACE TO THE REVISED EDITION

This book continues to be an outgrowth of a course, "Principles of Environmental Health," that I taught at the Harvard School of Public Health for twenty-seven years and for shorter periods of time, in modified form, at Harvard College and the Harvard University Extension School.

One of my primary objectives in preparing this revised edition was to incorporate new developments in the field. In the legislative arena, these included passage of the Food Quality Protection Act, which, among other things, repealed the Delaney Clause (Chapter 6), and passage of the Safe Drinking Water Act Amendments (Chapter 7), which require that drinking-water supplies be analyzed for a wide range of specific contaminants.

As with the first edition, my goal has been to write a book that provides comprehensive coverage of the field. In seeking to achieve this, I have taken care to present topics from both local and global perspectives, and in relation to both short- and long-range impacts. At the same time I have sought to provide perspective, as, for example, in summarizing data on the major causes of cancer (Chapter 1). As will be noted, diet and personal living habits (most importantly, the use of tobacco products) are estimated to be the sources of about 65 percent of current cancer cases. This demonstrates that many of the factors affecting our health are within our control; they do not necessarily arise through noncontrollable sources such as environmental pollutants.

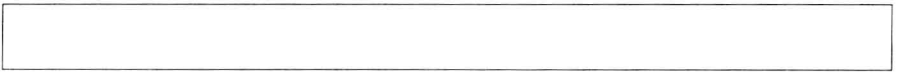
Also incorporated into the revised edition are discussions of a number of emerging and/or controversial issues in environmental and public health. These range from considerations of environmental justice, deforestation, and the protection of endangered species (Chapter 19) to topics such as

multiple chemical sensitivity (Chapter 2), the applicability of the threshold concept in evaluating the effects of toxic chemicals (Chapter 4) and radiation (Chapter 12), and the uncertainties in extrapolating laboratory data obtained through studies with animals, such as mice, to estimate related potential health effects in humans (Chapter 2).

Care has also been taken to ensure that the reader understands the limitations associated with techniques, such as epidemiology (Chapter 3) and risk assessment (Chapter 16), that are commonly applied in evaluating the impacts of various environmental stresses. In the discussions on epidemiology, for example, I point out that though this technique can be used to show an association between a given environmental stress and a specific health effect, it cannot be used to demonstrate causality.

Another feature of the revised edition is the effort to ensure that the reader understands the differences among clinical medicine, public health, and environmental health (Chapter 1). Equally important is the emphasis on using a total systems approach in assessing environmental problems. Although all of us recognize the need to manage and control various pollutants within individual segments of the environment (air, water, food), we also must understand and take into account potential interrelationships of these segments, one with another. Within this context, care has been taken to ensure that the reader is aware of the need to protect both humans and our natural resources. This is exemplified by a review of the concept of ecological risk assessment, and the discussion of primary and secondary standards for airborne contaminants—primary to protect the health of people; secondary to protect the environment. It is also exemplified by the discussion of acid precipitation (Chapter 5) and ozone depletion and global warming (Chapter 19).

As would be expected for an undertaking of this magnitude, I am grateful to a host of fellow environmental and public health professionals for sharing their talents and expertise with me. Special thanks are due my former colleagues at the Harvard School of Public Health, William A. Burgess, Melvin W. First, John D. Graham, David Hemenway, John B. Little, Richard R. Monson, Jacob Shapiro, Robert Schlegel, Andrew Spielman, and Jay A. Winsten. Other associates who provided invaluable support include John B. Garrick, William E. Kennedy, Matthew P. Moeller, Paul M. Newberne, and Cynthia Palmer. I also want to express my appreciation to Janet Francoeur, who prepared many of the figures used in the book. Finally, I deeply appreciate the editorial suggestions of Vivian Wheeler and Christine Thorsteinsson at Harvard University Press.



And God pronounced a blessing upon Noah and his sons and said to them, be fruitful and multiply and fill the earth.

And the fear of you and the dread and terror of you shall be upon every beast of the land, every bird of the air, all that creeps upon the ground, and upon all the fishes of the sea. Into your hands they are delivered.

Genesis 9:1–2

ABBREVIATIONS

AAEE	American Academy of Environmental Engineers
ACGIH	American Conference of Governmental Industrial Hygienists
AEA	Atomic Energy Act
AIDS	Acquired Immune Deficiency Syndrome
AIHA	American Industrial Hygiene Association
ALARA	As Low As Reasonably Achievable
ALI	Annual Limit on Intake
AMA	American Medical Association
ASME	American Society of Mechanical Engineers
ATSDR	Agency for Toxic Substances and Disease Registry, U.S. Department of Health and Human Services
BACT	Best Available Control Technology
BEIs	Biological Exposure Indices
BEIR	Committee on the Biological Effects of Ionizing Radiation, National Research Council
BOD	Biochemical Oxygen Demand
BST	Bovine Somatotropin
BTI	*Bacillus thuringiensis israeliensis*
BTK	*Bacillus thuringiensis kurstaki*
BWR	Boiling-Water Reactor
CDC	Centers for Disease Control and Prevention, U.S. Department of Health and Human Services
CEQ	Council on Environmental Quality
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act (Superfund)
CFC	Chlorofluorocarbon
CO	Carbon Monoxide
$C0_2$	Carbon Dioxide
COD	Chemical Oxygen Demand

CRCPD	Conference of Radiation Control Program Directors
DAC	Derived Air Concentration
DDT	Dichlorodiphenyltrichloroethane
DEET	Diethyltoluamide
DNA	Deoxyribonucleic Acid
DO	Dissolved Oxygen
DOE	U.S. Department of Energy
EIS	Environmental Impact Statement
EMAP	Environmental Monitoring and Assessment Program
EPA	U.S. Environmental Protection Agency
EPRI	Electric Power Research Institute
eV	Electron Volt
FDA	Food and Drug Administration, U.S. Department of Health and Human Services
FEMA	Federal Emergency Management Agency
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
GI Tract	Gastrointestinal Tract
GRAS	Generally Recognized As Safe
HHS	U.S. Department of Health and Human Services
HVAC	Heating, Ventilating, and Air Conditioning
Hz	Hertz (cycles per second)
IAEA	International Atomic Energy Agency
ICNIRP	International Commission on Non-Ionizing Radiation Protection
ICRP	International Commission on Radiological Protection
IIHS	Insurance Institute for Highway Safety
INPO	Institute of Nuclear Power Operations
IRIS	Integrated Risk Information System
IRPA	International Radiation Protection Association
IVHS	Intelligent Vehicle Highway Systems
LASER	Light Amplification by Stimulated Emission of Radiation
LD_{50}	Lethal Dose for 50 percent of the exposed population
LLRW	Low-Level Radioactive Waste
MCL	Maximum Contaminant Level
MRS Facility	Monitored Retrievable Storage Facility
MTD	Maximum Tolerated Dose
NAAQS	National Ambient Air Quality Standards
NAFTA	North American Free Trade Agreement
NASA	National Aeronautics and Space Administration
NCRP	National Council on Radiation Protection and Measurements
NEPA	National Environmental Policy Act
NHEXAS	National Human Exposure Assessment Survey
NIOSH	National Institute for Occupational Safety and Health, U.S. Department of Health and Human Services
NO_2	Nitrogen Dioxide
NPDES	National Pollution Discharge Elimination System
NPL	National Priorities List
NRC	National Research Council

NRPB	National Radiological Protection Board (UK)
NSC	National Safety Council
OECD	Organization for Economic Cooperation and Development
OSHA	Occupational Safety and Health Administration, U.S. Department of Labor
OTA	Office of Technology Assessment, U.S. Congress
PAHO	Pan American Health Organization
PC	Personal Computer
PCB	Polychlorinated Biphenyls
PST	Porcine Somatotropin
PWR	Pressurized-Water Reactor
RACT	Reasonably Available Control Technology
RCRA	Resource Conservation and Recovery Act
SARA	Superfund Amendments and Reauthorization Act
SO_2	Sulfur Dioxide
SUMA	Program Supply Management Program
TLVs	Threshold Limit Values
TSCA	Toxic Substances Control Act
UNESCO	United Nations Educational, Scientific, and Cultural Organization
USDA	U.S. Department of Agriculture
USNRC	U.S. Nuclear Regulatory Commission
UV Radiation	Ultraviolet Radiation
WHO	World Health Organization

CONTENTS

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THE SCOPE

MANY aspects of human well-being are influenced by the environment, and many diseases can be initiated, promoted, sustained, or stimulated by environmental factors. For that reason, the interactions of people with their environment are an important component of public health.

In its broadest sense, environmental health is the segment of public health that is concerned with assessing, understanding, and controlling the impacts of people on their environment and the impacts of the environment on them. Still, environmental health is defined more by the problems faced than by the approaches used. These problems include the treatment and disposal of liquid and airborne wastes, the elimination or reduction of stresses in the workplace, purification of drinking-water supplies, the impacts of overpopulation and inadequate or unsafe food supplies, and the development and use of measures to protect hospital and medical workers from being infected with diseases such as acquired immune deficiency syndrome (AIDS). Environmental health professionals also face long-range problems that include the effects of toxic chemicals and radioactive wastes, acidic deposition, depletion of the ozone layer, global warming, resource depletion, and loss of forests and topsoil. The complexity of these issues requires multidisciplinary approaches. Thus a team coping with a major environmental health problem may include scientists, physicians, epidemiologists, engineers, economists, lawyers, mathematicians, and managers. Input from all these experts is essential to the development and success of broad strategies that take into account both lifestyles and the environment.

Just as the field of public health involves more than disease (for example,

health care management, maternal and child health, epidemiology), the field of environmental health encompasses the effects of the environment on animals other than humans, as well as on trees and vegetation and on natural and historic landmarks. While many aspects of public health deal with the "here and now," many of the topics addressed within the subspecialty of environmental health are concerned with the previously cited impacts of a long-range nature.

Defining the Environment

To accomplish their goals effectively, environmental health professionals must keep in mind that there are many ways to define the environment. Although no single definition is without its deficiencies, each offers benefits in terms of perspective and understanding.

The inner versus outer environment. From the standpoint of the human body, there are two environments: the one within the body and the one outside it. Separating them are three principal protective barriers: the skin,

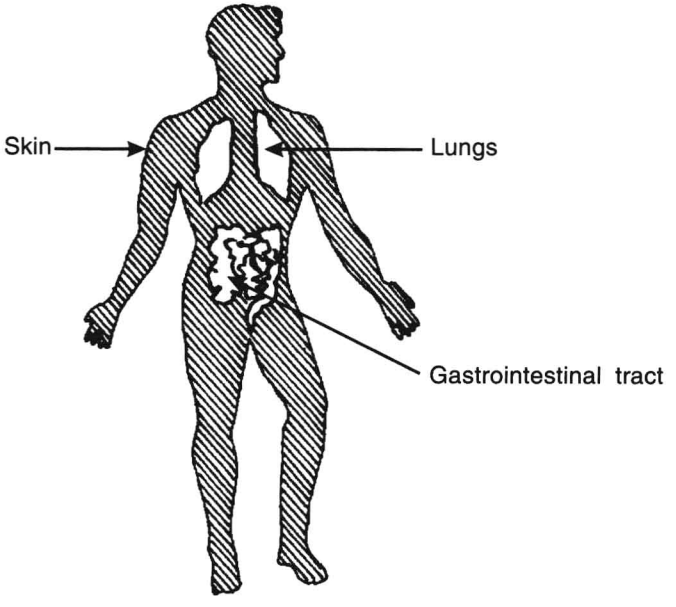

Figure 1.1 Barriers between the inner and outer environments

Table 1.1 Characteristics of the principal barriers between the outer and inner body

	Area		Thickness		Weight		Daily exposure	
Barrier	ft^2	m^2	in	μm	lb	kg	lb	kg
Skin	21	2	4×10^{-3}	100	30	12–16	Variable	
GI tract	2,150	200	4×10^{-4}	10–12	15	7	4–6	2–3
Lungs	1,500	140	1×10^{-5}	0.2–0.4	2	0.8–0.9	50	24

which protects the body from contaminants outside the body; the gastrointestinal (GI) tract, which protects the inner body from contaminants that have been ingested; and the membranes within the lungs, which protect the inner body from contaminants that have been inhaled (Figure 1.1, Table 1.1).

Although they may provide protection, each of these barriers is vulnerable under certain conditions. Contaminants can penetrate to the inner body through the skin by dissolving the layer of wax generated by the sebaceous glands. The GI tract, which has by far the largest surface area of any of the three barriers, is particularly vulnerable to compounds that are soluble and can be readily absorbed and taken into the body cells. Fortunately, the body has mechanisms that can protect the GI tract: unwanted material can be vomited via the mouth or rapidly excreted through the bowels (as in the case of diarrhea). Airborne materials in the respirable size range may be deposited in the lungs and, if they are soluble, may be absorbed. Mechanisms for protecting the lungs range from simple coughing to cleansing by macrophages that engulf and promote the removal of foreign materials. Unless an environmental contaminant penetrates one of the three barriers, it will not gain access to the inner body. And even if a contaminant is successful in gaining access, the body still has mechanisms for removing it. For example, materials entering the circulatory system can be detoxified in the liver or excreted through the kidneys.

Although an average adult ingests about 1.5 kilograms of food and 2 kilograms of water every day, he or she breathes roughly 20 cubic meters of air per day. This amount of air weighs more than 24 kilograms. Because people usually cannot be selective about what air is available, the lungs are the most important pathway for the intake of environmental contaminants

into the body. The lungs are also by far the most fragile and susceptible of the three principal barriers.

The personal versus ambient environment. In another definition, people's "personal" environment, the one over which they have control, is contrasted with the working or ambient environment, over which they may have essentially no control. Although people commonly think of the working or ambient environment as posing the greater threat, environmental health experts estimate that the personal environment, influenced by hygiene, diet, sexual practices, exercise, use of tobacco, drugs, and alcohol, and frequency of medical checkups, often has much more influence on well-being.

Table 1.2 summarizes the estimated contributions of these various factors to cancer deaths in an industrialized society. As may be noted, the personal environment is seen as accounting for 75 percent or more of such deaths. Cigarette smoking leads to increased deaths not only from lung cancer but

Table 1.2 Proportion of cancer deaths attributable to various factors, England and Wales, 1995

	Percentage of all cancer deaths	
Agent or class of agents	Best estimate	Range of estimates
Diet	35	20–60
Tobacco	31	29–33
Natural hormones	15	10–20
Infections	10	5–15
Electromagnetic radiation		
Ionizing 4.5		
Ultraviolet 2.5	8	5–10
Lower frequency <1		
Alcoholic beverages	5	3–7
Occupational exposure	3	2–6
Environmental pollution	2	<1–4
Medicines and medical procedures	1	0.5–2
Industrial products	<1	<1–4
Other	?	?

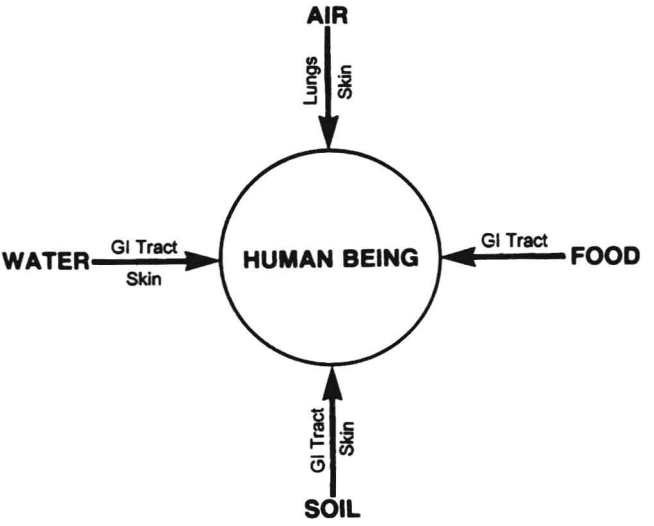

Figure 1.2 Routes of human exposure through the gaseous, liquid, and solid environments

also from heart disease. As a result, this single factor is estimated to account for 15 to 20 percent of all deaths in the United States (Surgeon General, 1989). The Centers for Disease Control and Prevention estimate that cigarette smoking is responsible annually for more than 400,000 deaths nationwide. The associated medical-care costs for 1993 were estimated at $50 billion, more than 40 percent of the total annual medical-care expenditures (Anonymous, 1994).

The amount of pollution taken into a smoker's lungs as a result of inhaling the various products from cigarettes is several orders of magnitude greater than the amount normally inhaled due to industrial airborne pollution. Unless it is controlled, cigarette smoke can account for a significant fraction of the fine-particle content of air inside buildings. In fact, it accounts for more than 1 percent of the fine-particle content of the outdoor air in Los Angeles (*New York Times*, 1994).

The gaseous, liquid, and solid environments. The environment can also be considered as existing in one of three forms—gaseous, liquid, or solid. Each of these is subject to pollution, and people interact with all of them (Figure 1.2). Particulates and gases are released into the atmosphere, sew-