Fourth Edition

Handbook of ENVIRONMENTAL HEALTH

Volume 1

Biological, Chemical, and Physical Agents of Environmentally Related Disease

Herman Koren • Michael Bisesi

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Dedication

To Donna Lee Koren and Christine Bisesi, our wives, dearest and very best friends, for all they have done to enhance our lives and encourage us to teach our students the true significance of improving the environment for all people.

Foreword

I have spent a career in this field. My years of experience have taught me that environmental health might best be described as a colorful, complex, and diverse spectrum of interrelated topics. These topics range from the individual to the compounded effects of pollution; to the impacts of contaminated air, water, land, food, and indoor and outdoor environments; and to biological, physical, chemical, and radiological hazards. Because this field is so broad, to protect both our environment and our people properly, it is important that one possesses a credible understanding of basic science, laws and regulations, governmental and private programs, disease and injury identification, and prevention and control. Moreover, because so many environmental concerns impact on other elements of the environment, it is important that even the specialists within our field appreciate and understand the implications of how their issues can impact other environmental concerns. A reading and comprehension of the material in these books can help greatly in building that overarching understanding that professionals in this field need to have.

The *Handbook of Environmental Health* has been, for the past 23 years, an excellent source for gaining that needed understanding of interrelated and current environmental topics. The presentations offered by this publication are particularly helpful inasmuch as they are comprehensive while concise and basic. The two volumes cover basic and applied chemistry relative to both toxicity to humans and the fate of natural and anthropogenic contaminants in the environment; basic and applied microbiology relative to both pathogenicity to humans and the fate of natural and anthropogenic contaminants in the environment; current status of each environmental problem area; discussion of the problem; potential for intervention; resources available for use, standards, practices, and techniques utilized to resolve the problem; surveillance and evaluation techniques; appropriate controls, laws, and regulations; future research needs; large number of current references; state-of-the-art graphics, and major environmental, including industrial hygiene, sampling and analytic instruments.

The fourth edition of Volume I, Chapters 1 and 2, provides a significant understanding of basic new environmental issues, energy, emerging infectious diseases, recent laws, emerging microorganisms, toxicology, epidemiology, human physiology, and the effects of the environment on humans. The remainder of the chapters discuss a variety of indoor environmental issues, including food safety, food technology, insect and rodent control, pesticides, indoor environment, institutional environment, recreational environment, occupational environment, and instrumentation. Some of the new and significantly expanded and updated sections include: new food codes and programs; emerging and reemerging insectborne disease; insecticide resistance; pesticides and water quality; indoor air pollution; asthma; monitoring environmental disease; homelessness and disease; emerging zoonoses; bacteria in hospitals and nursing homes; fungal and viral agents in laboratories; prions; guidelines for infection control; principles of biosafety; a variety of risk assessment techniques; and an updated overview of the occupational environment.

The fourth edition of Volume II discusses a variety of outdoor environmental issues including changes to the Clean Air Act; PM 2.5; toxic air pollutants; risk assessment and air, water, solid, and hazardous waste and the interrelationship between these areas; methyl bromide; air quality index; air, water, and solid waste programs; technology transfer; methyl tertiary butyl ether; toxic releases from waste; technical tracking systems; biological processes and solid and hazardous wastes; storm water runoff; ocean dumping; waste to energy; toxics release inventory; brownfields; contaminated governmental facilities; Superfund update; geographic information systems; pollution prevention programs; environmental justice; new laws; waterborne disease update; national mapping; EnviroMapper; safe drinking water standards; maximum contaminant level; crossconnections, backflow, and back-siphonage; sewage pretreatment technologies; leaching field chambers; constructed wetlands; drip and spray irrigation systems; peat bed filters; zone of initial dilution; new laws; wetlands; nonpoint source pollution; national water quality assessments; dredging waste; trihalomethanes; environmental studies; bioterrorism; and the Federal Emergency Management Agency. There are chapters on air quality management, solid and hazardous waste management, private and public water supplies, swimming areas, plumbing, private and public sewage disposal and soils, water pollution water quality controls, terrorism and environmental health emergencies, and instrumentation.

Two well-regarded environmental health professionals have written these two books. They have each conducted extensive research and are extremely knowledgeable about all areas of the environmental, industrial hygiene, and health related fields.

Dr. Herman Koren is a founding director of the environmental health science and internship program at Indiana State University and is a professor emeritus there. He has gained respect as a researcher, teacher, consultant, and practitioner in the environmental health, hospital, and medical care fields as well as in management areas related to these fields; nursing homes; water and wastewater treatment plants; and other environmental and safety industries for the past 47 years. Since his retirement from Indiana State University in 1995, he has continued his lifelong quest to gain and interpret the latest knowledge possible and to share it with students and other professionals. He also continues to give numerous presentations and workshops and has written and rewritten several books.

Dr. Michael Bisesi, professor and chairperson, department of public health, and associate dean, graduate allied health programs, Medical College of Ohio, School of Allied Health, has been in the environmental and occupational health fields for 20 years. He, too, is respected as a researcher, teacher, consultant, practitioner, and administrator. In addition to his environmental science and industrial hygiene accreditations, he is an expert in human exposure assessment and environmental toxicology. He also holds appointments in the School of Pharmacology and School of Medicine, has written numerous scientific and technical articles and chapters in scientific books, and is the author or co-author of several additional books.

The books are user-friendly to a variety of individuals including generalist professionals as well as specialists, industrial hygiene personnel, health and medical personnel, managers, and students. These publications can be used to look up specific information or to gain deeper knowledge about an existing problem area. The section on surveillance techniques helps the individual decide the extent and nature of a problem. The appropriate and applicable standards, rules, and regulations help the reader resolve a problem. Further information and assistance can be gained through the resource area and through the review of many of the updated bibliographical references. Except for Chapters 1, 2, 11, 12, in Volume I, and Chapters 8 and 9 in Volume II, all chapters follow the same format, thereby making the books relatively easy to use. The extensive index for both volumes in each book is also very useful.

Thank you, Professors Koren and Bisesi, for providing environmental health professionals, new or seasoned, generalist or specialist, with such a helpful resource.

Nelson Fabian
Executive Director
National Environmental Health Association
February 28, 2002

Preface

This handbook, in two volumes, is designed to provide a comprehensive but concise discussion of each of the important environmental health areas, including energy, ecology and people, environmental epidemiology, risk assessment and risk management, environmental law, air quality management, food protection, insect control, rodent control, pesticides, chemical environment, environmental economics, human disease and injury, occupational health and safety, noise, radiation, recreational environment, indoor environments, medical care institutions, schools and universities, prisons, solid and hazardous waste management, water supply, plumbing, swimming areas, sewage disposal, soils, water pollution control, environmental health emergencies, and nuisance complaints.

Sufficient background material is introduced throughout these texts to provide students, practitioners, and other interested readers with an understanding of the areas under discussion. Common problems and potential solutions are described; graphs, computerized drawings, inspection sheets, and flowcharts are utilized as needed to consolidate or clarify textual material. All facts and data come from the most recent federal government documents, many of which date from the late 1990s and early 2000s. Rules and regulations specified will continue to be in effect into the early 2000s. For rapidly changing areas in which the existing material used is likely to become dated, the reader is referred to the appropriate sources under resources and in the bibliography to update a given environmental health area or portion of an area as needed. This enhances the value of the text by providing basic and current materials that will always be needed and secondary sources that will enable the reader to keep up to date.

These books are neither engineering texts nor comprehensive texts in each area of study. Their purpose is to provide a solid working knowledge of each environmental health area with sufficient detail for practitioners and students. The text can be used in basic courses in environmental health, environmental pollution, ecology, and environment and people that are offered at all universities and colleges in the United States and abroad. These courses are generally taught in departments of life science, geology, science education, environmental health, and health and safety. For general areas of study, the instructor can omit specific details, such as resources, standards, practices and techniques, and modes of surveillance and evaluation. This same approach may be used by schools of medicine, nursing, and allied health sciences for their students. These texts are also suitable for basic introductory courses in schools of public health, environmental health, and sanitary science, as well as junior colleges offering 2-year degree programs in sanitary science and environmental science.

Practitioners in a variety of environmental health and occupational health and safety fields will find these volumes handy references for resolving current problems and for obtaining a better understanding of unfamiliar areas. Practitioners and administrators in other areas, such as food processing, water-quality control, occupational health and safety, and solid and hazardous waste management, will also find these reference books useful.

High school teachers often must introduce environmental health topics in their classes and yet have no specific background in this area. These books could serve as a text in graduate education courses for high school teachers as well as a reference source.

Public interest groups and users of high school and community libraries will obtain an overall view of environmental problems by reading Chapter 1; Chapter 2; and the sections in each chapter titled "Background and Status, Problems, Potential for Intervention, Resources, and Control." This volume also supplies a concise reference for administrators in developing nations because it explains tested controls and provides a better understanding of environmental problems; various standards, practices, and techniques; and a variety of available resources.

The material divides easily into two separate courses. Course I would correspond to the content of Volume I and would include Chapter 1, Environment and Humans; Chapter 2, Environmental Problems and Human Health; Chapter 3, Food Protection; Chapter 4, Food Technology; Chapter 5, Insect Control; Chapter 6, Rodent Control; Chapter 7, Pesticides; Chapter 8, Indoor Environment; Chapter 9, Institutional Environment; Chapter 10, Recreational Environment; Chapter 11, Occupational Environment; and Chapter 12, Major Instrumentation for Environmental Evaluation of Occupational, Residential, and Public Indoor Settings.

Course II, corresponding to the content of the Volume II, would include Chapter 1, Air Quality Management; Chapter 2, Solid and Hazardous Waste Management; Chapter 3, Private and Public Water Supplies; Chapter 4, Swimming Areas; Chapter 5, Plumbing; Chapter 6, Private and Public Sewage Disposal and Soils; Chapter 7, Water Pollution and Water Quality Controls; Chapter 8, Terrorism and Environmental Health Emergencies; and Chapter 9, Major Instrumentation for Environmental Evaluation of Ambient Air, Water, and Soil.

Because the problems of the environment are so interrelated, certain materials must be presented at given points to give clarity and cohesiveness to the subject matter. As a result, the reader may encounter some duplication of materials throughout the text.

With the exception of Volume I, Chapters 1, 2, 11, and 12, and Volume II, Chapters 8 and 9, all the chapters have a consistent style and organization, facilitating retrieval. The introductory nature of Volume I (Chapters 1 and 2) as well as the unusual nature of Volume II (Chapter 8) do not lend themselves to the standard format. Volume I (Chapter 12) and Volume II (Chapter 9) discuss instrumentation for the specific areas of each volume and therefore do not follow standard format.

In Volume I (Chapter 1), the reader is introduced to the underlying problems, basic concerns, and basic philosophy of environmental health. The ecological, economic, and energy bases provided help individuals understand their relationship to the ecosystem and to the real world of economic and energy concerns. It also provides an understanding of the role of government and the environmental health practitioner in helping to resolve environmental and ecological dilemmas created by humans. Chapter 2 on human health helps the reader understand the relationship between biological, physical, and chemical agents, and disease and injury causation.

In Volume II, Chapter 8, the many varied facets of terrorism and environmental emergencies, nuisances, and special problems are discussed. Students may refer to other chapters of the text to obtain a complete idea of each of the problems and the potential solutions.

The general format of Volume I, Chapters 3 to 11, and Volume II, Chapters 1 to 7, is as follows:

STANDARD CHAPTER OUTLINE

1. Background and status (brief)
2. Scientific, technological, and general information
3. Problem
   a. Types
   b. Sources of exposure
   c. Impact on other problems
   d. Disease potential
   e. Injury potential
   f. Other sources of exposure contributing to problems
   g. Economics
4. Potential for intervention
   a. General
   b. Specific
5. Resources
   a. Scientific and technical; industry, labor, university; research groups
   b. Civic
   c. Governmental
6. Standards, practices, and techniques
7. Modes of surveillance and evaluation
   a. Inspections and surveys
   b. Sampling and laboratory analysis
   c. Plans review
8. Control
   a. Scientific and technological
   b. Governmental programs
   c. Other programs
   d. Education
9. Summary
10. Research needs
    - The background and status section of each chapter presents a brief introduction to, and the current status of, each problem area. An attempt has been made in each case to present the current status of the problem.
    - The problem section is subdivided into several important areas to give the reader a better grasp of the total concerns. To avoid disruption in continuity of the standard outline, the precise subtitles listed may not be found in each chapter. However, the content of the subtitles will be present. The subtitle, impact on other problems, is given as a constant reminder that one impact on the environment may precipitate numerous other problems.
    - The potential for intervention section is designed to succinctly illustrate whether a given problem can be controlled, the degree of control possible, and some techniques of control. The reader should refer to the controls section for additional information.

- Resources is a unique section providing a listing of scientific, technical, civic, and governmental resources available at all levels to assist the student and practitioner.
- The standards, practices, and techniques section is specifically geared to the reader who requires an understanding of some of the specifics related to surveys, environmental studies, operation, and control of a variety of program areas.
- The modes of surveillance and evaluation section explains many of the techniques available to determine the extent and significance of environmental problems.
- The control section presents existing scientific, technological, governmental, educational, legal, and civic controls. The reader may refer to the standards, practices, and techniques section in some instances to get a better understanding of controls.
- The summary presents the highlights of the chapter.
- Research needs is another unique section intended to increase reader awareness to the constantly changing nature of the environment and of the need for continued reading or in-service education on the future concerns of our society.
- The reference section is extensive and as current as possible. It appears as the last area in each volume and provides the reader with sources for further research and names of individuals and organizations involved in current research.

Acknowledgments

I extend thanks to Boris Osheroff, my friend, teacher, and colleague, for opening the numerous doors needed to obtain the most current information in the environmental health field, and for contributing his many fine suggestions and ideas before and after reading the manuscript; to Ed O'Rourke for intensively reviewing the manuscript and recommending revisions and improvements; to Karol Wisniewiski for giving his review and comments on the manuscript; to Dr. John Hanlon for offering his encouragement and for helping a young teacher realize his potential; to all the environmental health administrators, supervisors, practitioners, and students for sharing their experiences and problems with me and for giving me the opportunity to test many of the practical approaches used in the book; to the National Institute of Occupational Safety and Health, National Institutes of Health, National Institute of Environmental Health Science, U.S. Environmental Protection Agency, U.S. Food and Drug Administration, Cunningham Memorial Library, Indiana State University, Indiana University Library, Purdue University Library, and the many other libraries and resources for providing the material that was used in developing the manuscript; to my wife, Donna Koren, and my student, Evelyn Hutton, for typing substantial portions of the manuscript; to my daughter, Debbie Koren, for helping me organize the materials and for working along with me throughout the night at the time of deadlines to complete the work.

In the second edition, Kim Malone typed portions of the new manuscript, retyped the entire manuscript, and was of great value to me. Pat Ensor, librarian, Indiana State University, was of considerable value in helping gather large numbers of references in all areas of the book. A very special thanks goes to my sister-in-law, Betty Gardner, for typing a substantial portion of the new manuscript, despite recurring severe illness. Her cheerfulness during my low periods helped me complete my work. Finally, thanks go to my wife Donna for putting up with my thousands of hours of seclusion in the den, while I was working, and for encouraging me throughout the project and my life with her. She has truly been my best friend.

In the third edition, Alma Mary Anderson, C.S.C., and her assistants, Carlos Gonzalez and Brian Flynn, redid the existing illustrations and added new ones to enhance the manuscript. Professor Anderson directed the production of all the new artwork. In addition, I thank Bill Farms for his assistance with the original computer-assisted drawings for the chapters on instrumentation in both volumes. My wife Donna typed much new material, and the previously mentioned libraries, Centers for Disease Control, and the University of South Florida were most helpful in my research efforts. I would like to recognize Dr. Michael Bisesi, friend and colleague, who became my co-author.

In the fourth edition, Professor Anderson, advisor of the graphic design area in the department of art, Indiana State University, provided many excellent graphics and endless hours of work inserting new material and correcting previous material in the manuscripts. Without her help this new edition would not have been possible. Thanks also go to my daughter and son-in-law, Debbie and Kenny Hardas, who dragged me into the computer age by purchasing my first computer and by teaching me to use it.

Dr. Michael Bisesi acknowledges his appreciation of his wife Christine Bisesi, M.S., C.I.H., C.H.M.M.; his two sons Antonio (Nino) and Nicolas (Nico); and his parents Anthony (deceased) and Maria Bisesi for their love and support. In addition, he wants to acknowledge his mentors Rev. Francis Young; George Berkowitz, Ph.D.; Raymond Manganelli, Ph.D.; Barry Schlegel, M.S., C.I.H.; John Hochstrasser, Ph.D., C.I.H.; Richard Spear, H.S.D.; Christopher Bork, Ph.D.; Keith Schlender, Ph.D.; and Roy Hartenstein, Ph.D. for sharing their knowledge, wisdom, and encouragement at various phases of his academic and professional career.

About the Authors

Herman Koren, R.E.H.S., M.P.H., H.S.D., is professor emeritus and former director of the environmental health science program, and director of the supervision and management program I and II at Indiana State University at Terre Haute. He has been an outstanding researcher, teacher, consultant, and practitioner in the environmental health field, and in the occupational health, hospital, medical care, and safety fields, as well as in management areas of these areas and in nursing homes, water and wastewater treatment plants, and other environmental and safety industries for the past 47 years. In addition to numerous publications and presentations at national meetings, he is the author of six books, titled *Environmental Health and Safety*, Pergamon Press, 1974; *Handbook of Environmental Health and Safety*, Volumes I and II, Pergamon Press, 1980 (now published in updated and vastly expanded format by Lewis Publishers, CRC Press, as a fourth edition); *Basic Supervision and Basic Management*, Parts I and II, Kendall Hunt Publishing, 1987 (now published in updated and vastly expanded format as *Management and Supervision for Working Professionals*, Volumes I and II, third edition, by Lewis Publishers, CRC Press); *Illustrated Dictionary of Environmental Health and Occupational Safety*, Lewis Publishers, CRC Press, 1995, second edition due in 2004. He has served as a district environmental health practitioner and supervisor at the local and state level. He was an administrator at a 2000-bed hospital. Dr. Koren was on the editorial board of the *Journal of Environmental Health* and the former *Journal of Food Protection*. He is a founder diplomate of the Intersociety Academy for Certification of Sanitarians, a Fellow of the American Public Health Association, a 46-year member of the National Environmental Health Association, founder of the Student National Environmental Health Association, and the founder and advisor of the Indiana State University Student National Environmental Health Association (Alpha chapter). Dr. Koren developed the modern internship concept in environmental health science. He has been a consultant to the U.S. Environmental Protection Agency, the National Institute of Environmental Health Science, and numerous health departments and hospitals; and has served as the keynote speaker and major lecturer for the Canadian Institute of Public Health Inspectors. He is the recipient of the Blue Key Honor Society Award for outstanding teaching and the Alumni and Student plaque and citations for outstanding teaching, research, and service. The National Environmental Health Association has twice honored Dr. Koren with presidential citations for "Distinguished Services, Leadership and Devotion to the Environmental Health Field" and "Excellent Research and Publications."

Michael S. Bisesi, Ph.D., R.E.H.S., C.I.H., is an environmental and occupational health scientist and board certified industrial hygienist working full-time as professor and chairman of the department of public health in the School of Allied Health at the Medical College of Ohio (MCO). He also has a joint appointment in the department of pharmacology in the School of Medicine, serves as the associate dean of allied health programs, and is director of the Northwest Ohio Consortium for Public Health. At MCO, he is responsible for research, teaching, service, and administration. He teaches a variety of graduate level and continuing education courses, including toxicology, environmental health, monitoring and analytical methods, and hazardous materials and waste. His major laboratory and field interests are environmental toxicology involving biotic and abiotic transformation of organics; fate of pathogenic agents in various matrices; and industrial hygiene evaluation of airborne biological and chemical agents relative to human exposure assessment. He also periodically provides applicable consulting services via Enviro-Health, Inc., Holland, OH.

Dr. Bisesi earned a B.S. and an M.S. in environmental science from Rutgers University and a Ph.D. in environmental science from the SUNY College of Environmental Science and Forestry in association with Syracuse University. He continues to complete additional postgraduate course work, including an MCO faculty development leave at Harvard and Tufts Universities in the summer of 1998. He also completed a fellowship at MCO in teaching and learning health and medical sciences and earned a graduate certificate.

Dr. Bisesi has published several scientific articles and chapters, including two chapters in the *Occupational Environment: Its Evaluation and Control* and three chapters in fourth and fifth editions of *Patty's Industrial Hygiene and Toxicology.* In addition, he is first author of the textbook *Industrial Hygiene Evaluation Methods* and second author of two other textbooks, the *Handbook of Environmental Health and Safety*, Volumes I and II. He is a member of the American Industrial Hygiene Association (fellow), American Conference of Governmental Industrial Hygienists, American Public Health Association, National Environmental Health Association, and Society of Environmental Toxicology and Chemistry.

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CHAPTER 1

Environment and Humans

Health and *safety* refer to the avoidance of human illness and injury through efficient use of the environment, a properly functioning society, and an inner sense of well-being. *Environmental health and safety* is the art and science of protecting human function; promoting aesthetic values; and preventing illness and injury through the control of positive environmental factors and the reduction of potential physical, biological, and chemical hazards.

To understand the relationship of the environment to humans and to understand how to protect humans from illness and injury, it will be necessary to discuss the ecosystem, ecosystem dynamics, and energy. Human impact on the environment and the various approaches, including risk assessment, epidemiological, economic, legal, and governmental aspects used to evaluate and resolve environmental problems, are discussed. To understand abnormal physiology, and the basis of human illness and injury, brief discussions on normal physiology, toxicology, and epidemic infectious disease are included. Finally, it is necessary to understand the role of professional environmental health practitioners, the skills that they need, and how they address the expanding scope of environmental problems.

ECOSYSTEM

Environments

Earth is divided into the lithosphere, or land masses, and the hydrosphere, or the oceans, lakes, streams, and underground waters. The hydrosphere includes the entire aquatic environment. Our world, both lithosphere and hydrosphere, is shaped by varying life forms. Permanent forms of life create organic matter and, in combination with inorganic materials, help establish soil. Plants cover the land and reduce the potential for soil erosion — the nature and rate of erosion affects the redistribution of materials on the surface of Earth. Organisms assimilate vast quantities of certain elements and molecules, such as carbon and oxygen. Animals, through respiration, release carbon dioxide into the atmosphere — carbon dioxide affects the heat transmission of the atmosphere. Organisms affect the environment and in turn are affected by it.

Two environments, biotic (living) and abiotic (nonliving), combine to form an ecosystem. An ecosystem can also be subdivided by more specific criteria into the following four categories: (1) abiotic, the nutrient minerals that are synthesized into living protoplasm; (2) autotrophic, the producer organisms (largely the green plants) that assimilate the nutrient minerals using energy and combine them into living organic substances; (3) heterotrophic, the consumers, usually the animals, that ingest or eat organic matter and release energy; and (4) heterotrophic reducers, the bacteria or fungi that return the complex organic compounds to their original abiotic state and release the remaining chemical energy. The biotic group in the ecosystem complex is essentially composed of the autotrophs, or producer organisms that synthesize organic substances, and the heterotrophs, or consumer or reducer organisms that decompose labile organic substances. The ecosystem is important when considering the food chain, which is in effect a transfer of energy from plants through a series of organisms that eat and, in turn, are eaten. Eventually, decay will start the process all over again.

The ecological niche is the combination of function and habitat of each of the approximately 1.5 million species of animals and 0.5 million species of plants on Earth. There are many interactions between species in the ecosystem, yet a balance is dictated by nature. The law of limiting factors states that a minimum quantity of essentials, such as nutrients, light, heat, moisture, and space, must be available within the ecosystem for survival of the organisms. In some instances where these limiting factors apply or where pesticides or other environmental elements are introduced into the ecosystem, the organism alters itself to exist within the new environment. This change is called mutation. Unfortunately, mutation becomes a serious concern in the area of pest control as well as in disease, because the new organism may be highly resistant to effective control and may therefore cause disease and physical destruction of plants and animals. The ecosystem is always in a dynamic instead of a static balance — changes in one part of the ecosystem cause changes in another.

Biosphere

The biosphere is that part of Earth — lithosphere and hydrosphere — in which life exists. However, this definition is not complete, because spores may commonly be found in areas that are too dry, too cold, or too hot to support organisms that metabolize. The biosphere contains the liquid water necessary for life; it receives an ample supply of energy from an external source, which is ultimately the Sun, and within it liquid, solid, and gaseous states of matter interface. All the actively metabolizing organisms operate within the biosphere. The operation of the biosphere depends on photosynthesis, during which carbon dioxide is reduced to form organic compounds and molecular oxygen. Oxygen, the by-product of photosynthesis, replenishes the atmosphere and most of the free water, which contains dissolved oxygen.

ECOSYSTEM DYNAMICS

Cycles

The ecosystem changes frequently. Several of the cycles that are important and that may be affected by humans include the hydrologic cycle, the carbon cycle, the nitrogen cycle, the phosphorous cycle, and energy flow. The hydrologic cycle is the movement of water from the atmosphere to Earth and back into the atmosphere. This is discussed more fully in Chapter 3 on water in Volume II.

The carbon cycle begins with the fixation of atmospheric carbon dioxide by means of photosynthesis performed by plants and certain algae. During this process carbon dioxide and water react to form carbohydrates, and free oxygen is simultaneously released into the atmosphere. Some of the carbohydrates are stored in the plant, and the rest are utilized by the plant as a source of energy. Some of the carbon that has been fixed by the plants is then consumed by animals, who respire and release carbon dioxide. The plants and animals die, decomposing by action of microorganisms and other catalysts in the soil, and the carbon in their tissues is then oxidized to carbon dioxide and returned to the atmosphere. The carbon dioxide is recycled through the plants and the process repeats itself (Figure 1.1).

The nitrogen cycle begins when atmospheric nitrogen is fixed or changed into more complex nitrogen compounds by specialized organisms, such as certain bacteria and blue-green algae. Some fixation may occur as a result of lightning, sunlight, or chemical processes; however, the most efficient nitrogen fixation is carried out by biological mechanisms. Other bacteria, fungi, and algae may also play an important role in nitrogen fixation. Basically the atmospheric nitrogen is changed into a nitrate that is absorbed by plants, eventually combining with other elements and becoming a plant protein. The plant protein decays when the plant dies, releases nitrogen as ammonia, and through bacterial oxidizing action becomes a nitrite; with further bacterial action the protein is reduced and released as atmospheric nitrogen. The plant protein may also be eaten by animals, may be broken down into molecules called amino acids, and eventually may be synthesized into an animal protein. Through decay of the dead animal or breakdown of excreted feces and urine, this protein is changed to ammonia. The ammonia returns to the nitrite stage through bacterial action, and again through bacterial action becomes atmospheric nitrogen (see Figure 1.1). A further description of the nitrogen cycle is found in Chapter 6 on sewage in Volume II.

In the phosphorus cycle, the element moves rapidly through similar stages, becoming locked in sediment or in biological forms such as teeth or bones. The primary sources of phosphorus for agriculture are phosphate rocks and living or dead organisms (see Figure 1.1).

Food Chain

The cycle of energy flow may also be described as the food web. The food web, or food chain (Figure 1.2), implies that an organism has consumed a smaller organism

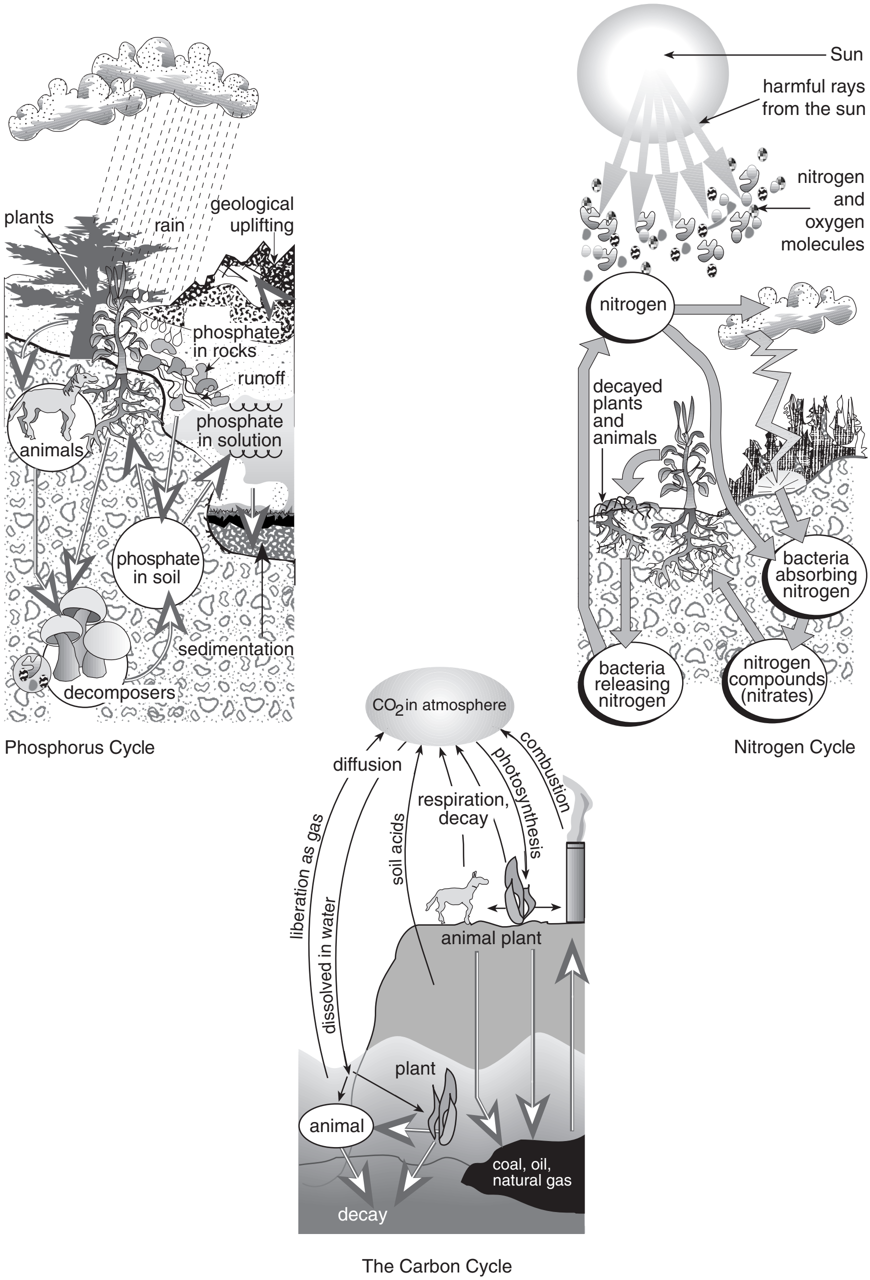

Figure 1.1 Ecosystem dynamics. (From Koren, H., *Illustrated Dictionary of Environmental Health and Occupational Safety,* CRC Press, Boca Raton, FL, 1995. With permission.)

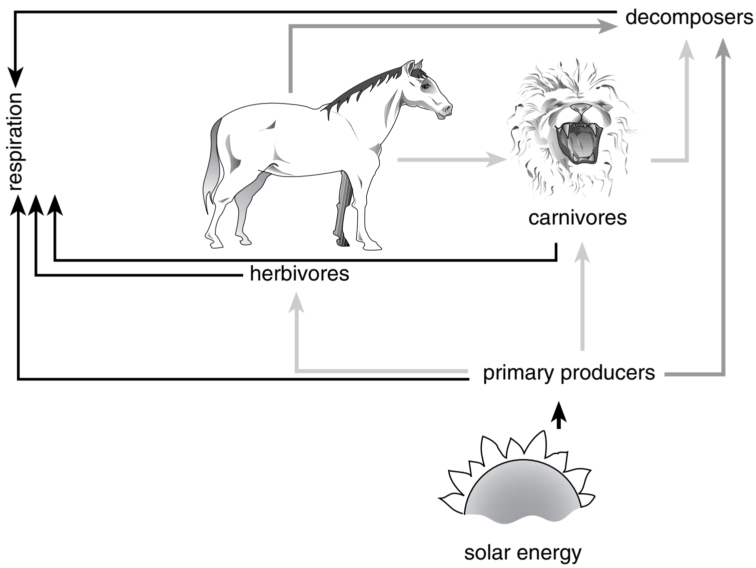

Figure 1.2 Food chain.

and is then consumed by a larger organism. Eventually, the microscopic plants and animals become the food supply for the small fish or animals that become the food supply for humans. The importance of the food chain is illustrated by biomagnification, in which the impurities found in water are concentrated in the lower forms of life and are reconcentrated substantially during the movement of the impurities through the food chain. For example, whereas people might only get 0.001 μg of mercury in drinking water, they might get 30 to 50 μg of mercury by consuming fish that have been bioconcentrating mercury.

Energy Cycles

Solar energy is absorbed by Earth and eventually reradiated into space as heat. The heat is distributed over the surface of Earth through circulation caused by the atmosphere and the oceans. Diurnal changes or changes occurring in a 24-hour period due to light, wind, temperature, and humidity are important near ground level and at high levels in the atmosphere. In certain localities land masses and sea breezes may affect the overall heat and weather patterns. However, total heat movement is not affected significantly by local conditions.

About 30% of the solar energy entering the atmosphere is deflected or scattered back toward outer space because of the atmosphere, the clouds, or Earth's surface. This portion of the solar energy is lost. About 50% of the incoming radiation reaches the ground or ocean, where it is absorbed as heat. The properties of the surface that receives the energy determine the thickness of the layer over which the available heat is distributed. In the oceans the surface wave motions effectively distribute the heat over a 300-ft layer of air. On land the energy transferred downward into the ground occurs very slowly through the process of molecular heat conduction. The penetration distance is very small. About 20% of the incoming solar radiation is absorbed as it goes through the atmosphere. In the upper atmosphere, oxygen and ozone molecules absorb an estimated 1 to 3% of the incoming radiation. This absorption occurs in the ultraviolet range and, therefore, limits the penetrating radiation to wavelengths longer than 300 nm. This absorption is very important, because it is the main source of energy for the movement of air in the upper atmosphere. This absorption also shields people on Earth from damaging effects of ultraviolet radiation. Most of the rest of the 20% is absorbed by water vapor, dust, and water droplets in the clouds. The energy that sustains all living systems is fixed in photosynthesis, as previously mentioned. Part of the energy fixed in plants and animals has been compressed over millions of years and is the source for stored energy, namely, coal, oil, and natural gas.

Current Ecosystem Problems

People and advanced technology affect the ecological niche by interfacing with the intricate function and habitat of various species of animals and plants. Discharges to air, water, and soil, including toxic and infectious chemical wastes, biological wastes, and radiological wastes create an environmental pressure that is detrimental to all life forms, including people. From the destruction of the rain forest of Brazil, because of the excessive clearing of trees, to the potential destruction of forests in the Northern Hemisphere due to acid precipitation, a huge number of ecosystems may be eliminated. Nature's diversity offers many opportunities for finding new pharmaceuticals, genetic mapping, genetic engineering, and potential power to improve crops. We are wasting our greatest natural resource on which we depend for food, oxygen, clean water, energy, building materials, clothing, medicine, sociological well-being, and countless other benefits.

Biological diversity includes two related concepts, genetic diversity and ecological diversity. Genetic diversity is the amount of genetic variability among individuals in a single species, whereas ecological diversity is the number of species in a community of organisms. An organism's ability to withstand the challenge of varying physical and chemical problems, parasites, and competition for resources is largely determined by its genetic makeup. The more successful organisms that survive pass on the genes to the next generation. An example of this would be in the case of climatic changes where plants have smaller, thicker leaves for losing less water in areas that are becoming arid. Genetic diversity is important in developing new crops to meet new conditions. This is how disease-resistant crops can be utilized to sustain life for people. Genetic variation among species is greater than within the species. It is difficult to determine which of these species are of extreme importance and will be essential to people in the future as new supplies of food, energy, industrial chemicals, and medicine. It is anticipated that the human population will increase by nearly 50% in the next 20 years, with much of this increase occurring in very poor nations. The resources needed to feed these individuals will be substantial, and many new forms of food will have to be developed to prevent starvation.

There appears to be adequate sources of fossil fuel for the immediate future. However, these fossil fuels, when burned, can potentially cause severe pollution. Eventually, fossil fuel sources will be depleted. It will then be necessary to utilize plants that can produce energy-rich materials, such as soybean oil. At present this process is very expensive.

Coastal waters contain several major natural systems. Because they directly abut the land, they are affected by activities on the land. Pollutants from coastal sewage treatment plants, industrial facilities, settling of air contaminants, and erosion of land, many hundreds of miles upstream, can cause considerable problems to the coastal waters. Oil slicks are extremely hazardous to ecosystems. Trace metals can be concentrated in the food chain and, thereby, become a hazard to people eating sea life. Toxic metals, such as mercury, lead, and cadmium, have been found in coastal waters.

Mollusks become indicators of environmental contamination and environmental quality. These shellfish, which live in the mud or sand bottoms of the aquatic ecosystems, accurately reflect some of the important characteristics of the water adjacent to the land. These organisms may show a direct adverse effect when they accumulate chemical substances or microorganisms. They are good for systematic monitoring, because they are stationary in nature (except for the early egg and larva stages) and filter large quantities of water to feed themselves. Because they are of significant commercial importance, reliable quantitative data are available on harvesting and other aspects of the mollusk life cycle.

In the past, the Environmental Protection Agency (EPA) sponsored studies of the accumulations of chlorinated organic pesticides in shellfish. Residues of the pesticide dichlorodiphenyltrichloroethane (DDT) were found for years after the use of the chemical was banned in 1972. The Mussel Watch Program has shown elevated levels of polychlorinated biphenyls (PCBs). High-level concentrations of silver, cadmium, zinc, copper, and nickel have been detected in various bodies of water. Mussels have also shown the presence of radionuclei as a result of weapon-testing programs and also from effluent that has come from nuclear reactors. Records of commercial catches of clams and oysters indicate that the number of mollusks in coastal waters has been steadily declining over the years. This may result from overfishing, loss of habitat, and deterioration due to pollution and natural disasters. It has been shown that the building of a sewage treatment plant has the potential to adversely affect shellfish habitats by altering water salinity.

The continued loss of tropical forests is the single greatest threat to the preservation of biological diversity. Many of Central America's ecosystems may be affected by these problems.

Wetlands have exceptional value because of their location at the land and water interface. They provide ecological, biological, economic, scenic, and recreational resources. Many wetlands are among the most productive ecosystems on the planet, especially estuaries and mangrove swamps. At least half of the biological production of the oceans occurs in the coastal wetlands. From 60 to 80% of the world's commercially important marine fish either spend time in the estuaries or feed on the nutrients produced there. Coastal wetlands help protect inland areas from erosion, flood, waves, and hurricanes. The wetlands are an important economic resource, because they provide cash crops, such as timber, marsh hay, wild rice, cranberries, blueberries, fish, and shellfish.

Desertification is the process that occurs in semiarid lands where sterile sandy desertlike ecosystems are created from grasslands, brushlands, and sparse open forests due to a loss of organic carbon in the form of stable humus from the soils. This desertification can be stimulated beyond natural forces by overgrazing of animals and by misuse of the area. This can lead to mass starvation and death.

ENERGY

Problems

Energy is utilized in four primary areas, residential, commercial, industrial, and transportation. Residential use is approximately 11.1 quadrillion British thermal units (Btu). Industrial use is approximately 27.1 quadrillion Btu. Transportation use is approximately 24.7 quadrillion Btu. Where energy is used to produce electricity or heating, the primary consumption of the energy is significantly higher than its end use. The distinction between the end use and primary energy consumption is important because this indicates the level of efficiency of energy use. It also indicates the amount of unnecessary carbon emissions.

Residential demand is the largest energy-consuming sector in the United States. Households are responsible for 20% of all carbon emissions of which 63% is attributed to the fuels used to generate electricity. With continued growth in the economy and population, residential use will always be a major factor in the production of contaminants resulting from electrical usage. The energy is also used to provide heating, cooling, and ventilation, which accounts for most of the direct use of fossil fuels, and as a power source for refrigerators, freezers, dishwashers, clothes washers and dryers, and stoves, as well as lighting and other items. Further, there has been a steady increase in the use of electricity because people now have more appliances and computers.

Commercial demand consists of businesses and other organizations that provide services to stores, restaurants, hospitals, hotels, schools, jails, and other structures. This sector is the smallest of the energy users. The greatest savings in energy relate to the use of insulation and improvement in the efficiency of equipment.

Industrial demand includes the agriculture, mining, construction, and manufacturing industries. This sector uses energy to produce or process goods of all types, and also produces a wide variety of basic materials such as aluminum and steel that are used to produce goods. Coal is mainly used for a boiler fuel and for production of coke in the iron and steel industry.

Transportation demand includes the use of all types of vehicles including trains and planes. About 33% of all carbon emissions and about 78% of carbon emissions from petroleum consumption come from the transportation sector. People select their vehicles based on size, horsepower, price, and personal preferences. At present carbon emissions are continuing to grow because of the selection of heavier and less efficient vehicles, and because of the increase in vehicles present on the highways. The primary energy source is oil, with all its problems related to pollution. Alternative-fuel vehicle sales are dependent on vehicle price, cost of driving per mile, vehicle range, fuel availability, and commercial availability.

HISTORY

Energy problems were brought to the attention of the American public and the world in 1973 as a result of the Arab oil embargo and the actions of the Organization of Petroleum Exporting Countries (OPEC). Unfortunately, in the years preceding these dramatic events, the United States was buying an increasing amount of petroleum abroad and utilizing more natural gas than was readily available. As a result of these shortages, President Richard M. Nixon authorized the allocation of scarce fuels. By May 1973, the Office of Emergency Preparedness was reporting widespread problems of gasoline stations closing due to lack of fuel. Voluntary guidelines were announced and a variety of emergency actions taken including the lowering of the speed limit to 55 mi/hr. Project Independence was conceived with the goal of self-sufficiency in energy production by 1980. Congress established the Federal Energy Administration in December 1973, and the President created the Federal Energy Office to deal with the immediate crisis. Funding was provided for additional research and development in a variety of energy areas.

Unfortunately, by 1978 the amount of fuel being purchased abroad continued to escalate. The variety of programs at the federal level were so confusing, complex, and spread out over a variety of agencies that the administration in Washington, D.C. requested the establishment of a new federal Department of Energy with an administrator of cabinet rank. It was hoped that the new department would bring organization to the chaotic mass of confusing energy problems and move the country toward self-sufficiency.

Conservation

Conservation and development of new energy sources or expansion of existing sources were two major phases of energy programs. Energy conservation was of critical importance to the United States; yet despite predictions of severe shortages, conservation attempts had not been entirely successful and great amounts of energy were still wasted. Greater energy efficiency was needed in cars and in electrical and gas equipment. Better insulated homes and a general reduction in energy usage was essential. The United States had to become less dependent on oil and gas as sources of energy.

Oil and Gas

Oil and gas in 1972 accounted for nearly 78% of U.S. energy consumption. By 1980, oil and gas remained the greatest sources of energy used, despite the fact that the United States had about a 300-year supply of coal available. Although in 1979, Alaska was providing new oil, the country was more dependent than ever on foreign oil. However, it was understood that no matter how many sources of oil and gas were developed, eventually the supplies would be depleted; therefore, it was necessary to examine other kinds of energy sources. These sources included oil shale, nuclear energy, geothermal energy, solar energy, fusion energy, and coal. Oil shale was available, but at rather high costs. Additional research was necessary to determine how best to extract the oil from the shale both economically and without creating surface environmental problems.

Nuclear

Nuclear power could certainly provide a continuing source of available energy to the country. However, many permits had been delayed because of consumer groups concerned with the possibility of nuclear accidents and with the disposal of the radioactive wastes. The threat of terrorist groups obtaining wastes from the fusion process and utilizing these materials to terrorize the world was also of great concern. In 1973, the U.S. nuclear electrical generating capacity was 20,000 MW, or over 5% of the nation's total electrical capacity.

Geothermal

Geothermal energy, produced by tapping Earth's heat, was being used at the geyser sites in Oregon and California, where the Pacific Gas and Electric Company employed geothermal steam as a power source for a 400-MW electrical generating facility. Geothermal resources included dry steam, hot steam, and hot water. At that time, because of cost factors, only dry geothermal heat was used to drive electric turbines.

Solar

Solar energy was both economically and technologically feasible. The benefits of capturing the sun's energy had been long recognized. Funding for solar energy research had increased and considerable research was needed. The 1979 federal budget included $137 million for solar research and development. Techniques under investigation included direct thermal applications, solar electric applications, and fuels from biomass. Direct thermal application consisted of solar heating for cooling of buildings and hot water supply, and the use of solar heat for agriculture and industrial processes. Agricultural applications were the drying of food, crop drying, lumber drying, heating and cooling of greenhouses, and heating of animal shelters. The solar electrical applications included research on the generation of electricity from windmills, solar cells (photovoltaic), solar thermal electric systems, and ocean thermal energy conversion. Theoretically, these systems were well understood; however, their applications were not yet economically feasible. The fuels produced from biomass suggested large-scale use of organic materials, such as animal manure, field crops, crop waste, forest crops and waste, and marine plants and animals. The conversion process was technically feasible. During World War II, much of the liquid fuel of France consisted of methanol produced from wood. Processes requiring study included fermentation to produce methane and alcohol, chemical processes to produce methanol, and pyrolysis to convert organic waste material to low Btu gaseous fuels and oils.

Coal

Coal was the one major source of energy that could certainly be utilized to reduce U.S. reliance on other nations. The most serious deterrent was the many contaminants, particularly sulfur, found in coal. Sulfur could be removed by utilizing new technologies in coal mining and conversion. Because coal made up 85% of the U.S. fossil energy resource base, it was wise to utilize it as well and as quickly as possible. New coal technology under development promised two very important changes in the potential pollution areas: the reduction of sulfur oxide in particulate matter from direct burning of coal, and the provision of liquid and gaseous fuel substitutes for domestic oil and gas production. The emphasis in research had shifted from conventional combustion to direct fuel to fuel conversion, that is, coal gasification and coal liquefication. Sulfur could be extracted even when coal was directly burned using fluidized beds in which crushed coal was injected into the boiler near its base. Coal was fluidized by blowing air uniformly through a grid plate. Sulfur dioxide was then removed by injecting the crushed coal with limestone particles less than ⅛ in. in diameter. The limestone particles were noncombustible and would bind the sulfur dioxide. This system also reduced the nitrogen oxides below emission standards for utility boilers of 0.7 lb of nitrogen dioxide per million Btu. The nitrogen dioxide could actually be reduced to 0.2 to 0.3 lb per million Btu. The gasification process involved the reaction of coal with air, oxygen, steam, or a mixture of these that yielded a combustion product containing carbon monoxide, hydrogen, methane, nitrogen, and little or no sulfur. The energy of the product ranged from 125 to 175 Btu per standard cubic foot for a low Btu gasification process to about 900 to 1000 Btu per standard cubic foot for a high Btu gasification process. The high Btu gasification process was comparable with the energy content of natural gas. The liquefication transformed the coal into a liquid hydrocarbon fuel and simultaneously removed most of the ash and sulfur. Hydrogen was frequently added in many of the direct catalytic liquefication techniques.

ENERGY DILEMMA

1980s

The trauma of the 1970s led to a more active role by government in the 1980s to try to resolve energy problems in the country. The Energy Security Act and the Crude Oil Windfall Act of 1980 gave the President additional power to encourage the development of oil and gas reserves and a synthetic fuels industry. Because coal was the greatest fuel resource, there was an attempt to substitute coal for oil in various industries. Energy was used more efficiently because of a variety of conservation programs. The federal conservation and solar programs were passed by Congress, and additional funds were allotted for weatherization assistance for low-income people and tax breaks for others who made their homes more efficient. Funds were provided by the Solar Energy and Conservation Bank to finance the use of solar energy systems. Solar wind and geothermal tax credits were made available for residential users. Funds were provided for research and development in the use of energy sources other than fossil fuels. The biomass program and the alcohol tax credits provided $1.6 billion through 1990 to promote the conversion of grain, farm residues, and other biomasses to alcohol fuels. Through 1990, $16.5 billion were allotted to improve transportation efficiency by enhancing public transportation programs. A fuel economy program was put in place and funds were provided for enforcement of the 55 mi/hr speed limit.

Auto efficiency standards were raised from 20 mi/gal for the 1980 model year vehicle to 27.5 mi/gal by 1985. A gas guzzler tax was added to new vehicles with mileage below 15 mi/gal. A building energy conservation code and an appliance efficiency standard code was established to improve fuel conservation and efficiency. As a result of all this effort, the growth of energy usage slowed substantially from the previous years.

By 1984, the national energy picture had continued to brighten substantially. Prices of gasoline had dropped and the price of crude oil had dropped significantly. This progress was due in part to the decontrol of the domestic petroleum markets and the removal of restrictions on energy use. Potential new sources of energy were under development in the oceans abutting the United States. This area is larger than the country's land mass and includes many of the deep water areas, as well as the outer continental shelf. Further, the OPEC nations were in disarray because of the long war between Iran and Iraq, and the propensity for cheating on the amount of oil that each country was permitted to produce to maintain their high income. Continued conservation of energy because of the many permanent changes made in energy use over the years helped keep the price of oil at lower levels.

In 1984, 1608 geothermal leases were in effect, in which 30 were capable of production and 12 actually were in production.

There was an estimated 2 trillion barrels of shale oil in the Green River formation in northwestern Colorado, northwestern Utah, and southwestern Wyoming. Of this amount, it was estimated that 731 billion bbl of oil could be extracted commercially. It was also estimated that in Utah, approximately 2 billion bbl of oil were recoverable with current technology. Approximately 100 to 200 million bbl could be recovered by surface mining. The question was not the availability of these energy resources, but the cost of developing them.

Since the Three Mile Island debacle of March 1979, numerous public protests occurred about the building and use of nuclear power as a source of energy. A need still exists for facilities for the permanent disposal of the high radioactive waste that is generated during the production of electricity in the nuclear power plants. Until very recently it was assumed that the nuclear waste was to be handled appropriately on-site. However, it has been disclosed that numerous leaks of nuclear waste from nuclear power plants have occurred over the decades. For example, serious problems in Ohio must be corrected to prevent disease. In 1990, the cleanup of these sites were estimated to cost $31.4 billion.

1990s

In 1988, the United States consumed more energy than in any previous year in its history. The demand for petroleum was about 17 million bbl/day, which was the highest point since 1980. However, the strong underlying energy efficiency trend continued, except for the use of energy in the transportation sector. In 1991, energy usage was 81.5 quad. A quad is equivalent to 1 quadrillion Btu. The U.S. domestic oil production, which was on the rise in the 1980s, started to decline again. The running aground of the *Exxon Valdez* in Prince William Sound, Alaska, caused an ecological debacle temporarily cutting the amount of oil coming from Alaska down to 20% of its normal flow. Although oil flow recovered and prices declined, one wonders about future catastrophes and their effect.

Because of lower oil prices during 1989, U.S. exploration decreased sharply. In 1989, there were only 740 drilling rigs, whereas in 1981 there were 4500 functioning drilling rigs. A need exists for a long lead time simply to get ready for further exploration for oil in the United States. Environmental and conservation groups attempted to limit further oil exploration in Alaska because of the incident that occurred in March 1989.

On August 2, 1990, Iraq invaded Kuwait. By the end of February 1991, Iraq had set on fire or damaged 749 oil facilities in Kuwait. The restoration of oil production from Kuwait was a long, complicated, and expensive process.

The demand for natural gas is expanding. This means gas production in excess of 20 trillion ft^3/year. Electricity, despite increased efficiency in usage, is projected to rise. Because no newly ordered nuclear power plants were on-line by the year 2000, fossil-fuel plants must continue to provide most of the generating capacity.

Despite the hope of the early 1970s, nuclear power has never achieved anywhere near the amount of electrical output that had been anticipated. This is in part due to the concern of citizens and a variety of lawsuits, and in a large part due to the Three Mile Island incident in 1979. The shoddy construction and need to obtain multiple permits, such as in Indiana, have further aggravated the situation. The U.S. Nuclear Regulatory Commission (NRC) has listed a series of unresolved safety issues. These include systems interactions, seismic design criteria, emergency containment, containment performance, station blackout, shutdown decay, heat-removal requirements, seismic qualification of equipment in operating plants, safety implications of control systems, hydrogen control measures and effects of hydrogen burns on safety equipment, high-level waste management, low-level waste management, and uranium recovery and mill tailings.

With the increasing problems related to oil and gas, as well as nuclear power, electric utilities and others increasingly have turned to coal and natural gas as sources of fuel and power. This occurs at a time when acid precipitation, in the form of acidic rain and snow, continues to be an issue. The damage caused by acid rain is increasing, as well as pressure from Canada to do something about it. Although new energy technologies related to coal, as well as other sources, have been put pretty much on a holding pattern, it seems that it may now be necessary to explore these further and to utilize other means of securing energy.

Although it is true that the Clean Air Act of 1990 put numerous additional constraints on the use of coal as a source of energy, at some time in the future it may be economically feasible to clean up the coal and use this abundant energy resource.

Current Concerns of Fossil Fuel

Oil

The World Resources Institute states that the world has already consumed between one-third and a little less than one-half of its ultimately recoverable oil reserves. Global production of oil is expected to start declining between 2007 and 2014. The economic impacts will depend largely on the price and availability of energy alternatives. The transportation sector, including motor vehicles, airplanes, and trains, will be most affected. Unfortunately, people in those sectors are not taking this information seriously. Oil demand will increase each year as the Third World countries start to recover from the economic neglect in which they have been involved for many years. By the 1970s, the average productivity of domestic wells began to decline, and domestic oil production leveled. Alaskan production at the end of the 1970s and through 1988 partially offset the declines in the lower 48 states. In 1989, Alaskan production declined. In 1995, the United States produced 6.5 million bbl/day with 79% of the total coming from onshore wells and 21% coming from offshore wells. By 1994, petroleum imports reached a 17-year high of 45% returning almost to the peak level of 47% in 1977. Domestic oil production will continue to decline increasingly, causing the country to import foreign oil.

Coal

In 1995, an estimated 1 trillion tons of coal were produced in the United States with approximately 47% coming from the West. Surface mining helped produce low-sulfur coal but also increased the potential for further contamination of the immediate environment. Coal production is expected to increase, with Western production growing to 50% of the total. Coal, the second leading source of carbon emissions behind petroleum products, is expected to produce 676 million tons of carbon emissions in 2020, or 34% of the total. Most of the increases in coal emissions result from electricity generation.

Gas

From 1990 through 1998, natural gas consumption in the United States increased by 14%. The greater use of natural gas as an industrial and electricity generating fuel is in part due to its clean-burning qualities in comparison with other fossil fuels. There has also been lower cost due to greater competition and deregulation in the gas industry as well as an expanding transmission and distribution network. However, based on current economic realities, these costs may vary widely.

Natural gas, when burned, emits less greenhouse gases and criteria pollutants per unit of energy produced than other fossil fuels because gas is more easily and fully combustible. The amount of carbon dioxide produced for an equivalent amount of heat is less for gas than oil or coal. However, because the major constituent of natural gas is methane, it also directly contributes to the greenhouse effect through venting or leaking of natural gas into the atmosphere.

Methane gas is 21 times as effective as carbon dioxide in trapping heat. Although methane emissions amount to only 0.5% of U.S. emissions of carbon dioxide, they cause about 10% of the greenhouse effect in the country. Natural gas consumption has increased considerably worldwide. Domestic natural gas production is expected to increase an average of 2% for the coming years.

Projected Increase in Carbon Emissions

The use of fossil fuels in the future will increase and along with it more carbon will be emitted. These emissions are projected to increase by an average of 1.3% a year to the year 2020, when they will be approximately 1.956 trillion tons. Increasing concentrations of carbon dioxide, methane, nitrous oxide, and other greenhouse gases may increase Earth's temperature and affect the climate.

Kyoto Protocol

From December 1 to 11, 1997, representatives from more than 160 countries met in Kyoto, Japan, to negotiate binding limits for greenhouse gas emissions for developed countries. The Kyoto Protocol sets emission targets for these countries relative to their emissions in 1990 to achieve an overall reduction of about 5.2% from current levels. These countries are known as Annex I countries. The reduction target is 7% for the United States and 6% for Canada and Japan, with European Union countries targeted at 8%. Non-Annex I countries have no targets under this protocol.

The greenhouse gases covered by the protocol are carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride. Sources of emissions include energy combustion, fugitive emissions from fuels, industrial processes, solvents, agriculture, and waste management and disposal. The targets were to be achieved on average between 2008 to 2012. However, in 2001, President George W. Bush decided to remove the country from this agreement and to review the entire process further.

Cogeneration Systems

To meet the Kyoto Protocol, it will be necessary to change the way we produce electricity to make it more efficient. Currently we use more than 21 quadrillion Btu of energy from the combustion of coal, natural gas, and oil to produce the equivalent of only 7 quadrillion Btu of electricity available at the plant gate. Of the energy, 67% is lost as waste heat, which accounts for 346 million tons or about 24% of U.S. carbon emissions. Cogeneration systems simultaneously produce heat in the form of hot air or steam, and power in the form of electricity by a single thermodynamic process, usually using steam boilers or gas turbines; therefore, reductions of energy losses occur when process steam and electricity are produced separately. Advanced turbine systems will be needed to accomplish this.

Wood as an Energy Source

Wood has declined in use as a primary heating fuel in the residential area. However, as a secondary source of heating, it has increased. About 20% of households in the United States use woodstoves or fireplaces.

Nuclear Energy

Approximately 20% of the nation's electricity is generated by 109 operating nuclear reactors in 32 states. Nuclear power is used by 6 states for more than 50% of their electricity and by 13 additional states for 25 to 50% of their electricity. Nuclear power continues to be an important source of electricity worldwide, although its future is uncertain in some parts of the world. Nuclear power is used by 30 countries to produce almost 25% of their combined electricity generation. Worldwide new nuclear plants are being planned. However, in the United States there has been a campaign to shut down nuclear power plants where possible. Nuclear power is a good solution to the energy problem providing that it is engineered to avoid nuclear mishaps and will not contaminate the environment. The personnel need to be well-trained in the operation of the facility and must not attempt to take shortcuts, as was done in 1999 in Japan where people were subjected to radiation because of poor training and incompetence on the part of the personnel.

Renewable Energy

Renewable energy includes biomass, geothermal, hydrothermal, photovoltaics, solar thermal, and wind. Hydrogen is considered to be a viable sustainable energy carrier for transportation. At present approximately 7% of total energy used in the United States comes from renewable energy technologies. Facilitating technologies including energy storage, electricity transmission and distribution, and power electronics are essential to reduce the cost of these new technologies and to make them available for use in place of fossil fuels.

Biomass

Biomass is nature's storehouse of solar energy and chemical resources. Plant matter is a massive quantity of renewable energy, whether raised for that purpose or grown wild. Carbon dioxide from the atmosphere and water from Earth are combined in the photosynthetic process to produce carbohydrates that are the building blocks of biomass. The solar energy is stored in the chemical bonds of the structure and when burned efficiently the oxygen from the atmosphere combines with the carbon in the plants to produce carbon dioxide and water. This makes biomass a renewable resource for energy. Biomass production worldwide is about eight times the total annual world consumption of energy from all sources. Biomass residues have long been burned by forest industries and other industries to generate process steam electricity. Because biomass is stored solar energy, it can be used as needed to provide power when other renewable sources such as solar energy may not be available. Roughly 8000 MW of electricity capacity is currently available in the United States vs. <200 MW in 1979. Biofuels primarily from forest, agriculture, or municipal solid waste residues provide about 3.5% of U.S. primary energy. Because the physical and chemical composition of biomass feed stocks varies widely, there may be a need for some special handling or conversion technologies for specific biofuels. To generate electricity biofuels can be cofired with coal in conventional coal plants, burned in steam plants, gasified to power gas turbines, and used for fuel cells. Almost all biomass electric plants use steam turbines that are generally of a small scale, 30 MW. Biomass gasifies at lower temperatures and works more quickly than coal, reducing the gasification costs. After the biomass is gasified, the gas products are cleaned of particulate and other contaminants before being burned in a steam-injected gas turbine, or other turbine. Biomass systems are now cost competitive in many areas where a low-cost waste feedstock is available. Burning or gasifying biomass in a power plant generates much less sulfur oxides than coal but still does produce nitrogen oxides depending on combustion chamber temperatures.

The agricultural industry could produce large quantities of trees and grasses that would protect soils, improve water quality, and be converted to electricity, heat, liquid, or gaseous fuels. This could be a new cash crop for the agricultural industry.

Geothermal

Geothermal electricity generation systems extract heat from the ground to drive turbines. Geothermal energy is stored energy inside the Earth, either remaining from the original formation of the planet or generated by the decay of radioactive isotopes inside it. Only in certain active areas such as volcanic zones or along tectonic plates, is geothermal energy sufficiently concentrated and near enough to the surface to be used economically.

Geothermal energy comes in four forms:

1. Hydrothermal fluids
2. Geopressured brines
3. Hot dry rocks
4. Magma

Hydrothermal fluids are the only commercial geothermal resource at this time. They are hot water or steam in porous or fractured rock at depths of up to 4.5 km, and with temperatures ranging from 90 to 360°C. Geopressured brines are hot salty waters containing dissolved methane that are about 3 to 6 km below the Earth's surface. They are trapped under sediment layers at high pressures. Hot dry rock are regions where there is little or no water but considerable heat. Additional research is needed to turn this into a cost-effective technology. Magma is molten rock with temperatures of about 700 to 1200°C typically occurring at depths of 6 to 10 km.

Although magma energy is the largest supply of all geothermal resources, it is the most difficult to extract. Considerable research is needed to make this into an effective energy source. Geothermal energy is listed as a renewable resource, but it can be depleted if too much is withdrawn. This occurs when there is a more rapid removal of underground water and vapor resources than that which is replaced naturally.

Technologies used with geothermal resources for producing electricity include direct steam, single-flash, double-flash, and binary systems. The simplest technology is the piping of hydrothermal steam directly from underground reservoirs to drive turbines. These may be found in Yellowstone National Park. Single-flash units are similar to the steam units but use underground hot water instead. As it is pumped to the surface from the deep underground the pressures are reduced and steam is partially produced in a flash tank. A double-flash system uses a second flash tank that operates at pressures between the pressure of the first flash tank and air pressure. Binary systems pump hot water to the surface and then use a heat exchanger to transfer the heat to a working fluid. This fluid is vaporized by the heat and then drives the turbine. The environmental impact of geothermal power varies with the resource and the technology used. Direct steam and flash systems generally release gases to the atmosphere such as hydrogen sulfide. Small quantities of brines may also be released. Binary systems generally reinject all gases and brines into the reservoir.

There are about 170 geothermal power stations in 21 countries that produce about 5700 MW of electricity, The United States has the largest installed capacity.

Hydroelectricity

Hydroelectric generation systems use the energy in flowing water to turn a turbine. Currently, hydropower provides about 20% of the world's electricity supplies. In its conventional form with dam storage, hydropower can provide base, intermediate, or peak power. It is especially valuable in backing up intermittent power from solar and wind sources. U.S. hydropower resources are fairly well developed. More power, however, could potentially be obtained from existing facilities by upgrading equipment and installing equipment at dams that are not now used for power. Turbine efficiencies are typically in the 75 to 85% range, making hydroelectric power a fairly mature industry. Although hydroelectric power is reliable and cost-effective once constructed, and does not release carbon dioxide, a number of environmental concerns exist. These include inundating wildlife habitat; changing aquatic ecosystems; and changing water quality, especially temperature, dissolved oxygen and nitrogen, and sediment levels.

Photovoltaics

Photovoltaics, or solar cells, convert sunlight directly into electricity. Unlike wind turbines or solar thermal systems, photovoltaics have no moving parts. Instead they use solid-state electronics. Over the past three decades photovoltaic efficiencies and reliability have increased significantly.

A photovoltaic cell is made by depositing layers of various materials so as to create an intrinsic and permanent electric field inside. When light strikes the material, it can free an electron from weak bonds that bind it. Once freed, the electric field pushes the electron out of the photovoltaic cell and sends it through an external wire to become a source of power before returning to the cell completing the circuit. The higher the efficiency of the cell, the higher the cost is. A number of technologies are in use including thin-film plates, single crystal and polycrystalline flat plates, and concentrator systems (which are most costly). Thin film uses little material approximately 1/100 the size of a human hair on a low-cost substrate such as glass, metal, or plastic. Although a variety of toxic chemicals are used in the manufacture of the photovoltaic cells, the emission of these chemicals is minimal.

Solar Thermal

Solar thermal electric plants use mirrors to concentrate sunlight on a receiver holding a fluid or gas, thereby heating it and causing it to turn a turbine or to push a piston connected to an electrical generator. Solar thermal systems are typically categorized by the type of collector used such as the parabolic trough, central receiver, parabolic dish, and solar pond. Parabolic troughs systems account for more than 90% of the world solar electric capacity. The systems have long, 100 meters or more, trough-shaped mirrors with the tube at the focal line along the center. The trough tracks the sun's position in the sky. There is a clear glass with a black metal pipe carrying heat-absorbing fluid down the middle. To minimize heat loss from the black absorbing pipe back to the outside, it is covered by special coatings to reduce the amount of heat it radiates. Central receivers have a large field of mirrors known as heliostats, surrounding a fixed receiver mounted on a tower. Each of the heliostats independently tracks the sun and focuses the flight on the receiver where it heats a fluid or gas. The fluid or gas expands through a turbine. A parabolic dish uses a large dish or set of mirrors on a single frame with two-axis tracking to reflect sunlight on to the receiver mounted at the focus (Figure 1.3).

The solar resource varies by the hour, day, season, geography; and with the local climate. Sunlight at Earth's surface has two parts, direct or beam radiation coming directly from the sun and diffuse radiation that has been first scattered randomly by the atmosphere before reaching the ground. Together they are total or global radiation. Direct radiation is more sensitive to atmosphere conditions than diffuse radiation is. Heavy urban smog can reduce direct radiation by 40% and total radiation by only 20%.

Wind

Wind energy systems use the wind to turn their blades, which are connected to an electrical generator. Wind systems provide intermittent power based on the availability of the wind. Small wind systems are often backed up with battery storage. Large wind turbines can be either on an individual site or more commonly in "wind

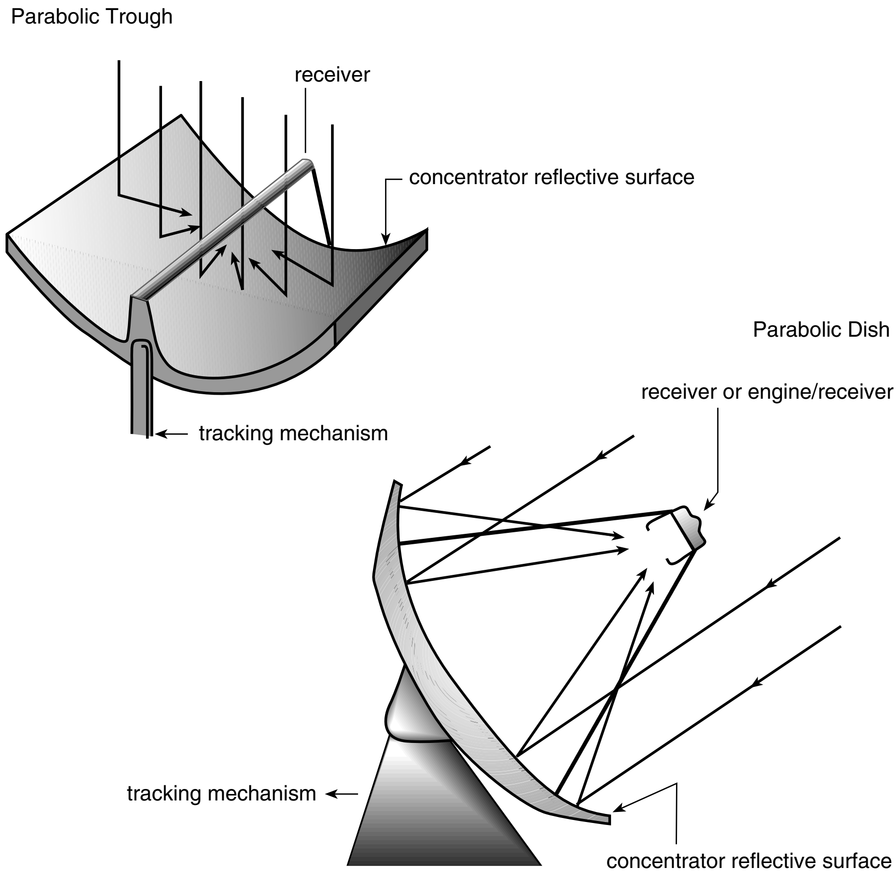

Figure 1.3 Solar thermal collectors. (From *Renewing Our Energy Resources*, Office of Technology Assessment, publication OTA-ETI-614, 1995.)

farms," and are connected to the electricity grid. Three key factors in wind energy are the power of the wind and its speed, the variation in available wind speeds at any given site over various time periods ranging from minutes to seasons, and the variations in wind speed with different elevations above the ground. The power available in the wind increases with the cube of the wind speed. Wind turbines must handle a large range of power. This includes the speed at which the turbine reaches its maximum power to the speed at which the turbine is stopped to prevent damage. This has led to a variety of techniques for efficiently collecting power at low speeds and for limiting and shedding excess wind power from the turbine blades at high speeds. Because of the sensitivity of wind power to wind speed, it is necessary to carefully choose a wind site. A 10% difference in wind speeds gives a 30% difference in available wind power. Wind speeds can vary dramatically over the course of seconds or minutes due to turbulence, hours due to diurnal variation, days due to weather fronts, and months due to seasonal variations. The best locations are where there are strong sustainable winds with little turbulence. The variation of winds with distance above ground level is due to wind shear. Typically, winds at 50 meters are about 25% faster and have twice as much power as winds at 10 meters above the ground. Wind shear places great stress on turbine blades.

There are two primary forms of wind turbines, the propeller style horizontal axis wind turbine and the less common vertical axis wind turbine. Turbine blades must manage the very high levels of stress while efficiently collecting energy over long periods of time and at a low cost. Large, modern wind turbines have become very quiet. At distances greater than 200 meters the swishing sound of the rotor blades is usually masked completely by wind noise in the leaves of trees or shrubs. Mechanical noise has virtually disappeared because of better engineering to avoid vibrations.

The United States produces more electricity from wind power than any other country in the world. The largest group of installations are located in three large wind development regions in California. New wind development programs are being tried in the Great Plains states because their wind capacity is several times greater than in California. Iowa and Minnesota are examples of this. Either in place of large wind farms or along with them organization of small clusters of wind developments is underway.

In Denmark, commercial-sized offshore wind turbine parks are becoming a reality. From 2000 to 2007, 750 MW of power will be built, with an additional 3300 MW planned to go on-line by the year 2030. Larger wind turbines, cheaper foundations, and new research on offshore wind conditions are increasing the confidence of the power companies, the Danish government, and the turbine manufacturers. There are increased wind speeds over the water.

Energy Used for Transportation

In the 1970s, the renewable fuel considered for transport in the United States was ethanol that came from corn. Converting corn to ethanol is expensive because of all the energy inputs needed to grow the corn and convert it to ethanol. Today, advances in biotechnology are allowing scientists to convert cellulose to sugars that can be fermented to ethanol by using cheaper feedstocks such as wood, grass, and corn stalks. Advances in gasification and catalysts are also lowering the cost of producing methanol and hydrogen from biomass.

The U.S. transportation system is essential to maintaining the economy of the country with highway transportation as a major factor. Highway transportation is dependent on internal combustion engine vehicles using almost exclusively petroleum. The United States consumes more than one third of the world's transport energy. Transportation uses about one fourth of total U.S. primary energy and nearly two thirds of the oil. The oil burning exacerbates local and global environmental problems. Motor vehicles account for 30 to 65% of all urban air pollution in the country and up to 30% of carbon dioxide emissions.

Methanol

Methanol is a liquid fuel that can be produced from natural gas, coal, or biomass. The major advantage to methanol is that it would require fewer changes in vehicle design. Flexible-fuel vehicles would be able to operate on methanol, ethanol, gasoline, or mixtures of these fuels. These types of vehicles would help in the transition from gasoline as a primary transportation fuel.

Ethanol

Ethanol, like methanol, is a liquid fuel that can be used in internal combustion engines. It can be produced from biomass. About one third of Brazil's automobile fleet runs on ethanol-produced sugars. The engines only require a minor modification to make this work. Ethanol and methanol produce less ozone and are less carcinogenic than gasoline, but ethanol produces formaldehyde and methanol produces acetaldehyde.

Hydrogen

Hydrogen is an extremely clean fuel that can be burned or electrochemically converted to generate electricity in fuel cells. Hydrogen can be produced from a variety of sources including:

1. Gas or coal
2. Biomass or municipal waste gasification
3. Direct photochemical conversion
4. Direct photobiological conversion
5. Thermal decomposition
6. Electrolysis of water

Producing hydrogen from gas or coal creates additional carbon dioxide and therefore is not considered to be the best process. Although there is an abundance of coal in the United States, new processes would have to be developed to make the new transportation fuel environmentally safe.

Biomass or municipal waste gasification is a direct method of producing hydrogen by extracting the hydrogen from fast growing grasses or trees. Biomass gasification relies on the technology that has been developed for other applications and therefore is one of the most advanced direct approaches to hydrogen production. It is the least expensive of the new methods of direct hydrogen production from renewable sources.

In direct photochemical conversion, sunlight strikes an electrolytic solution in which photosensitive semiconductors and catalysts are suspended. The solar energy is absorbed by the catalysts creating localized electrical fields that cause the electrolytic splitting of water into hydrogen and oxygen.

In direct photobiological conversion, various bacteria and algae have been isolated that produce hydrogen either from organic materials through digestion or directly from water and sunlight through photosynthesis. Both methods use entirely renewable resources including sunlight, biomass, and biological organisms to produce hydrogen.

In thermal decomposition concentrated solar thermal energy can achieve temperatures exceeding 5000°F. At these temperatures water thermally decomposes into hydrogen and oxygen. The problem facing engineers today is to capture the gases separately before they spontaneously recombine.

In electrolysis of water, an electrical current passes through electrodes immersed in an electrolytic solution divided into two chambers by a semipermeable membrane. The electrical energy splits the water molecule into hydrogen and oxygen gases, which are released and collected at the electrodes. The energy efficiency of electrolysis generally exceeds 80%. The problem is that unlike other renewable sources it takes electricity produced by other sources to carry out the process.

Transportation and storage of hydrogen gas is a key issue. A hydrogen infrastructure would have to be developed with safe storage and transportation of the fuel. In addition, there would be a need for a large onboard storage tank if the fuel was used directly in the engine. However, the fuel can be converted into electricity and the vehicle can be powered by a battery. A pipeline is the easiest form of hydrogen transmission, although the gas can be compressed or liquefied and transported in tankers as well. Advanced high-pressure tanks capable of containing pressures up to 10,000 lb/in.^{2} have been used in the space program. Most hydrogen is now stored at pressures up 3600 lb/in.^{2} which is common for natural gas and other compressed industrial gas storage systems. Hydrogen can be stored more easily than electricity until needed.

From the pure form of hydrogen, energy is released by burning or converted without combustion to electricity in fuel cells. A fuel cell is an electrochemical device without moving parts. This device uses catalysts, electrodes, semipermeable membranes, and electrolytic substances to control the combination of hydrogen and oxygen to produce energy and form water as a by-product. The energy released by the chemical reaction is captured electrochemically as electricity. Currently, there is a 50% efficiency rating. With emerging fuel cell technologies it is hoped that efficiency will rise beyond 60%.

In October 1996, the Hydrogen Future Act became law. The act mandates that government-sponsored hydrogen research, development, and demonstration project expenditures of over $100 million be conducted during the next 5 years in the United States. In addition, more than $20 million a year is available through the National Fuel Cells in Transportation Program. The Mercedes Corporation believes that fuel cells is the technology most likely to replace internal combustion engines in automobiles. Toyota Corporation, Chrysler Corporation, Daimler Benz, and other corporations are currently experimenting with fuel cell automobiles,

HEALTH IMPLICATIONS OF NEW ENERGY TECHNOLOGIES

Coal, which is our most abundant fossil fuel, presents a potential threat to human health and the environment. Coal miners excessively exposed to coal dust may suffer from lung diseases known as pneumoconioses, including black lung disease, silicosis, and emphysema. The fossil fuel by-products include two major groupings: coal tar, which comes from the combustion or distillation of coal, and polycyclic aromatic hydrocarbons. Polycyclic aromatic hydrocarbons (PAHs) are potential carcinogens found in mixtures within fossil fuels and their by-products. Coal tar products can cause skin and lung cancer through the cutaneous and respiratory routes, respectively.

Human exposure to complex mixtures of PAHs has been extensive, and carcinogenic effects following long-term exposure to them have been documented. Coke oven emissions and related substances, such as coal tar, have long been associated with excess disease. The first observation of occupational cancer, that is, scrotal cancer among London chimney sweeps, was made by Percival Pott in 1775. More recently, lung and genitourinary cancer mortality have been associated with coke oven emissions. Human tumorigenicity also has been associated with the exposure to creosote. Creosote is a generic term that refers to wood preservatives derived from coal tar creosote or coal tar oil, and includes extremely complex mixtures of liquid and solid aromatic hydrocarbons.

Bituminous coal is the starting point for coal liquefication and coal gasification. The mere process of breaking up the coal structure appears to release a large number of potentially carcinogenic compounds. Some of these compounds include the PAHs benz(*a*)anthracene, chrysene, and benzopyrene. In the coal gasification process, where coal is exposed to molecular oxygen and steam at temperatures of 900°C or higher, much of the hydrocarbon structure is destroyed; therefore, the levels of carcinogenic compounds can be greatly reduced. However, at these temperatures the hazards from carbon monoxide increase, as well as the potential hazards from other toxic agents such as hydrogen sulfide and other carbon–nitrogen products that may be released to the environment.

Coal liquefication occurs in the temperature range of 450 to 500°C. This is the most economical temperature range to produce pumpable liquid. During the initial conversion reaction, hydrogen is added to the coal, which produces a wide range of compounds containing condensed aromatic configurations. Many of these are carcinogenic. A potential also exists for the production of other toxic compounds, including carbon monoxide.

Oil shale is a generic name for the sedimentary rock that contains substantial organic materials known as kerogen. The kerogen content of oil shale may vary between 5 and 80 gal of oil per equivalent ton. The extraction of the oil from the oil shale occurs when the shale is heated to 350 to 550°C under an inert atmosphere. The products include oil vapor, hydrocarbon gases, and carbonaceous residue. Major concerns related to the retorting shale process include (1) the production of 1 ton of spent shale per barrel of oil; (2) the volume of the shale increasing by more than 50% during the crushing process and a considerable amount of alkali minerals contained in the oil shale possibly leaching into the groundwater supply; (3) the creation of a problem in areas where water is in short supply because of a large amount of water needed for controlling dust and reducing the alkalinity of spent shale.

During the processing of the oil shale, organic materials containing nitrogen, oxygen, and sulfur are produced in large quantities. Further, waste gases containing hydrocarbons, hydrogen sulfide, sulfur dioxide, and nitrogen oxides are formed.

Geothermal energy is a general term that refers to the release of the stored heat of the Earth that can be recovered through current or new technologies. The amount of contaminants found in the energy source varies dramatically from area to area.

In any case, geothermal fluids may contain arsenic, boron, selenium, lead, cadmium, and fluorides. These fluids also may contain hydrogen sulfide, mercury, ammonia, radon, carbon dioxide, and methane. Wastewater management from geothermal processes is an environmental problem if the spent liquids are put into surface water. They may contaminate the surface water and also cause an elliptical dish-shaped depression, such as occurred in New Zealand. If the liquids are injected under high pressure back into the geologic formation, they may enhance seismic activities. Another problem related to the production of geothermal energy is noise. Some noise levels reach 120 A-scale decibels (dBA). At this level, blowouts can occur and produce accidents with potential injuries. Airborne emissions and noise can affect human health. The most significant potential air emission problem is hydrogen sulfide gas. Hydrogen sulfide is a very toxic gas that produces immediate collapse with respiratory paralysis at concentrations above 1000 ppm by volume. Serious eye injuries can occur at 50 to 100 ppm by volume. Further, hydrogen sulfide has a very offensive odor (rotten eggs) that can be detected by the human nose at very low concentrations.

The photovoltaic solar cell is an efficient, direct energy-conversion device. Solar cells are used for powering most satellites. The major health hazards involved relate to the mining and the various steps needed in the production of the silicon cells. Other cells utilized include cadmium sulfide and gallium arsenide. The health hazards involved relate to the production and use of these chemicals in the occupational setting. If satellite solar power stations come on-line in the future, there will need to be an extensive research effort to determine if there will be potential biohazards due to the microwave beams being brought back to Earth from the solar space stations.

Biomass is composed of plant material and animal waste used as a source of fuel. Health hazards may be associated with the emissions from biomass combustion residuals, biomass gasification residuals, biomass liquefication, and the related air and water pollutants. The burning of biomass creates the same primary air pollutants as in the burning of coal. Unburned hydrocarbons, sulfur oxides, and high-fugitive dust levels are created. Organic acids and minerals that affect water quality may be found in boiler water treatment chemicals, in leachates from ash residues, and in biomass storage piles. Residential wood burners, because of incomplete combustion, release carbon monoxide and unburned hydrocarbons that may include photochemically reactive chemicals as well as carcinogens. Emissions from biomass gasification may originate from the process stack, waste ponds, storage tanks, equipment leaks, and storage piles. These contaminants include oxides of nitrogen, hydrogen cyanide, hydrocarbons, ammonia, carbon monoxide, and particulates. The process water and condensates also may contain phenols and trace metals. The tars produced by the thermochemical decomposition of organic substances may contain PAHs, some of which are known carcinogens. Anaerobic digestion may lead to the production of odors associated with gaseous decay products such as hydrogen sulfide and ammonia gases. The effluent contains large quantities of biochemically oxygen-demanding organic materials, organic acids, and mineral salts.

Nuclear power plants have the potential for providing abundant supplies of electricity without contributing substantial amounts of pollutants to the environment

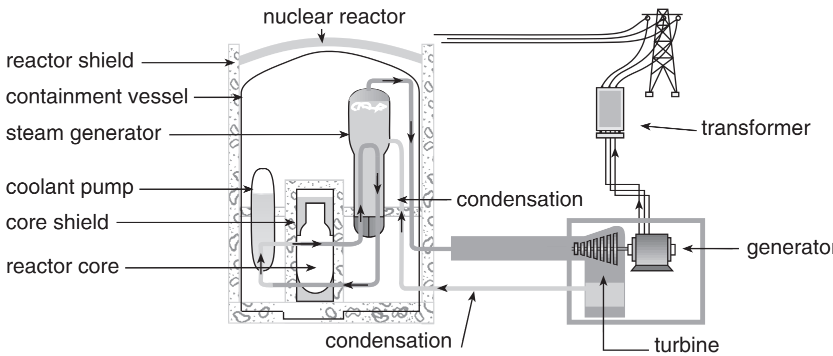

Figure 1.4 Nuclear energy site.

(Figure 1.4). The industry, however, has failed to deliver on the promise because the costs of making nuclear energy safe have spiraled out of control. The nuclear cycle starts with the mining of uranium and the resulting risk of lung cancer in miners attributable to the alpha radiation from the decay of radon-22 daughter products. Further, there are injuries associated with the mining and quarrying of uranium. During the milling of uranium ore, small airborne releases of radon and the residues or tailings still contain most of the radioactive species of the original ore and require careful disposal. Next, the uranium oxide is converted to uranium hexafluoride. This enrichment increases the percentage amount of fissionable uranium-235. Finally, fuel rods are fabricated during the processing of the uranium after it has been mined. (The potential amount of worker radiation exposure that comes from gaseous solid wastes is small.) The reactor then produces energy. Finally, after the fuel rods are spent, the irradiated rods are removed from the reactor cooler and stored for long periods of time to permit decay of the short-lived fission products before reprocessing. Radioactive water and waste must be contained.

Engineers can build reactors that are safer than those now in operation. The basic technology has been available for more than 25 years. This technology has been ignored in favor of water-cooled reactors, which have already been proved in nuclear submarines. However, these reactors are particularly susceptible to the rapid loss of coolant, which led to the accidents at Three Mile Island and Chernobyl. All nuclear reactors split large atoms into smaller pieces and thereby release heat. It is necessary to keep the core of nuclear fuel from overheating and melting into an uncontrollable mass that may breach the containment walls and release radioactive material. One way to prevent a meltdown is to make sure that the circulating coolant, which is water, will always be present in adequate quantities. To prevent mechanical failures from interrupting the transfer of heat, most reactors employ multiple backup systems. This technique is known as "defense in depth." The problem with this technique is that it can never be 100% safe against a meltdown.

The U.S. Department of Energy wanted to use a new strategy in Idaho Falls, ID. The agency wanted to build a series of four small-scale modular reactors that use fuel in such small quantities that their cores could not achieve meltdown temperatures under any circumstances. The fuel would be packed inside tiny heat-resistant ceramic spheres and cooled by inert helium gas. The whole apparatus would be buried below ground. The main problem is that the smaller units produce less electrical output and, therefore, are less economical initially. However, over time the units may become more efficient.

During the early morning hours on March 28, 1979, the most serious accident in the history of U.S. nuclear power took place. A series of highly improbable events involving both mechanical failure and human error led to the release of a considerable amount of radioactivity and the evacuation of preschool children and pregnant women within 5 mi of the Three Mile Island nuclear power plant, located near Middletown, PA. The accident occurred at Unit 2 of the complex. It was initially triggered by the failure of a valve and the subsequent shutting down of a pump supplying feed water to a steam generator. This in turn led to a "turbine trip" and a shutdown of the reactor, in itself was not the problem, because the backup systems that were used anticipate such failures. However, a pressure relief valve failed to close, which led to the loss of substantial amounts of reactor coolant, usually in quench tanks. Auxiliary feed water pumps were nonoperational because of closed valves, in violation of NRC regulations. The operator failed to respond promptly to the stuck relief valve. There were faulty readings on the control room instruments that led the operators to turn off the pumps for the emergency core cooling system. The operator shut down the cooling pumps more than an hour after the emergency began. Two days after the initial problems, a large bubble of radioactive gas, including potentially explosive hydrogen, was believed to have formed in the top of the reactor. Then President Jimmy Carter established a 12-member committee to review the accident and make recommendations. The major findings of the commission after a 6-month study concluded (1) the accident was initiated by mechanical malfunction and exacerbated by a series of human errors; (2) the accident revealed very serious shortcomings in the entire government and private sector systems used to regulate and manage nuclear power; (3) the NRC was so preoccupied with the licensing of new plants that it had not given adequate consideration to overall safety issues; (4) the training of power plant operators at Three Mile Island was extremely inadequate even though it conformed to NRC standards; (5) the utility owning Three Mile Island and the power plant failed to acquire enough information on safety to make good judgments; (6) an extremely poor level of coordination and a lack of urgency on the part of all levels of government existed after the accident occurred. The NRC had not made mandatory, state emergency or evacuation plans.

Other potential emergency situations have occurred in the past. On December 12, 1952, the accidental removal of four control rods at an experimental nuclear reactor at Chalk River, Canada, near Ottawa led to a near meltdown of the reactor uranium core. A million gallons of radioactive water accumulated inside. Fortunately, no accident-related injuries occurred. On October 7, 1957, a fire occurred in the reactor north of Liverpool, United Kingdom. Like the Chernobyl facility, the Windscale Tile 1 plutonium production plant used graphite to slow down neutrons emitted during nuclear fission. Contamination occurred on 200 square miles of countryside. Officials banned the sale of milk from the cows grazing the area for more than a month. It was estimated that at least 33 cancer deaths could be traced to the effects of the accident. On January 3, 1961, a worker's error in removing control rods from the core of an SL-1 military experimental reactor near Idaho Falls, ID, caused a fatal steam explosion, and three servicemen were killed. On March 22, 1975, a worker using a lighted candle to check for air leaks in the Brown Ferry reactor near Decatur, AL, touched off a fire that damaged electrical cables connected to the safety system. Although the reactor's coolant water dropped to dangerous levels, no radioactive material escaped into the atmosphere. On March 8, 1981, radioactive wastewater leaked for several hours from a problem-ridden nuclear power station in Tsuruga, Japan. Workers who mopped up the wastewater were exposed to radiation. The public did not become aware of the accident for 6 weeks until radioactive materials were detected. On January 4, 1986, one worker at the Kerr-McGee Corporation, a uranium processing plant in Gore, OK, died from exposure to a caustic chemical that formed when an improperly heated, overfilled container of nuclear materials burst. Some of the radiation flowed out of the plant. More than 100 people went to local hospitals.

April 26, 1986, the worst disaster in history relating to a nuclear plant occurred at Chernobyl in the former Soviet Union. A loss of water coolant seemed to trigger the accident. When the water circulation failed, the temperature in the reactor core soared over 5000°F, causing the uranium fuel to begin melting. This produced steam that reacted with the zirconium alloy of the fuel rod to produce explosive-type hydrogen gas. Apparently, a second reaction produced free hydrogen and carbon monoxide. When the hydrogen combined with the oxygen, it caused an explosion, which blew off the top of the building and ignited the graphite. Next, a dense cloud of radioactive fission products discharged into the air as a result of the burning graphite. In subsequent days, radioactive materials were found in Finland, Sweden, Norway, Denmark, Poland, Romania, and Austria. In Italy, freight cars loaded with cattle, sheep, and horses from Poland and Austria were turned back because of the concern due to abnormally high levels of radiation found in many of the animals. Britain cancelled a spring tour of the London Festival Ballet, which was to go to the former Soviet Union. In West Germany, officials insisted that children be kept out of sand boxes to avoid contamination. Slight amounts of radiation were found in Tokyo, in Canada, and in the United States. In the immediate vicinity of the reactor and up to 60 mi from the reactor, the topsoil may be contaminated for decades. The residents of Kiev, 80 mi from the disaster and the surrounding areas, were told to wash frequently and to keep their windows closed. They were warned against eating lettuce and swimming outdoors. Water trucks were used to wash down streets to wash away radioactive dust. It will be many years before an accurate determination is made about the number of people who will die as a result of this catastrophe. Approximately 100,000 people will have to be monitored for the rest of their lives for signs of cancer. In 1995, large populated areas surrounding the reactor site in the Ukraine and in nearby Belorussia remain contaminated with high levels of radioactivity. The cost of the cleanup could run as high as $358 billion.

On September 30, 1999, Japan had the worst nuclear accident in the history of its nuclear industry. Three workers were responsible for the accident when they used bucketlike containers to mix uranium. These men worked for the J. C. O. company, a private organization that ran the nuclear power plant in Tokaimura. The three workers were sent to the hospital with two of them suffering potentially lethal doses of radiation. Another 46 people were also exposed to the radiation. Apparently, J.C.O., a wholly owned subsidiary of Sumitomo Metal Mining Company, has admitted that it had for years deviated from government-approved procedures by having its own illegal manual. The company was not required to be prepared for possible atomic reactions because the uranium-processing plant was in principle not supposed to set off a reaction. The atomic reaction that occurred as the result of the accident is similar to that which happens in a nuclear reactor. Processing uranium, if done properly, does not cause an atomic reaction. By using the bucketlike containers instead of the proper equipment, the mixing could be shortened from 3 hr to 30 min. Firefighters called in to help the injured workers were never warned of a potential release of radioactivity and therefore did not have proper protective clothing. Nearly 2 hours elapsed between the accident and any notice to local residents that something had occurred.

In the United States, since 1980, each utility that owns a commercial nuclear power plant has been required to have both on-site and off-site emergency response plans as a precondition for obtaining and maintaining a license to operate the plant. The on-site emergency response plans are approved by the NRC, whereas the off-site plans are approved by the Federal Emergency Management Agency (FEMA). The NRC incident response operations has published over 500 reports on a broad range of operational experience since 1980. A congressional committee is currently investigating how to revitalize the nuclear power industry, because the energy produced does not include by-products that contribute to the amount of carbon dioxide or other contaminants released into the air.

It should be understood that the nation will have to make a myriad of difficult decisions concerning the conservation and use of fuel. Obviously the burning of carbonaceous fuels has significantly contributed to air pollution and accompanying health problems. The energy problem has affected our entire economy by the purchase of energy from abroad. An adequate program of conservation, development and use of energy sources within our own country will provide us with the needed energy and yet prevent the many potential hazards that may occur as a result of the burning of fossil fuels.

ENVIRONMENTAL PROBLEMS RELATED TO ENERGY

The major environmental problems related to energy are caused by pollutants created by fossil fuels; destruction of the natural environment by removal or spillage of fossil fuels; and effects of the continued rise in cost of fossil fuels on the economy, and therefore, on our way of life. The pollutants are detailed in Volume II, Chapter 1, on air pollution. With an increased need for fossil fuels comes an increase in the destruction of the natural environment. Improper fuel removal, fuel storage, or fuel transportation degrades the environment; destroys the aesthetic value of many of our most beautiful areas; and causes destruction of fish, wildlife, and plant life. The problems related to health, aesthetics, and economics are critical, because they are totally interrelated and therefore must be considered as a unit.

APPLICABLE CONCEPTS OF CHEMISTRY

Chemicals in general and those that contaminate the environment are classified as organic and inorganic. The fate of chemicals in environmental matrices of air, water, and soil relative to human exposure and toxicity are influenced by several fundamental properties.

Organic chemicals are based on carbon-12 ($^{12}_{6}C$) as the foundation element present in all molecules and compounds. The atoms that compose organic molecules are predominantly held together via intraatomic forces called covalent bonds. The covalent bonds involve sharing of electrons between the elements. Electronegativity is the measure of an atom attraction for orbital electrons. If the difference in electronegativity between two covalently bonded atoms is relatively low, then electrons are shared somewhat equally and the bond is considered nonpolar. When the difference in electronegativity between covalently bonded atoms is relatively high, then electrons between the bonded atoms are unequally shared and the bond is polar. Polar bonds are characterized as having a slightly positive end (pole) adjacent to the atom with lower electronegativity and a more negative end (pole) in the region adjacent to the more electronegative bonded atom.

Hydrocarbons are organic compounds composed of only carbon bonded to carbon and carbon bonded to hydrogen atoms. The covalent bonds formed between adjacent carbon atoms are nonpolar because no difference exists between electronegativity when carbon bonds to carbon, due to totally equal sharing of electrons. These bonds are called *coordinate covalent bonds*. The difference in electronegativities of carbon and hydrogen atoms is not substantial enough for a relatively positive pole and negative pole to exist. When only single carbon to carbon (C–C) bonds are present, the organic compound is classified as an alkane. Compounds containing double carbon to carbon (C=C) or triple carbon to carbon (C≡C) bonds are called alkenes and alkynes, respectively. These compounds are straight-chain aliphatics when they have distinct end groups or cyclic aliphatics when they form closed ring structures. Aromatic hydrocarbons consist of at least one or more benzene molecules, which are six-carbon ring structures with three alternating double bonds.

Functional groups are specific atoms or groups of atoms bonded to hydrocarbon structures. The presence and type of atom or group alters the chemical and physical properties of an organic molecule and, in turn, its function. According to the functional group, the organic molecules are classified as alcohols, aldehydes, acids, ketones, esters, thiols, and so forth. Examples of some common functional groups appear in Table 1.1.

Inorganic chemical compounds are not based on the element carbon as a foundation element and, accordingly, include all chemicals that are not classified as organic. Inorganic elements and, in turn, the composition of compounds include both metals and nonmetals. Some inorganic compounds, such as water, contain covalent bonds, but many compounds, such as salts, have ionic bonds. Because the ionic bonds are formed between atoms that have such a high difference in electronegativity, one or more electrons are lost by one atom and accepted or gained by an adjacent atom. As a result, the atom that loses the electron is oxidized and referred to as a *reducing agent* and the atom that gains the electrons is reduced and referred to as an *oxidizing*

Table 1.1 Examples of Some Organic Functional Groups

Hydrocarbons	R–H
Organohalides	R–X[a]
Alcohols	R–OH
Aldehydes	R–(C=O)–H
Acids	R–(C=O)–OH
Thiols	R–SH
Amines	$R–NH_2$
Amides	R–(C=O)NH
Nitro	$R–NO_2$
Ethers	R–O–R
Esters	R–O–(C=O)–R
Ketones	R–(C=O)–R
Peroxides	R–O–O–R
Nitriles	R–C≡N
Azo	R–N=N–R

Note: R represents an aliphatic or an aromatic group.

[a] Where X=Cl, Br, F, I.

agent. Thus, reducing agents lose or donate electrons which in turn causes their atomic charge to increase (oxidation) and the charge on atom that accepts or gains the electrons to decrease (reduction). Ionic bonds are polar because they form between a positively charged atom (cation) and a negatively charged atom (anion).

Biochemicals refer to compounds associated with living or once living organisms. The five kingdoms of organisms, Animalia, Plantae, Protozoa, Monera (bacteria) and Fungi, consist of biochemicals. The five major classes of large biochemicals, or biomacromolecules, are proteins (amino acid polymers), carbohydrates (simple monomeric- and oligomeric-, and complex polymeric-sugars), nucleic acids (nucleotide polymers such as deoxyribonucleic acid [DNA] and ribonucleic acid [RNA]), lipids (fats, waxes, steroids), and lignin (phenolic polymers). Only the plants contain lignin. Carbon (C), hydrogen (H), nitrogen (N), oxygen (O), phosphorus (P), and sulfur (S) account for >99% of the elements in living or once living organisms.

As implied earlier, relative to the environmental health sciences, the chemical and physical properties greatly influence the overall characteristics and fate of these molecules in the environment, when human exposure and impact are considered. Chemical properties, especially the elemental composition and arrangement in molecules and compounds, influence the likelihood that a chemical will be transformed biologically, chemically, or physically into various products and by-products. In relation, the products and by-products formed as a result of transformation reactions most commonly reflect elements present in the original matter or parent compound that underwent change. For example, natural organic matter, such as manures, biological sludges, and decaying vegetation, originated from and consists of living or once living matter. As a result, the matter contains various components including biomacromolecules that are elementally composed predominantly of combinations of C, H, N, O, P, and S in the form of polymers and oligomers. When transformation involves aerobic oxidation reactions, the ultimate products reflecting decomposition are carbon dioxide, water, nitrates, nitrites, phosphates, and sulfites and sulfates; or instead anaerobic reduction products methane, hydrogen, ammonia, and hydrogen sulfide.

Chemical and physical properties also influence transport (mobilization) and storage (immobilization) of contaminants in an environmental matrix or human system. Chemical functional groups can affect intermolecular bonding between contaminants and various structures found in soil, water, and living cells. For example, positively charged or cationic metals readily bond to and store at negatively charged oxygen atoms associated with silicon oxide structures of soil particles.

The physical properties of solubility of hydrophilic chemicals or insolubility of hydrophobic chemicals in water depends on the presence and number of nonpolar and polar bonds in the molecules, as well as their molecular shapes and three-dimensional structures (stereochemistry). For example, water molecules (H–O–H) have covalent bonds because the respective electrons are shared between one oxygen and each of the two hydrogen atoms. The bonds are actually polar covalent bonds because the electrons are unequally shared. Indeed, the entire water molecule is polar because of the polarity of the bonds and its stereochemistry. In general, relatively polar molecules are soluble or miscible in polar water (polar), whereas relatively nonpolar or lipophilic molecules are not soluble in water, but are soluble in fats or oils (lipids; nonpolar).

Density and specific gravity are related physical properties also important factors influencing the fate of contaminants in the environment and relevant to human exposure. The density of a solid, liquid, or gas is the mass of the substance for a given volume. For example, the density of water is 1 g/ml or 8.33 lb/gal. The specific gravity of a substance equals its density divided by the density of a reference substance such as water or air. For example, the specific gravity of water equals 1 because the density of water (8.33 lb/gal) is divided by a reference density, in this case water or 8.33 lb/gal. Relatively nonpolar and therefore insoluble contaminants in water that have a density greater than 8.33 lb/gal or specific gravity of >1 sink, and those with a density of <8.33 lb/gal or specific gravity of <1 float.

Air has a molecular weight of about 28.8 g/mol, based on a rounded approximation of 21% oxygen (O_2; mol wt = 32 g/mol) and 79% nitrogen (N_2; mol wt 28 g/mol). At normal temperature and pressure (NTP) or 25°C and 760 mmHg, 1 mol of air is equivalent to a volume of 24.45 l of gas (22.5 l/mol at STP or 0°C and 760 mmHg). The density of air at NTP, therefore, is 28.8 g/mol divided by 24.25 l/mol which equals approximately 1.18 g/l. Also, gaseous contaminants with a density greater than 1.18 g/l at NTP tend to sink in air and those with lower densities tend to rise in air.

Vapor pressure is the final physical property to be discussed here in this section. True gases, such as oxygen and nitrogen, are designated as such because they are totally in the gaseous state at standard temperature and pressure (STP) and NTP. Vapors are gases too, but are generated from volatile materials that are predominantly in a liquid and sometimes in a solid state at STP and NTP. Volatile liquids and solids can evaporate and generate gaseous vapors into the air as a result. Vapor pressure is a measure at a defined temperature of the pressure in the headspace of a closed container partially filled with a liquid, such as the organic solvent benzene. The measured pressure stabilizes at a point of equilibrium, meaning the number of molecules evaporating from the liquid state to the gaseous vapor state equals the number of molecules of the gaseous vapor state condensing back to the liquid state. Benzene solvent has a vapor pressure of 75 mmHg at 20°C and is very volatile. A direct relationship exists between increased temperature and increased vapor pressure. The higher the vapor pressure for a given liquid or solid, the more volatile it is or more readily it will evaporate.

Accordingly, chemical and physical properties, in combination with numerous other factors, influence the fate of chemicals. The fate relative to transport, storage, and alteration of chemicals is discussed briefly in the next section.

TRANSPORT AND ALTERATION OF CHEMICALS IN THE ENVIRONMENT

Humans are part of the flow of energy; in the biosphere we interact with thousands of plants and animals. Because of our power and productivity, we have the ability to alter the ecosystems of Earth, of which we are a part, in a beneficial or harmful manner. Technological advancement since the early 1800s has been revolutionary instead of evolutionary. In the great movement forward to improve our own lifestyle, we have destroyed many of the natural ecosystems and severely polluted much of the air, water, and soil. To better understand the nature of the environmental alterations, it is important to understand the role of chemicals in the environment and how they are transported and altered.

Much of the environment is made up of chemicals, the largest amount of which are occurring naturally and have few detrimental effects on humans. However, we change the form, distribution, and concentration of these chemicals and synthesize or produce, either as products or as by-products, chemicals that are naturally found in the environment, as well as chemical compounds that are not. It is necessary to understand the movement of those chemical compounds that are not natural and to understand the movement of all these chemicals through the environment, their concentrations, the degree of human exposure, and the potential hazards to human health, such as initiatives and promotion of cancer (Figure 1.5).

Once a contaminant is released into the environment, the chemicals are transported and transformed in a variety of complex ways. Chemicals are transported widely throughout the environment by active and passive movement through air, water, biota (biological life), and soil. In addition, they serve as vectors of transport. Chemicals are transformed by chemical or biochemical reactions, and diluted, diffused, or concentrated by physical or biological processes. Some substances diffuse upward, where they are degraded by ultraviolet light; or diffuse downward, where they are adsorbed onto the surfaces of suspended particulate matter. Other substances are dissolved in water droplets and returned to Earth by rainfall. Weather conditions may set up cycles of elimination of toxic substances from air onto land and then into water, and eventually reintroduction into the air. Where sources of pollution are in close proximity to sources of water usage, an extensive and potentially hazardous series of chemicals may be transported directly into the water source and may cause significant health problems following human exposure (Figure 1.6).

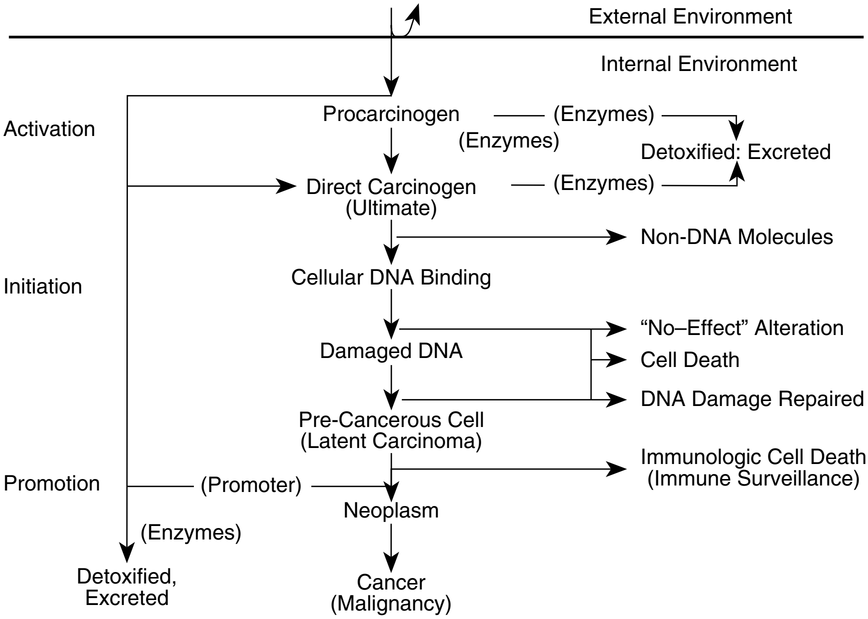

Figure 1.5 Chemicals in the environment. (From *Environmental Toxicology and Risk Assessment: An Introduction, Student Manual,* U.S. Environmental Protection Agency, Region V, Chicago, IL, Visual 3.8.)

Humans are exposed to chemical contamination through inhaled air, ingested water and food, absorption through the skin, and at times through a combination of these modes. We may be continuously, intermittently but repeatedly, or sporadically exposed. We may be exposed to chemicals present in substantial or in minute quantities. In some instances, chemicals present in minute quantities are more hazardous than those in large quantities. There is also direct intentional exposure through chemicals added to foods and cosmetics, and by those involved in the preparation of drugs. Good sense dictates limiting the level of exposure of any chemical that may cause adverse responses in an individual. Human health is endangered not only at the point of use or discharge of a specific chemical but also at varying points in the ecosystem. Unfortunately, many of the fundamental changes occurring in the environment are poorly understood. Reconcentration, specifically bioconcentration, is a process involving potentially harmful human exposure to chemicals (Figure 1.7). Plants and animals accumulate certain chemicals at levels higher than those of ambient environment. Chemicals also may be absorbed by air- or waterborne particles that are inhaled and concentrated in the lungs.

Dispersion of Contaminants

Contaminants tend to spread continuously within the environment. Indeed, when contaminants that are released into the environment accumulate to concentrations equal to or above an accepted threshold, then the ecosystem or environment becomes

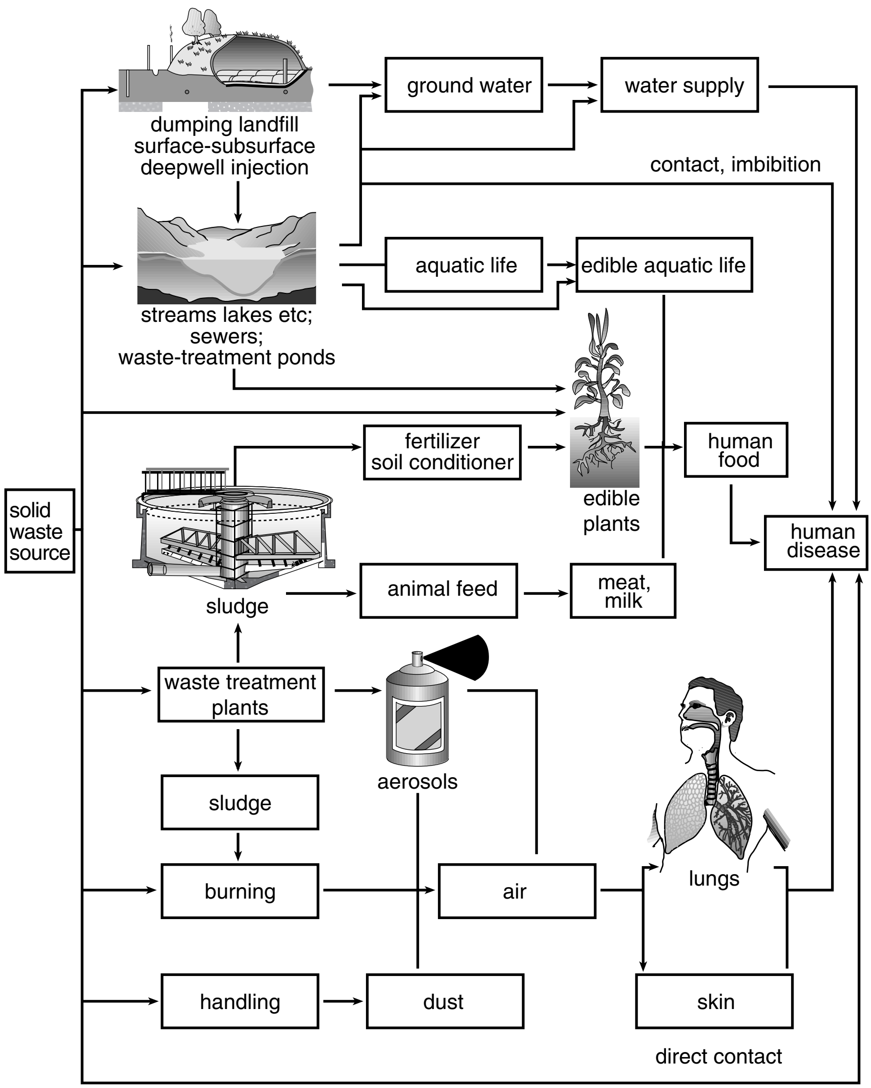

Figure 1.6 Chemical waste and human disease pathways (postulated).

polluted. The characteristics of the medium affect dispersion of the contaminants. Contaminants are actively dispersed via convective or turbulent manner. Convection is the circulatory motion that occurs in a fluid at a nonuniform temperature owing to the variation of its density and the action of gravity. Turbulence in the atmosphere is a complicated phenomenon that depends on the wind velocity; the direction of the wind; the altitude; the friction of the air over the surface of Earth; the temperature of the air; the pressure in the air; and the presence or absence of bodies of water, mountains, and flat areas. Dispersion from ground-level sources are seen almost immediately downwind from the source. Dispersion from tall smoke stacks or any

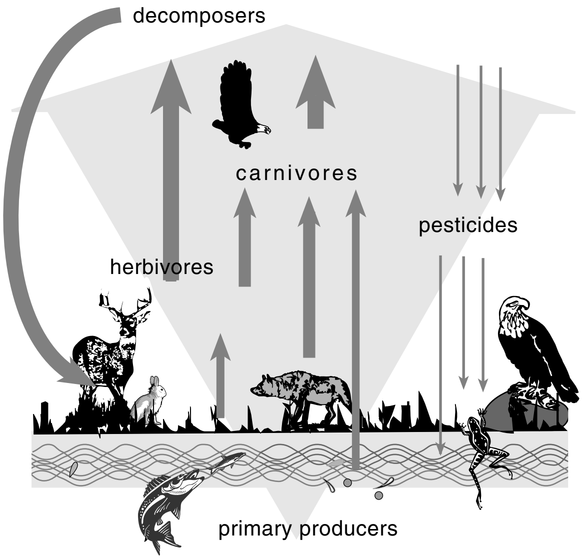

Figure 1.7 Bioconcentration. (Adapted from Koren, H., *Illustrated Dictionary of Environmental Health and Occupational Safety,* Lewis Publishers, CRC Press, Boca Raton, FL, 1995. With permission.)

elevated discharge may be found for considerable distances from the source. Contaminants also are passively dispersed through the atmosphere. The passive process is known as diffusion and implied movement of contaminants based on a concentration gradient. The contaminants diffuse through the air from areas of high to low concentration. This is most applicable to gases and vapors.

Dispersion in the hydrosphere is much more varied and complex than dispersion in the atmosphere. The dilution volumes and mixing characteristics, as well as the rate of transport of the contaminants, vary with rivers, lakes, estuaries, coastal waters, and oceans. The contaminants in the water may further contaminate the land, the groundwater supply, and the air.

The environment of the soil is very complex with regard to the dispersion of contaminants. The dispersion depends on the specific nature of the chemicals; the type, texture, and structure of soil; and other factors, such as moisture, pH, and temperature. Most chemical contaminants do not move readily through the soil once they enter it. Gases may easily diffuse through air pockets and pores in the soil. Soil water is the major means of moving chemicals downward through pores and channels to the lower horizons of the soil or upward to the point of evaporation. Water also may move the contaminants in a lateral manner or help in surface runoff depending on the slope of the soil. The more rapidly water percolates into and leaches through the soil, the more readily the chemicals may diffuse into the pores between the soil particles.

Alteration of Chemical Contaminants

Contaminants are removed from the atmosphere by a variety of means. The contaminants may either be in the original form or may have altered during the dispersion process. Particles are physically removed from the atmosphere by gravity, impacting on objects, and through rain, snow, or sleet. The larger the particle, the more rapidly it will settle out. The particles may attract gases, vapors, or viruses and bacteria. Gases and vapors also may be dissolved in moisture, or through chemical reactions in the atmosphere they may be chemically converted into other compounds. Photochemical interaction is the most significant catalyst for altering physical and chemical air contaminants. Ultraviolet energy from the sun can interact with air contaminants resulting in oxidation and transformation of chemical structures.

Chemicals found in water may be bioconcentrated in fish or plant life, deposited on surfaces, or converted into other products by the self-purification process that is related to chemical and biochemical oxidation. Physical self-purification may occur when the chemicals bond to suspended particles in water.

The persistence of chemicals in the soil is a complex function, related to physical, chemical, and biological factors. The major means of removal of contaminants in soil are by degradation due to biotic microbial action, abiotic chemical degradation, evaporation, volatilization from the surface, and uptake by vegetation.

To get some better understanding of transport and alteration of chemicals in the environment, seven chemicals have been chosen for discussion. All have been identified on the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, Superfund) National Priorities List. They are part of a large group that pose a significant potential threat to human health, as determined by the Agency for Toxic Substances and Disease Registry. These chemicals are chrysene, chloroform, cyanide, lead, 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD), tetrachloroethylene, and trichloroethylene.

Chrysene is found in the environment from natural sources, such as forest fires and volcanoes, and from people-made sources. Chrysene, like all PAHs, is formed during high-temperature pyrolytic processes. Combustion is the major source of environmental chrysene. Virtually all direct releases into the environment are to the air, although small amounts may be released to the water and land. Chrysene is removed from the atmosphere by photochemical oxidation and dry or wet deposition onto land or water. This chemical is very persistent in either soil or sediment. Biodegradation is a slow process. The half-life of chrysene in the soil is estimated to be 1000 days.

Incomplete combustion of carbonaceous materials is the major source of chrysene in the environment. Residential heating and open burning are the largest combustion sources. The inefficient combustion process creates uncontrolled emissions, with heating in the home as the greatest contributor to chrysene emissions. Hazardous waste sites can be concentrated sources of PAHs on a local scale and, therefore, may contain larger quantities of chrysene. Chrysene in the atmosphere is expected to be associated primarily with particulate matter, especially soot. Chrysene in aquatic systems is expected to be strongly bound to suspended particles or sediments. Chrysene is expected to be strongly sorbed to surface soils.

Chloroform is a colorless or water-white liquid used to make fluorocarbon-22. It is also used as a pesticide and as a solvent in the manufacture of pesticides and dyes. Chloroform is discharged into the environment from pulp and paper mills, pharmaceutical manufacturing plants; chemical manufacturing treatment plants, and from the chlorination of wastewater. Most of the chloroform released ends up in the air. It may be transported for long distances before becoming degraded by reacting with photochemically generated hydroxyl radicals. Significant amounts of chloroform from the air may be removed by precipitation. However, the chloroform may reenter the air by volatilization. When released to soil, chloroform either volatilizes rapidly from the surface or leaches readily through the soil to the groundwater, where it may persist for relatively long periods of time. It is estimated that its half-life in the atmosphere is 70 to 79 days. However, when chloroform is found in photochemical smog, its half-life is 260 days.

Volatilization is the primary mechanism for removal of chloroform from water. Its half-life in water may vary from 36 hr to 10 days. Although chloroform has been found to adsorb strongly to peat moss and less strongly to clay, typically it volatilizes rapidly in either dry or wet soil.

Although cyanides are naturally occurring substances found in a number of foods and plants and produced by certain bacteria, fungi, and algae, the greatest amount found in the environment comes from industrial processing. Hydrogen cyanide is used primarily in the production of organic chemicals. Cyanide salts are used primarily in electroplating and metal treatment. The major sources of cyanide released to water are reported to be discharges from metal finishing industries. The major source of the cyanide released to air is vehicle exhausts, and the major sources of cyanide released to soil appear to be disposal of cyanide waste in landfills and the use of cyanide-containing road salt. Cyanide released to air appears to be transported over long distances before reacting with photochemically generated hydroxyl radicals. The half-life of cyanide is 334 days. In water, cyanide may volatilize; or if in an alkali metal salt form, cyanide may readily disassociate into anions and cations. The resulting cyanide ion may then form hydrogen cyanide or react with metals to form metal cyanides. Insoluble metal cyanides are expected to adsorb to sediment and possibly bioaccumulate in aquatic organisms.

In soil, cyanides may occur in the form of hydrogen cyanide, alkali metal salts, or immobile metallocyanide complexes. At soil surface with a pH less than 9.2, hydrogen cyanide is expected to volatilize. In subsurface soil, where the cyanide present is at a low concentration, it is probably biodegradable. In soil with a pH less than 9.2, hydrogen cyanide is expected to be highly mobile, and where cyanide levels are toxic to microorganisms such as in landfills or in spills, the cyanide may reach the groundwater.

Lead is a naturally occurring element that may be found in Earth's crust and in all parts of the biosphere. It is released into the atmosphere by a variety of industrial processes and from leaded gasoline. The deposition of lead found in both soils and surface waters generally comes from the atmosphere. Lead is transferred continuously among air, water, and soil by natural chemical and physical processes, such as weathering, runoff, precipitation, dry deposition of dust, and stream or river flow. Long distance transport of up to about 600 mi may occur. Lead is extremely persistent in both water and soil. In the atmosphere, lead exists primarily in the particulate form. The chemistry of lead in the water is highly complex, because it may be found in a multitude of forms. The amount of lead that remains in solution depends on the pH of the water and the dissolved salt content. In most soils, the accumulation of lead is primarily a function of the rate of deposition from the atmosphere. Most lead is maintained strongly in the soil and very little is transported into surface water or groundwater.

The chemical TCDD, or simply dioxin (which is an inaccurate colloquial name except when it is used as a reference standard), is not intentionally manufactured by any industry. It is inadvertently produced in very small amounts as an impurity during the manufacture of certain herbicides and germicides. It is also produced during the incineration of municipal and industrial wastes. The environmental fate of 2,3,7,8-TCDD is not understood with certainty for air, water, and soil, but nonetheless is considered a potent toxin.

Tetrachloroethylene is a nonflammable liquid solvent widely used for dry-cleaning fabrics and textiles, and for metal-degreasing operations. It is used as a starter chemical for the production of other chemicals. It is also called perchloroethylene, perc, PCE, perclene, and perchlor. Most of the tetrachloroethylene used in the United States is released into the atmosphere by evaporative losses. The dry cleaning industry is the major source. When the chemical is released in water, it rapidly volatilizes and returns to the air. However, rainwater dissolves this chemical, and once again it falls to the land. The usual transformation process for tetrachloroethylene in the atmosphere is the result of the reaction with photochemically produced hydroxyl radicals. The degradation products of this reaction include phosgene (a severe respiratory irritant) and chloroacetyl chlorides.

Trichloroethylene is used as a solvent for removing grease from metal parts. It is released into the atmosphere by evaporative losses. It may also be released into the environment through gaseous emissions from waste-disposal landfills, and it may leach into groundwater from waste-disposal landfills. It is dissolved in rainwater. The dominant transformation process for trichloroethylene in the atmosphere is its reaction with sunlight-produced hydroxyl radicals. The degradation products of this reaction include phosgene, dichloracetyl chloride, and formyl chloride.

ENVIRONMENTAL HEALTH PROBLEMS AND THE ECONOMY

The environment and the economy are not mutually exclusive; together they form an integral system. As the public demands a higher quality environment, the economy must adjust to meet this need. In the past, Americans have placed a high priority on convenience and consumer goods. There seemed to be no need for concern over the air, water, or the earth. The economic system was established such that incentives were given to individuals to better their position in our society without taking into account the problem of environmental degradation. The rich endowment of natural resources; the large amounts of investment, technology, and education; the influx of skilled immigrants; and the political and economic systems in the United States have combined to produce an economy with enormous material wealth. American business and industry, through its technological developments, produce huge amounts of goods and services. Consumers continually demand new products, and business and industry have accommodated consumers. Old products are discarded as quickly as new ones become available.

However, a new demand for better environmental quality and cleaner surroundings has emerged in the United States. The American public is demanding cleaner water, cleaner air, relief from noise and congestion, and more aesthetically pleasing environment. Concurrently, the supposedly unlimited supply of water and air is befouled with huge quantities of pollutants, creating severe health, economic, and aesthetic problems. Exotic chemicals have entered the environment and moved through the food chain to a point where they are becoming a potentially dangerous health hazard.

During the last 25 years, the production of synthetic organic chemicals, containers, packaging, and electronic equipment has increased sharply. As production has increased, consumer demand has increased. Unfortunately, although the products are available to the consumer at reasonable prices, these prices do not fully represent the cost to our society, because they do not include the cost of waste of our natural resources or the cost of environmental degradation. Due to the unfair economic incentive for use of raw materials vs. reuse of recycled materials, further destruction of our environment occurs. The dumping of wastes into the air, water, and land must end. The burden of the cost of the environmental cleanup and environmental improvement must be borne by all. Pollution costs include higher prices resulting from damage to crops, materials, and properties; and from disease and injury. The actual costs of control measures are difficult to assess, because one must take into account abatement programs; expenditures by business and industry; expenditures by government, research and development; monitoring devices; and assorted equipment and service purchases.

Dollars spent improving the environment are an investment in life and human society, although the benefits of these investments may not be readily seen. Imposing environmental controls results in the reallocation of resources, which in the short run may cause adverse economic effects, such as higher prices, temporary unemployment, and plant dislocations. The decrease in medical bills, the increase in recreational activities, the decrease in damage to materials, and the provision of a better society must be weighed against the temporary cost increases. Marginal firms that fail to meet these costs will be forced to close. The ultimate good to the greatest number of people should be the deciding factor in determining what should or should not be done to improve the environment. However, in any given area where changes are undertaken, adequate additional funds must be made available if the area is likely to suffer economic dislocation. In some cases where health is not endangered by pollution, it may be best to carefully and cautiously make temporary exceptions to certain standards in an effort to ease the strain on local economies. These exceptions should only be made with the greatest of care.

RISK–BENEFIT ANALYSES

In all areas, but particularly with regard to chemicals, it is necessary to compare the social benefits of a given environmental substance with the risk it causes to our society. Many pesticides are potentially extremely dangerous, and yet without the availability of pesticides the country and the world would be rampant with disease and would probably suffer from famines and starvation. It is therefore necessary to evaluate each of the environmental substances to determine the relative safety of the substance; the relative efficiency in production of the substance compared with the use of natural resources; and the relative impact on the environment at various stages of manufacture, use, or disposal. In all cases, risk–benefit analyses must be completely considered. The benefits include the value of the use of the substance to the consumer; its aesthetic value; the conservation of natural resources and energy resulting from the production of the substance; and the economic impact of employment, regional development, and balance of trade in the production of the substance. The risks include the adverse effect on health; the potential for death occurring as a result of use of the substance; the environmental damage to air, water, land, wildlife, vegetation, aesthetics, and property; and the misuse of natural resources and energy. Establishing risk–benefit analyses for each substance utilized within the environment is difficult. However, with analyses of these types, society can determine the necessary trade-offs between potential hazard and employment, health, gross national product, balance of trade, conservation of natural resources, and environmental quality.

Cost–Benefit

The four case studies to be discussed include the following: lead in gasoline, air toxics issues, incineration at sea, and municipal sewage sludge reuse and disposal.

Lead in Gasoline

In the case of the lead-in-gasoline rule, a careful quantitative analysis was used. Lead in gasoline has been regulated by the EPA for more than 15 years. There was a concern that leaded gasoline was being used in cars that required unleaded gasoline. This would affect the pollution control catalysts. A further concern was that the lead was a potential risk to children's health. Although previous rules had reduced lead in gasoline, in March 1984, the EPA set a very tight phase-down schedule. The final rule issued in March 1985 was more stringent than the original proposal. It required that lead in gasoline be reduced from 1.1 g per leaded gallon to 0.5 g per leaded gallon by July 1985, and to 0.1 g per leaded gallon by January 1986. Not all of the lead was removed from leaded gasoline, because of the potential effect it would have on older engines. Since the 1920s, refineries have added lead to gasoline as an inexpensive way of boosting octane. With the removal of lead, refineries had to do additional processing or use other additives, which tended to raise the cost of gasoline.

The EPA used a computer model of the refining industry that had been developed by the Department of Energy to estimate the cost of the rule. The computer model included various equations that showed how different inputs could be turned into different end products at varying costs and the constraints on the industry's capacity. To estimate the cost of the rule, the EPA first ran the model specifying the then current lead limit of 1.0 g per leaded gallon and computed the cost of meeting the demand for the refined products. It then ran the model specifying the lower lead limits and recomputed the overall cost. The difference between the original and anticipated lead limits was the estimated cost of the tighter standard. Based on that analysis, the EPA estimated that the rule would cost less than $100 million in the second half of 1985 to meet the 0.5 g per leaded gallon standard and approximately $600 million in 1986 to meet the 0.1 g per leaded gallon standard. They next ran extensive tests using more pessimistic assumptions, such as an unexpected high demand for high-octane unleaded gasoline, an increased downtime for equipment, and a reduced availability of alcohol additives. The 0.1 g per leaded gallon rule met virtually all conditions. It was extremely unlikely that a combination of these conditions would occur at the same time.

The benefits of the rule were estimated for the maintenance of good health in children and the improvement in educational efforts, compared with the efforts of children who were exposed to lead. Further, benefits were estimated based on the reduction in damage caused by excessive emissions of pollutants from vehicles using the wrong gasoline, the impacts on vehicle maintenance, and the impacts on fuel economy. The EPA also used existing data to study the relationship between levels of lead in the blood and blood pressure to make some estimate of the health effects that adults would have from this rule. In each category, the EPA first estimated the impact of reduced lead in physical terms. In the case of children's health effects, the agency used statistical studies relating to lead in gasoline and blood lead levels projected in children. The EPA also estimated the cost to people and society and the environment by allowing the lead levels to stay the same vs. the reduced lead levels. It was determined that the benefits of the lead rule exceeded the cost by a 3:1 ratio; and that if the potential benefits in reductions in blood pressure, illness, and death were to be counted, the ratio would rise to 10:1.

Air Toxics

Risk assessment techniques were used to determine the environmental hazards of toxic air emissions. A study was made to determine how much of the air toxics problems could be controlled by using existing EPA programs. A new toxic strategy was then developed and put into place. It had three main parts: (1) direct federal regulation of significant nationwide problems, (2) state and local control of significant pollutant problems that were national in nature, and (3) an increased study of geographic areas that were subjected to particularly high levels of air pollution. In the initial study, 42 air toxic compounds were evaluated, basically for their potential to cause cancer. A determination was made of how many people were exposed across the country. An estimate of the risk associated with each compound in this national exposure was determined. The estimate was of long-term cancer incidents (a 70-year time frame) associated with these compounds. The analysis suggested that the air toxics problem was complex, caused by many pollutants and sources, varied significantly from city to city, and even varied within a city. In the 1990s, the EPA reduced air toxic pollutants by nearly 1 million tons per year, which is almost a 10 times greater reduction than was achieved from 1970 to 1990. This success was related directly to the technology- and performance-based standards set by the EPA.

Apparently, preexisting EPA air toxic strategies that focused on regulating each pollutant as part of national emissions standards were too narrowly set up to be effective. A comparison of air quality data for 1970 and 1980, however, showed that significant reductions in national cancer incidents related to air pollution had occurred as a result of the reduction of air pollutants. Air toxic problems were examined in detail in Baltimore, Baton Rouge, Los Angeles, Philadelphia, and Phoenix. In the original study, 14 compounds were identified as causing the greatest concern for cancer risk among the general population, and how these compounds could be controlled was studied. Again, cancer was the indicator of health effects, because other health effect indicators were more difficult to determine. Emission sources were identified in each of the five cities for these 14 compounds. Human exposure modeling was used to determine the degree of risk experienced by the people of these selected areas and the cancer incidents expected from this risk. The assumption was made that there would be a full implementation of the criteria of the pollutant programs.

The greatest incidents of cancer are associated with vehicles or area sources, such as numerous small pollution sources, like wood stoves. Point-source pollution sources, which are large, relatively identifiable sources of pollution, such as utilities and steel plants, appear to account for little of the total incidents.

All these data suggest that the health problems of air toxics may require a targeted strategy to make the best use of available resources. The data also suggest that additional focus must be made on small and nontraditional sources to get the greatest benefit for the health of the individuals. Additional attention needs to be given to wood smoke, vehicles, waste oil burning, and gasoline stations. The risk assessment here has helped to highlight the important areas where the greatest amount of good results will occur from the smallest amount of dollar expenditures.

Incineration at Sea

Industry generates more than 70 billion gal of hazardous waste each year in the United States. This waste must be safely managed through treatment, storage, and disposal. Because the EPA is restricting the use of management practices through permitting, regulation, and enforcement programs, there is a need to determine how best to get rid of this hazardous waste. Incineration is a technique used to help destroy this hazardous waste. Public opinion, however, is strongly against the issuing of permits for new incinerators.

Between 1974 and 1982, the EPA issued permits for four series of burns conducted by the incinerator ship Vulcanus. Three of the burns were in the Gulf of Mexico and one in the Pacific Ocean. Public opposition to incineration at sea has intensified greatly. The EPA undertook a number of studies to determine whether incineration on land or in the oceans is more desirable.

The EPA developed a risk assessment study that compared the human and environmental exposure most likely to occur from releases of land-based incineration vs. ocean incineration. The study used existing information and added new analysis of the emissions, transport, fate, and alternate effects. Both systems used land transportation, transfer and storage operations, and final incineration. The ocean system also included an ocean transportation step. For the purposes of the study, the waste was assumed to be a combination of 35% PCBs by weight and 50% ethylene dichloride (EDC) by weight. These two chemicals were used to simplify the waste stream. The analysis was to determine the statistically expected amount of pollutant released from accidental spills and air emissions. The transportation and handling accounted for less than 15% of the expected releases, whereas the incineration accounted for about 85%.

During land transportation, there were two types of potential losses. They were vehicular accidents and spills from the containers in route. Vehicular accidents were expected to occur on the average of once every 4 to 5 years and container failure, once every 3 to 4 years. The analysis of transfer and storage of the waste was considered and three types of releases were anticipated: (1) spills when unloading the waste from tank trucks, (2) spills from equipment at the waste transfer and storage facilities, (3) and fugitive emissions in transfer and storage. Spills from transfer and storage components are infrequent events estimated to occur at about 0.50% per year, and from the tank trucks loading of waste to ship in the ocean system is approximately 0.002% per year. It was recognized that spills of this low quantity would likely be contained at the facility.

About 320 voyages of incineration ships have been made in the North Sea since 1972, and no casualties or spills have occurred. The spill rates from ships were based on worldwide historical data. It was estimated that the frequency of all spills for the Vulcanus would be about 1 per 12,000 operating years.

The study estimated and compared the possible human health and environmental effects due to incinerator releases and fugitive releases from the transfer and storage equipment.

The analysis of human health risk was based on the most exposed individual, who lives at the location, and the persons at the highest overall risk due to air concentrations from the incinerator stack and transfer storage facility. This risk is based on the cancer potential for an individual who has 70 years of continuous exposure. The risk on land-based incineration was 3 chances in 100,000, whereas the risk on ocean burning was in a range of 1 in 1,000,000 to 6 in 10,000,000. The relative risk on land for incineration of PCB waste is about 40 times more than on the ocean. For EDC waste, the ratio of land to ocean risk is about 30:1.

The conclusions of the incineration study were as follows: (1) incineration, whether on land or at sea, is a valuable and environmentally sound option; (2) no clear preference is made for ocean or land incineration as it relates to human health risk and the environment; (3) future demands will significantly exceed the capacity for disposal of hazardous waste; (4) continuing research is needed to improve current knowledge of combustion processes and effects; and (5) EPA needs to improve its public communications effort in the area of hazardous waste management.

Municipal Sludge Reuse and Disposal

Sludge management is a major part of municipal sewage disposal. Municipalities generate about 6.5 million dry tons of wastewater sludge a year. Municipal sewage sludge contains over 200 different substances, such as toxic metals, organic chemicals, and pathogenic and other organisms. The five major sludge use or disposal options currently available are land application, distribution and sale of sludge products, landfill, incineration, and ocean disposal that is used on a research or an emergency basis only. The EPA developed standards in February of 1993, for the use or disposal of sewage sludge. These standards are for land application, surface disposal, reduction of pathogens and vector attractions, and incineration. This Round One regulation also set limits for metals, and total hydrocarbons. These standards are in compliance with Section 405 of the Clean Water Act. They are titled, "Standards for the Use or Disposal of Sewage Sludge" (Code of Federal Regulations Title 40, Parts 257, 403, and 503, known as the Part 503 Sludge Rule). As the result of a citizen's suit, the EPA was required to propose Round Two regulations by December 15, 1999 and to take final actions by December 15, 2001, These changes were based on risk assessment results and involved only dioxin and dioxin-like compounds in biosolids. The proposed limit is 300 parts per trillion toxic equivalents of dioxins, above which biosolids may not be applied to the land. All facilities would be required to test the level of dioxins present in their biosolids before they could be land applied except where treatment plants treated less than 1 million gal/day of wastewater, and small businesses prepared less than 290 dry tons of sewage sludge a year.

Biosolids are treated sewage sludge. They are nutrient-rich organic materials resulting from the treatment of domestic sewage in a treatment facility. When treated and processed, these residuals can be recycled and applied as fertilizer to improve and maintain productive soils and stimulate plant growth.

Sludge disposal has always been a substantial portion of the cost of wastewater management. Over the last 20 years, restrictions have been placed on ocean dumping and landfill disposal, causing wastewater treatment facilities to consider agricultural use of sludge as a cost-effective alternative. About 36% of sludge is applied to the land for agriculture, production of turf grass, and reclamation of surface mining areas; 38% is land filled; 16% is incinerated; and the rest is discarded on the surface by other means.

The Midwest has a long history of using treated sludge on cropland, which is used to grow corn and small grains for cattle feed. In Madison, WI, the demand for sludge as a soil amendment exceeds the local supply. Coastal cities such as New York City and Boston send much of their sludge to other parts of the country, because they can no longer dispose the sludge at sea.

Pollution Prevention

Pollution prevention is a variety of techniques with a single objective — to achieve the most efficient use of resources to reduce or eliminate waste. Pollution prevention reduces or eliminates the generation of pollutants or waste, minimizes or eliminates the use of toxic materials in manufacturing, substitutes less harmful materials for toxic ones, reduces the chance of moving pollutants to a different media (e.g., air to water), and maximizes the efficient use of resources. Pollution prevention starts in the public sector with changes in a variety of public departments and their operations. It then includes the private sector and people at large. Better management of transportation saves fuel and reduces emissions. This is an example of an effective program. The substitution of calcium magnesium acetate for sodium chloride as a road salt reduces well contamination. Energy efficiency reduces the need for fuel to produce energy and reduces pollutants that come from burning hydrocarbons.

ENVIRONMENTAL HEALTH PROBLEMS AND THE LAW

The environmental health practitioner works for a unit of the local, state, or federal government; or, if working for industry, is constantly dealing with various levels of government. (For a detailed discussion on the functions of government, the reader is encouraged to refer to one of the many publications on local, state, and federal government.) For the purposes of this book, a brief discussion on federal–state relationships, legislative procedure, pressure groups, local government, and state and local finances is included.

The governmental system in a democratic society performs two distinct functions. It provides a foundation for debate on issues and a vehicle for the solution of problems. It also provides a service and regulatory function, because individuals in a complex society cannot provide for all their needs. These needs include adequate police, fire, and health protection. For the society to operate properly, the individual or group must adhere to rules and regulations formulated and enforced by the elected government.

According to the U.S. Constitution and amendments thereto, federal powers include the control of interstate and foreign commerce, conduct of foreign policy, and national defense. The federal government cannot levy direct taxes, other than income taxes, except in proportion to the population of the states. The federal government cannot abridge civil rights. The state is sovereign. The powers not delegated to the federal government or prohibited by the Constitution are reserved for the states or the people. The state powers include the administration of elections; establishment and operation of local government; education; intrastate commerce; creation of corporations; police force; and promotion of health, safety, and welfare. Although the federal government cannot dictate organization and administration of programs, or the establishment of policy, it has gained some control via its use of funds. For a state to receive federal funds, it must adhere to certain requirements established by the federal government for the use of these funds. These requirements include preparation and submission of plans, approval of plans by a central federal agency, establishment of necessary state agencies, provision for matching state funds, and supervision and auditing of state programs by the appropriate federal agencies.

Public policy is a result of the interaction of groups and individuals. The formulated policy is not necessarily ideal for the public. Major pressure groups — including business, industry, agriculture, labor, medicine, and religion — try to influence the legislature to pass laws beneficial to their own self-interest. These groups also pressure administrative agencies to make or change decisions on policies that are not in the best interest of the public. These groups compete with each other for public support. They use sizable sums of money to influence opinions on legislation. Citizens groups properly educated and stimulated by trained professional public health workers could use the techniques of the pressure groups to establish public policy that would be beneficial to the citizens and would improve the environment.

The state is divided into local government, including counties, townships, villages, cities, and boroughs. Local government functions may include all the functions of the state government, such as the powers of taxation; establishment of budgets; licensing; and administration of health, safety, and environmental programs. The local government is expected to deliver quality service and to protect the public. It should prevent the duplication of efforts, budgets, and facilities of the state government. Environmentalists must recognize that although concern for the environment is foremost in their minds, the county commissioners or township supervisors may be more concerned with other programs, such as road building, recreational facilities, and police and fire service. The environmentalist has to compete for budget monies with each of the other operating departments.

State and local governments obtain their funds for operation from taxes levied on sales, automobile licensing, gasoline, corporations, personal income, alcohol and tobacco, gross receipts, property, and establishment licensing. In many cases, tax rates become oppressive and yet income derived from taxes is inadequate to finance properly the necessary programs for the community. Then it becomes necessary for the federal government to supply funds; in this way, the federal government exercises control in some states even at the township level.

Law and Public Health

Public health policies are discussed briefly, because environmental health practitioners should have some understanding of the law to function in their capacity as either industry leaders or government officials. (For more detailed discussion, many books are available describing current laws relating to the environment.)

Law is the rule of civil conduct prescribed by the supreme power in a state commanding what is right and forbidding what is wrong. Law should represent the community desires or commands, apply to all members of the community, be backed by the full power of the government, and provide the administration of justice under the law for all people. The purpose of law is to protect by the regulation of human conduct of the individual from other individuals, groups, or the state, and vice versa. Statutory laws are basically legislative acts passed by a legislative body; common laws are established customs of the community; equity is a decision by a judge in a given situation where rules and regulations have been violated; and administrative laws are rules and regulations in a given area established by an agency authorized by the legislature. The value of administrative laws is that the rules and regulations established can be changed readily when new scientific data are available. If regulation were part of a statute, the legislature would have to go through the complex process of rewriting the act.

Public health law is that body of statutes, regulations, and precedents that protects and promotes individual and community health. Public health law is founded on the Preamble to the Constitution, which ordains that the government shall "… promote the general welfare"; and Section 8, Article 1 of the Constitution, which

"… provide(s) for the common defense and general welfare." The interpretation of these clauses and other clauses of the Constitution by the U.S. Supreme Court has established the legal basis for public health. The law of eminent domain empowers the state with the authority to seize, appropriate, or limit the use of property in the best interests of the community. This power is reflected in the establishment of zoning and land use regulations that are so essential to the preservation of a good environment.

Nuisance laws, originating in the Middle Ages, are used repeatedly in environmental health work. Basically they state that the use of private property is unrestricted only as long as it does not injure other persons or their property. If an injury occurs, a nuisance exists. Large numbers of public health officials use nuisance laws to eliminate problems caused by sewage, solid waste, air pollution, and insects and rodents.

The public health law owes its effectiveness to the police power of the state. In times of great stress, such as severe fires, floods, and outbreaks of diseases, the private property of an individual might be summarily appropriated, used, or even destroyed if the ultimate relief, protection, or safety of the community demands that such action be taken. The legislature can and does delegate police power to an administrative agency for use in the event of an emergency. If public officials fail to use the delegated police power, they are guilty of nonfeasance of office. The use of this police power is determined by the chief administrative office, usually the state secretary of health, in consultation with the governor of the state.

Administrative law is that series of rules, regulations, and standards needed to implement statutes. The development and use of sound rules, regulations, and standards based on strong scientific data put the burden of proof on the defendant, who has to show that the rules have not been fairly applied, rather than that they have limited value. Through judicial presumption, the judge assumes that the laws are correct, because they are based on sound scientific criteria or on the judgment of a group of experts. The judge only decides if the law is applied fairly.

Licensing is an important means of control and enforcement of environmental standards. If an individual or business does not meet the standards, a license is denied or revoked. An individual operating without a license is subjected to severe penalties.

Environmental health practitioners must be conscious of those actions that may occur in the enforcement of environmental health laws. These actions include: (1) misfeasance, which is the performance of a lawful action in an illegal or improper manner; (2) malfeasance, which is wrongful conduct by a public official; and (3) nonfeasance, which is an omission in doing what should be done in an official action.

Environmental Law

For historical purposes, the Rivers and Harbors Act of 1899 was passed by Congress to prevent the illegal discharge or deposit of refuse or sewage into navigable waters of the United States. This law was used before 1972 to penalize some corporations for polluting the water.

The National Environmental Policy Act of 1969 signed into law on January 1, 1970 (Public Law 91-190), amended by PL 94-52 and PL 94-83 in 1975, set forth the continuing responsibility of the federal government to:

1. Fulfill the responsibilities of each generation as trustee of the environment for succeeding generations
2. Assure safe, healthful, productive, aesthetically, and culturally pleasing surroundings for all Americans
3. Attain the widest range of beneficial uses of the environment without degradation, risk to health or safety, or other undesirable and unintended consequences
4. Preserve important historic, cultural, and natural aspects of our national heritage, and maintain, wherever possible, an environment that supports diversity and variety of individual choice
5. Achieve a balance between population and resource use that will permit high standards of living and a wide sharing of life's amenities
6. Enhance the quality of renewable resources and approach the maximum attainable recycling of depletable resources

The National Environmental Policy Act (NEPA) also states that all federal agencies shall:

1. Utilize a systematic, interdisciplinary approach ensuring the integrated use of the natural and social sciences and the environmental design arts in planning and in decision making when planning may be an impact on the human environment
2. Identify and develop methods and procedures, in consultation with the Council on Environmental Quality, ensuring that other environmental amenities and values be given appropriate consideration in decision making, along with economic and technical considerations
3. Include in every recommendation or report on proposals for legislation and other major federal actions significantly affecting the quality of the human environment, a detailed statement by the responsible official on:
   a. the environmental impact of the proposed action
   b. any adverse unavoidable environmental effects should the proposal be implemented
   c. alternatives to the proposed action
   d. relationship between local short-term uses of the environment and the maintenance and enhancement of long-term productivity
   e. any irreversible and irretrievable commitments of resources involved in the proposed action should it be implemented
4. Study, develop, and describe appropriate alternatives to recommended courses of action in any proposal involving unresolved conflicts, as well as alternative uses of available resources
5. Recognize the worldwide and long-range character of environmental problems and, where consistent with the foreign policy of the United States, lend appropriate support to initiatives, resolutions, and programs designed to maximize international cooperation in anticipating and preventing a decline in the quality of the world environment
6. Make available to states, counties, municipalities, institutions, and individuals advice and information useful in restoring, maintaining, and enhancing the quality of the environment
7. Initiate and utilize ecological information in the planning and development of resource-oriented projects

8. Establish the Council on Environmental Quality, whose functions are as follows:
   a. To assist and advise the President in the preparation of the environmental quality report, which will be submitted to the Congress starting in 1970 (this report is an excellent digest of various environmental health issues)
   b. To gather timely and authoritative information concerning the conditions and trends in the quality of the environment, currently and for the future
   c. To review and appraise the various programs and activities of the federal government
   d. To develop and recommend to the President, national policies to foster and promote the improvement of environmental quality
   e. To conduct investigations, studies, surveys, research, and analyses relating to ecological systems and environmental quality
   f. To document and define changes in the natural environment
   g. To report at least once every year to the President on the state and condition of the environment
   h. To make and furnish studies, reports, and recommendations with respect to matters related to policy and legislation

Since 1970 when the NEPA Act was passed and a Council on Environmental Quality was established, Congress has passed a large number of laws and amendments to the laws, related to a variety of environmental issues that potentially affect the health of people and affect the environment and ecosystems. These laws include, but are not limited to, the Asbestos School Hazard Detection and Control Act; Asbestos School Hazard Abatement Act; Asbestos Hazard Emergency Response Act; Chemical Safety Information Site Security and Fuel Regulatory Act; Clean Air Act (CAA); CERCLA; Consumer Product Safety Act (CPSA); Emergency Planning and Community Right-to-Know-Act; Energy Supply and Environmental Coordination Act; Energy Policy Act; Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA); Food, Drug, and Cosmetic Act (FDCA) amendments; Food Quality Protection Act; Hazardous Materials Transportation Act; Lead Contamination Control Act; Medical Wastes Tracking Act; National Environmental Education Act; Noise Control Act; Nuclear Waste Policy Act; Occupational Safety and Health Act; Oil Pollution Act; Pollution Prevention Act; Radon Gas and Indoor Air Quality Research Act; Resource Conservation Recovery Act (RCRA); Surface Mining Control and Reclamation Act; Superfund Amendments and Reauthorization Act (SARA); Toxic Substances Control Act (TSCA); and Uranium Mill-Tailing Radiation Control Act.

A number of laws related to water and water pollution have been enacted since the original Rivers and Harbor Acts of 1899. These laws include clean water amendments of the Federal Water Pollution Control Act; Coastal Zone Management Act; Deep Water Port Act; Marine Protection, Research, and Sanctuaries Act; National Ocean Pollution Planning Act; Outer Continental Shelf Lands Act; Ocean Dumping Act; Ocean Dumping Ban Act; Port and Tanker Safety Act; Shore Protection Act; Safe Drinking Water Act (SDWA); Water Resources Planning Act; and Water Resources Research Act.

The major amendments to the CAA were added in 1977 and updated in 1983, with again a major amendment passed in 1990. There had been a substantial debate for the last 10 years concerning how to change the law. The congressional findings included: (1) that the predominant part of the nation's population was located in rapidly expanding metropolitan and other urban areas that generally cross the boundary lines of local jurisdictions and expand into multiple states; (2) that the growth and the amount of complexity of air pollution brought about by urbanization, industrial development, and increased use of motor vehicles has resulted in growing dangers to the public health and welfare, crops, property, and air and ground transportation; and (3) that the prevention and control of air pollution at its source was the primary responsibility of the state and local governments and that federal financial assistance and leadership was necessary for the improvement of air quality.

The law provides an elaborate federal–state scheme for controlling conventional pollutants, such as ozone and carbon monoxide. The 1990 amendments create tighter controls on tail pipe exhaust; reduction of acid rain, nitrogen oxides, and air toxics, which may be carcinogenic; and protection of the ozone layer by phasing out chlorofluorocarbons, carbon tetrachloride, methylchloroform, and hydrochlorofluorocarbons. Over the past 10 years, the EPA has added numerous regulations to further upgrade air quality.

The Chemical Safety Information, Site Security and Fuels Regulatory Relief Act of 1999 establishes new provisions for reporting and disseminating information under the provisions of the CAA. The law has two distinct parts that pertain to flammable fuels and public access to worst-case scenario data. Flammable fuels used as fuel or held for sale as fuel at a retail facility are removed from coverage under the risk management plan submitted to the EPA required by the CAA. Flammable fuels used as a feedstock or held for sale as fuel at a wholesale facility are still covered by the CAA. The law exempts worst-case scenario data from disclosure under the Freedom of Information Act and limits its public availability for at least 1 year. The federal government is to assess the risks of Internet posting of these data and to determine the benefits of public access to the data. These data are to be available to qualified researchers as long as they do not release it to the public.

CERCLA of 1980, also known as the Superfund, was designed to handle the problems of cleaning up the existing hazardous waste sites in the United States. The act, which was originally passed in 1980, was updated numerous times until 1988. The hazardous waste problems range from spills that need immediate attention to hazardous waste dumps that are leaking into the environment and posing long-term health and environmental hazards.

SARA, reauthorized and amended by CERCLA, expanded the federal government response and authority, clarified that federal facilities were subject to the same requirements as private industry. The CERCLA response effort is guided by the National Oil and Hazardous Substances Pollution Contingency Plan, better known as the National Contingency Plan. This plan describes the steps that responsible parties must follow in reporting and responding to situations in which hazardous substances are released into the environment.

The Emergency Planning and Community Right-to-Know Act of 1986 established state emergency response commissions, emergency planning districts, emergency planning committees, and comprehensive emergency plans. A list of extremely hazardous substances has been prepared and published.

This law was passed in response to concerns about the environmental and safety hazards potentially caused by the storage and handling of toxic chemicals. These concerns were triggered by the disaster in Bophal, India, in which more than 2000 people died or were seriously injured from the accidental release of methyl isocyanate. The various states and facilities are required to notify local emergency planning districts concerning materials stored at, or released from, those sites. The local community has to prepare plans that will deal with the emergencies relating to the hazardous substances and must inform local residents of the potential for serious problems.

The amendments to the Emergency Planning and Community Right-to-Know Act Sections 311 and 312 were passed in 1999. These final rules raise the gasoline and diesel fuel thresholds that trigger material safety data sheets reporting and chemical inventory reporting. It is now possible to store 75,000 gal of gasoline or 100,000 gal of diesel fuel entirely underground at retail gas stations without having to comply with the rules on underground storage tanks.

The Energy Reorganization Act of 1974 redirected federal energy efforts. Congress created the Nuclear Regulatory Commission and the Energy Research and Development Administration, which later became the Department of Energy in 1977. The Energy Reorganization Act also established the goal of efficient energy utilization while enhancing environmental protection.

The Energy Supply and Environmental Act of 1974 was updated in 1978. The purposes of this act were to provide for a way to assist in meeting the country's fuel requirements in a consistent, practical manner, and to protect and improve the environment. It allowed for coal conversion or coal derivatives to be used in place of oil in power plants. This, of course, can contribute to greater levels of air pollution.

The CPSA of 1970, updated in 1984, established the Consumer Product Safety Commission as an independent regulatory agency. The CPSA gives the commission the power to regulate consumer products and to oppose unreasonable risks of injury or illness. It also regulates consumer products, except for foods, drugs, pesticides, tobacco and tobacco products, motor vehicles, aircraft and aircraft equipment, and boats and boat accessories. The law authorized the commission to publish consumer product safety standards to reduce the level of unreasonable risks. The commission has recalled hair dryers containing asbestos because of potential hazards. It also may regulate carcinogens.

The Federal Facility Compliance Act amends Section 6001 of RCRA to specify that federal facilities are subject to "all civil and administrative penalties and fines, regardless of whether such penalties or fines are punitive or coercive in nature." Therefore, the federal government was made to adhere to the same legal framework as the private sector and to comply with all applicable environmental rules and regulations.

The FIFRA was originally passed by Congress in 1947 and was amended in 1996 by the Food Quality Protection Act. It provides for the registration of new pesticides; the review, cancellation, and suspension of registered pesticides; and the reregistration of pesticides. It is concerned with the production, storage, transportation, use, and disposal of pesticides. It also includes areas of research and monitoring.

A new safety standard, "reasonable certainty of no harm," must be applied to all pesticides used on foods.

The Food, Drug and Cosmetic Act, which is an amendment to the Food and Drug Act of 1906, and the federal FDCA of 1938, has been further amended numerous times. It was the first federal statute to regulate food safety. The amendment of 1938 established the general outlines for the authority of the Food and Drug Administration (FDA). Various parts of the law regulate food additives; food contaminants; naturally occurring parts of food or color additives to food, drugs, or cosmetics; and potential carcinogens. In 1958, the Food Additives amendment, better known as the Delaney clause, stated, "… that known additives shall be deemed to be unsafe if found to induce cancer when ingested by man and/or animal, or if it is found, after tests which are appropriate for the evaluation of food additives, to induce cancer in man or animal …."

In 1996, the Congress replaced the outdated Delaney clause with a scientific-based data program used to determine food safety and pesticide availability. The new law, enacted on August 3, 1996, is the Food Quality Protection Act that establishes national uniform safe residue levels for pesticides and allows consideration of the benefits to nutrition and food supply of these pesticides. It also provides important incentives and better methods of registration for new chemicals, safer crop protection chemicals, and high-value minor crops. It establishes an extra margin of safety for residues on foods consumed in high amounts by infants and children. It requires consideration of chemical exposure from sources other than food, such as drinking water and home pesticide use. It requires consideration of common mechanisms of toxicity from other chemicals. The safety standard provided by the new law of reasonable certainty of no harm is a more flexible standard than the zero-risk Delaney clause. The extra margin of safety for infants and children would be imposed only when there were demonstrable health effects shown in the data in the registration of the pesticide. Risk assessments for food exposure would be based on the best available information. When data were absent or incomplete, better data would be obtained before regulatory decisions were made. Risk assessments would be based on actual, not theoretical health risks, when dealing with multiple sources of exposure. The implementation process for the new law would be open, transparent and follow established administrative procedures for federal rules and regulations. The registration of new crop protection products would be accelerated.

The Food Quality Protection Act of 1996 made changes in the FIFRA as well as in the federal FDCA, with the EPA establishing tolerances (maximum legally permissible levels) for pesticide residues in food.

The Hazardous Materials Transportation Act of 1975 as amended by the Hazardous Materials Transportation Uniform Safety Act of 1990 is the major transportation-related statute affecting the Department of Transportation. The objective of the law, according to Congress, is to improve the regulatory and enforcement authority of the Secretary of Transportation to protect the nation adequately against risk to life and property that are inherent in the transportation of hazardous materials and commerce. The 1990 act included provisions to encourage uniformity among different state and local highway routing regulations, to develop criteria for the issuance of federal permits to motor carriers of hazardous materials, and to regulate the transport of radioactive materials.

The Noise Control Act of 1972 was amended last in 1978. The findings of Congress were as follows: (1) that inadequately controlled noise presents a growing danger to the health and welfare of the population of the United States; (2) that the major sources of noise include transportation vehicles and equipment, machinery, appliances, and other products used in commerce; (3) that, although the primary responsibility for control of noise belongs to the state and local governments, federal action is needed to deal with major noise sources in commerce.

Because aircraft contribute considerable amounts of noise to the environment, two laws were passed and further amended to reduce these noise sources. The first law was titled an Act to Require Aircraft Noise Abatement Regulation. This law was signed in 1968 and amended several times until it became the Quiet Communities Act of 1978. Then Congress decided to control and abate aircraft noise and sonic booms. The second law was the Aviation Safety and Noise Abatement Act of 1979, enacted in 1980 and amended in 1982. The purpose of the act was to provide assistance to airport operators to prepare and carry out noise compatibility programs, to provide assistance to assure continued safety in aviation, and to serve other purposes. It helped establish a single, reliable system for measuring noise, and also a single system for determining the exposure of individuals to noise at airports.

In early 1981, the Director of the Office of Noise Abatement and Control at the EPA was informed that the White House Office of Management and Budget had decided to end funding for the noise control agency and that the matter was nonnegotiable. Of the 28 environmental health and safety statutes passed between 1958 and 1980, the Noise Control Act of 1972 is the only one stripped of budgetary support. Because Congress did not repeal the law, the EPA remains legally responsible for enforcing the regulations issued under this act, without any budgetary support legislated for that purpose. Noise continues to be a serious public health hazard.

The Occupational Safety and Health Act of 1970 established the Occupational Safety and Health Administration (OSHA), and the National Institute for Occupational Safety and Health (NIOSH). OSHA sets and enforces regulations to control occupational health and safety hazards, including exposure to carcinogens. NIOSH is responsible for research; for various evaluations, publications, and training; and for the regulation of carcinogens by supporting epidemiological research and recommending changes in health standards to OSHA.

The Occupational Health and Safety Act provides three mechanisms by law for setting standards to protect employees from hazardous substances. The act initially authorized OSHA to adopt the health and safety standards already established by federal agencies or adopted as national consensus standards. This authority was given for the first 2 years in 1972 and 1973. The act also authorizes OSHA to issue emergency temporary standards (ETSs) that require employers to take immediate steps to reduce workplace hazards. The ETSs may be issued by OSHA when the agency determines employees are exposed to grave danger and emergency standards are necessary. Although the public has not had a chance to comment on a standard, because of the nature of the potential hazard, it must be enforced. However, the final standard must be issued within 6 months of the emergency standard. The third way that OSHA sets standards is to issue new permanent exposure standards and to modify or revoke existing ones. However, the informal rule making that goes along with modifying or revoking existing standards is subject to court review. The OSHA approach to rule making can result in requirements in monitoring and medical surveillance, workplace procedures and practices, personal protective equipment, engineering controls, training, record keeping, and new or modified permissible exposure limits (PELs). The permissible exposure limits are the maximum concentration of toxic substances allowed in the workplace air.

NIOSH has published many occupational safety and health guidelines with technical information about chemical hazards for workers. In addition, the institute publishes the criteria documents (CDs), alerts, current intelligence bulletins (CIBs), health and safety guides (HSGs), symposium or conference proceedings, NIOSH administrative and management reports, scientific investigations, data compilations, and other worker-related booklets. The CDs are recommended occupational safety and health standards for the Department of Labor. Usually, a recommended exposure limit (REL) is part of the recommended standard. The CIBs relate important public health information and recommend protective measures to industry, labor, public interest groups, and academia. The HSGs provide basic information for employers and employees to help ensure a safe and healthful work environment.

OSHA in 1994 adopted standards related to air quality in indoor work environments. The standards were based on a preliminary determination that employees working in indoor environments faced a significant risk of impairment to their health due to poor indoor air quality, and that compliance with the provisions proposed in the notice would reduce that risk. The standards were proposed to apply to all indoor, but not industrial work environments with the environmental tobacco smoke provision also applying to industrial work environments. Employers were to implement controls for specific contaminants and their sources such as outdoor air contaminants, microbial contaminants, maintenance and cleaning chemicals, pesticides, and other hazardous chemicals within the work environment. The regulations were to include sick building syndrome, building-related illnesses, indoor air contaminants, microbial contaminants, environmental tobacco smoke, exposure to the sources, various health effects, risk assessments, and regulatory impact.

The Oil Pollution Act of 1990 streamlined and strengthened the EPA's ability to prevent and respond to catastrophic oil spills. A trust fund financed by a tax on oil is used to cleanup oil spills if the responsible party is unable or unwilling to do so. The law requires all oil storage facilities and vessels to submit plans detailing how they will respond to large discharges. EPA has published regulations for aboveground storage facilities whereas the Coast Guard has done so for oil tankers.

The Pollution Prevention Act of 1990 focused industry, government, and public attention on reducing the amount of pollution through cost-effective changes in production, operation, and raw materials use. Pollution prevention also includes increased efficiency in the use of energy, water, other natural resources; and the protection of our resource base through conservation, recycling, source reduction, and use of sustainable agriculture. Congress determined that the nation produced millions of tons of pollution each year and spent tens of billions of dollars controlling this pollution. There were significant opportunities for industry to reduce or prevent pollution at the source through cost-effective changes in production, operation, and raw material usage. Such changes offered industry substantial savings in reduced raw materials, pollution costs, and liability costs as well as protected the environment and reduced risks to workers' health and safety. A change was made in the focus on rules and regulations to emphasize multi-media management of pollution and source reduction instead of only treatment and disposal. Congress declared that it be the national policy that pollution should be prevented or reduced at the source whenever possible and that recycling where feasible be used in an environmentally safe manner.

The Radon Gas and Indoor Air Quality Research Act of 1986 included the following findings by Congress: (1) high levels of radon gas pose a serious health threat in structures in certain areas of the country; (2) certain scientific studies suggest that exposure to radon, including naturally occurring radon and indoor air pollutants, may cause a public health risk; (3) existing federal radon and indoor air pollution research programs are fragmented and underfunded; (4) need exists for adequate information concerning exposure to radon and indoor air pollutants; and (5) this need should be met by appropriate federal agencies. Additional radon legislation was passed in 1988 as part of TSCA.

RCRA of 1976 was updated through 1988. This law replaced the previous Solid Waste Disposal Act. The Used Oil Recycling Act of 1980 amended RCRA and then was incorporated into the main text of the act.

RCRA provides for regulating the treatment, transportation, and disposal of hazardous waste. Hazardous waste is defined as solid waste that may cause death or serious disease, or may present a substantial hazard to human health or the environment if it is improperly treated, stored, transported, or disposed. Solid waste includes solid, liquid, semisolid, or contained gaseous materials from a variety of industrial and commercial processes. This definition excludes solid or dissolved materials found in domestic sewage or related to irrigation, industrial discharges subject to CWA, or mining wastes. RCRA requires the EPA to develop and issue criteria for identifying the characteristics of hazardous wastes. Defining characteristics of hazardous wastes are:

1. It poses a present or potential hazard to human health and environment when it is improperly managed.
2. It can be measured by a quick, available, standardized test method; or it can be reasonably detected by generators of solid wastes through their knowledge of their wastes: ignitability, corrosivity, reactivity, and extraction procedure toxicity.

RCRA also includes the regulation of underground storage tanks that may be used for a variety of storage processes. Further, this act includes a program in medical waste tracking.

In 1996, the Land Disposal Program Flexibility Act was signed into law. It modifies the Hazardous and Solid Waste Amendments of 1984. It provides that