



# Project Summary

## Review of Recent Research in Indoor Air Quality

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**This report reviews indoor air quality research in an effort to define the state-of-the-art.**

**Several approaches were taken. About 150 recent journal articles, symposium presentations, and bibliographic reports were reviewed and are presented in an annotated bibliography, arranged by subject. In addition, about 30 prominent researchers in indoor air quality were contacted, these contacts are summarized. Significant articles (prior to 1980) were also reviewed; these are listed in a separate unannotated bibliography. Two tables summarize the information in the annotated bibliography and contact summaries.**

**The report also briefly discusses the quality and apparent deficiencies of the reviewed data base of articles, reports, and books.**

***This Project Summary was developed by EPA's Industrial Environmental Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).***

### Introduction

Indoor air quality is recognized as a significant factor affecting the well-being of the average American. In recent years, energy conservation (e.g., weatherizing buildings and the greater use of unvented combustion (heating) devices) has apparently increased indoor concentrations of hazardous air pollutants. Thus the identification and evaluation of sources of indoor air pollution and their control has received increasing attention

from Federal and State agencies concerned with health and environmental protection.

The objective of this report is to establish the state-of-the-art in indoor air quality research by contacting prominent researchers in the field, summarizing their efforts and capabilities, and reviewing published articles and reports. The report is intended to assist the indoor air quality research community in assessing the content and quality of its recent research efforts, to highlight milestone indoor air quality studies or symposia, and to identify research facilities available to the user community. This information should enhance coordination of government and private research efforts.

### Procedure

The attempt to define the state-of-the-art in indoor air pollution research involve a review of recent literature, and telephone contacts with prominent investigators. The literature review includes searches of computer files, citation lists in several compendiums, and review articles. Manual searches of journals that frequently publish indoor air quality research provided articles current through December 1983. Primary emphasis was on peer-reviewed journal articles, rather than government reports or symposium presentations. Personnel at about 30 prominent investigating laboratories were contacted to assess the extent of ongoing research in indoor air quality. Specific inquiries into the nature of the work, measurements performed, funding levels, sponsor, and special facilities provided an up-to-date inventory. The report includes an

annotated bibliography and summaries of contacts with investigators.

## Results and Discussions

The principal result of the literature review was an annotated bibliography, arranged by subject. Most citations in the bibliography are from peer-reviewed journal articles, dated between 1980 and 1983. Presentations from a few, very recent symposia are also included to provide the most current work. Government reports -- other than annotated bibliographies, literature reviews, or general treatises -- are not included. Some pre-1980 articles were included because their subject matter seemed unique or they represented significant work that was frequently cited thereafter.

As shown in the Table 1 outline, the bibliography is organized under five major headings: I. Characterization and Measurement, II. Control Methods, III. Health Studies, IV. Modeling, and V. General Reviews. Areas I, II, and IV were of prime concern for this project, and, consequently, are further divided into topics. Many articles, of course, span several subject areas; where this occurs, the work was classified according to the primary objective of the research.

The annotated bibliography is by no means complete. Nevertheless, several observations may be made about these studies and perhaps generalized to indoor air quality research. "Characterization and Measurement" (Area I) has certainly received the most attention. Researchers have expended much effort to sample various premises for levels of certain pollutants. In some studies, an identified pollutant source (e.g., a gas-fired range) is present; in others, many premises are sampled to determine an average exposure level; or an attempt is made to relate indoor to outdoor pollutant levels. Many studies seem to reflect the perception that indoor air quality is determined largely by outdoor air quality. Two significant changes in the habits of building occupants challenge this perception: (1) the reduction of air infiltration rates to conserve energy has further insulated indoor from outdoor air, and (2) the popularity of unvented combustion sources for space heating suggests that indoor pollutant sources may be far greater than outdoor sources. However, few studies have attempted to determine emission rates from these unvented combustion sources.

In "Control Methods" (Area II) most studies have measured the effect of ventilation rates on indoor air quality.

**Table 1. Outline of Annotated Bibliography**

I.	<i>Characterization and Measurement</i>
A.	<i>Aerosols</i>
	1. <i>Indoor aerosols</i>
	2. <i>Tobacco smoke</i>
	3. <i>Asbestos</i>
	4. <i>Fibrous glass and mineral wool</i>
	5. <i>Viable aerosols</i>
B.	<i>Indoor/Outdoor Relationships</i>
	1. <i>Fixed site</i>
	2. <i>Exposure monitoring</i>
C.	<i>Gaseous Pollutants</i>
	1. <i>Inorganics (also CO, CO<sub>2</sub>)</i>
	2. <i>Organics (not CO, CO<sub>2</sub>)</i>
D.	<i>Radon</i>
E.	<i>Consumer Products</i>
F.	<i>Combustion Sources</i>
G.	<i>Odor</i>
II.	<i>Control Methods</i>
A.	<i>Air Purifying Methods</i>
B.	<i>Ventilation</i>
C.	<i>Source Modification</i>
D.	<i>Miscellaneous</i>
III.	<i>Health Studies</i>
IV.	<i>Modeling</i>
A.	<i>General Models</i>
B.	<i>Radon</i>
C.	<i>Formaldehyde</i>
D.	<i>Ozone</i>
V.	<i>General Reviews</i>
A.	<i>Treatises</i>
B.	<i>Bibliographies</i>

This trend may also reflect the early emphasis on ventilation as the principal control option. Few studies deal with other control options (e.g., air purification), and only one study considered source modification to reduce emission rates. In "Modeling" (Area IV), several studies attempted to predict indoor pollutant levels using mass-balance approaches. These models typically consider one or perhaps a few pollutants and are

therefore incomplete in characterizing indoor environment. Their accuracy is also limited by the input parameters, e.g. source emission rates and mixing factors.

In summary, based on a review of the articles contained in the annotated bibliography, several study areas appear to deserve further investigation including: (1) determining source emission rates, especially with regard to their use in mathematical models; (2) further study of control options (e.g., air purifiers and source modification); and (3) more sophisticated modeling efforts that consider more than one or two pollutants.

Twenty-three organizations considered active in indoor air quality research were contacted by telephone. The report documents these contacts, summarizing the information that was obtained. The information includes the name of the investigator, project sponsor, project title, and a general description and categorization of the research. Separate contact summaries are provided for each project; thus, a particular organization may have several summaries.

## Conclusions and Recommendations

The review of current literature (through December 1983) and the telephone survey of prominent investigators indicate that most indoor air quality research has been directed toward the characterization and measurement of indoor pollutants. Within this area, many studies have sought to establish an average concentration level of a pollutant or the relationship between indoor and outdoor pollutant levels.

A small but significant body of research provides preliminary information on source types and emissions. Particular emphasis has been directed toward the characterization of sources of formaldehyde and home combustion sources. Control and mitigation of indoor air quality problems has generally emphasized the use of ventilation techniques.

Mathematical modeling of indoor air concentrations has been attempted; results indicate some success, based on comparisons with pollutant monitoring results.

Further study to characterize emission rates from exclusively indoor sources (e.g., kerosene heaters) would be beneficial. Also of benefit would be further study of control options other than ventilation; e.g., source modification to reduce emission rates or air purifying

methods to reduce pollutant levels. The development of mathematical models could lead to a cost-effective mechanism for assessing the total health significance of indoor air quality. Expanding these models to consider a wider range of pollutants (or integrating them with laboratory and field measurements of input parameters) would provide a more complete characterization of the indoor environment.

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*The complete report, entitled "Review of Recent Research in Indoor Air Quality," (Order No. PB 84-206 515; Cost: \$17.50, subject to change) will be available only from:*

*National Technical Information Service  
5285 Port Royal Road  
Springfield, VA 22161  
Telephone: 703-487-4650*

*The EPA Project Officer can be contacted at:  
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