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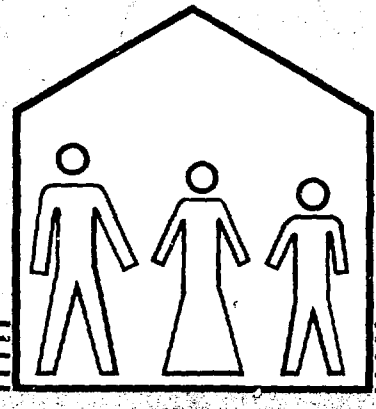
ABSTRACT BOOK

SEVENTH ORNL LIFE SCIENCES SYMPOSIUM

INDOOR AIR AND HUMAN HEALTH:

Major Indoor Air Pollutants and Their Health Implications



Knoxville, Tennessee · October 29–31, 1984

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PROGRAM HIGHLIGHTS

Sunday, October 28

5:00	**Registration** (continuing each day throughout the symposium)
7:30–9:00	**Mixer**

Monday, October 29

8:00	Speakers' Breakfast
9:00	**Opening Session**
10:15–12:30	**Session I. Radon**
2:00–4:35	**Session II. Microorganisms**
6:30	**Reception** (no-host bar)
7:30	**Banquet**

Tuesday, October 30

8:00	Speakers' Breakfast
9:00–12:05	**Session III. Passive Cigarette Smoke**
1:35–4:40	**Session IV. Combustion Products**

Wednesday, October 31

8:00	Speakers' Breakfast
9:00–12:05	**Session V. Organics**
1:35–2:55	**Session VI. Panel and Audience Discussion**
2:55	**Closing**

OPENING SESSION

INDOOR AIR QUALITY—ELECTRIC UTILITY CONCERNS

R. M. Perhac
Electric Power Research Institute
Palo Alto, California

The electric utility industry has interest and a stake in indoor air quality for two principal reasons. The first relates to energy conservation and the second to ambient air quality standards and the protection of human health. Because of its concern for conservation, the industry in many parts of the nation has been promoting more extensive use of home insulation, solar-heated homes, and construction of homes and other buildings with low air-exchange rates. These all lead to lower air-exchange rates and the attendant potential concern that pollutants might accumulate indoors and thereby pose a health concern.

The second reason deals with human health in general terms of man's overall activities. Man spends over 75% of his time indoors, yet ambient air quality standards are based on outdoor measurements. Further, standards are designed to protect the most sensitive segments of the population, that is, those persons who spend perhaps even more than 75% of their time indoors. If we are to evaluate man's total exposure to atmospheric pollutants, we need an accurate assessment of indoor atmosphere as well as the overall mobility pattern of individuals. Whether or not, therefore, the indoor environment poses a threat to health, we need information on the indoor environment to assess total exposure.

EVALUATION OF CHANGES IN INDOOR AIR QUALITY OCCURRING OVER THE PAST SEVERAL DECADES

R. B. Gammage
Health and Safety Research Division
Oak Ridge National Laboratory
Oak Ridge, Tennessee

D. T. Mage
Data Management and Analysis Division
Environmental Protection Agency
Research Triangle Park, North Carolina

Since World War II, there are good reasons for believing that the overall quality of indoor air has decreased inside buildings. Two factors appear primarily responsible for such a reduction: (1) New materials composed of (or containing) synthetic chemicals have multiplied in number and in the extent of their incorporation into building materials, insulation, furnishings, and other household materials. (2) The energy crises of the 1970s encouraged the construction of better-insulated and more air-tight buildings and the use of alternative sources of heating.

The attendant lower rates of the ingress of fresh air have tended to promote increased concentrations of airborne contaminants. Occupants of modern energy-efficient buildings are more prone to experience ailments associated with the sick-building syndrome. Changes in human habits have sometimes served to change indoor air quality or increase the time spent indoors and thus the time of exposure. Examples of such changed personal habits are recently decreased cigarette smoking and increased TV watching. Some health-related issues that will be discussed (and are possibly related to changing indoor air quality) include increased numbers of perceived formaldehyde-related illnesses and decreasing male sperm densities in relationship to increasing organic exposures.

SESSION I

Radon

Chairman: *W. Lowder*
U. S. Department of Energy

OVERVIEW

Naturally occurring radioactive gas radon is always present in the air that man breathes. Indoor concentrations are typically 2 to 10 times those in outdoor air. Inhalation of the decay products of radon attached to particulates results in an alpha dose to the critical cells of the respiratory tract that has been shown to produce lung cancer in miners. Current estimates of radon exposure and the consequent risk indicate that on the order of 10% of nonsmoking-related lung cancers may be produced by radon. There are also hints in the current literature that the respective roles of radon and smoking in the induction of lung cancer may not be unrelated. Thus, radon has been generally recognized as one of the most significant indoor pollutants in terms of potential human health effects, considering both current exposure levels and the trend toward increased exposures induced by the application of advanced conservation technology in new housing.

The papers at this session will treat current knowledge concerning both radon exposure and risk—and the implications of the uncertainties in this knowledge for future research.

INDOOR RADON EXPOSURES: SOURCES, RANGE, AND ENVIRONMENTAL INFLUENCES

A. V. Nero, Jr.
Applied Science Division
Lawrence Berkeley Laboratory
Berkeley, California

The radiation dose from inhaled daughters of ^{222}Rn constitutes about half of the total effective dose equivalent to the general population from natural radiation. Moreover, it is clear that indoor levels are sometimes ten or more times the average, with the actual concentration dependent on a variety of factors. The apparent level of exposures and the risk of lung cancer estimated to be associated with them have given rise to a broad program of research characterizing indoor concentrations and the factors affecting them. In the United States, monitoring efforts in the actual housing stock, where the greatest part of the population dose occurs, have been piecemeal. Nonetheless, data from dozens of areas are available, and a systematic appraisal of this data strongly suggests that annual-average concentrations in single-family houses — the dominant element in the housing stock — are approximately lognormally distributed, with a geometric mean in the vicinity of 0.8 pCi/L ^{222}Rn and a geometric standard deviation of approximately 3. This implies an average residential indoor concentration exceeding 1 pCi/L and a substantial number of homes (perhaps a million) exceeding 8 pCi/L, the approximate equivalent of a recently recommended remedial action standard.

The main contributors to the wide range observed are variability in source strengths and ventilation rates, with the first being the more important. Variability in the equilibrium between ^{222}Rn and its daughters is thought to be of secondary importance. Considering the observed source strength in itself — estimated on the basis of measurements of indoor concentration and ventilation rate — it is clear that the radon observed indoors must arise primarily from the soil. Public water supplies drawn from groundwater are estimated to contribute only about 1% (with a larger but ill-defined contribution from private wells), with the contribution from building materials apparently in the same range. These observations have fostered considerable interest in characterizing the mechanisms for radon transport through soils and into homes, including what appears to be most important: air flow driven by the stack

effect and by winds. Investigating this question has a level of complexity and scientific challenge that is entirely comparable to that of work being carried out to understand the influence of particulates and air-movement patterns on the behavior of radon daughters — another question of substantial importance. More complete source characterization lies at the heart of efforts to efficiently identify geographic areas and homes with high concentrations and to effectively reduce unacceptably high levels.

LUNG DOSIMETRY AND RISK ASSESSMENT

N. H. Harley
Institute for Environmental Medicine
New York School of Medicine
New York, NY

Only within the past few years has the significance of the indoor levels of radon in homes been realized. Occupational standards have existed since the mid 1950s, yet indoor levels exceed the occupational standard in many locations. The basic data on lung cancer mortality from inhalation of the short-lived daughters of radon are obtained from the four large studies of underground miners. The results of these studies, which will not be complete for perhaps another 20 years, must be used for the purpose of projecting the lifetime risk to populations other than miners.

The alpha dose delivered to the bronchial epithelium from inhalation of the short-lived daughters can be used to assess the effects across populations since it is the dose that confers the lung cancer risk.

There are three major dosimetric models that have been developed by various radiation protection authorities in different countries. There are three major risk projection models developed to evaluate current environmental and occupational exposures. These dosimetric models and risk projection models will be critically reviewed with respect to their biological integrity, and the reasons for their widely divergent results will be described.

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EPIDEMIOLOGY AND RISK ASSESSMENT

W. H. Ellett and *N. S. Nelson*
Environmental Protection Agency
Washington, D.C.

A number of risk assessments have been developed to quantitate the potential risk from indoor radon. Although all of these assessments make use of essentially the same epidemiologic data base, estimated cancer risks differ by a factor of 6 or more, depending on the assumptions made in the subsequent analysis. The end result is that the estimated risks are relatively independent of the observed data. This indicated to us that a close examination of the assumptions might be worthwhile. That is, how closely does a particular assumption actually model the clinical observation and what is the numerical effect of a given assumption on the final risk estimate? We compare the assumption made by various groups of risk assessors (ICRP, NCRP, EPA, etc.) and attempt to identify which are the crucial assumptions that lead to such a wide numerical range in the estimated risks of lung cancer attributable to indoor radon.

EUROPEAN RADON SURVEYS AND RISK ASSESSMENT

F. Steinhäusler
Division of Biophysics
University of Salzburg
Salzburg, Austria

In western Europe, several large-scale national programs have been initiated in the past few years to assess the exposure of the general population to radon and radon daughters. The overall organization is carried out mainly by the Commission of the European Communities (CEC) under the present 1980–1984 Radiation Protection Research Programme. So that the comparability of the data obtained in several national studies can be ensured, the CEC has organized an international intercomparison programme in close collaboration with the Organization for Economic Cooperation and Development–Nuclear Energy Agency in Paris.

In the presentation, the largely varying key issues, ranging from exhalation studies to lung cancer risk assessments in the various European national programmes, will be addressed together with the current view of the regulatory aspects of the control of indoor radon daughter exposure.

SESSION II

Microorganisms

Chairman: *P. R. Morey*
National Institute for Occupational
Health and Safety

DIMENSIONS OF PROBLEMS WITH ALLERGENS AND PATHOGENS IN THE INDOOR ENVIRONMENT

P. R. Morey
Centers for Disease Control
National Institute for Occupational
Safety and Health
Morgantown, West Virginia

The extent of health problems caused by allergens and pathogens in the indoor environment is difficult to estimate. This is partly due to the broad array of arthropods, algae, protozoans, fungi, and bacteria that evoke human responses, and also to the broad range of environments in residential, commercial, and public buildings where exposure occurs. Despite uncertainty about the magnitude of the health effects caused by exposure, the impact of some allergens and pathogens is appreciable.

Outbreaks of hypersensitivity pneumonitis in both large and small office buildings are well documented. Attack rates vary from less than 1% to over 50%. Remedial measures have ranged from simply cleaning a component of the ventilation system to the total replacement of the heating and air-conditioning system together with all building furnishings. Cases of hypersensitivity pneumonitis in residences are also well documented, with the most common causes being contaminated forced-air heating systems, contaminated humidifiers, and flooding disasters.

Asthma may be caused by pollens, acarids (e.g., house dust mite), animal dander, fungi, and insect emanations. While the indoor environment offers some protection from pollen, the growth and proliferation of other allergens, especially molds and acarids, is encouraged by moisture and high relative humidity. Some studies in residences have been made on the parameters that are associated both with the elevation and with the reduction of microbial aerosols in the indoor environment.

The occurrence of Legionnaire's disease both in commercial buildings and in hospitals has been widely publicized. For the most part, Legionnaire's disease has been associated with the infiltration into the built environment of aerosols containing *Legionella pneumophila* from external sources such as cooling towers. Pathogenic microorganisms may also be disseminated into the intramural environment by the use of hot tubs (dermatitis caused by *Pseudomonas* spp.), whirlpools, cold mist vaporizers, and nebulizers.

The national concern for energy conservation has, especially in large buildings, brought about an emphasis on air recirculation at the expense of the introduction of make-up or outside air into the indoor environment. The increased use of recirculated air in buildings where infectious sources and susceptibles are present 24 h/d (e.g., hospitals, apartment houses) can become a serious problem if microorganisms are not removed by means of cleaning or preventive maintenance.

The purpose of this session on microorganisms is to introduce the topic of contamination of indoor air by microbial aerosols. We will emphasize exposure to airborne fungi and bacteria that may occur in various indoor environments, including residences, schools, office buildings, and hospitals. A common theme will be the potential risk associated with exposure to microbial aerosols in the building environment and what evidence, if any, there is for the association of increased risk and energy conservation measures. Practical solutions to problems as well as avenues for future research are highlighted.

INDOOR SOURCES FOR AIRBORNE MICROBES

H. A. Burge
University of Michigan
Ann Arbor, Michigan

Almost any interior surface, when wet, provides sufficient nutrients for one or more organisms to survive and often multiply. Bacteria, which primarily emanate from living hosts (human, animal, arthropod), may multiply in and become aerosolized from nonliving reservoirs such as humidifier fluids, air-conditioner surfaces, and flush toilet reservoirs. Fungi and actinomycetes, entering primarily from outdoor environments, may multiply in similar situations as well as on damp fabric, painted surfaces, and even petroleum hydrocarbon films.

Many appliances that provide enrichment environments for microorganisms also provide the impetus for their aerosolization. Thus, cool mist vaporizors, air conditioners, flush toilets, and refrigerators can actively spray microbial particles into the air. Human activity such as bed making, vacuuming, or cleaning contaminated appliances can strikingly increase microbial aerosol levels by disturbing spore-laden substrates.

Controlling indoor microbial pollution involves eliminating sources as well as substrates. Closed windows combined with air conditioning during the growing season will drastically reduce indoor mold spore levels. Limiting pet occupation of interiors may reduce bacterial loads. Maintaining relative humidity below 40% in summer and winter and keeping surfaces dry will prevent microbial growth. Regular thorough cleaning of necessary appliances and restricting the use of humidifiers and vaporizors will further reduce microbial levels.

While dangerous microbial pollution can be a severe problem, epidemiologically it is not common. Except in specialized environments, concern is necessary only when symptoms are present that indicate a possible interior allergen or pathogen exposure situation.

ENDOGENOUS MOLD EXPOSURE: ENVIRONMENTAL RISK TO ATOPIC AND NONATOPIC PATIENTS

P. P. Kozak
Cummins, Kozak and Gilman, Inc.
Orange, California

Continuous exposure to mold spores normally occurs both indoors and outdoors. Evaluation and documentation of exogenous mold exposure has traditionally been of interest mainly to the plant pathologist and allergist, whereas the pulmonologist, allergist, and epidemiologist have been primarily concerned with the indoor exposure.

Our knowledge of the variety and quantity of endogenous mold spore exposure is inadequate. Limited studies have been performed in the home, but most of these have been restricted to a single sample. Factors including rural location, shade, level of organic debris near the home, and landscape maintainance have all had an impact on the endogenous mold spore level. Simply closing doors and windows and sealing home interiors from the outdoors will reduce the indoor viable mold spore level to approximately 30% of that outdoors. A continuously operating central electrostatic filter can further reduce the endogenous viable mold spore level by an additional 50%.

When prolonged or repeated water damage occurs indoors, a variety of mold genera can selectively dominate the indoor mold spore flora. Some genera (*Chaetomium, Stachybotrys,* and *Torula herbarium*) flourish on jute-backed carpet, whereas other genera (especially the hyaline spores such as *Aspergillus, Penicillum,* and *Scopulariopsis*) thrive on water-damaged dry wall, wallpaper, paper products, and wicker and straw baskets.

Endogenous mold spore exposure can cause a variety of diseases depending on various host factors, concentration and frequency of exposure, and the viability or nonviability of the mold spores. Inhaling spores of *Aspergillus fumigatus,* as an example, could precipitate an episode of asthma or allergic bronchopulmonary aspergillosis in a sensitive atopic patient, or a lethal systemic infection in an immunocompromised patient.

A variety of sampling techniques exist for studying endogenous mold exposure. Depending on the particular interest of the researcher, one or more techniques are generally required to adequately define this exposure. These techniques were described earlier and include a variety of viable and nonviable volumetric procedures. All of these have a common

deficiency in that they measure an exposure at a stationary site. With recently developed personal volumetric samplers, we now have a tool for more precise measurements of patients/workers exposure. Significant home surveys using this new sampler have yet to be reported.

Using volumetric viable and nonviable techniques, we have been evaluating the endogenous mold spore exposure occurring in homes in Southern California for the past seven years. During that period, we have evaluated approximately 450 homes. Data will be presented regarding the normal endogenous mold exposure occurring in this area. Conditions associated with altering this exposure pattern will be discussed, along with its potential impact on inhabitants of those homes.

HYGIENIC SIGNIFICANCE OF MICROORGANISMS IN THE HOSPITAL ENVIRONMENT

R. B. Kundsin
Brigham and Women's Hospital
Harvard Medical School
Boston, Massachusetts

Microorganisms can be found in the environment associated with dust, droplets, and droplet nuclei. Their state of suspension determines their final deposition and also suggests the methods most appropriate for their control. Droplet nuclei are airborne for long periods and are carried by air currents until inhaled or vented. Their control is more difficult than that of dust and droplets which settle out rapidly on horizontal surfaces and can be eliminated by germicides. All can be destroyed by ultraviolet irradiation.

Urinary tract infections, surgical wound and respiratory tract infections rank highest in the hospital's overall nosocomial infections. What role the hospital's environment plays in each can be scientifically determined.

Patients and personnel can be victims as well as sources of microorganisms found in the environment: victims when they become colonized by hospital flora, sources when they become shedders of these microorganisms.

The airborne component of surgical wound infections depends on two factors: the number of shedding carriers in the operating room and the length of the procedure. A benign fallout of two organisms per square foot per minute becomes a thousand microorganisms per square foot of exposed tissue over an 8-h operation. Airborne particulates augment invasiveness.

Industry has been compelled to monitor and eliminate airborne particulates where precision processes are used. However, despite complex procedures, surgery is done and prostheses are implanted with complete abandon as to the viable and nonviable particulates circulating in the operating suite.

Strangely, the airborne dissemination of pollen is an accepted medical fact, whereas the impact of airborne transmission of bacteria and viruses is still disparaged.

IMPACT OF INDOOR AIR PATHOGENS ON HUMAN HEALTH

J. C. Feeley
Center for Infectious Diseases
Centers for Disease Control
Atlanta, Georgia

Respiratory infections have been estimated to cause 50 to 60% of all community-acquired illnesses. The economic impact of this both from the standpoint of health care cost and the loss of productivity in the work place is in the millions of dollars.

Although most of these infections are of viral etiology, bacterial diseases do occur and have caused substantial problems in settings such as hospitals, day care centers, and schools. *Legionella pneumophila*, the cause of Legionnaires' disease and Pontiac Fever, is a bacterium that has been predominantly associated with outbreaks in hospitals, office buildings, and hotels. It has been documented in some of these outbreaks to be transmitted by circulated conditioned air. Two other bacteria (*Neisseria meningitidis* and *Haemophilus influenzae*) that have been associated with outbreaks in day care centers and schools are examples of bacteria that are airborne in their spread but do not appear to be transmitted by recirculated conditioned air.

The sampling of air for these bacteria, the influence of energy conservation on their spread, and intervention methods for preventing their transmission will be discussed.

SESSION III

Passive Cigarette Smoke

Chairman: *I. Tager*
Channing Laboratory

OVERVIEW

The potential health consequence of passive exposure to cigarette smoke has become a subject of increased scientific and public debate. However, many issues remain to be resolved before a clearer picture of these consequences can emerge.

Identification and quantitation of environmental tobacco smoke presents problems related to the selection of the most relevant chemical compounds in terms of health effects. Some compounds that have been studied have alternative sources for their origin. Nicotine is a unique component, but its relationship to other constituents of tobacco smoke is poorly understood. Proper control for the many factors that influence the accumulation of products of tobacco smoke has not been applied in most studies. The interplay of factors that influence the deposition of an aerosol such as passive smoke requires elaboration so that more accurate estimates of actual exposures can be developed.

Current studies of the potential health effects of passive exposure to cigarette smoke have suggested effects on acute and chronic cardiopulmonary morbidity. However, methods for detecting exposure complicated by the incomplete control of potential confounding factors such as family size, socioeconomic status, etc., present the need for further investigation.

This session will explore each of the above issues in an attempt to define the present state of knowledge and to articulate the needs for further research.

CONSTITUENTS OF SIDE-STREAM AND MAINSTREAM TOBACCO SMOKE AND MARKERS TO QUANTIFY EXPOSURE

M. W. First
Harvard School of Public Health
Boston, Massachusetts

Identification and quantification of environmental tobacco smoke are fraught with difficulties that begin first by selecting which of the more than 3000 chemical compounds contained in tobacco smoke to measure, and then ultimately by judging how well the one(s) selected represent the totality of airborne tobacco smoke that may be present in a diversity of indoor environments. Often, the smoke components of greatest health interest are present in air in very low concentrations, thus making collection and analysis especially difficult. This had led to the widespread use of easily measured smoke components such as carbon monoxide and total suspended particulate matter as convenient surrogates for the constituents of real interest. The special problem associated with the use of these and most other surrogate compounds, even when they are present in sufficient amounts to be measured reliably, is the presence of alternative sources of the same or similar compounds unconnected with tobacco smoking and often generating higher concentrations.

Additional difficulties arise in connecting airborne tobacco smoke (usually composed of elements having very different residence times in air and hence very different reaction opportunities) to freshly formed mainstream smoke, about which almost all our knowledge of the composition and effect of tobacco smoke is related. Nicotine is a unique compound associated with tobacco that appears in the particulate phase of smoke in relatively high concentrations. It has low volatility when present in smoke particles, has low reactivity in air, and can be detected and measured at extremely low concentrations in air by simple and reliable methods. Nicotine appears to be the ideal tracer for environmental tobacco smoke and a well established metabolite of smokers; however, little information has been developed on how nicotine relates to all other constituents in tobacco smoke after dilution and variable residence times in air.

INDOOR AIR QUALITY AND HEALTH IMPACT IN THE RESIDENTIAL ENVIRONMENT

J. A. J. Stolwijk, M. Berwick, and *B. P. Leaderer*
Department of Epidemiology and Public Health
Yale University School of Medicine

J. B. Pierce
Foundation Laboratory
New Haven, Connecticut

In a study directed primarily at the effect on indoor air quality and human health of the use of unvented kerosene space heaters, we followed 169 households with kerosene space heaters and 164 control households for a period of 12 weeks. Data on the residential structure and equipment were obtained from tax assessor records and from a baseline questionnaire. The same questionnaire provided a simple health profile and a description of occupant behavior relevant to indoor air quality. For each of six 2-week periods, a telephone survey elicited from each household information about the use of kerosene heaters and about the presence of one or more of a list of 19 acute symptoms in the household. All households were monitored for total NO_2 exposure with a Palmes tube for one 2-week period. A number of households were also monitored for SO_2 and formaldehyde. A yet smaller number of households were monitored continuously for NO_2, NO, CO_2, SO_2, and particulates.

The results indicate an association of the number of hours of kerosene heater use with an increased number of days with reported symptoms in young children.

BIOLOGICAL POTENTIAL AND EXPOSURE–DOSE RELATIONSHIPS FOR CONSTITUENTS OF CIGARETTE SMOKE

J. Brain
Harvard School of Public Health
Boston, Massachusetts

Central to the issue of the potential health impact of passive cigarette smoking is an understanding of the fate of inhaled smoke. Deposition patterns of any aerosol such as passive cigarette smoke depend on the size, shape, and density of the individual particles or droplets. In particular, the description of particle diameters, preferably in terms of aerodynamic diameters, is essential. Time and concentration are important since they modify tobacco smoke through processes such as evaporation and agglomeration. Factors independent of particle size such as respiratory airway anatomy, breathing pattern, and underlying pulmonary disease also influence the deposition of tobacco smoke. Lung clearance mechanisms also affect deposition.

The concentration of respirable particulates in areas where there are smokers may range from 100 to 700 $\mu g/m^3$. This is up to 25 times higher than that found in nonsmoking areas. Assuming mean values for collection efficiency of 10% and 70% for passive and active smokers, respectively, the deposition would be approximately 0.50 mg for a nonsmoker over an 8-h day in a room with 500 $\mu g/m^3$ of smoke. In comparison, a smoker would deposit approximately 400 mg of tar in his/her lungs if he/she smoked two packs of cigarettes with an average tar rating of 20 mg per cigarette during the same time period. Although the amount of cigarette smoke deposited in the lungs during passive smoking is small compared to that encountered by the active smoker, large numbers of persons are involved. In the United States in 1979, 36.9% of men and 28.2% of women were current smokers (Surgeon General 1980). The majority of homes have at least one smoker. Thus, exposure to passive smoke by children, even in early childhood, is widespread and likely to remain so because of the increasing frequency of smoking among U.S. adolescent girls. Further study of dose and response is warranted.

CRITICAL REVIEW OF THE RELATIONSHIP BETWEEN PASSIVE EXPOSURE TO CIGARETTE SMOKE AND LUNG CANCER

J. M. Samet
Department of Medicine
University of New Mexico
Albuquerque, New Mexico

A causal association has been long established between active smoking and the development of lung cancer. Only recently, however, have epidemiological data suggested that passive smoking may be a risk factor for lung cancer in nonsmokers and potentially in active smokers themselves. This putative role of passive smoking appears plausible on the basis of the chemical composition of side-stream smoke; dose-response relationships in active smokers, which do not suggest a threshold for respiratory carcinogenesis, are also consistent.

The role of passive smoking as a risk factor for lung cancer in nonsmokers has now been examined in several case-control and cohort studies. This presentation will review the available data with an emphasis on the methodological problems involved in studying passive smoking. Both case-control and cohort studies are subject to misclassification from the use of questionnaire variables for characterizing exposure. Information bias may affect the results of case-control investigations. Confounding by unreported active smoking may occur in either design.

An enlarging and controversial epidemiological literature supports the hypothesized role of passive smoking in nonsmokers. Significantly increased relative risks for lung cancer have been demonstrated in case-control studies in Greece and in the United States, and also in a cohort study in Japan. Nonsignificant increases in risk were found in the American Cancer Society cohort and in a case-control study from the United States. Methodological differences and varying exposure intensities may in part explain these discrepant results.

CRITICAL REVIEW OF THE RELATIONSHIP BETWEEN PASSIVE EXPOSURE TO CIGARETTE SMOKE AND CARDIOPULMONARY DISEASE

M. W. Higgins
University of Michigan School of Public Health
Ann Arbor, Michigan

Nonmalignant pulmonary diseases and conditions that have been associated with passive exposure to cigarette smoke in epidemiological or clinical studies include bronchitis, emphysema, pneumonia, and asthma, as well as chronic respiratory symptoms, acute changes in pulmonary function, and reduced lung function. In some studies, passive smoking was associated with higher rates of hospitalization for respiratory illnesses, with more frequent visits to physicians or more days of bed disability or restricted activity. However, these relationships were not found in other studies, or they were present in only one sex or were limited to persons in a certain age range. Incidence of respiratory illnesses was related to maternal but not paternal smoking habits in some studies of children.

In one study mortality from ischemic heart disease was higher in nonsmokers whose husbands smoked than in nonsmokers whose husbands did not smoke. In another study the duration of exercise before the onset of anginal pain was shorter with exposure to environmental tobacco smoke. Increases in heart rate and blood pressure were observed as acute reactions to environmental tobacco smoke in healthy young people and in patients with angina.

An evaluation of these findings is difficult because evidence is inadequate and results are inconsistent; measures of passive smoking have usually been derived from available information on smoking habits of parents, spouses, or other associates of nonsmokers. Potential confounding factors such as age, socioeconomic status, family size, and other environmental exposures have not been ascertained or controlled adequately, and the possibility that some subjects smoke themselves cannot be ruled out.

The evidence linking passive smoking to respiratory symptoms and illnesses and reduced pulmonary function is quite strong. Consequently, further well-designed studies of cardiopulmonary disease and passive smoking are needed, and they should include more precise objective measures of exposure.

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SESSION IV

Combustion Products

Chairman: *D. Bates*
University of British Columbia

OVERVIEW

Much evidence suggests that children may have an increased incidence of respiratory infections if they are exposed to oxides of nitrogen in the home. This session is designed to (1) explore the strengths of that epidemiological data; (2) answer the question of whether it has irreversible consequences on pulmonary function; (3) explore mechanisms whereby oxides of nitrogen may predispose one to infections; (4) relate experimental exposure data to probable levels in the home; and (5) illustrate what is known about the irreversibility of bronchiolitis, both experimental and clinical.

MEASUREMENTS OF INDOOR AIR POLLUTION RELEVANT TO COMBUSTION

J. D. Spengler
Harvard University School of Public Health
Boston, Massachusetts

Unvented combustion of biomass fuels or fossil fuels and pyrolysis of vegetation, oils, food, or building materials can generate a variety of gaseous and particulate matter. Cleaner, low-molecular-weight fuels such as methane and propane produce CO_2, CO, NO, NO_2, and H_2O upon combustion. In addition and depending on fuel additives, reduced sulfur compounds, nitrates, hydrocarbon fragments (including aldehydes) and HCN may be produced. Reported literature concentrates on CO, NO, and NO_2 measurements. Concentrations of NO_2 averaged over days range from 20 to 200 mg/cm^3 in residential units. Combustion of kerosene produces many of the same contaminants as combustion of gaseous fuels. In addition, kerosene burners are a source of ultrafine particles comprised primarily of unburned or condensed hydrocarbons.

In developing countries, biomass fuels such as crop residue, wood, charcoal, soft coal, and animal dung are used for cooking and heating. For the most part, these fuels are burned in primitive facilities requiring manual regulation of the fuel charging rate and control of combustion air. As a result, different burning facilities and types and conditions of fuel yield varying rates of emission of CO, RSP, POM, and NO_x among other contaminants. Particulate concentrations of several milligrams per cubic meter and benzo(a)pyrene concentrations of micrograms per cubic meter have been reported from studies in rural India.

INTERFERENCE WITH LUNG DEFENSES BY NITROGEN DIOXIDE EXPOSURE

J. A. Graham and *F. J. Miller*
Health Effects Research Laboratory
Environmental Protection Agency
Research Triangle Park, North Carolina

Studies reported from our laboratory have indicated that variations in concentration, duration, and exposure profile play an important and complex role in evaluating the potential toxicological effects of nitrogen dioxide (NO_2) on lung defense systems. Suppression in alveolar macrophage function, mucociliary clearance, and/or the immune system can make the host more susceptible to respiratory disease. Use of animal infectivity model systems has been particularly effective in assessing the integrated effects of NO_2 on lung defenses. Animal studies offer the advantage of being able to help identify the likely causative agents in pollutant mixtures such as those present in indoor air, since experiments can involve exposure to environmental contaminants alone or in combination with other chemicals. Interaction of NO_2 with other stressors, such as heat and exercise, can also be studied. Judgments concerning the toxicological implications of the results in animal studies for the likelihood of human risk from exposure to NO_2 require an increased knowledge of respiratory tract deposition of NO_2 in various animal species and man, along with species sensitivity information, to understand whether an identical delivered dose to man and animal evokes an identical response.

RESPONSE OF THE LUNG TO CHRONIC NO_2 EXPOSURE

J. Kleinerman and *R. Gordon*
Department of Pathology
Mount Sinai School of Medicine
New York, N.Y.

The effects of chronic exposure to NO_2 are complex and cannot be extrapolated from the acute responses. Four distinct systems appear to participate in the development of the chronic reaction: epithelial cells, connective tissues, inflammatory cell proteases, and antiproteases.

Epithelia in all portions of the airways are injured and undergo proliferative changes; these changes are most pronounced in the region of the terminal bronchioles and proximal alveolar ducts. Continued exposure is associated with persistent broncholalveolar epithelialization and the eventual development of epithelial nodules and ridges in the region of the bronchioles. An analysis of epithelial cell types shows a decrease in the proportion of secretory cells and an increase in intermediate or basal cells in the bronchi and bronchioles. This change persists 9 months after removal from NO_2 and may represent a permanent alteration in the population of the airway's epithelium.

Morphometric studies indicate that the mean linear intercept increases and the internal surface area decreases significantly after 3 to 5 months of NO_2 exposure. These findings, which are characteristic of emphysema, persist even after removal from NO_2 for periods of 9 months and suggest that these are permanent alterations.

Desmosine, a unique amino acid, is a degradation product of elastin. Its measurement is an index of elastin content. Urinary desmosine in animals exposed to NO_2 is significantly greater during the first 9 days of exposure, after which exposed and control values are similar. This suggests that the period during which elastin is destroyed may be limited only to the initial exposure period. The desmosine content of the lung after 3 weeks of NO_2 is less in exposed hamsters than in controls. After 12 months of NO_2, the desmosine content of exposed lungs is significantly greater than controls. This change persists even following removal from NO_2 for 6 months.

Current concepts of the pathogenesis of emphysema are based on the existence or development of an imbalance of proteases (elastases) and antiproteases (antielastases). Neutrophils are present in small numbers only for a short period after initiation of NO_2 exposure and are replaced

thereafter by macrophages. While both of these cells have the potential to secrete elastase, it is not clear at present which (if any) of these cells may be responsible for the early changes in lung elastin content. The antiproteases in the lung ($alpha_1AP$ and $alpha_2M$) are both increased during NO_2 exposure when measured by quantitative immunochemical methods. It remains to be determined if the functional antiprotease activity in circumstances of chronic NO_2 exposure mirrors these changes.

EPIDEMIOLOGICAL STUDIES OF CHILDHOOD ILLNESS AND PULMONARY FUNCTION ASSOCIATED WITH GAS STOVE USE

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Epidemiological studies on the association between either childhood respiratory symptoms or illness (or levels of pulmonary function) and home gas stove use have reached different conclusions. Most have agreed, however, that although respiratory symptoms and illness appear to be associated with gas stove use, this is not reflected in lower levels of pulmonary function.

Validity of these studies, as of all epidemiologic studies, requires that biases that might spuriously either create or minimize an association be absent or controlled. Such biases include selection bias, in which compared groups are selected by different criteria; information bias, in which data quality varies in the compared groups; and confounding bias, in which the association of interest is distorted by an extraneous causative factor.

Studies on effects of gas stove use are more likely to be invalidated because of confounding biases rather than either selection or information biases, although information biases might affect the association between reporting of symptoms or illness and gas stove use. Factors that could potentially be associated with both gas stove use and respiratory problems (therefore confusing the association) include socioeconomic status, indoor temperature, and humidity. The pertinent epidemiologic data will be reviewed with the objective of determining whether, or how well, these and other potentially biasing factors have been controlled. Through this review it will be possible to assess the validity of these studies and to make recommendations for the design of future studies.

SIGNIFICANCE OF CHILDHOOD RESPIRATORY INFECTIONS

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Acute respiratory infections are the most common cause of acute illness morbidity in persons of all ages, and their incidence is highest in the early years of childhood. Symptoms and signs of lower respiratory tract involvement occur with varying frequency in infections with different respiratory pathogens. Furthermore, the clinical syndromes of lower respiratory infection (LRI) vary with the etiology of the infection. We will review data from two studies of respiratory infections in young children that will address these issues.

The clinical expression of LRI varies not only in the etiology of the infection but in relation to certain patterns of host physiologic and immunologic response, and also in relation to microenvironmental exposure to air pollutants. Furthermore, long-lasting differences in lung function may be linked to LRI experience in early childhood. We will review the current state of knowledge in these areas.

SESSION V

Organics

Chairman: *L. A. Wallace*
Environmental Protection Agency

OVERVIEW

Organic pollutants may cause cancer. They are feared constituents of chemical and industrial emissions (Cancer Alley, New Jersey) and hazards waste dump sites (Love Canal, New York). Multibillion dollar federal programs (Superfund, NESHAPS) have been initiated to regulate the sources. But are we looking in the right direction?

Recent studies have implicated the indoor environment as possibly more important than the usual suspects. If corroborated, this finding will have profound implications for builders, regulators, and researchers.

REVIEW OF ANALYTICAL METHODS FOR VOLATILE ORGANIC COMPOUNDS IN THE INDOOR ENVIRONMENT*

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Successful methods for the analysis of volatile organics in the indoor environment must fulfill several criteria. They must be capable of detecting pollutants at ambient levels (i.e., ppt–ppb). They must make use of collection and measuring devices that are lightweight, compact, and quiet. They should be easy to calibrate and use in the field. Finally, they should provide accurate and reproducible analysis with a minimum of artifactual and contamination problems. A number of devices that have been laboratory or field tested (or both) have been developed to meet these criteria.

Monitors can be classified into two general categories: (1) continuous devices that measure pollutants on the spot and (2) integrating devices that collect the pollutant for later analysis. Continuous devices are the more complex but have the advantage of providing exposures profiles of air pollutants. These two types of devices may be further divided into active monitors, which use a pump to pull air across a sensor or collector, and passive devices, which rely on diffusion to bring the pollutants into contact with sensor or collector.

The analytical performance of the currently available methods in each of these categories will be reviewed. Information on instrumentation, detection limits, sensitivity, interferences, precision, and accuracy will be discussed.

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EVALUATION OF SAMPLING AND ANALYSIS METHODOLOGY FOR POLYNUCLEAR AROMATIC COMPOUNDS IN INDOOR AIR

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Sampling and analysis methodology were developed for the collection and quantification of polynuclear aromatic hydrocarbons, their nitro derivatives, and their nitrogen heterocyclic analogs (PNAs) in indoor air. The methodology was evaluated in a study of air in nine homes performed in the winter of 1983–84. The study included homes with and without woodburning fireplaces, gas appliances, and smoking occupants, and with a range of ventilation rates. The range of PNA concentrations in the homes and factors that systematically contribute to those concentrations were estimated. The practical limitations on the sampling equipment and methodology were identified.

HUMAN INDOOR EXPOSURE TO ORGANICS: A REVIEW OF MAJOR STUDIES

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Exposure to volatile organic substances other than formaldehyde in indoor air has been investigated in several studies since 1975. The largest of these was the Environmental Protection Agency (EPA) team study (1980 to 1984), including 350 households in northern New Jersey and 200 in California. A second study was EPA's Halocarbon Study (1980 to 1983) in three cities involving 150 households. Smaller studies have been carried out by IITRI (34 Chicago homes), CPSC (40 Tennessee homes), and EPA (4 public access buildings).

All of these studies have included both qualitative identifications of hundreds of organic constituents of indoor air and quantitative measurements for a smaller group (20 to 30) of target compounds. These findings will be reviewed and discussed in relation to body burden, relative indoor-outdoor contributions to exposure, and ultimate health effects.

ASTHMATIC RESPONSE IN PATIENTS CHALLENGED WITH FORMALDEHYDE VAPOR AND UREA-FORMALDEYDE FOAM DUST

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Selected patients were studied who had symptoms suggestive of asthma suspected or being caused by exposure to formaldehyde. These patients had histories of exposure to formaldehyde vapor that either coincided with the onset of asthma or aggravated their symptoms. The levels of formaldehyde exposure at their homes or work ranged from 0.1 to 1.2 ppm. The patients were tested with bronchial challenges of 0.1, 1, and 3 ppm of formaldehyde vapor and randomly interspersed room-air placebos. Each challenge to either formaldehyde vapor or placebo was for 20 min. Pulmonary function was measured before and for 24 h after each challenge. In no case were we able to substantiate that exposure to formaldehyde vapor (3 ppm or less) was causing or aggravating the asthmatic symptoms.

One patient did develop severe asthma following the insulation of her home with urea-formaldehyde foam. However, like the other patients tested, she did not respond adversely when inhaling formaldehyde vapor at 3 ppm. In contrast, this patient developed an asthmatic attack when challenged with buoyant foam dust at her home. The relevancy of these findings to reports of respiratory and other irritations in sensitive individuals exposed to indoor levels of formaldehyde will be discussed.

ORGANIC COMPOUNDS INDOORS: SOURCES, CONCENTRATIONS, AND HEALTH EFFECTS

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Prior to the early 1970s, buildings were considered to afford protection from outdoor air contaminants. It is now known that indoor contaminant levels are often higher than outdoors, and at times exceed ambient and even occupational standards. Energy conservation measures that serve to "tighten" building structures have intensified indoor air quality problems. In these structures, indoor air contaminants may be a significant health hazard, especially for the elderly, children, and the chronically ill, who spend a large percent of time indoors and are more susceptible to potential health effects of pollutants.

Organic vapors have been measured from numerous indoor sources such as construction materials, furnishings, consumer products, pesticides, combustion fuels, and occupants. Indoor/outdoor comparisons have shown that many more organic vapors are found indoors than outdoors and typically in greater concentrations. More than 250 different organic compounds (over 1 ppb) have been identified in indoor air. Almost every class of compounds is represented.

Health effects observed from exposure to organic vapors come primarily from occupational studies where a compound may typically be singled out and concentrations and exposure estimates may be determined. Organic vapor compounds found indoors are in greater numbers and lower concentrations than in occupational settings. The possibility of additive or synergistic effects may be important for long-term low-level exposures. Although many of the common compounds measured in indoor air are relatively inert, known and suspected mutagens and carcinogens have also been measured.

SENSORY IRRITATION IN HUMANS EXPOSED TO LOW CONCENTRATIONS OF MIXTURES OF COMMON ORGANIC COMPOUNDS

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Sixty-two human subjects suffering from "indoor climate symptoms" were exposed to various total concentrations (0, 5, 25 mg/m^3) of a mixture of 22 common indoor air pollutants in the climate chamber of the Institute of Hygiene, University of Aarhus. Among several objective and subjective measurements, performance tests and investigations of irritation to the trigeminal nerve endings were undertaken. The digit span test and testing memory impairment showed significantly decreased scores during exposure to organic gases and vapors, whereas the graphic continuous performance test and testing the ability to attend and concentrate showed no significant effect of exposure. In two tests (Stinger's and the nasal spray test) designed to evaluate the sensitivity to irritation of the trigeminal nerve, no significant effects of exposure were found.

SESSION VI

Panel and Audience Discussion

Moderator: *D. Bates*
University of British Columbia