Indoor Air Quality: An Overview of Policy and Regulatory Issues

Ken Sexton

Historically, nonindustrial indoor environments—residential, commercial, institutional, and public buildings—have been considered relatively nonhazardous. During outdoor air pollution episodes, small children and individuals with respiratory illnesses are encouraged to stay indoors. Although this practice may be good advice if the goal is to reduce human exposures to photochemical oxidants (such as ozone), there is increasing evidence that concentrations of many other air pollutants are routinely elevated in private and public buildings.[1] Among these airborne contaminants are passive tobacco smoke, formaldehyde, carbon monoxide, nitrogen dioxide, radon decay products, asbestos fibers, respirable particles, volatile organic compounds, bacteria, viruses, fungi, and aeroallergens (see Table 1).

The potential hazards of indoor air pollution have only recently attracted the attention of scientists, engineers, physicians, regulatory officials, industrial associations, and environmental groups. As a result, there is more discussion but little data by which to evaluate health risks for most contaminants.

The Need to Safeguard Indoor Air Quality

Based on current knowledge, there are several major reasons why safeguarding indoor air quality in nonindustrial environments should be an important national health concern. Time/activity surveys have shown that most urban residents spend 19 to 23 hours per day indoors, including 14 to 16 hours at home.[2] Therefore, even if indoor pollutant concentrations are low, they make a significant contribution to time-weighted, integrated exposures. Epidemiological investigations of air pollution health effects that do not account for indoor exposures are subject to systematic and random bias, both of which may alter results. Moreover, some groups, such as infants, young children, the infirm, and the elderly, are inside virtually all the time. Because these groups are likely to be especially sensitive to air contaminants, the healthfulness of indoor air is an important consideration.

Complex indoor environments created by synthetic building and insulating materials, cleaning and personal care products, wood preservatives, pesticides, and unvented heating and cooking appliances, promote widespread exposures to a broad spectrum of airborne contaminants.[3] Measured concentrations indoors can exceed existing ambient air quality standards and occasionally approach occupational exposure limits. Available evidence indicates, for example, that many volatile organic compounds, such as benzene, toluene, and methyl alcohol, are regularly present at elevated concentrations inside residences and office buildings.[4]

Dr. Sexton is Director for Scientific Review and Evaluation at the Health Effects Institute, 215 First Street, Cambridge, MA 02142.

He was previously Director of the Indoor Air Quality Program, Department of Health Services, State of California.

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Accurate estimates of human exposure are a prerequisite for realistic appraisal of air pollution health risks. Yet, past estimates are often flawed because population exposure studies have traditionally relied on outdoor (ambient) measurements, which cannot adequately characterize an individual's exposure to many air pollutants. In-home measurements are consistently the best single estimator of personal exposure.[5]

The ability of outdoor monitors to define personal exposure is a function of the degree to which readings reflect actual concentrations experienced by individuals. The relationship between outdoor and individual values is complicated by the fact that people spend much of their time indoors or in areas distant from fixed monitors, where pollutant concentrations may be drastically different. Unless temporal and spatial variations in pollutant concentrations are taken into account, misclassification of exposures can lead to spurious conclusions concerning public health risks.

Increases in energy prices and in costs of new electricity-generating stations have encouraged individuals and institutions to seek alternative fuels and to reduce energy consumption. Because more than one-third of U.S. energy is consumed in buildings, efforts have been made to reduce energy use in the residential and commercial sectors. Common approaches include adding insulation, reducing air-exchange rates, and switching fuels. The impact of these changes on human health is uncertain at present, but it is clear that reducing forced and natural ventilation can lead to a buildup of pollutants indoors. Toxic and carcinogenic emissions from building materials, fur-

Table 1. Summary of major indoor air contaminants, important sources, and potential health effects.

Contaminants	Indoor Sources	Potential Health Effects
Respirable Particles	Tobacco smoke, cooking, unvented combustion appliances, aerosol sprays, condensation of vapors, resuspended house dust.	Depending on particle composition: mucous membrane irritation, respiratory infections, emphysema, heart disease, lung cancer.
Formaldehyde	Particleboard, plywood, insulation, furnishings, adhesives, synthetic building materials, tobacco smoke.	Mucous membrane irritation, skin rash, chemical sensitivity, lower respiratory irritation, pulmonary edema, central nervous system effects, possible human carcinogen.
Microorganisms (Bacteria, Viruses, Fungi)	Air-cooling equipment, humidifiers, flush toilets, carpeting, people, pets, plants.	Acute respiratory infections (e.g., influenza, Legionnaire's disease, Pontiac Fever, Q Fever).
Aeroallergens (Allergic Agents)	Plant pollen, animal dander, insect parts, house dust, molds, mites, algae, detergents, chemical additives.	Allergic reaction, pneumonitis.
Combustion Gases (CO and NO_2)	Unvented combustion appliances, attached garages, woodstoves, fireplaces, tobacco smoke.	CO: oxygen deprivation due to COHb, impaired vision and brain function, fatal at high concentrations. NO_2: increased respiratory infection rate, bronchoconstriction, pulmonary edema.
Radon	Underlying soil, building construction materials, well water.	Lung cancer.
Organic Vapors	Solvents, adhesives, synthetic building materials, aerosol sprays, pesticides, cooking, furnishings, paint, metabolic processes, tobacco smoke.	Mucous membrane irritation, narcotic at high concentrations, central nervous system effects, damage to heart, kidney, and liver, many documented or suspected human carcinogens.
Fibers (Asbestos, Mineral, Synthetic)	Insulation, fire retardants, building construction materials, furnishings, texture paints.	Skin irritation, mucous membrane irritation; asbestos is associated with increased incidences of lung cancer, pleural and peritoneal mesotheliomas, and gastrointestinal tract cancer.

nishings, kerosene heaters, wood-burning stoves, passive tobacco smoke, and unvented gas heaters will only add to indoor pollution hazards.

Complaints about inadequate indoor air quality and building-related illnesses in residences and offices are a burgeoning problem for local, state, and Federal health officials.[6] As it is commonly used, the term "building-related illness" refers to an illness outbreak among building occupants, with no secondary spread of the illness to others outside the building with whom affected individuals come into contact.

Adverse reactions to indoor environments include feelings of discomfort due to thermal incompatibility, unpleasant odors, lack of air movement, insufficient lighting, or excessive noise. Health effects vary in severity from mucous membrane irritation, allergic reactions, skin rashes, headaches, nausea, or fatigue to more chronic long-term illnesses, such as upper respiratory disease, chemical sensitivity, repressed immune system response, or malignancy. Infectious and allergic agents, chemical contaminants, poor ventilation, and job-related stress are also among the potential causes of building-related illness.

Because many diseases have latency periods of ten years or more, building occupants could be suffering from irreversible health effects but exhibit no symptoms at the present time. Thus, much of the concern about unhealthful indoor air quality focuses on the long-term health implications of indoor pollution exposures, especially the possibility of adverse health consequences in the absence of acute symptoms.

Addressing Indoor Air Quality Problems

The specter of a major public health threat from contaminated indoor air presents government decisionmakers with a dilemma. Is the problem serious enough to warrant government intervention, and if so, what preventive or remedial actions are appropriate? Unfortunately, informed policy decisions are hindered by a paucity of data on the magnitude as well as the scope of associated health risks. Before the need for government actions to protect public health can be assessed adequately, a coordinated and comprehensive effort must be undertaken to resolve critical technical uncertainties, policy issues, and regulatory questions.

The process of addressing indoor air quality issues involves five major components: problem definition, health risks estimation, mitigation measures assessment, identification and resolution of public policy issues, and decisions about appropriate government responses (see Table 2).

Problem Definition

Defining the nature and extent of indoor environmental hazards is a necessary first step in evaluating whether the government needs to intervene to safeguard indoor air quality. Major components of a comprehensive assessment of indoor air pollution problems include emission sources, ventilation effects, indoor concentrations, human activ-

Table 2. Summary of the major steps in the process of addressing indoor air quality issues.

I.	**Problem Definition**
	Emission Sources
	Dilution
	Indoor Concentrations
	Activity Patterns
	Exposures
	Health Consequences
II.	**Health Risk Assessment**
	Number of People Exposed
	Severity of Exposure
	Dose–Response Relationship
III.	**Applicability of Mitigating Measures**
	Ventilation
	Source Removal
	Source Modification
	Air Cleaning
	Behavioral Adjustment
IV.	**Resolution of Policy Issues**
	Building "Publicness"
	Conservation Benefits
	Voluntary Versus Nonvoluntary Risks
	Importance of Short-Term/Long-Term Health Effects
	Public Versus Private Responsibility
	Local, State, or Federal Intervention
	Appropriate Government Responses
V.	**Alternative Government Responses**
	No Action
	More Research
	Public Information
	Economic Incentives
	Moral Suasion
	Legal Liability
	Guidelines
	Rules/Regulations

ity patterns, exposure distributions, and health effects.

Most research efforts to date have focused on various aspects of defining the problem. The most studied indoor pollutants are nitrogen dioxide and carbon monoxide from unvented combustion appliances (primarily gas-cooking stoves), formaldehyde from urea-formaldehyde foam insulation, building materials, and furnishings, and mass concentrations of airborne particulate matter from a variety of indoor sources. Increasingly, however, attention is shifting to potential health risks from indoor exposures to passive tobacco smoke, radon decay products, volatile organic compounds, and particulate-phase organics. Despite the fact that microorganisms indoors may be a major contributor to increased morbidity and mortality, measurements of bacteria, viruses, and fungi inside buildings are rarely made.

Health Risks

To evaluate public health risks adequately, reliable information is required on indoor exposures, number of people exposed, and associated health effects. But such assessment is hampered because available data are often fragmented, anecdotal, and sometimes contradictory. For example, risk estimates have been attempted for some indoor pollutants, such as passive tobacco smoke[7] and radon,[8] but the calculated values are extremely uncertain because there is little data on indoor exposures. It is precisely *this* type of information, however, which is necessary before control options and strategies can be evaluated and compared on the basis of risk reductions. Although the significance of indoor air pollution exposures for acute and chronic health effects remains uncertain in most cases, the size of the exposed population renders the potential health risks significant.[9]

Mitigating Measures

Control methods for indoor air pollution can be grouped into five general categories: ventilation, source removal or substitution, source modification, air purification, and behavioral adjustments to reduce exposures (avoidance). Table 3 summarizes the applicability of available controls to spe-

Table 3. Summary of mitigating measures for indoor air contaminants (see Endnote 1).

Control Measure Description	Pollutant	Example
Ventilation: Dilution of indoor air with fresh outdoor air or recirculated filtered air, using mechanical or natural methods to promote localized, zonal, or general ventilation.	Radon and radon progeny: combustion by-products; tobacco smoke; biological agents (particles).	Local exhaust of gas stove emissions; air-to-air heat exchangers; building ventilation codes; venting sub-slab area to remove radon gas or volatile organic compounds.
Source removal or substitution: Removal of indoor emission sources or substitution of less hazardous materials or products.	Organic substances; asbestiform minerals; tobacco smoke.	Restrictions on smoking in public places; removal of asbestos.
Source modification: Reduction of emission rates through changes in design or processes; containment of emissions by barriers or sealants.	Radon and radon progeny: organic substances; asbestiform minerals; combustion by-products.	Plastic barriers to reduce radon levels; containment of asbestos; design of buildings without basements to avoid radon; catalytic oxidation of CO to CO_2 in kerosene burners.
Air cleaning: Purification of indoor air by gas adsorbers, air filters, and electrostatic precipitators.	Particulate matter: combustion by-products; biological agents (particles).	Residential air cleaners to control tobacco smoke or wood smoke; ultraviolet irradiation to decontaminate ventilation air; formaldehyde-sorbant filters.
Behavioral adjustment: Reduction in human exposure through modification of behavior patterns; facilitated by consumer education, product labeling, building design, warning devices, and legal liability.	Organic substances: combustion by-products, tobacco smoke.	Smoke-free zones; architectural design of interior space; certification of formaldehyde concentrations for home purchases.

cific contaminants. Control classifications are not mutually exclusive and effectual strategies might use combinations to limit exposures resulting from indoor sources.

For centuries, ventilation has been the primary means of providing adequate indoor air quality in large buildings. Traditional forms of ventilation allow free exchange of indoor and outdoor air, but fail to conserve heat or humidity. When energy costs spiralled in the 1970s, however, many energy-efficient buildings featured reduced air-exchange rates, which caused an indoor buildup of air pollution. Recent improvements in air-to-air heat exchangers may allow for maintenance of both indoor air quality and energy conservation, but these devices are still in a relatively early stage of development.

Removing the source of a contaminant has obvious benefits. Prohibition of urea-formaldehyde foam insulation in residences and removal of asbestos products from school buildings, for example, are two recent solutions. But such strategies are most effective when substitute materials are readily available, and when affected parties agree on the necessity of action. Substitution of materials must be pursued cautiously to assure that new problems are not created in eliminating the old. Difficulties may also arise when removal programs require changes in behavior, conflict with consumer preferences, adversely affect specific groups, or involve an economic penalty.

Modifying the source of a contaminant to restrict emissions is often a practical alternative. For example, changes in process or design might be used effectively to limit release of combustion by-products from gas-fired appliances, woodstoves, kerosene heaters, and coal furnaces. Special sealants might be useful in limiting airborne releases from radon- and formaldehyde-emitting surfaces.

Purifying the air inside buildings is another option for improving air quality. Various kinds of small and relatively inexpensive air-cleaners are now on the market. Sales of these devices have expanded rapidly in the past few years and exceeded two million units in 1981.[10] Although there is clearly a demand for air-purifiers, their efficiency has not been tested adequately.[11] Consumers have no assurance that the air-cleaners they purchase are effective in reducing health risks.

Individuals can greatly influence their own exposures, particularly within residences, and less so in commercial, industrial, and institutional settings.[12] Modifying behavior patterns can be a useful control technique, but this approach presupposes that individuals have sufficient information and motivation to take action. Strategies to promote individual action might include: public information programs to enhance consumer awareness; testing and labeling of products used in the home; development of simple contaminant sensing devices; and better definition of legal rights and liabilities. Fostering public awareness of the need to maintain healthful indoor air quality should therefore be considered a critical element of any contaminant control strategy.

Designing workable and effective indoor control strategies requires an understanding of several pertinent factors. Contaminant characteristics need to be assessed, including such factors as concentrations, reactivity, physical state, and particle size, if applicable. Emission source configurations must also be taken into account. Are discharges continuous or intermittent, are they point or area releases, and do they originate primarily indoors or out? Another major consideration is the nature of exposure–response relationships. Are individuals to be protected from long–term exposures to relatively low concentrations or periodic short–term exposures to peak concentrations? Finally, the type of indoor enclosure is important. Some ameliorating measures are more suited to private residences than to public buildings, or to new, as opposed to older, structures.[13]

Policy Issues

Providing and maintaining healthful air quality in nonindustrial indoor environments is more than just a complex technical issue. Realization that contaminated indoor air may pose a significant health hazard raises complicated public policy questions about the proper role of government in safeguarding public health inside private and public buildings.[14] Although little effort has been devoted to identifying, let alone resolving, the critical policy questions, it is becoming increasingly apparent that this process must move forward before meaningful progress can be made in ameliorating indoor air quality problems.[15] Here are some of the major questions that must be addressed:[16]

(1) Does the role of government depend on the degree of "publicness" for a particular building? And if so, what is an appropriate response to air quality problems in private, as opposed to public, buildings?
(2) Is consideration of the difference between voluntary and nonvoluntary risks important for choices about government intervention?
(3) What are the trade-offs (e.g., costs versus benefits) between energy conservation measures and healthful indoor air quality?
(4) Should the emphasis be placed on protecting building occupants from long-term chronic exposures or short-term peak exposures?
(5) Should everyone, including sensitive individuals (e.g., infants, the elderly, those with asthma and emphysema), be afforded the same degree of protection from indoor air contaminants?
(6) What are the responsibilities incumbent upon different sectors of society (e.g., individuals, building owners and operators, architects, developers, contractors, manufacturers, government), which have a stake in the issue?
(7) If it is decided that government intervention is justified, what forms of intervention are appropriate?
(8) If government actions to ameliorate problems are deemed necessary, at what level of government (i.e., local, state, or Federal) should authority and responsibility be vested?

Government Response

Although scientists and health officials have come to realize that contaminated air inside buildings is a major exposure route for certain air pollutants, policymakers must deal with the question of how best to protect public health in the face of incomplete and sometimes contradictory information. Moreover, workable strategies to mitigate indoor air quality problems must balance the need to protect individual privacy against government's responsibility to protect citizens' health and safety.[17] But, to date, there has been no systematic evaluation of governmental options for dealing with unhealthful indoor environments.[18]

Resolution of the important public policy issues highlighted earlier will obviously affect decisions about the appropriate forms of intervention (see Table 2). For example, if it is determined that air quality inside private residences is a matter of personal choice (as public policy so states for saccharin and cigarettes), then government efforts to ameliorate health hazards should focus on public information programs and product labeling requirements to ensure that individuals have sufficient information to make informed choices.[19] Likewise, if air quality inside offices and schools is deemed to be a "public good" (implying that air pollution exposure in these indoor environments represents an involuntary risk over which building occupants have little or no control), then government actions might include rules and regulations to protect public health. A number of potential governmental responses to indoor air quality problems come to mind. The government could

(1) take no action, based on findings of inconsequential public health risks or unfavorable cost/benefit ratios;
(2) encourage more research to fill critical knowledge gaps that are central to decisions about the necessity of government intervention;[20]
(3) treat as personal choice issue (e.g., as with saccharin or cigarettes) and emphasize public information programs and product labeling;[21]
(4) institute economic incentives or disincentives to encourage maintenance of adequate indoor air quality;[22]
(5) use moral suasion to promote voluntary industry codes and standards that reduce indoor exposures;[23]
(6) define legal responsibility and liability for safe and healthful indoor environments;[24]
(7) establish exposure guidelines to aid individuals, professionals, and regulatory officials in achieving and maintaining safe indoor air quality;[25]
(8) promulgate rules and regulations, including design standards (e.g., building codes, minimum ventilation requirements), emission standards (e.g., emission limitations for appliances, consumer products, building materials), and indoor air quality standards (e.g., specify maximum allowable concentrations of important contaminants).[26]

Regulatory Issues

Because concerns about adverse health consequences from air pollution have focused traditionally on outdoor and occupational (primarily industrial) exposures, Federal and state government programs concentrate on protecting public

health from outdoor air pollutants or protecting workers' health from dangerous air pollutants in the industrial workplace. The U.S. Environmental Protection Agency (EPA) sets and enforces National Ambient Air Quality Standards (NAAQS), which are designed to protect the general public to within an adequate margin of safety. The Occupational Safety and Health Administration enforces consensus standards for industrial work environments, which are designed such that no employee will suffer material impairment of health or functional capacity. However, no one Federal agency has responsibility or authority for indoor air quality in the nonworkplace.[27]

This regulatory omission does not occur because there is a lack of precedent for government authority and responsibility to protect public health and welfare inside buildings. It is common practice, for instance, to regulate construction and operation of public buildings to ensure that adequate provisions are made for health and safety. Government inspectors routinely enforce building codes, health regulations, safety rules, and fire ordinances. While government has an obligation to protect public health in indoor as well as outdoor environments, the justification for direct government intervention (e.g., rules and regulations) varies according to the characteristics associated with different types of indoor settings (e.g., public access, occupational, or nonoccupational).[28]

Creation of a regulatory framework for protection of indoor environmental quality poses special policy issues that bear directly on choices about appropriate public responses.[29] Promulgation of indoor air quality standards and other regulations must acknowledge that individuals (especially in private residences) are already making decisions about their own air quality.[30] Development of effective and reasonable policy requires an appreciation of the scope for private action, as well as consideration of the likelihood that public intervention will foster improved private choices.

This is not to suggest that rules and regulations have no part to play in safeguarding indoor air quality. This form of intervention is, however, not necessarily optimal or even desirable in certain types of indoor environments. Although indoor air quality is often spoken of in a generic sense, there are, of course, different types of indoor settings—for example, (1) occupational, both industrial and nonindustrial, (2) nonoccupational, including residential, commercial, institutional, and public, and (3) transportation microenvironments, such as automobiles, airplanes, subways, and trains.

The role of government varies according to the "publicness" of a particular space as well as according to the nature of air pollution health risks, either voluntary or nonvoluntary. Understanding the diversity of nonindustrial indoor environments will be an important preliminary to the design and implementation of practical and cost-effective control strategies.

The rationale for government regulation of outdoor air pollution is based in part on a definition of outdoor air as a "public good" and on the realization that those who suffer the effects of such pollution are neither compensated by nor powerful in influencing polluters. The situation is quite different for some indoor environments, especially private residences, for both the costs and benefits of pollution control are internalized within households.[31]

If occupants foul the air in their home, they are forced to breathe it. If they attempt to improve its quality by increasing ventilation or installing air-cleaning devices, they bear the costs and enjoy the benefits. For some contaminants, such as tobacco smoke, odorants, and water vapor, benefits are readily recognizable through improvements in perceptible air quality and reduction of corrosion, soiling, and molds. Benefits will include reduced health risks due to lower exposures for those pollutants harmful to human health, but below perception thresholds.[32]

The closed-loop cost-benefit cycle within residences suggests that individual decisions are important determinants of indoor air quality.[33] However, unlike residential energy consumption, where monthly bills from the local utility company provide periodic feedback to consumers, indoor contaminants may be below irritation or odor thresholds. Thus, although individuals are already making decisions about their own air quality, it is not clear that these are "informed" decisions. Among the factors likely to affect individual choices are perceived costs and benefits, susceptibility to pollutants, awareness of health risks, and perceptions of exisiting indoor air quality. In private residences, government actions aimed at improving personal decisions about indoor air quality may be preferable to rules and regulations (e.g., simple warning devices, product labeling, or information programs).

It has been suggested that the Clean Air Act be amended to give the U.S. Environmental Protection Agency authority to control indoor air pollution in much the same way that outdoor air pollution is currently controlled.[34] Irrespective of the salient public policy issues outlined earlier, the practicality of dealing with indoor air hazards through a regulatory approach, particularly in private residences, is open to question.[35] Despite the fact that there are some similarities between indoor and outdoor air, the complex set of regulations comprising the Clean Air Act should not automatically serve as a guide for indoor control strategies.

Setting and enforcing strict indoor air quality standards, similar to existing National Ambient Air Quality Standards, would be impractical because of the prohibitive monitoring costs and the difficulty of enforcement within approximately 82 million residences in the United States. Perhaps the most serious impediment to implementing a regulatory approach is public antipathy towards this form of intervention inside the home. Restriction of indoor pollution sources, certification of "safe" indoor concentrations, product emission standards, disclosure of potential sources upon transfer of ownership, and specification of minimum ventilation requirements are examples of government actions that are likely to be less costly and more effective than indoor air quality standards.

Not all buildings are residences, and not all residences are owner-occupied. The rationale for direct government intervention aimed at improving indoor air quality (e.g., rules and regulations) is much stronger in public, as opposed to private, buildings. Air quality in large public buildings, for instance, has many characteristics of a public good. A person sensitive to tobacco smoke would not rationally pay the costs of cleaning the air in a large convention hall. The costs would greatly exceed any personal benefits an individual might derive from smoke-free air, and those who did not contribute could not be excluded from enjoying the benefits.[36] In this situation, indoor air has many characteristics of a public good and the rationale for regulation is similar to that for outdoor air pollution.

There is also substantial justification for regulatory intervention in private and public buildings where occupants do not have control over their own environment—for example, modern high-rise office buildings. Typically, building managers are responsible for operation and maintenance of heating, ventilation, and air-conditioning (HVAC) systems. Occupants of the building, including both employers and employees, often have little or no direct control of temperature, fresh air input, and ventilation rate. Because HVAC systems are normally operated to minimize energy costs (a parameter easily monitored through utility bills), the health and comfort of tenants (ambiguous parameters that are difficult to quantify) rarely become an issue unless a significant number of complaints are reported.

Because health risks in this situation tend to be nonvoluntary, government has a responsibility to safeguard public health by defining what constitutes acceptable indoor air quality and taking steps to ensure that those criteria are met. Examples of government actions that might be warranted include specification of minimum ventilation rates necessary to achieve healthful indoor air quality, establishment of emission limitations for building materials, and development of indoor air quality guidelines or standards for important contaminants.

As a practical matter, however, several impediments currently constrain government actions aimed at ameliorating indoor air pollution problems:[37]

(1) Adequate Federal funding for indoor air research has not been available, despite laudable efforts by the Department of Energy and the Consumer Product Safety Commission.
(2) There is not yet a firm scientific basis for action, including sufficient data concerning the number of people exposed, the severity and pattern of exposures, and related health consequences.
(3) No organized, broad-based constituency has developed to champion the cause of clean indoor air, which means that there is little political urgency associated with indoor air quality legislation.
(4) Federal officials have been reluctant to act without specific statutory responsibility and authority.
(5) Regulators are averse to being drawn into the nettlesome question of whether government should intervene in private indoor spaces, especially residences.
(6) Some regulatory officials and environmentalists fear that explicitly acknowledging the importance of indoor exposures in assessing health risks will weaken the case for ambient (outdoor) air quality standards.

Existing Statutory Authority and Government Activity

Federal Government

The Environmental Protection Agency is the lead agency within the Federal government for control of air pollution. The legal mandate for EPA's authority is derived primarily from the Clean Air Act.[38] However, the act gives EPA responsibility for "ambient air," a term that has been interpreted to mean that portion of the atmosphere, *external to buildings*, to which the general public has access.[39] The U.S. General Accounting Office (GAO) concurs with this interpretation, but has acknowledged that indoor air pollution has received little support precisely because no one Federal agency has jurisdiction over nonindustrial indoor environments.[40] The GAO pointed out that the few Federal actions that have been taken were piecemeal and lacked coordination between agencies. They recommended that Congress amend the Clean Air Act to provide EPA with the authority and responsibility for air quality in the nonworkplace.

In addition to the Clean Air Act, several other statutes might be interpreted to allow the EPA to take action on indoor air quality. The Toxic Substances Control Act (TSCA) is aimed at controlling hazardous air pollutants.[41] EPA has already used this statute to require asbestos removal in schools[42] and is currently considering the need for regulatory action to deal with the issue of formaldehyde exposures.[43] The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) provides a mandate for the regulation of pesticides, including their application indoors.[44] The Uranium Mill Tailings Radiation Control Act (UMTRCA) applies to uranium mill tailings, especially as they are used for landfill in residential areas or in the construction of dwellings.[45] Because such uses could lead to elevated radon concentrations indoors, EPA has established guidelines for acceptable radon concentrations inside homes built in high risk areas.[46] The Safe Drinking Water Act (SDWA) might also be used to deal with indoor radon problems in instances where drinking water is derived from radon-emitting substrata.[47] Because volatile organic compounds and radionuclides from hazardous waste sites can migrate through the soil and enter nearby buildings, the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) or "Superfund" Authority could also be used to address certain indoor air quality problems.[48]

In response to concerns about inadequate Federal funding for indoor air quality research, the 97th Congress passed specific funding legislation for EPA research and development on indoor air issues. The entire bill (S.2577) was vetoed by the President, however, because of provisions that he felt provided for excessive interference with the Science Advisory Board.[49] Congress subsequently appropriated $2 million in fiscal year 1984 for EPA to intensify its research efforts on indoor air quality.[50] Another $2 million was appropriated by Congress for fiscal year 1985, despite the fact that EPA did not request additional funding.[51] Overall, current funding for indoor air quality research constitutes about 3% of EPA's total air pollution research budget.

Besides EPA, a number of other Federal agencies have responsibility for specific aspects of nonindustrial indoor air quality.[52] The Occupational Safety and Health Administration (OSHA) is responsible for safeguarding workers' health in the workplace. Nevertheless, most OSHA activities have focused on industrial work environments, with relatively little attention given to problems in nonindustrial settings, such as building-related illnesses in office buildings.

The Department of Energy (DOE) is responsible for energy conservation programs that affect residences and new buildings. DOE has funded studies to develop, evaluate, and standardize measurement techniques, as well as research to examine human health effects from organic vapors, airborne particles, and radon. The Bonneville Power Administration (BPA) in Oregon is currently financing a project to measure a variety of indoor pollutants inside homes within its service area and to determine the impact of weatherization measures on indoor air quality.[53]

Ensuring that consumer products are safe and do not present unreasonable health risks is the responsibility of the Consumer Product Safety Commission (CPSC). CPSC has banned the use of asbestos-containing spackling compounds, proposed a ban of urea-formaldehyde foam insulation (overturned in court), and initiated studies of emissions from unvented combustion appliances, including kerosene heaters and gas-fired space heaters.

The Department of Housing and Urban Development (HUD) establishes building standards for

HUD-funded projects and material standards for mobile home construction. HUD has required that indoor radon concentrations be below established minimums in high natural radium areas of Montana and South Dakota before homebuyers qualify for HUD-assisted financing. HUD refused to approve FHA-financed loans for construction of new homes on reclaimed phosphate lands in Florida, due to the possibility of elevated indoor radon levels. HUD recently promulgated regulations specifying formaldehyde-emission limitations for plywood and particle-board products.[54]

The Federal Trade Commission (FTC) is responsible for ensuring that consumer advertising contains accurate, truthful, and useful information. The FTC recently charged two manufacturers of room air cleaners with falsely advertising that their devices effectively remove tobacco smoke and other pollutants from indoor air. In reaching consent agreements with the FTC, both companies agreed not to misrepresent the capabilities of their air cleaners.[55]

During 1983, the Congressionally-mandated Interagency Committee on Indoor Air Quality (ICIAQ) was established to coordinate Federal research activities.[56] A representative from EPA serves as chairman, while members of DOE, the Department of Health and Human Services (DHHS), and CPSC serve as co-chairs. Among the other Federal agencies involved in the ICIAQ are BPA, the Department of Defense, FTC, GSA, the Department of Justice, HUD, the National Aeronautics and Space Administration, the National Bureau of Standards, OSHA, the Tennessee Valley Authority, and the Department of Transportation. The ICIAQ is presently compiling an inventory of Federal indoor air research to identify knowledge gaps and to avoid unnecessary duplication.

The scientific, technical, legal, regulatory, policy and political issues associated with unhealthful indoor air quality are not yet well-defined. Federal funding for research is inadequate and the situation is not likely to improve dramatically in the foreseeable future. Moreover, as more information is obtained, it is highly probable that existing and potential indoor hazards will continue to be identified, and that increased media attention will stimulate public awareness about the issues. In the future, public pressure for government programs to define the nature of the problem and to ameliorate indoor environmental hazards is likely to increase and provide legislators with more incentive to take action.[57]

Given the present atmosphere of limited government intrusion, regulatory reform, and increasing reliance on free-market economics, there is little likelihood of a major Federal indoor air quality program in the near term. Barring a change in Administration policies, a legislative mandate, or an indoor environmental crisis, funding levels and statutory authority are likely to remain about the same for the next several years. Yet, even if explicit statutory authority is forthcoming, non-regulatory approaches to the problem (e.g., to provide public information, to develop occupant warning devices, to encourage voluntary industry codes, or to publish exposure guidelines) are certain to be an integral part of control strategies.

State and Local Government

State and local health agencies have been much more active than Federal agencies in dealing with indoor air quality issues. Massachusetts, for instance, banned the use of urea-formaldehyde foam insulation,[58] and both Minnesota and Wisconsin have promulgated formaldehyde standards in new mobile homes.[59] In California, the sale of unvented combustion space heaters for use in residential buildings as well as their operation inside dwellings is prohibited.[60] Many state and local governments (primarily cities) have instituted anti-smoking ordinances that are aimed at reducing nonvoluntary exposures to passive tobacco smoke.[61]

State and local (i.e., city or county) health departments are the agencies that deal most closely with citizens' concerns and questions about unhealthful indoor air quality. In recent years, complaints about inadequate indoor air quality and requests for information about specific indoor pollutants (i.e., formaldehyde and asbestos) have increased significantly.[62] A recent national survey revealed that 32 states have a program or person(s) responsible for evaluating exposures to one or more indoor air pollutants.[63] Twenty-nine states have programs to assess nonindustrial exposures to formaldehyde, although the quality varies widely. The State of California is currently the only state that has established a permanent and comprehensive indoor air quality program.[64] Among the other states that have been most

active in indoor air quality issues are Massachusetts,[65] Minnesota,[66] New Jersey,[67] New York,[68] North Carolina,[69] Texas,[70] Washington,[71] West Virginia,[72] and Wisconsin.[73]

Despite the expanding number of homeowners and office workers who are reporting indoor air quality problems, most government agencies are not able to respond adequately. Air quality in private residences, offices, schools, and commercial and public buildings remains an institutional "grey area," where authority and responsibility at the state level are ill-defined. Moreover, most state and local health agencies lack the funding and expertise necessary to deal effectively with indoor air quality issues.

Building occupants experiencing acute health symptoms that seem to be associated with nonindustrial indoor exposures (i.e., mucous membrane irritation, allergic reaction, skin rash, headaches, nausea, and lethargy) are frequently left on their own. These individuals typically respond in one of four ways: (1) They resign themselves to some chronic level of discomfort and go on about their business; (2) They seek medical help in diagnosing the cause of existing symptoms (e.g., medical doctors or allergists); (3) They hire a private firm to investigate the source of the problem; or (4) They pursue their grievance through private lawsuits in civil law (e.g., take legal action against the seller of the building, architect or designer, or manufacturer of building materials).[74]

Although government health agencies generally do not have the resources necessary to respond directly to consumer concerns about indoor health hazards (e.g., by measuring indoor contaminant concentrations), they can and should be a valuable source of information to aid individuals in making choices about their own indoor air quality. Several states, including California, Minnesota, Wisconsin, and Texas, as well as health organizations, such as the American Lung Association, have prepared informational pamphlets to aid individuals in understanding important indoor air quality issues. A listing of private companies available to provide indoor air monitoring services has been published recently by the California Indoor Air Quality Program.[75]

Conclusion

Evidence continues to mount that air pollution is a problem indoors as well as out. The current national trend towards energy-efficient buildings has raised concerns about possible adverse effects on human health. Unfortunately, insufficient data are currently available to assess public health risks associated with energy conservation measures, such as reducing air-exchange rates, switching fuels, and adding insulation. Nevertheless, it is clear that reducing forced and natural ventilation can cause a buildup indoors of toxic and carcinogenic emissions from passive tobacco smoke, building materials, unvented combustion appliances, furnishings, and underlying soil. Increasing reports of building-related illness among occupants of homes and offices provide evidence of the direct relationship between the quality of indoor air and acute or short-term health effects. While less well-defined, the possibility of chronic, irreversible health consequences due to indoor exposures cannot be ignored.

Realization that indoor air quality in nonindustrial environments (e.g., residences, offices, schools, commercial and public buildings) is often less healthful than that outdoors presents policymakers with a conundrum. National Ambient Air Quality Standards have been promulgated for several outdoor air pollutants to protect public health. As a result, billions of dollars have been spent to control atmospheric emissions from mobile and stationary sources. Yet, even for those airborne contaminants that have both outdoor and indoor sources, such as carbon monoxide and nitrogen dioxide, exposures to concentrations above the standard frequently occur indoors due to indoor combustion sources. Although the health effects of breathing carbon monoxide or nitrogen dioxide are the same indoors as out, existing NAAQS apply only to air external to buildings.

When the Clean Air Act and its amendments were promulgated during the 1970s, relatively little data were available concerning indoor air quality. Even now when it is obvious that nonindustrial indoor air is not uniformly healthful, there is little likelihood that the Federal government will soon establish a regulatory framework. This reticence can be traced to several factors: a general perception that environmental regulations have become overly restrictive; the absence of abundant media attention and lack of widespread public outcry about the need for government action; current Federal policies, which include fiscal retrenchment, limited government intrusion, regulatory reform, and increasing reliance on free-

market economics, and unanswered policy questions about the proper role of government in safeguarding air quality inside public and private buildings.

The relative lack of government response does not alter the fact that consideration of indoor exposures is essential for realistic assessment of air pollution health risks. Although outdoor air monitors continue to provide data about compliance with NAAQS, we now know that they are inappropriate for estimating human exposures. This leads to an anomalous situation, wherein NAAQS are set to protect public health, and outdoor air monitors are used to measure compliance with NAAQS, even though outdoor measurements provide little or no information concerning actual exposures. Thus, a substantial fraction of the population residing in an area that is nominally in compliance might still be exposed to concentrations in excess of existing outdoor standards. Because such exposures occur inside buildings, they currently have no relevance for enforcement of the Clean Air Act.

If only the health implications of exposures are considered, then there is no obvious reason why air quality standards should not apply indoors as well as out. In actuality, however, the prohibitive costs and practical difficulties of monitoring and enforcing standards in tens of millions of buildings make application of the complex Clean Air Act regulations difficult, if not impossible. Furthermore, if NAAQS were extended indoors, every state would immediately be in noncompliance for carbon monoxide, nitrogen dioxide, and particulate matter, thereby necessitating enactment of specified penalties.

Indoor air pollution raises complicated public policy questions about the role of government in safeguarding health and welfare inside buildings. Although differences between indoor and outdoor environments clearly have policy ramifications, little attention has been given to identifying and resolving important issues. The diversity of indoor environments, differences between public and private buildings, and distinctions between voluntary and nonvoluntary risks must be taken into account before effective and workable control strategies can be designed and implemented. Rules and regulations are not necessarily the most appropriate forms of government intervention for ameliorating indoor air quality problems. Moreover, if government insists on pursuing a regulatory approach, there is small likelihood that setting strict indoor air quality standards will prove to be effectual, especially in private residences.

The discovery of indoor air pollution illustrates that exposures are even more complex than initially supposed. It is unrealistic and counterproductive to think that air pollution health risks can be divided neatly into indoor and outdoor categories. Both exposure routes must be considered before health benefits of current and future control strategies can be assessed accurately.

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