# Indoor Air Quality and Human Health

Isaac Turiel

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# Preface

The primary impetus for writing this book came about as I discovered a lack of publicly available and understandable information on the subject of indoor air pollution and its public health effects. Through my work at Lawrence Berkeley Laboratory, I found that many people outside the research community were interested in learning of the results of the laboratory's research and wished to apply this knowledge to their own situations. My colleagues and I often received requests from architects, ventilation engineers, health professionals, reporters, and members of the general public for information on indoor air pollution.

My objectives are to provide general information on indoor air pollution sources and the pollutants commonly found indoors, and also to explore the potential health effects arising from exposure to these pollutants. At this time it is not possible to predict accurately the health risks for people living in homes with air quality problems relative to those living in homes without such problems. However, guidance can be given as to what exposure levels are likely to cause adverse health effects and what control techniques are available to ameliorate these effects. Since this is a rapidly evolving field of research, it is probable that new and important research will become available during the time it takes to bring this book to market. A revised edition of this book will most likely be necessary in several years.

This book attempts to reach several types of readers. First, I hope it will be read by architects and engineers involved in building design, environmental-health practitioners concerned with the health effects of indoor air pollutants, and government officials at various levels involved with the regulatory aspects of the indoor air environment. In addition, I would like to reach the concerned citizen who wants to learn more about

particular issues; for example, many office workers and homeowners have a lively interest in the potential health effects of breathing other people's cigarette smoke or of being exposed to formaldehyde emitted from urea-formaldehyde foam insulation. Another topic that many readers will probably find of interest is that of choosing appropriate control techniques for various pollutants.

The scope of research on indoor air pollution is wide and ever-changing. It is not possible to cover all areas of research in detail in one book of this size. Readers who wish to delve deeper into any topic are referred to the Sources and Suggested Reading for each chapter, at the end of the book. There are many more journal articles and reports available than can be referenced here, but those that are cited provide an entrée into the literature.

The sources referred to in this book were selected to illustrate particular points. In many cases, numerous articles illustrate the same point. I trust that researchers will not feel slighted if their work is not discussed, since what the book offers is not a literature review but rather a balanced discussion of the issues of indoor air pollution.

In order to reach a wide audience with diverse backgrounds, it was necessary to explain some concepts and define some terms that are well known to some readers of this book. I hope that this has been done without either irritating the knowledgeable or mystifying the newcomer. On the other hand, I have decided not to define such terms as hydrocarbons and nitrogen oxides in the text but to reserve such definitions for the Glossary.

Several readers reviewed the manuscript and offered suggestions, noted omissions, or discovered inaccuracies. These people are Dorothy Dickey and William Nazaroff of Lawrence Berkeley Laboratory; Ken Sexton, Director of the Indoor Air Quality Program at the Department of Health Services, State of California; Dr. John Spengler of the Harvard School of Public Health; and Professor Frederick Shair of the California Institute of Technology.

My wife, Ellen Matthews, wrote part of Chapter 10 on legal aspects of indoor air pollution and also reviewed the entire manuscript, offering many helpful suggestions. Finally, several people at Stanford University Press offered encouragement and editing advice along the way, most notably Grant Barnes and William Carver. I want especially to thank Andrew Alden for suggesting many valuable editorial improvements.

I.T.

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# 1

# Introduction

On the average, North Americans and Europeans spend 80 to 90 percent of their time indoors; thus, the air we breathe is mostly indoor air. Although that may appear to be obvious, until recent years most health studies did not take this fact into account. In the past, studies concerned with the effects of air pollutants on human health considered only the exposure to outdoor pollutants, but indoor pollutants are a distinct and diverse group of their own.

In order to understand the effects of airborne substances on human health, it is important to know how much time people spend both outdoors and indoors, and also the concentrations of the pollutants to which they are exposed. Working people divide their time between home and work, while homemakers spend as much as 85 percent of their time at home. At home, people smoke, cook, paint, clean, heat the air for comfort, and carry out many other activities that can add harmful substances to the indoor air. The house itself, even the soil beneath it, can be a source of indoor air contaminants. Table 1.1 summarizes the main sources of indoor air pollutants and the contaminants they emit. Note that not all of these contaminants come from indoor sources.

Awareness of indoor air quality could be said to be a child of the 1973 oil embargo, for with that event came the surge of energy-conserving practices and devices that had a direct effect on the nation's indoor air. Making machines run more efficiently and designing furnaces to waste less heat are entirely beneficial actions, but putting certain types of insulation in houses, reducing ventilation in office buildings, and stopping drafts by "tightening" homes had unexpected side effects: indoor air pollution–related complaints began to increase as pollutants were kept bottled up

Table 1.1. Summary of Sources and Types of Indoor Air Pollutants

| Sources | Pollutant types |
|---|---|
| Outdoor | |
| Stationary sources | Sulfur dioxide, ozone, particulates, carbon monoxide, hydrocarbons |
| Motor vehicles | Carbon monoxide, lead, nitrogen oxides |
| Soil | Radon, microorganisms |
| Indoor | |
| Building construction materials | |
| Concrete, stone | Radon |
| Particle board, plywood | Formaldehyde |
| Insulation | Formaldehyde, fiberglass |
| Fire retardant | Asbestos |
| Paint | Organics, lead |
| Building contents | |
| Heating and cooking combustion appliances | Carbon monoxide, nitrogen oxides, formaldehyde, particulates |
| Copy machines | Ozone, organics |
| Water service | Radon |
| Human occupants | |
| Metabolic activity | Carbon dioxide, water vapor, odorants |
| Biological activity | Microorganisms |
| Human activities | |
| Tobacco smoking | Carbon monoxide, particulates, odorants |
| Aerosol sprays | Fluorocarbons, odorants |
| Cleaning | Organics, odorants |
| Hobbies and crafts | Organics, odorants |

indoors for longer periods of time. It should be noted that not all indoor air quality problems are a result of energy-efficiency improvements.

Several of these pollutants are of great importance and appear frequently in the news. Although our knowledge is still incomplete, the consensus is that three contaminants deserve the most intense study: (1) radon, a natural radioactive gas, (2) formaldehyde, a widely used chemical that emanates from many household items, and (3) tobacco smoke. The health effects involved range from eye and throat irritation through asthma and chronic respiratory disease to lung cancer.

These three do not exhaust the list. Residential kerosene heaters have dangers known and not-so-well known. Schools and offices may subject their occupants to asbestos-laden air. Many modern, airtight offices have been subject to epidemics of "tight-building syndrome." Utility-sponsored programs to weatherize houses, if not done carefully, may have unexpected impacts on customers' health. Finally, there are the spectacular outbreaks of illnesses such as Legionnaire's disease. This book provides the most up-to-date information for each of these issues, including ways to control exposure to contaminants indoors.

## Exposures and Standards

Two factors that must be assessed in order to predict health effects are exposure levels and typical human responses for various levels of exposure. The type of exposure meant here is an *integrated* exposure, that is, the mathematical product of a pollutant concentration a person is exposed to and the time period over which the exposure occurs. Because the concentrations of pollutants that an individual is exposed to over the course of a day are often highly variable, the job of determining integrated exposures can be very difficult. Exposures may be acute (high concentrations for short time periods) or chronic (low concentrations for long time periods). Adverse health effects can be produced by either type of exposure.

For some airborne pollutants, the health effects of short-term exposures are well known. Data are often lacking, however, for long-term exposures to low concentrations of pollutants as experienced by occupants of residential and commercial buildings. The effect of a pollutant is often expressed in the form of a dose-response relationship. The *response* may range from eye irritation or headaches to lung cancer or death. For most of the pollutants we consider, the *dose* can be thought of as the amount of contaminant inhaled and reaching a particular part of the body; the dose is thus dependent upon the integrated exposure, the rate at which the individual takes in air, and the body's clearance rate for each contaminant. It is important to keep in mind that individuals vary in their respiratory rates and in their responses to various contaminants.

The federal government's efforts to monitor and improve air quality have concentrated on measuring pollutant concentrations in outdoor air and on controlling sources of outdoor air pollution. Because of this emphasis, there are large gaps in our knowledge of the integrated exposures to air pollutants experienced by various segments of the population. For example, we know comparatively little about the characteristics and concentrations of pollutants that homemakers, young children, and infirm adults are exposed to at home; neither are office workers a well-studied group. There are, however, a substantial number of studies from which we can make inferences about the range of exposures experienced by these groups given specific assumptions.

Once typical exposures are determined, health effects can be estimated for some pollutants. In this book we compare typical pollutant exposures to either dose-response relationships or to government health standards. These two approaches are often equivalent, since in most cases the health standards are derived from analysis of dose-response relationships. The health standards we refer to are those established by the Occupational