Day 1: First Morning Session

What is the scientific evidence for health problems associated with the indoor environment?

The morning presentations described the scientific evidence for health problems associated with the indoor environment. In the course of the presentations and the audience's response to them, many issues relevant to the Surgeon General's goals were made evident.

Overview

John D. Spengler, Ph.D.
Harvard University School of Public Health

The first speaker, Dr. John Spengler, provided an overview of research on toxic agents in the indoor environment and how modern building practices affect the health of building occupants. As Winston Churchill said, "we shape our buildings and, in time, our buildings shape us." It is often difficult to anticipate indoor environmental quality problems since prevailing building materials and construction practices change faster than scientists are able to evaluate their potential health impacts. For example, we are finding that fiberglass ductwork cannot be cleaned as effectively as sheet metal ducts. In addition, new synthetics and glues release novel types of organic compounds into the air that may cause allergic symptoms; and emulsifiers used for the new generation of high-resolution inkjet printers introduce complex new compounds into the indoor environment of offices. Added to this are relatively well understood toxic agents (such as radon, nitrogen dioxide, and carbon monoxide) that are often concentrated in the indoor air environment as an unintended consequence of energy conservation practices or inadequate ventilation.

In a study conducted in public housing during the heating season, the increased frequency of respiratory symptoms among infants at risk for asthma was correlated with increased indoor levels of nitrogen dioxide, which reached levels that exceeded U.S. Environmental Protection Agency (EPA) outdoor standards. Another study measured personal exposures to volatile organics with known carcinogenic risk potential in New York City and Los Angeles. It showed that contributions from the indoor air environment greatly exceeded those from outdoor exposure. Problems due to high levels of mold in indoor environments, currently a "hot" issue because of media attention, are often exacerbated by modern building practices. Use of building materials such as vinyl siding, aluminum studs, gypsum, and synthetic wood products reduce the water-holding capacity of homes. Inadequate ventilation and drainage practices can trap moisture behind siding, encouraging mold growth. Increased manufacture and use of synthetic organic compounds have increased the presence of these compounds in the environment worldwide, and have also increased their concentration in indoor air and dust samples (88 different compounds were found in samples from 120 homes in one study).

The indoor environment also presents some unique problems. For example, DDT levels were still found to be high in indoor dust samples taken recently in Cape Cod, even though DDT has declined in the outdoor environment since the ban on its use in the 1970s. This is because DDT does not break down rapidly indoors in the absence of ultraviolet (UV) light exposure. Significant concentrations of many potentially toxic chemicals are found in the indoor environment. These include pesticides, phthalates (used as plasticizers and emulsifiers), O-phenylphenols (disinfectant), 4-nonylphenol (detergent metabolite), 4-t-butylphenol (adhesive), and polybrominated diphenyl ethers (a class of chemicals with flame retardant properties that may act as endocrine disruptors via thyroid hormone, and bioaccumulate and concentrate in breast milk). A study conducted in Sweden highlighted the significance of phthalates that may be found in the indoor environment (Bornehag C-G, Sundell J, Weschler CJ, Sigsgaard T, Lundgren B, Hasselgren M, and Hägerhed-Engman L. The association between asthma and allergic symptoms in children and phthalates in house dust: a nested case-control study. *Environmental Health Perspectives*, 2004:112: 1393–1397.).

Asthma and Allergic Effects

Thomas A. E. Platts-Mills, M.D., Ph.D.
University of Virginia Asthma and Allergic Disease Center

Dr. Thomas Platts-Mills discussed indoor environment quality factors responsible for increased asthma incidence, particularly among urban African-American children, a trend reflected in the 20-fold increase in hospital admissions for acute asthma attacks between 1958 and 1997. Asthma is an allergic reaction causing constriction of smooth muscle, reducing patency of the bronchioles. Determining the most important allergens to prioritize from a public health standpoint can be difficult because of the complexity of allergic responses, individual differences in susceptibility, and complicated dose-response patterns for specific indoor air allergens due to sensitization and desensitization effects. Dr. Platts-Mills pointed out the difficulties in addressing asthma incidence and severity as a public health issue. For example, children in New Zealand have very high mite exposure whereas children in Sweden have very little or none; the prevalence of wheezing in New Zealand (21%) is more than twice that in Sweden (8%). Recent evidence suggests that asthma is in large part attributable to the allergic response to dust mites. Dust mite, cockroach, and *Alternaria* (fungal) allergens have strong positive associations with asthma. Higher exposure to such allergens generally leads to both higher sensitization and higher prevalence of asthmatic symptoms. Dog and cat allergens, on the other hand, can induce asthmatic reactions, but when present at higher levels for longer periods of time, also seem to induce tolerance. The presence of multiple cats and dogs in a house, particularly when children are exposed during the first year of life, can significantly reduce asthma risk.

U.S. asthma mortality rates by quintile of median income show the highest mortality for asthma in the poorest segment of the population in 1987–1989 National Center for Health Statistics (NCHS) data, but not in 1969–1972 data, indicating that something has changed over that time interval (it is not clear what). Cockroach allergen may be more important in certain parts of the country. In Northern low-humidity cities (e.g., Boston, Chicago, New York), dust samples from public housing have cockroach allergens but virtually no dust mite allergens or pet dander (since pets are not allowed). In the South (e.g., Atlanta), however, dust mite and mold allergens are just as important as cockroaches. In rural areas, asthma incidence is substantially reduced by the presence of cows kept in a barn near the house. While there is good evidence that the effect of cows is attributable to endotoxin, this does not explain the tolerance induced by cats or dogs. Indeed, measurements of airborne endotoxin show lower levels in homes with a cat. The presence of IgE antibody to cats is lower in countries where a large proportion of homes have cats, suggesting that development of tolerance to cat allergens may be a primary protective factor. Similarly, the "hygiene hypothesis" has also been advanced to explain the historical asthma increase. It suggest that factors such as decreased exposure to soil mycobacterium and changes in bacteria colonizing the gut have contributed to a population with increased sensitization to other common allergens. However, changes in hygiene do not adequately explain the scale, time course, or consistency of the historical asthma increase over the period 1960–1995.

Dr. Platts-Mills emphasized the observation that increased body weight and decreased physical activity have been associated with increased inflammation and wheezing among allergic children. In this case, the time course of increasing inactivity and obesity is more closely coincident with the increase in asthma. This is an interesting association from a public health point of view because interventions to reduce obesity and increase physical activity may also reduce asthma morbidity and mortality.

Non-Asthma and Non-Allergic Building-Related Health Effects

Clifford S. Mitchell, M.S., M.D., M.P.H.
Johns Hopkins University Bloomberg School of Public Health
Michael Hodgson, M.D., M.P.H.
Department of Veterans Affairs

Dr. Clifford Mitchell gave a presentation developed by Dr. Michael Hodgson and himself. He discussed non-asthma and non-allergic adverse health effects associated with the indoor environment. This presentation, covering a broad range of agents, interactive factors, and health endpoints, concentrated on defining the complexity of interacting factors that impact on taking a public health approach to indoor environment issues.

Dr. Mitchell presented a model of building-related health effects that is based on understanding the complex relationships between the building, building systems and contents, and building occupants. Hazards within the built environment may be related to:

- Building structure and/or design (e.g., the permeability of the envelope to moisture);
- Mechanical systems within the building (e.g., ventilation and heating systems);
- Furnishings within the building (fabrics, adhesives, paints, etc.);
- Human occupants of the building; and
- Other sources both inside and outside the building.

All of these can give rise to potential health hazards and modify the risk associated with hazards. These potential hazards include:

- Chemicals such as formaldehyde offgassing from carpets or building envelope materials;
- Biological agents such as bacteria and fungi in condensed water in air conditioning systems;
- Particulates generated from building materials or occupant activity within the building;
- Physical agents including noise and ergonomic hazards; and
- Psychological stressors.

Some of the hazards, such as carbon monoxide (which accounts for more than 100 fatalities per year), or *Legionella* bacteria, may be intrinsically associated with building systems. Others may be associated with building design (for example, hazards that may contribute to the risk of falls from heights). Health and comfort can also be affected by physical factors, such as lighting and heat, and by the physical organization of the space. The ultimate health consequences of these hazards depend not only on building-related factors, but also on characteristics of the population and various effect modifiers. For example, transmission of infectious viral agents within a building may be influenced by airflow, temperature, and humidity. However, the spread of infectious agents also depends on demographic features of the building occupants, including their genetic susceptibility and health history, and could also potentially be modified by other exposures inside and outside the building.

The health effects that have been associated with buildings are quite diverse. Building-associated infections include *Legionella* and fungal infections. Other infectious agents, although not necessarily unique to building systems, may nonetheless be either contained or disseminated by conditions within the building. For example, in at least one case, a tuberculosis species has been shown to be released during building demolition. Also of current concern is the deliberate release of toxic or infective agents in buildings as an act of terrorism. Non-infectious pulmonary effects include hypersensitivity pneumonitis and inhalation fevers. There is also great interest in understanding more about the potential non-infectious pulmonary effects of mold exposures. In addition, there is increasing awareness of various irritation phenomena related to chemical, physical, and biological exposures, and the extent to which these irritation phenomena may play an important role in conditions such as reactive airways dysfunction syndrome (RADS). Building air-handling systems play a critical role in the distribution of and exposure to physical, chemical, and biological agents. The air-handling systems can affect the amount of moisture in a building and thereby prevalence of upper respiratory tract symptoms. Evidence suggests that irradiating the coils of heating, ventilation, and air conditioning (HVAC) units with ultraviolet light (UV), even without cleaning them, can significantly reduce microbial load and resulting irritation symptoms. This has been verified in blinded studies where building occupants were not aware whether the UV was on or off.

Dr. Mitchell described a few additional risk factors about which research is just getting underway. Two such areas are the relationship between obesity and building design and cancer in relation to lighting and hormone levels. Lighting is known to affect circadian rhythms and hormone levels, but little is known about the health implications of changes in lighting spectrum and levels. Building design, operation, and maintenance can all have critical impacts on worker health and well-being, and some interventions have been found to improve health. However, there is little understanding of why or how these mechanisms reduce exposure. Still, it is clear that many problems that are recognized are associated with well-characterized building system failures and could have been prevented had basic engineering and obvious health considerations been taken into account. It is important to understand the role of susceptible populations in evaluating the impact of building changes and to address the need of more sensitive populations, such as children and the immunocompromised.

Building-Related Health Effects and Potential Economic Impact

Eileen Storey, M.D., M.P.H.
University of Connecticut Health Center

Dr. Eileen Storey discussed the potential economic impacts of health problems related to indoor environment quality problems, important both as a socioeconomic issue in itself and as a potential source of “leverage” for encouraging employers and building owners to implement changes to benefit the health of building occupants. Even in the absence of serious health effects and morbidity, discomfort of building occupants because of temperature or can translate into lower productivity, reduced job satisfaction, increased employee turnover, and greater work loss due to illness. On the other hand, remediation efforts can be hampered by short-term disruption costs, relocation costs, and labor relations issues. Although productivity issues related to building comfort can be difficult to quantify, one blinded study of typing speed showed a 4%–6% loss of measurable work output when old carpeting was present in the environment. Office building managers respond to a loss of tenants and property value as a primary motivator in taking on the costs of assessment and remediation. Employers may be less aware of more subtle effects on productivity. As people are made more sensitive to these issues, the economic implications should increase. School buildings serve as a primary focus for indoor environmental issues because of strong teacher and parent awareness and involvement. However, remediation programs can cause substantial diversion of attention and resources that will not always be productive unless the efforts are well directed. Asthma is a leading chronic disease causing lost school days, but the relationship of indoor environment quality problems to other symptoms, such as headaches and fatigue (reported by staff and students in association with particular halls and classrooms), has rarely received the type of follow-up attention that might be useful in identifying and correcting subtle building problems before they result in major health problems.

Questions and Comments

This first series of presentations stimulated a large number of questions and comments, many focused on the school environment. One “healthy schools” advocate maintained that schools should be given priority over office environments because they have a higher concentration of more vulnerable people in closer physical proximity. Several participants pointed to particular problems associated with investigating and mitigating indoor environment issues in schools, including:

- Overcoming fears of unwelcome publicity and getting approval from school boards and administrators;
- Building problems within a school district can vary greatly among individual schools because of great variation in building age and, consequently, construction characteristics;
- Curriculum trends that have reduced or eliminated recess and physical education during the school day, leading to the type of increase in inactivity cited by Dr. Platts-Mills as a possible asthma risk factor;
- The location of school facilities on land with poor drainage or a high water table (the least desirable land in a development, donated by the developer for public use); and
- Budget constraints, which may result in deferred maintenance that can create and exacerbate moisture problems.

While dampness is recognized as a problem, several people commented on the lack of standards for what can be considered a “dry” or “wet” building environment. There are no clear quantitative data on how humidity affects mucosal symptoms (in the case of dryness) on one hand, and mold and other dampness-related problems on the other.

An audience member raised the issue of multiple chemical sensitivity (MCS), considering the role of highly allergic or chemically sensitive individuals as a sentinel population. Other countries have given more attention to this issue. Canadian and Swedish demonstration projects have shown that it is possible to build for hypersensitive people, but also that it is very hard to remediate problems for them after construction. A Japanese conference on indoor air quality emphasized MCS, and an extensive bibliography on the subject is available. Dr. Mitchell pointed out that prevention of MCS symptoms ties into many of the same concerns and approaches used to address asthma and allergy issues, so the problem can be dealt with in a practical way regardless of how valid one finds claims of MCS. He stressed that a quality remediation approach (rather than just covering up problems) can improve many health problems, including MCS.

Highlights of the Scientific Evidence for Health Problems Associated with the Indoor Environment Session

There is good scientific evidence that allergies, asthma, and the spread of respiratory infections are influenced by the indoor environment.

There is a need for better understanding of the influence of agents such as mold species and chemicals on respiratory diseases, immunological and cognitive disorders, and other health endpoints.

The relationship between the indoor environment and health is complex. It encompasses a broad range of chemical, physical, and biological agents; interactive factors; individual susceptibilities; and health endpoints.

Some of the indoor environmental control and remediation techniques used to deal with asthma and allergy issues will likely address some of the other indoor environment health issues.

New building materials and construction practices are being introduced with little understanding of their impact on the indoor environment and the health of the occupants. Data are also lacking on dose-effect relationships for many of the known toxic indoor agents and the interplay of genetic and other health risk factors, making it difficult to predict the effectiveness of control and remediation techniques with precision.