HB

283

STATE OF ALASKA
1990 LEGISLATIVE SESSION

Bill Version: HB 283
Publish Date:

FISCAL NOTE

REQUEST:

Revision Date:
Title: An Act relating to indoor air quality standards for certain
Sponsor: M. Davis
Requestor:

Agency Affected: Department of Administration
BRU: Leasing and Facilities
Components: Leases, Administration

EXPENDITURES/REVENUES: (Thousands of Dollars)

OPERATING	FY 91	FY 92	FY 93	FY 94	FY 95	FY 96
PERSONAL SERVICES	51.3*	26.1*	0	0	26.1*	0
TRAVEL	0	0	0	0	0	0
CONTRACTUAL	710.2*	99.9*	27.7*	28.8*	225.5*	0
SUPPLIES	0	0	0	0	0	0
EQUIPMENT	0	0	0	0	0	0
LAND & STRUCTURES	0	0	0	0	0	0
GRANTS, CLAIMS	0	0	0	0	0	0
MISCELLANEOUS	0	0	0	0	0	0
TOTAL OPERATING	761.5*	126.0*	27.7*	28.8*	251.6*	0
CAPITAL	0	0	0	0	0	0
REVENUE	0	0	0	0	0	0

FUNDING: (Thousands of Dollars)

GENERAL FUND	761.3*	126.0*	27.7*	28.8*	251.6*	0
FEDERAL FUNDS	0	0	0	0	0	0
OTHER	0	0	0	0	0	0
TOTAL	761.3	126.0	27.7	28.8	251.6	0

POSITIONS:

FULL-TIME	1	0	0	0	0	0
PART-TIME	0	.5	0	0	.5	0
TEMPORARY	0	0	0	0	0	0

ANALYSIS: (Attach a separate page if necessary)

*Based on a scenario in which the new standard would require 50% of expiring leases to be rebid and have increased costs of 10%. There would be Ø fiscal impact for FY 90.
(See attached analysis.)

Prepared by: Robert J. Link
Phone: 465-2250
Division: General Services and Supply
Date: 2/21/90

Approved by Commissioner: Frank S. Baxter
Date: 2/22/90
Agency: Department of Administration

Distribution (by preparer):
- Legislative Finance
- Legislative Sponsor
- Requestor
- Office of Management and Budget
- Impacted Agency(ies)

15/11K1/021609-0/1&2

Rev: 11/89

Although the Department supports setting standards for air quality that would ensure a uniform, acceptable level for clean indoor air in state offices, it must be noted that there would be a significant fiscal impact on the cost of leased space.

The extent of the impact is not known because the proposed standard has not been established. Increased costs are contingent not only upon the variance between any new standard and the current codes governing heating, ventilation, and air conditioning (HVAC) specifications, but also are dependent upon the inclusion of a method for waiver. In areas where there is absolutely no possibility of obtaining compliance, or when compliance is determined to be too costly, an alternative, other than closure of state offices, must be provided in the Bill.

Currently, the state has 115 leases for office space in excess of the 2,000 square foot threshold in HB 283. These 115 leases contain approximately 1,600,000 square feet at a combined monthly cost of approximately $2,050,000.

The renewal or expiration schedule for the next six (6) fiscal years is:

* FY 91: 38 leases = 551,873 square feet @ $544.6 per month.

* FY 92: 10 leases = 125,188 square feet @ $189.6 per month.

* FY 93: 4 leases = 28,833 square feet @ $43.0 per month.

* FY 94: 3 leases = 26,183 square feet @ $31.9 per month.

* FY 95: 6 leases = 216,064 square feet @ $491.7 per month.

* FY 96: CURRENTLY NO ESTABLISHED LEASES ARE SCHEDULED FOR RENEWAL OR EXPIRATION IN FY 96. BECAUSE MOST LEASES RUN FROM 1 TO 3 YEARS PLUS VARIOUS RENEWAL OPTIONS, ONLY LEASES COMMENCING DURING OR AFTER FY 90 WILL HAVE AN IMPACT IN FY 96.

****

ADDITIONAL PERSONNEL:

The number of leases that would have to be rebid in order to comply with revised air quality standards in FY 91 and FY 92 will place a severe strain on an already overextended purchasing staff. If the standards are substantially changed, additional staff will be required. Based on a scenario of rebidding 50% of expiring leases which have renewal options, one Purchasing Agent III, Range 18, step A @ $51,300 per annum will be needed to develop bids and manage moves for an estimated 14 leases for approximately $250,000 s.f. during FY 91. A half-time position would be needed in FY 92 and FY 95.

****

CONTINUATION OF FISCAL NOTE ANALYSIS
For HB 283

INCREASED OPERATING COSTS:

The only experience we have had with setting more stringent HVAC requirements is in the case of Lease #1445, the Department of Labor Building, in Anchorage. The more stringent requirements were voluntarily complied with by the lessor, who has indicated an increased operating cost of approximately 10%. Increases cover only the additional cost of electricity, gas and filters required by the higher standard of operation. This does not reflect any cost for actual changes to a system, just the increased operation of a current system.

Based on the Department of Labor project, a cost increase of 10% should be anticipated on all affected or noncomplying office spaces. This estimate may be too low for locations other than Anchorage where natural gas provides a low cost energy source.

Using a 10% cost factor and applying it to scenarios of 25%, 50% and 75% of the leases that require replacement or renewal during each fiscal year, the following additional costs can be anticipated:

FISCAL YEAR	LEASES IMPACTED @ 25%	LEASES IMPACTED @ 50%	LEASES IMPACTED @ 75%
* FY 91:	$163.4	$326.8	$490.2
* FY 92:	$ 37.6	$ 75.1	$112.7
* FY 93:	$ 8.7	$ 17.3	$ 26.0
* FY 94:	$ 7.9	$ 15.7	$ 23.6
* FY 95:	$ 64.8	$129.6	$194.5
* FY 96:	* $ N/A	$ N/A	$ N/A
TOTAL =	$282.4	$564.5	$846.7

*No existing leases are scheduled for renewal or expiration in FY 96.

****

MOVING EXPENSES

Moving expenses may be expected for leases that must be vacated due to new standards. Basic moving costs are estimated to be $1.50 per square foot.

For example, in FY 91, 9 leases containing 40,683 square feet of office space are expiring and must be rebid. An additional 27 leases containing 511,190 square feet will require renewal. If just 25 percent of the renewable space must be replaced due to new air quality standards, the additional cost for moving alone would be approximately $191.7.

The renewal schedule for the next six (6) fiscal years and the cost to move 25, 50 or 75 percent of the renewable leases is:

FISCAL YEAR	NUMBER OF LEASES	RENEWABLE SQUARE FEET	COST TO MOVE 25%	COST TO MOVE 50%	COST TO MOVE 75%
91	27	511,190	$191.7	$383.4	$575.1
92	7	74,335	$ 12.4	$ 24.8	$ 37.2
93	2	13,883	$ 5.2	$ 10.4	$ 15.6
94	1	8,708	$ 6.6	$ 13.1	$ 19.7
95	5	63,926	$ 48.0	$ 95.9	$143.9

****

TOTAL ESTIMATED OPERATING AND MOVING COSTS:

Based on the forgoing, using 50 percent as a median, the increased operating, moving and personnel costs that would be associated with major changes to air quality standards are estimated to be:

FISCAL YEAR	OPERATING COSTS		MOVING COSTS		PERSONAL SERVICES		ANNUAL ESTIMATE
FY 91	$ 326.8	+	$ 383.4	+	$ 51.3	=	$ 761.5
FY 92	$ 75.1	+	$ 24.8	+	$ 26.1	=	$ 126.0
FY 93	$ 17.3	+	$ 10.4	+	$ 0.0	=	$ 27.7
FY 94	$ 15.7	+	$ 13.1	+	$ 0.0	=	$ 28.8
FY 95	$ 129.6	+	$ 95.9	+	$ 26.1	=	$ 251.6
FY 96	$ 0.0	+	$ 0.0	+	$ 0.0	=	$ 0.0
TOTALS =	$ 564.5		$ 527.6		$ 103.5		$1195.6

****

Since there is no way of knowing how many leases will need to be rebid, we have used 50 percent of the renewing leases as a factor in reaching the assumptions presented with the Fiscal Note.

Depending on the extent of the changes to current standards and the need for major changes to the HVAC of existing buildings, additional lease costs will be encountered.

P.O. Box 110601
Anchorage, Alaska 99511

April 17, 1989

Representative Johnny Ellis
Alaska State Legislature
P.O. Box V
Juneau, Alaska 99811

REC'D APR 20 1989

Dear Representative Ellis:

I am writing to you about an issue that may affect all of us - indoor air pollution. We take for granted the air we breathe, especially the fact that the air we breathe will not harm us. An increasing number of people are realizing this is not true. We Alaskans spend most of our time indoors, we have a greater chance than people in southern states that the air we breathe indoors may affect us.

I am a state worker and I know the indoor air quality at my work place affects my health. New Hampshire and Maine recognized indoor air quality problems and passed laws in 1988 to set minimum ventilation standards in their state office buildings. HB283 directs The Department of Labor to establish minimum ventilation rates for state office buildings. I encourage the Health, Education and Social Services Committee to hold hearings on this bill before the end of the session.

Enclosed is an EPA information sheet describing some facts about indoor air pollution. I look forward to working with you to provide a safer work environment and thereby lower state health care costs.

Sincerely,

Bill Ashton

cc: Carl Hild, Alaska Health Project w/o enclosures
Deborah Williams, American Lung Association of Alaska, w/o enclosures
Rich Seiffert, Alaska Cooperative Extension Service, w/o enclosures
Penny Palmquist, ASEA w/o enclosures

0693L
88-2332
01
1370L

Chapter 68

SB 269-FN

STATE OF NEW HAMPSHIRE

In the year of Our Lord one thousand nine hundred and eighty-eight

AN ACT

relative to indoor air quality in certain state buildings.

Be it Enacted by the Senate and House of Representatives in General Court convened:

68:1 New Chapter; State Buildings. Amend RSA by inserting after chapter 10 the following new chapter:

CHAPTER 10-A

CLEAN INDOOR AIR IN STATE BUILDINGS

10-A:1 Definitions. In this chapter "clean air" means the standards set by the division of public health services, department of health and human services, in consultation with department of labor.

10-A:2 Clean Air Required.

I. The director of plant and property management, department of administrative services, or any other state agency authorized to build, acquire, or lease office space, shall require that, after January 1, 1989, any new state building, any existing building acquired by the state, any initial lease of a state building by the state, or any building bequeathed to the state shall meet clean air standards before it may be used for any state purposes, other than storage.

II. The division of public health services, department of health and human services, shall be responsible for certification in writing to the director of plant and property management or other appropriate state agency head that the buildings listed under paragraph I meet the clean air standards.

III. Any person entering into an initial lease for any building listed under paragraph I which does not meet the clean air standards may terminate such lease.

10-A:3 Rulemaking.

I. The director of plant and property management shall adopt rules, under RSA 541-A, relative to:

(a) Content and format of any forms necessary under RSA 10-A:2, I.

(b) Manner of acquiring certification from the division of public health services.

(c) Any other matter necessary to the administration of this chapter.

II. The director, division of public health services, after consultation with the commissioner of labor, shall adopt rules, under RSA 541-A, relative to what constitutes the clean air standard.

III. The director, division of public health services shall adopt rules, under RSA 541-A, relative to:

(a) Content and format of any forms necessary under RSA 10-A:2, II.

(b) Certification procedures.

(c) Any other matter necessary to the administration of this chapter.

1ь-A:4 Exceptions.

I. This chapter shall not apply to the university system of New Hampshire.

II. The governor and council, upon recommendation by the director of plant and property management or other state agency authorized to build, acquire, or lease office space, may suspend the enforcement of all or part of this chapter or any rule adopted under it upon finding that an emergency or hardship exists which makes compliance with the provisions of this act unfeasible.

68: 2 Effective Date. This act shall take effect January 1, 1989.

Approved April 11, 1988
Effective January 1, 1989

N H Rules
from RSA 10-B authority

DRAFT

Chapter 1800 Occupational Health Rules
Statutory Authority: RSA 10-B

Part He-P 1804 CLEAN AIR IN STATE BUILDINGS

He-P 1804.01 "Initial Lease" means any lease of a bulding executed on behalf of a state agency when either no prior lease of that building by the state agency existed or the previous lease of that building by that state agency has expired.

He-P 1804.02 Testing Required - It shall be the responsibility of the builder, seller, lessor, or donor (or the donor's executor) of a building, or portions of buildings subject to these rules, which is to be built for, leased, rented, sold or bequeathed to the state, to cause such building or portions thereof to be tested in order to demonstrate compliance with the clean air standards set forth under He-P 1805. Samples shall be collected by a Certified Industrial Hygienist or an individual who is under the supervision of a Certified Industrial Hygienist. Tests shall be conducted by laboratories accredited by the American Industrial Hygiene Association.

He-P 1804.03 Certification of Clean Air Standards - The builder, seller, lessor, or donor (or donor's executor) shall certify the quality of the indoor air present in buildings, or portions of buildings, subject to these rules. Certification shall be deemed complete upon written receipt by the Division of Public Health Services of the following information:

(a) Mailing address for the building
(b) City or town where the building is located
(c) Identification of those sections of the building subject to these rules
(d) Names, addresses, and telephone numbers of persons conducting sampling or analysis pursuant to He-P 1804.01.
(e) Copies of test results used to determine compliance with He-P 1805
(f) One of the following two statements:

(1) "I hereby certify that sampling and analyses conducted pursuant to He-P 1804.02 was performed in accordance with best professional practice and accurately represents usual conditions in the areas tested. I further certify that the indoor air quality of this building, or those portions of said building subject to these rules, is in compliance with He-P 1805."; or

(2) "I hereby certify that sampling and analysis conducted pursuant to He-P 1804.02 was performed in accordance with best professional practive and accurately represents usual conditions in the areas tested. I further certify that the indoor air quality of this building, or of those portions of said building subject to these rules, is not in compliance with He-P 1805.".

(g) Notarized signature of the builder, seller, lessor or donor (or donor's executor).

(h) Documentation of the qualifications of person(s) conducting either sampling or analysis necessary to demonstrate compliance with He-P 1805. Such documentation shall include a work performance history and copies of any relevant special licenses or accreditations held by persons so employed.

He-P 1804.04 Certification by the Division of Public Health Services - If the information submitted pursuant to He-P 1804.02 demonstrates compliance with all standards established in He-P 1805 then the Division shall issue a statement of certification in accordance with RSA 10-B:2 II. The following information shall be included in the statement of certification:

(a) Mailing address of the building.
(b) Actual location of the building.
(c) Identification of those sections of the building subject to these rules.
(d) The following statement:

(1) "I hereby certify, based upon information submitted pursuant to He-P 1804.02, that the indoor air quality of the building described above complies with He-P 1804.05.".

(e) Signature of the Director, Division of Public Health Services.

He-P 1805 INDOOR AIR STANDARDS

He-P 1805.01 Ventilation - Ventilation standards shall be in accordance with the American Society of Heating, Refrigerating and Air Conditioning Engineers., Inc. standards established in the edition published in 1981 entitled "Ventilation for Acceptable Indoor Air Quality."

He-P 1805.02 Noise - Noise standards shall be the preferred noise criteria established by the American Institute of Architects Architectural Graphic Standards Seventh Edition published in 1981 by John Wiley and Son, Publisher.

He-P 1805.03 Radon - The maximum allowable concentration of radon shall be 4.0 picocuries of radon per liter of air.

He-P 1805.04 Carbon Dioxide - The maximum allowable concentration of carbon dioxide shall be 800 parts of carbon dioxide per million parts of air.

He-P 1805.05 Asbestos - The maximum allowable concentration of asbestos shall be 0.1 fibers of asbestos per cubic centimeter of air.

He-P 1805.06 - Formaldehyde - The maximum allowable concentration of formaldehyde shall be 0.1 part of formaldehyde per million parts of air.

JCP/dkl/1407s

STANDARDS PRESENTATION

CALIFORNIA OCCUPATIONAL SAFETY AND HEALTH STANDARDS BOARD

Adopt new Section 5142 as follows:

5142. ~~Control by Ventilation.~~ Mechanically Driven Heating, Ventilating and Air Conditioning (HVAC) Systems to Provide Minimum Building Ventilation.

(a) Operation:

(1) The HVAC system shall be maintained and operated to provide at least the quantity of outdoor air required by the State Building Standards Code, Title 24, Part 2, California Administrative Code, in effect at the time the building permit was issued.

(2) The HVAC system shall be operated continuously during working hours except:

(A) during scheduled maintenance and emergency repairs;

(B) during periods not exceeding a total of 90 hours per calendar year when a serving electric utility by contractual arrangement requests its customers to decrease electrical power demand; or

(C) during periods for which the employer can demonstrate that the quantity of outdoor air supplied by nonmechanical means meets the outdoor air supply rate required by (a)(1) of this Section. The employer must have available a record of calculations and/or measurements substantiating that the required outdoor air supply rate is satisfied by infiltration and/or by a nonmechanically driven outdoor air supply system.

(b) Inspection and Maintenance:

(1) The HVAC system shall be inspected at least annually, and problems found during these inspections shall be corrected within a reasonable time.

(2) Inspections and maintenance of the HVAC system shall be documented in writing. The employer shall record the name of the individual(s) inspecting and/or maintaining the system, the date of the inspection and/or maintenance, and the specific findings and actions taken. The employer shall ensure that such records are retained for at least five years.

(3) The employer shall make all records required by this Section available for examination and copying, within 48 hours of a request, to any authorized representative of the Division, to any employee of the employer affected by this Section, and to any designated representative of said employee of the employer affected by this Section.

Note: Authority cited: Section 142.3, Labor Code.
Reference cited: Section 142.3, Labor Code.

Standard Proposed in New Jersey to Cover Public Employees

PROPOSED STANDARD

Ventilation and Air Quality for
Public Buildings and Places of Employment
for Public Employees*

Background:

Indoor air quality has been responsible for a significant number of complaints from CWA members, including headache, drowsiness, nausea, eye and respiratory tract irritation, dizziness, skin itching or rash, difficulty in breathing and sinus congestion.

Offices and other indoor environments have always been subject to atmospheric contamination. Unfortunately, such problems are on the increase and associated with the measures being taken for energy conservation, and with the introduction of pollution creating new technology and building products. Building tightening, early shutdown and late startup of the ventilation system, reducing or eliminating outdoor air, greater air recirculation, lower air velocities, eliminating humidification or dehumidification systems, and vapor, dust and microbe accumulation are being permitted without consideration being given to possible adverse health effects.

The causes of indoor air problems are well-known and largely preventable. But because no adequate standard has been adopted and enforced, very little is being accomplished to rectify these problems.

Overview of the Standard:

The proposed standard calls for acceptable indoor air quality to be achieved by providing ventilation air of best available quality and specified quantity** to occupied building spaces. The standard specifies how much outdoor air must be supplied per person in smoking and nonsmoking areas. It further requires that outdoor air must be drawn from an area relatively free from pollution sources. It is felt that measurements can be readily taken of the quantities of air supplied; physical inspection and observation can reveal if the intake is properly sized. Thus the standard is enforceable.

The alternative performance standard method of accepting air quality in occupied building spaces as long as certain identified contaminants are kept below set limits has been rejected. It relies almost totally on difficult, costly and imprecise air monitoring and set limits which may be too permissive or nonexistent for some contaminants.

*Excluding laboratories and hospitals.

**The outdoor air requirements for ventilation have been taken from ASHRAE Standard 62-1981, "Ventilation for Acceptable Indoor Air Quality".

We believe our approach is reasonable. It is based on the following beliefs:

1. Outdoor air quality is almost always better than air quality in a poorly-ventilated indoor space.

2. Employees are entitled to breathe indoor air of no worse quality than outdoor air.

3. Where serious outdoor air quality problems exist which impact indoor air quality, the work site should be relocated until the pollution is controlled at the source. Cleaning outdoor air before bringing it indoors is technologically impractical in most cases.

4. Various air contaminants will build up in inadequately ventilated occupied spaces. These may include carbon monoxide, formaldehyde, ozone, oxides of nitrogen, fibrous building materials, microbes.

5. The health effects of exposure indoors to low levels of various air contaminants is not well-known and ought to be minimized.

6. The phenomena of hypersensitivity pneumonitis (HP) will also be controlled by the measures required in the standard. NIOSH found in investigations of five large office buildings where HP was reported that several buildings were characterized by a history of repeated flooding and all contained mechanical systems with pools of stagnant water and microbial slimes.

7. NIOSH, in more than 200 indoor air quality investigations in a variety of office buildings, found five major problems—contamination generated inside the office space (21%), contamination from sources outside the office space (10%), contamination from building materials and products (3.5%), biological contamination (3.5%), and tight building-related problems in which ventilation was inadequate (52%).

It can therefore be anticipated that 50% of buildings will not be in compliance with the ventilation requirements in the table of this standard, showing the need for the standard. Since the other 50% of buildings can be expected to already be in compliance, the reasonableness of meeting the standard is also shown.

8. Contaminants released at roof level may spread over the entire roof and enter nearby ventilation intakes. Contaminants carried by the wind over the side may flow back up onto the roof. Thus, design of exhaust vents is an important issue in the standard.

4. To assure discharge away from the building, effluents must be exhausted above the roof contour height or the roof eddy zone. If this is not possible, high velocity, vertical discharge above the roof at the highest practical level is required. Architectural roof fences intended to improve appearance shall not be permitted to interfere with discharge.

Stacks must be designed and located for satisfactory operation during all wind conditions. In no case should discharge be at roof level or at velocity below average wind velocity. The stacks should be located on the highest roof of a building whenever possible. Stack caps that deflect the effluent downward or drastically reduce velocity should not be used.

5. If possible the building should be operated so that inside pressure is slightly positive with respect to the atmosphere to prevent pollutants entering through idle exhaust ducts and miscellaneous stacks and vents.

6. Distribution of air shall be such that no occupied area receives less than 75% of the amounts specified in the table.

7. Distribution of air shall be such that no occupied area has drafts.

8. At a minimum, ventilation systems shall operate during all hours when buildings are occupied. Early startup may be required after periods of shutdown for holidays and weekends. When required for energy conservation purposes, early shutdown shall not exceed 30 minutes.

9. Relative humidity in occupied spaces shall be in the 30-60% range. HVAC systems with water spray units should be equipped with proper demisters and dehumidifiers, and cooling coils should be run at a temperature low enough to dehumidify ventilation air. In buildings where relative humidity is excessive, outdoor air may initially have to be passed over refrigeration coils for dehumidification prior to passage into AHUs.

10. Humidifiers in HVAC systems should preferentially use steam as a water source. Humidifiers utilizing recirculated water are not recommended as these may become rapidly contaminated with organic dusts and microorganisms.

11. Filters used in AHUs shall have a moderate (50 to 70%) efficiency as measured by the American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE) atmospheric dust spot test, and in general should be the extended surface type. To prolong the life of these filters and to improve cost effectiveness, prefilters (such as the roll type) should be used to filter the air prior to passage over the higher efficiency filters. Filters of this efficiency will remove spores as well as organic dusts that support microbial growth.

C. Preventive Maintenance Programs Affecting Ventilation and Air Quality

1. All external and internal water leaks shall be promptly and permanently repaired.

2. Floors, walls, ceilings and work surfaces shall be kept clean, dry and dust-free.

3. Stagnant water shall not be allowed to accumulate under cooling deck coils of AHUs. Proper inclination and continuous drainage of drain pans is required. AHU components should be routinely inspected at regular intervals. If contamination with microbial slime is found, it shall be removed. Steam lancing can be used to remove slime providing that this treatment does not damage heat exchange surfaces. Chlorine generating slimicides and proprietary biocides may be used to remove slime from AHUs provided that these chemicals are removed before AHUs are reactivated.

4. Filters used in AHUs shall be replaced at regular intervals.

5. Humidifiers which use recirculated water shall be subject to a fastidious preventive maintenance program involving regular inspection, cleaning, and disinfection.

D. Remedial Action in Buildings where HP or Similar Diseases are Occurring

1. Where carpet, upholstery, ceiling tiles and other porous furnishings are grossly contaminated with microbes, it is better to discard these items rather than attempt disinfection.

2. During building cleanup, microbially-laden materials should be carefully removed so as to minimize aerosolization of respirable antigenic materials. Structural and other building surfaces should be vacuumed with an instrument incorporating a high efficiency particulate air filter and then disinfected with bleach or proprietary biocide.

E. Employee Access to Information

1. The following documents must be prepared and available for inspection and copying at each work site by employees and their representatives and State enforcement agencies.

a. Written standard operating procedures for the ventilation system including the method used for regulating percentage of outdoor air and what percentage is used.

b. Written standard maintenance procedures for the ventilation system.

c. A schematic diagram of the building exterior and roof showing all intakes and exhausts and specifying the nature of effluents, velocity in fpm of exhausts, volumes in cfm of intakes and exhausts and stack heights.

d. A diagram showing wind directions and percentage of the time wind blows in each direction at effluent exhaust points.

e. A schematic diagram showing location, type and sequence of all central ventilation equipment including fans, ductwork, air cleaners and filters, energy recovery unit, humidification and dehumidification systems, plenums, air-conditioning and heating equipment, etc.

f. A schematic diagram showing layout of ductwork and intake vents and windows, and exhaust vents for each floor specifying volumes in cfm for vents and windows. Layouts shall also show each desk or other work station, walls, doors and partitions. Smoking and non-smoking areas shall be indicated and the location of equipment covered in 3B.

2. The following information shall be posted at each work site:

a. The name and telephone number of person(s) responsible for compliance with these standards.

b. The name and telephone number of person(s) to whom problems may be reported.

c. Any malfunctions, breakdowns, repairs or changes in ventilation equipment or procedures which are occurring and an estimation of when standard procedures are expected to resume.

d. The layouts described in Section 1f for each floor shall be posted on that floor.

e. The equipment listed in 1e shall be labeled clearly on its exterior in a prominent place.

3. An employee representative shall be assured the opportunity to observe any inspection and/or testing of the ventilation system and receive a copy of results.

F. Building Materials and Furnishings

1. The following shall not be used indoors unless it has been determined in advance that their use will not create measurable levels of air contaminants for more than one week after installation or first use.

a. Particle board, plywood, floor coverings, carpet backings, textiles and other materials containing formaldehyde resins.

b. Urea-formaldehyde foam insulation.

c. Adhesives, paints and sealants containing solvents, isocyanates and other organic chemicals.

d. Flooring, insulation, coating, textiles or other materials containing asbestos.

2. During installation or application of the materials listed in 1a-c, the building spaces involved shall not be occupied.

3. After installation or application of the materials listed in 1a-c, the building spaces involved shall be overheated for a minimum of 12 hours followed by ventilation for a minimum of 12 hours to bake out the organic contaminants, before the spaces are reoccupied.

G. Construction, Renovations, Roofing

1. When dusty construction or renovations occur, dust shall be contained by sealing the construction and renovation work areas with plastic sheeting and maintaining them under negative pressure using high volume dust collectors vented outside the building.

2. When roofing using heated or volatile sealants occurs, intakes in the roofing work area shall be baffled, extended through temporary ductwork or otherwise rearranged so that contaminated air is not drawn in.

3. When the procedures in 1) and 2) are ineffective or not used, affected building spaces shall not be occupied during construction, renovation or roofing work.

Table: Outdoor Air* Requirements for Ventilation

	Smoking		Nonsmoking
Offices		cfm/person	
Office Space	20		5
Meeting and Waiting Space	35		7
Food and Beverage Services			
Kitchens	—		10
Dining Rooms, Cafeterias, Fast Food Facilities	35		7
		cfm/ft.^{2} floor	
Parking Garages, Auto Repair Shops	15		15
Public Spaces			
Corridors and Utility Rooms	0.02		0.02
Public Restrooms	75	cfm/stall or urinal	[illegible]

*Outdoor air is taken from the external atmosphere and, therefore, not previously circulated through the system. If proper air cleaners and adequate temperature controls are provided, part of this air may be recirculated but the outdoor air portion must never be less than 5 cfm/person or 30% of the total required, whichever is higher

United States
Environmental Protection
Agency

Office of
Research and Development
Washington DC 20460

Office of
Air and Radiation
Washington DC 20460

July 1988

EPA

Indoor Air Facts No. 4

SICK BUILDINGS

INTRODUCTION

A new building term--sick building--has been coined in recent years. A building is characterized as "sick" when its occupants complain of health and comfort problems that can be related to working or being in the building. Problems associated with sick buildings are "sick building syndrome" (SBS) and "building related illness" (BRI). (These terms generally apply to problems related to indoor air pollution; they are not used to characterize buildings where complaints stem solely from inadequate temperature or humidity control.)

A World Health Organization Committee estimates that up to 30 percent of new and remodeled buildings may have such problems. In fact, almost every building may at some time experience indoor air quality (IAQ) problems. Frequently, the problems result from the building being used, operated, or maintained in ways unforeseen by those who originally designed it, or from poor judgment in the building design itself.

SBS Symptoms -- A building is said to manifest SBS when:

• A substantial percentage of building occupants complain of symptoms associated with acute discomfort--headache; eye, nose, or throat irritation; dry cough; dry or itchy skin; dizziness and nausea; difficulty in concentrating; fatigue; and sensitivity to odors.
• The cause of the symptoms is not known.
• Most of the complainants report relief upon leaving the building.

BRI Symptoms -- When occupant exposure to indoor contaminants results in a clinically defined illness, disease or infirmity, the building is said to manifest building-related illness, which is characterized by:
• Complaints of symptoms such as cough; chest tightness; fever; chills, and muscle aches which can be associated with illness.
• The cause or causes of the symptoms are believed to be exposure to indoor pollutants.
• Complainants may require prolonged recovery times after leaving the building.

It is important to note that it is normal for some percentage of building occupants to experience one or more of such symptoms, and that occupant complaints may also result from an illness contracted outside the building, acute sensitivity (allergies, perhaps) of certain individuals, job-related stress or dissatisfaction, or other psychosocial factors. Nevertheless, studies show that such symptoms may be caused or exacerbated by indoor air contamination.

CAUSES OF SICK BUILDINGS

Indoor air problems that have been cited as causes of or contributing factors to sick buildings include:

• Inadequate ventilation.
• Pollutants emitted inside the building.
• Contamination from outside sources.
• Biological contamination.

These causes usually act in combination, and often supplement other occupant complaints such as inadequate temperature, humidity, or lighting. However, even after a building investigation, specific causes of SBS problems may remain undetermined.

Inadequate Ventilation -- Prior to the 1973 oil embargo, most building heating, ventilating, and air conditioning (HVAC) systems were designed and operated to provide as much as 15 cubic-feet-per-minute (cfm) of outside air for each building occupant. To save energy, conservation measures have been implemented which reduce the amount of outdoor air provided for ventilation to only 5 cfm per occupant. Also, many HVAC systems do not effectively distribute the ventilation air to people in the building. The result is inadequate ventilation which allows pollution levels from existing sources to increase. This is thought to be a major contributing factor to SBS.

Indoor Pollutants -- Some indoor pollutants come from sources inside the building. For example, adhesives, carpeting, vinyl or rubber molding, manufactured wood products, copying machines, pesticides, and cleaning agents may emit volatile organic compounds (VOCs), including formaldehyde. Research shows that some VOC's can cause acute and chronic health effects at high concentrations, and some are known carcinogens. Tobacco smoke is also a source of indoor air pollution, contributing to harmful levels of VOCs and respirable particulate matter.

Contamination from Outside Sources -- The indoor air can also be contaminated from sources outside the building. This occurs primarily when pollutants from motor vehicle exhausts, plumbing vents, and building exhausts (such as toilets and kitchens) enter the building through improperly located outside air intakes, windows, and other openings. In addition, combustion products such as carbon monoxide and nitrogen dioxide can enter a building from an attached or underground garage. These pollutants can cause both SBS and BRI symptoms.

Biological Contamination -- Another major cause of sick buildings is biological contamination by bacteria, molds and their spores, pollen, viruses, and other biological material. Such contamination is often associated with HVAC systems. For example, biological contamination may breed in stagnant water allowed to accumulate in humidifiers and cooling coil condensate pans, or where water has collected on ceiling tiles, carpeting, insulation, and internally lined duct work. Physical symptoms related to biological contamination include cough, chest tightness, fever, chills, muscle aches, and general allergic type responses such as mucous membrane irritation and upper respiratory congestion. One such indoor bacterium, Legionella, has caused Legionnaire's Disease and other illnesses.

WHAT ABOUT RADON AND ASBESTOS?

Because SBS and BRI problems are associated with acute (short-term) symptoms, indoor pollutants such as radon and asbestos, which are of concern because of their long-term health effects, are not considered to be among the causes of sick buildings. However, this does not mean that they do not pose an important health risk. Radon and asbestos should be included in any comprehensive effort to evaluate a building's IAQ, radon particularly in low-rise buildings and asbestos in older buildings.

ASSESSING THE PROBLEM–THE FIRST STEPS

The first step for individuals with symptoms similar to SBS or BRI is to be examined by a physician to determine the cause of the symptoms and to establish whether the symptoms may be related to the work environment. Consultation with a Board-certified specialist in occupational medicine may also be advisable.

If it is determined that the working environment may be the cause of the symptoms, supervisors, building maintenance personnel, and union representatives will need to work together to identify and resolve the problem. Initially, this effort should include checking to make sure adequate ventilation is being provided, and, if practical, either modifying or removing suspected pollutant sources. If, for example, a biological contaminant is suspected, actions to be considered might include replacing water-stained ceiling tile and carpeting; removing room humidifiers; and cleaning and properly maintaining air handling equipment. Relocating your work space elsewhere in the building might also be discussed.

In many instances such coordinated effort by employees, management, building maintenance personnel, and others, will resolve an indoor air quality problem. However, in other instances, it may be necessary for an IAQ consultant to study the building.

WHAT IAQ CONSULTANTS LOOK AT

Because there may be many different sources of symptoms and complaints in a sick building, IAQ consultants will try to use investigatory procedures that are practical, economically feasible, and sensitive enough to detect the multiple sources of potential problems. Their procedures can be applied to investigating a sick building, a "non-complaint" building as a preventive measure, or to the design of a new or remodeled building. The process usually involves three phases: a *consultation phase, and qualitative and quantitative diagnostics phases.*
The purpose of the **consultation phase** is to identify the nature of existing or potential IAQ problems. Investigators obtain preliminary information on problems and complaints in confidential discussions and perform a walk-through of the building. At this time, they may formulate preliminary hypotheses about the cause or causes of the IAQ problems and present preliminary recommendations. In many cases, this is all that is necessary to resolve an IAQ problem.

In the **qualitative diagnostics phase**, the investigators characterize problems and complaints and evaluate the building's environmental control system design and performance relative to building performance criteria. They may evaluate suspected health problems and sample air for suspected pollutants. If discomfort or SBS is suspected, the investigators may do an engineering analysis of the HVAC system and other building support systems. If BRI is thought to be the problem, they may recommend immediate medical assistance along with appropriate biological or chemical sampling.

Finally, in the **quantitative diagnostics phase**, investigators perform on-site

investigations and laboratory and engineering analyses which include objective measurements of chemical, physical, and biological parameters, and subjective responses of occupants to their environment. The report generally includes a series of recommendations for remedial actions, maintenance procedures, and building systems operation.

SOLUTIONS TO SICK BUILDING PROBLEMS

Solutions to sick building problems usually include combinations of the following:

- **Pollutant source removal, modification, or substitution.** This is the most effective way to resolve an indoor air quality problem when specific sources causing the problem can be identified. This approach reduces or eliminates the emissions from a pollutant source, and may be used in combination with increased ventilation to dilute the indoor pollutant level. Examples of this method include cleaning or replacing contaminated filters in the HVAC system, removing water-stained ceiling tile and carpeting; instituting a no or restricted smoking policy; exhausting combustion products to the outdoors; and using and storing paints, adhesives, solvents, and pesticides in well-ventilated areas. In fact, resolution of a building which manifests BRI usually requires removal of the pollutant source.

• **Time of use adjustment of a pollutant source.** This is another important IAQ control strategy. When feasible, pollutant sources should be used when the least number of people will be exposed, e.g., painting during weekend or non-working hours, and allowing building materials in new or remodeled areas to off-gas pollutants under high ventilation conditions before occupancy.

• **Increasing ventilation rates.** This can often be a cost-effective means of reducing indoor pollutant levels. In buildings with mechanical ventilation systems, outdoor air quantities should be provided at rates at least as high as those specified in appropriate standards or codes. The American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) proposed ventilation standard 62-1981R specifies a minimum of 15 cfm per person. It is important to check that ventilation systems are operated and maintained to provide *at least* these rates. Also, when there are strong pollutant sources, additional ventilation should be provided to dilute or exhaust contaminated air. Optimally, local exhaust should be employed to remove indoor pollution near such sources as restrooms, copying rooms, and printing facilities. (For a more detailed discussion of ventilation, see Indoor Air Facts No. 3, Ventilation and Air Quality in Offices.)

• **Air filtration and purification.** These processes can be used in combination with source control and ventilation where specific problems are identified and practical air cleaning options exist. Particulate filtration, for example, is a highly advanced technology, but increased performance can involve significantly higher costs. Ordinary furnace filters do not effectively capture pollen and other small particles, but higher performance filters are more expensive. Vapor and gas removal equipment is also available for some pollutants, but the technology for general use in ordinary occupied spaces is expensive and requires frequent maintenance.

• **Education.** This is the most important control method. If building occupants, management, building maintenance personnel, and others fully understand the sources and effects of indoor pollutants, they can act together to reduce indoor pollutant exposures.

FOR FURTHER INFORMATION

For additional information on indoor air pollution, contact your state or local health departments, non-profit agencies such as your local American Lung Association, or the following:

Division of Respiratory Disease Studies
National Institute for Occupational Safety and Health
944 Chestnut Ridge Road
Morgantown, WV 26505

Public Relations Office
American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE)
1791 Tullie Circle, NE
Atlanta, Georgia 30329

Building Owners and Managers Association International
1250 Eye Street, NW
Washington, DC 20005

Additional copies of this fact sheet and others in the Indoor Air Series are available from:

Public Information Center
U.S. Environmental Protection Agency
Mail Code PM-211B
401 M Street, SW
Washington, DC 20460

SCIENTIFIC AMERICAN May 1988 Volume 258 Number 5

A1

Controlling Indoor Air Pollution

Airborne combustion products, toxic chemicals and radioactivity are more abundant indoors than outdoors. Should indoor air be regulated? If so, how? Putting risks in perspective helps to answer both questions

by Anthony V. Nero, Jr.

Because emissions from factories, power plants, waste dumps and automobiles can harm people as well as the biosphere in general, many countries have established extensive systems for identifying and controlling such pollution. Yet the greatest exposures to airborne combustion products, volatile toxic chemicals and radioactivity typically occur not outdoors but inside residences, offices and other nonindustrial buildings—settings that traditionally have been neglected by pollution-control agencies. Indeed, the health risks incurred merely by breathing the air at home can substantially exceed the general limits on risk that regulatory agencies impose in controlling pollutants in outdoor air or drinking water.

On the other hand, the risks from inhaling indoor pollutants are typically less than those associated with many voluntary activities that are regulated only marginally, if at all. By choosing to smoke cigarettes a person greatly increases the likelihood of later suffering from heart disease and lung cancer. Yet smoking is controlled indirectly in the U.S., where manufacturers are required only to print warnings on cigarette packages and in advertising.

The risks posed by indoor pollutants are in fact comparable in magnitude to those associated with exposure to chemicals or radiation in industrial settings. Living in certain houses and working at certain jobs are also similar in that both involve assuming some risk from exposure to pollutants in exchange for some personal benefit (a home or a salary). Yet the approach for regulating occupational exposures, which is based primarily on setting concentration limits for each pollutant, would be extremely difficult to apply in controlling the quality of indoor air. The causes of indoor air pollution are so diverse and the concentrations are so variable that continual monitoring would be required in virtually all buildings—more than 80 million in the U.S. alone. Moreover, governments may hesitate to intrude into private houses in the name of pollution control, preferring merely to warn people of the dangers and let them decide for themselves whether or not to take action.

Although building codes could be rewritten to reduce the chance of having high pollutant levels in new structures, the incidence of buildings with indoor concentrations five, 10 or even 100 times the average justifies an active effort to find and fix such buildings now. The effort may affect hundreds of thousands of houses in the U.S., requiring as large an environmental program as has ever been undertaken. The scope of such a program, the variability in structures and pollutant concentrations and the balancing of personal choice, risk and benefit make construction of an effective and sensible overall strategy for the control of indoor air quality a daunting challenge to the research and regulatory community.

The pollutants found in indoor air are similar to those found outdoors and in some instances actually come from outdoor sources. Yet the pollutants measured in the highest concentrations indoors are those that arise from within buildings or their substructures. They reach such levels simply because they are emitted into a small volume—the indoor atmosphere—from which they cannot easily escape.

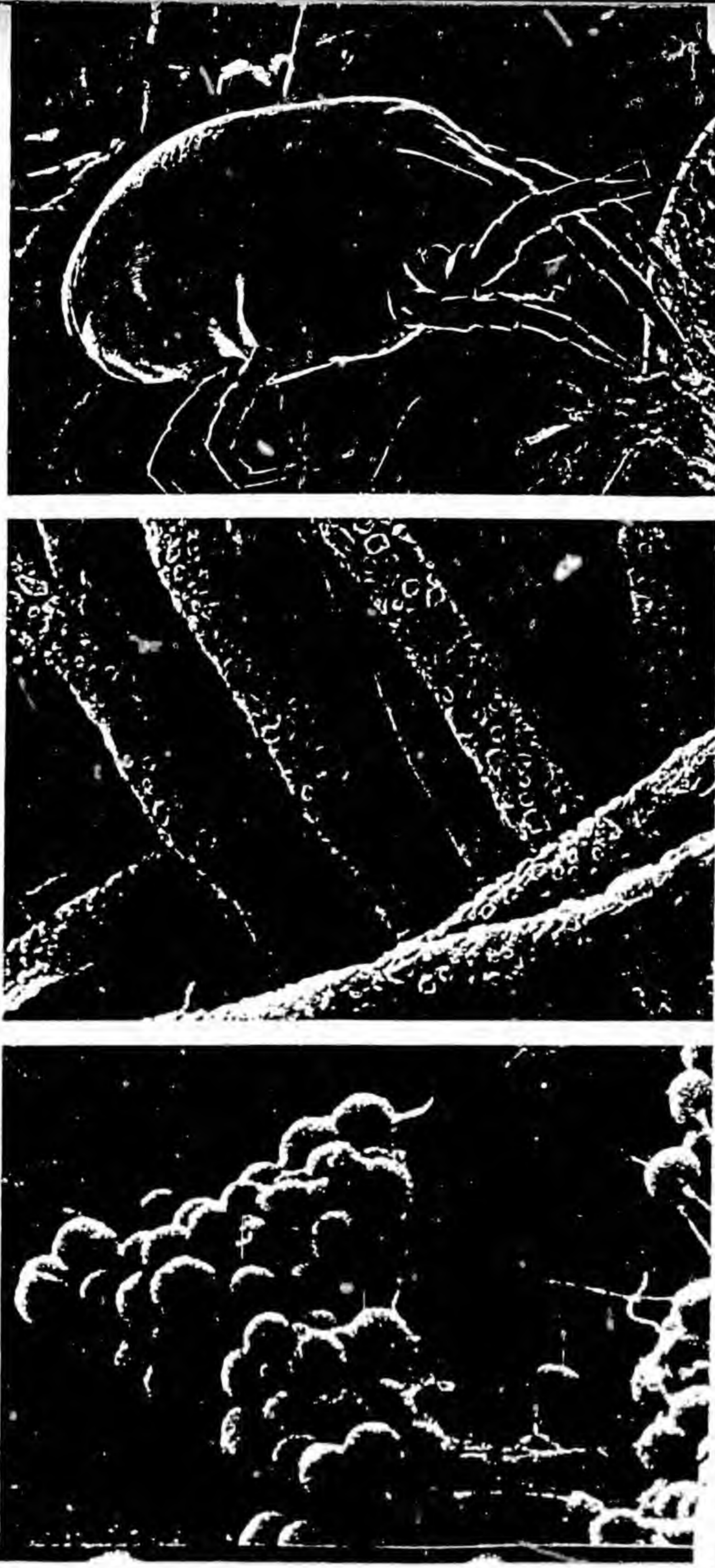
One of the most familiar indoor pollutants is cigarette smoke, which is composed mainly of organic aerosols, or tiny airborne particles. Heating and cooking appliances that burn natural gas, kerosene, oil and wood (or peat, coal and dung, as is the case in some countries) also emit varying quantities of respirable particles along with carbon oxides, nitrogen oxides and trace organic chemicals. Less familiar indoor pollutants include methylene chloride, formaldehyde and a vast range of more complex organic chemicals that are given off by building materials, furniture, cleaning fluids, pesticides, paints and paint strippers. Respirable fibers of asbestos can be released indoors from insulating material in older buildings. Indoor air pollutants even include the products of living organisms or the organisms themselves, such as bacteria, fungi and house mites. Perhaps most disconcerting for the occupants of many houses is the fact that the ground on which the houses sit is a major source of radon, a radioactive gas that is generated naturally as a product of the nuclear decay of radium, an element present in trace quantities throughout the earth's crust.

These classes of pollutants, which

are almost always present in indoor air, vary over a wide range of concentrations among residential and office buildings. The variability depends primarily on the rate at which each pollutant is emitted into the indoor atmosphere. A home with vented heating and cooking appliances (and without smokers), for example, will ordinarily not have high concentrations of combustion products in the air. Similarly, measurements of radon concentrations done in 100 U.S. houses in the late 1970's showed that differences in the entry rate of the gas accounted for most of the variability in the concentrations among the houses.

It is now understood that radon enters houses in the air that is drawn from the underlying soil by small differences in air pressure between indoors and outdoors. These pressure differentials (amounting to no more than .0001 atmosphere) arise in part from the "stack" effect: the tendency for air to rise whenever it is warmer than the surrounding atmosphere. (The stack effect is the working principle of a chimney.) Hence whenever it is warmer indoors than outdoors, air tends to flow in through the lower part and out through the upper part of a building's shell (its substructure, walls and roof). It does this by "infiltrating" through various openings, particularly around windows and doors and penetrations for pipes and wiring. Winds blowing against a building can also produce similar pressure differences—and thus airflows—across the building's shell, although the airflows exhibit a pattern substantially different from the patterns produced by the stack effect. Only a small part of the infiltrating air actually comes from the soil, but this is what carries the radon into houses. The entry rate of the gas therefore depends on the permeability of the soil to airflow, along with other geologic, meteorologic and structural factors.

The bulk of the infiltrating air actually comes from the outdoor atmosphere and accounts for the general ventilation of small structures such as houses. (In contrast, large structures such as office buildings usual-



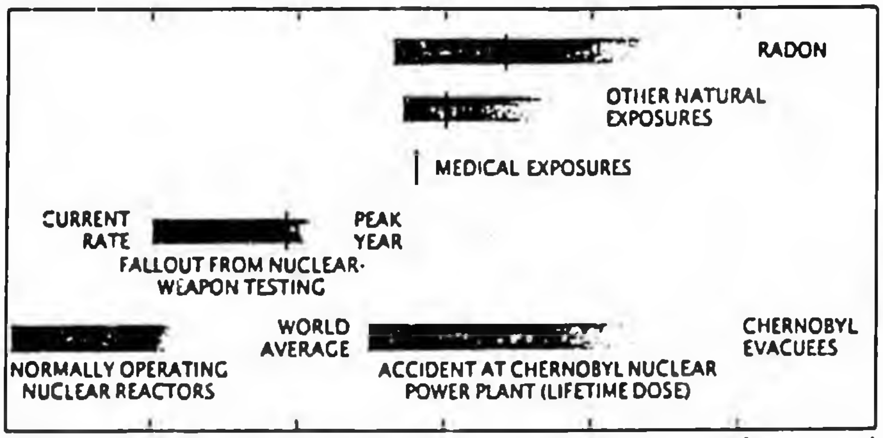
MICROORGANISMS found in ordinary household dust, such as mites (*top*), fungi (*middle*) and bacteria (*bottom*), are classified as indoor air pollutants because they can cause allergic reactions and other illnesses, as more familiar pollutants do.

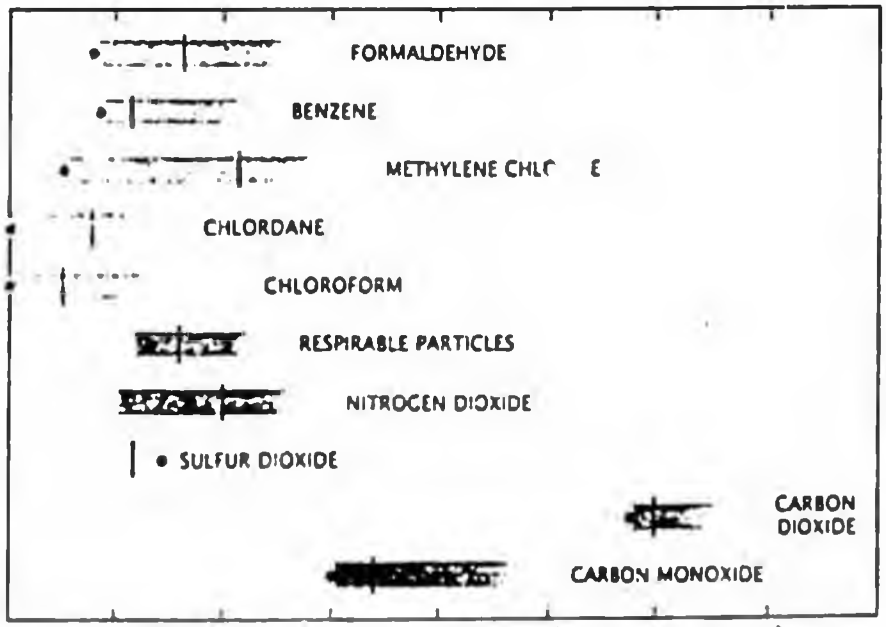
ly rely on fans, air conditioners and ducts to provide ventilation.) A surprising amount of outdoor air manages to leak into a house by means of infiltration. In most houses outdoor air replaces the volume of indoor air every one to two hours.

Such an exchange of air represents a constant energy "drain," since energy has to be expended to heat or cool the outdoor air as it replaces the indoor air. Consequently in the mid-1970's energy-conscious homeowners in the U.S. and elsewhere began to reduce infiltration by weather stripping, plugging openings in the building's shell and caulking around windows and doors. Studies indicate that these measures reduce ventilation rates by roughly 10 to 30 percent, depending on how carefully the measures are implemented. While the modest decreases result in useful energy savings, the resulting changes in the concentrations of indoor pollutants are small compared with the ten- or hundredfold difference in concentrations observed between one house and another.

There is in addition a third factor that determines indoor pollutant concentrations: the rate at which a particular pollutant reacts with other airborne species or interior surfaces. Nitrogen dioxide, for example, is found to be removed from indoor air as much by such reactions as by ventilation. The chemical form and concentrations of radon's decay products (isotopes of polonium, lead and bismuth) also depend on the amount of airborne particles and the pattern of air movement in a particular building, influencing the radiation dose the products ultimately impart to the lungs when they are inhaled. Many other potentially important aspects of indoor-air chemistry remain virtually unexplored.

Taken together, the variability in entry rates, ventilation rates and reaction rates is the cause of an impressive range of concentrations for most indoor pollutants. No better example can be given than that of radon. In the U.S. concentrations in single-family houses vary over four orders of magnitude (factors of 10)—from a few becquerels per cubic meter of air to more than 10,000, with an average level of about 50 becquerels per cubic meter. (One becquerel is equal to one radioactive decay per second. Another common unit of measurement is the picocurie per liter, which is equal to 37 becquerels per cubic meter.) The average indoor level represents a radiation dose about three times larger than the dose most people get from X rays and other medical procedures in the course of their lifetime. Those exposed to higher levels receive proportionately higher doses. Indeed, hundreds of thousands of Americans living in houses that have high radon levels receive as large an exposure of radiation yearly as those people living in the vicinity of the Chernobyl nuclear power plant did in 1986, when one of its reactors exploded and released radioactive material into the environment.



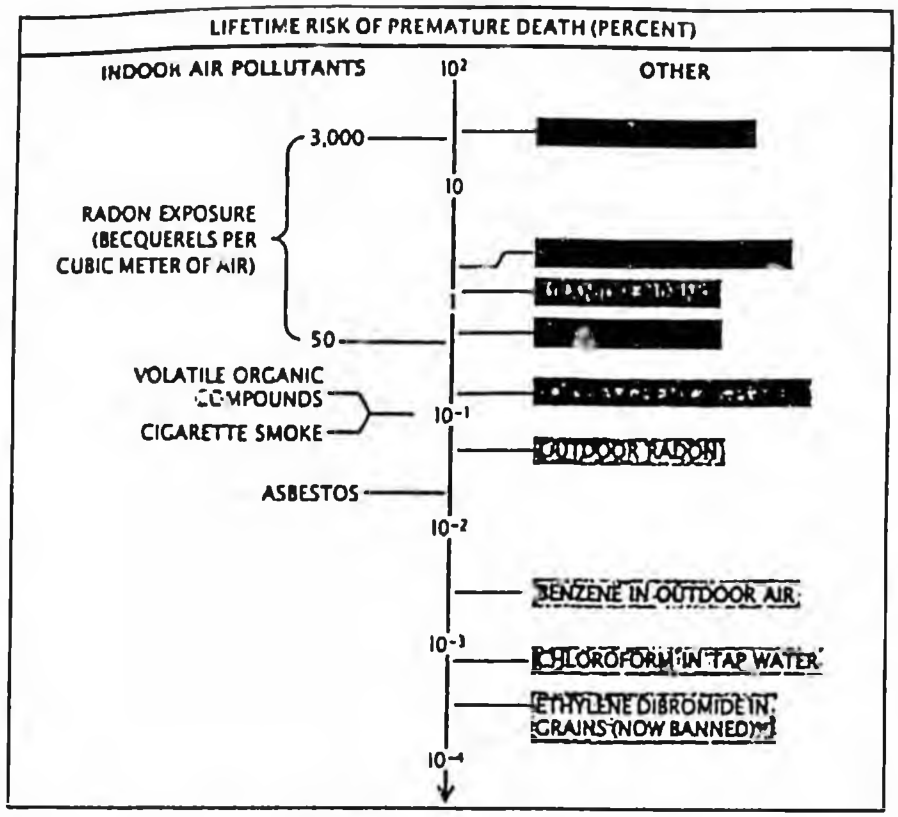


INDOOR AIR-POLLUTION LEVELS (*bars*), measured in terms of radiation exposure due to radon (*orange*), concentrations of organic chemicals (*blue*) and concentrations of combustion products (*green*), span orders of magnitude (factors of 10). Furthermore, the average indoor levels (*lines*) are generally higher than the average outdoor levels (*dots*). Exposures from other sources of radiation (*red*) are shown for comparison.

The wide range of pollutant types and concentrations entails a correspondingly wide range of health risks. Cigarette smoke, asbestos fibers, the decay products of radon, formaldehyde and many other organic chemicals are demonstrated or potential carcinogens. Most of these pollutants can also lead to chronic or acute diseases, such as respiratory infections and allergic responses, as can combustion products in general and a variety of indoor bacteria and fungi. Extremely high levels of carbon monoxide—a combustion product—can even result in immediate death. Yet only in a relatively few cases, such as acute allergic reactions or carbon monoxide poisoning, is there a clear-cut relation between a given exposure to an indoor pollutant and an associated health effect. More often than not a given instance of respiratory disease or cancer cannot be directly attributed to a specific cause, environmental or otherwise.

Instead scientists study the occurrence of pollution-related diseases in heavily exposed groups (sometimes human beings but more often animals) in order to obtain probabilistic relations between exposures to pollutants and the chance that the diseases will appear in the general population. This approach provides the basis for estimating, albeit usually with substantial uncertainty, the risk of cancer and other diseases associated with the lower pollutant concentrations generally found in water and air, both indoors and outdoors.

In quantifying such health risks one must also consider the risk of suffering nonfatal diseases. Because these illnesses can occur with higher frequency, the overall risk they pose may be judged to be as important as, say, the risk of cancer. Yet it is difficult to treat all illnesses—fatal or otherwise—on a common basis; this would require an equivalence between days sick and days of life lost. It may also be inappropriate to do so, since acute illnesses such as allergic responses are immediately apparent to the sufferer, not merely hypothetical risks, as is the case with cancer.



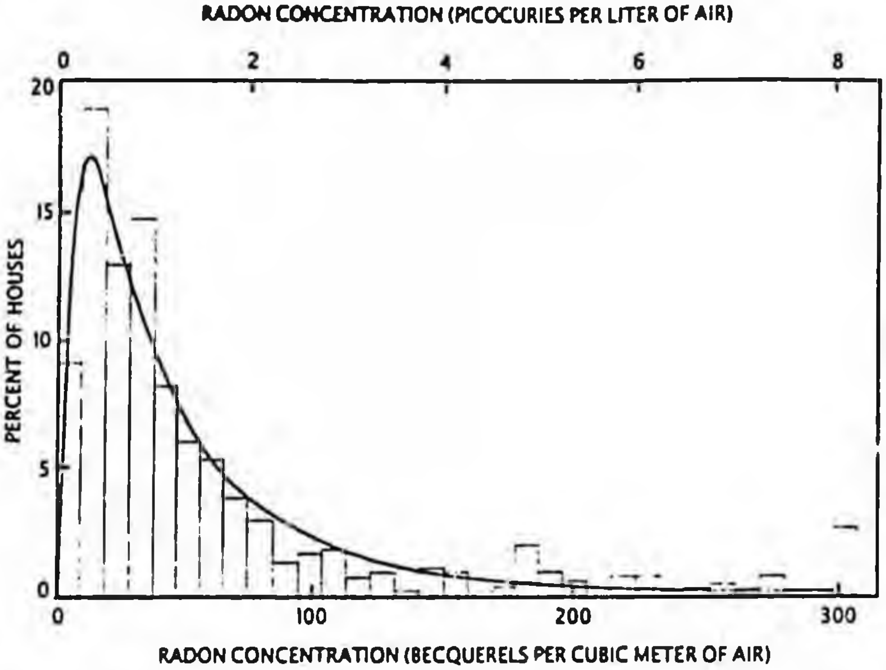
ESTIMATED PROBABILITY of suffering a fatal disease is substantially higher for exposure to indoor air pollutants (*black*) than for exposure to the pollutants in outdoor air, drinking water and food (*pale red*). The risk of death from exposure to indoor pollutants, however, is no more than that from certain voluntary activities (*red*), such as smoking, and occupational hazards (*gray*), such as those faced in mining uranium.

In order to estimate the risks posed by indoor radon, for example, results from epidemiologic studies of underground miners who were exposed to high concentrations of radon's decay products are extrapolated to the lower exposures characteristic of a typical house. Based on these estimates, the average indoor concentration of radon in the U.S. corresponds to a chance of contracting lung cancer of about one in 250, or .4 percent, which would account for approximately 10,000 lung-cancer deaths per year in the country. Although the risk estimates for indoor radon exposure do have a degree of uncertainty, it is much less than for estimates of risk from other environmental-pollutant exposures, such as those from toxic chemicals, which are usually based on extrapolating doses and responses a thousandfold. In fact, no extrapolation is needed to estimate the health risks in houses with exceedingly high levels of radon. For example, people who have lived for 20 years in houses that have 1,000 becquerels of radon per cubic meter (which number in the tens of thousands in the U.S.) face an additional 2 or 3 percent chance of contracting lung cancer.

These figures are nothing short of remarkable. Pollutants in the outdoor environment are regulated so that the estimated risks of premature death from exposure to them are usually less than .001 percent. Indeed, just about the only environmental risks—at least for fatal disease—that are comparable to indoor radon arise from other indoor pollutants. Although the estimate is highly tentative, the risk of cancer arising from exposure to a wide range of organic chemicals in the indoor environment can be said to be about .1 percent. The risk of premature death due to typical exposures to asbestos is thought to be about .02 percent, with most of this risk resulting from indoor exposures. Both of these estimates require more than an order of magnitude greater extrapolation from epidemiologic or animal studies than the estimates of the risk associated with radon exposure. Finally, the risk of lung cancer attributed to breathing smoke from other people's cigarettes is estimated to be about .1 percent.

Yet the level of risk posed by pollutants at concentrations found indoors is either in the same range as or lower than other risks that are accepted in exchange for some personal benefit. These risks include diseases caused by occupational exposures to toxic chemicals and work-related accidents as well as automobile accidents, which people are willing to accept—within reasonable bounds—in order to earn a salary or to have the convenience of personal transportation. The risk of death from automobile accidents, for example, averages about 2 percent in the U.S. People also seem willing to accept a .5 percent risk of dying in a fall or fire at home in return for the comfort of living indoors. Many are even ready to accept the 30 percent risk of premature death associated with smoking—a risk that is rivaled only by exposure to the highest indoor radon levels known—for the sake of personal pleasure.

How, then, can one approach the problem of indoor air pollution, which entails risks that exceed common "environmental" risks but not the risks people tacitly accept when driving, smoking or simply living



DISTRIBUTION OF RADON CONCENTRATIONS suggests that about 2 percent of the houses in the U.S. (numbering some one million) have concentrations greater than or equal to 300 becquerels per cubic meter of air, which is five times the average level.

in houses? Any overarching strategy for controlling the risks associated with indoor-pollutant exposures requires three basic, interdependent elements: a system of advisory or regulatory standards that determines the overall attack on the problem, a methodology for identifying the situations of greatest concern and a framework for selecting control techniques suited to each situation.

The underlying system of standards can take fundamentally different forms, depending on the objectives. One objective might be to control the average exposure of the entire population; a contrasting objective is to avoid extreme levels, thereby limiting individuals' risk of disease, fatal or otherwise. In any case, the objectives can be achieved by formulating standards that either control the factors affecting pollutant concentrations or establish limits on the concentrations themselves.

Actually both types of standard are applied in the control of outdoor pollution. The release of pollutants from automobiles and power plants, for example, has been controlled by standards that modify such factors as combustion processes. Concentration limits in turn are embodied in standards for outdoor air and water, which are meant to protect the population at large to a higher degree than individuals who are exposed to the same pollutants in the workplace.

Concentration limits for outdoor air usually apply to a large environmental region—an "air basin," such as that of Los Angeles—so that exposures are more or less consistently limited throughout a large population. Because conditions vary greatly from one building to another, a comparable approach to controlling indoor pollution would entail dealing with some 80 million air-quality-control "districts" in the U.S.—one for each building. As a result concentration limits for indoor pollutants are most effectively aimed at avoiding excessive individual exposure rather than controlling the average exposure of a population.

The fact that the indoor environment has significant inherent risks has to be recognized and near-term attention focused on the exceptional situations—including truly high levels of radon, organic chemicals or combustion products, as well as the occasional excessive levels of flaking asbestos and even house mites. This approach contrasts sharply with suggestions to limit formaldehyde concentrations to zero (within the limits of instrumental sensitivity) or to limit indoor radon concentrations to outdoor levels (about 10 becquerels per cubic meter of air). These proposals do not appear to recognize that the risks associated with average exposures to formaldehyde and radon are solidly within the range of risks that are normally accepted.

Nevertheless, average exposures to indoor pollutants can also be gradually lowered as a long-term goal. This can be achieved by establishing standards that regulate the factors affecting indoor-pollutant concentrations. For this reason it is important to identify how source, ventilation and structural characteristics affect the concentrations. Such knowledge can be applied in the formulation of specific criteria for the design, fabrication and utilization of new buildings and furnishings that will ensure acceptable indoor air quality in the great majority of cases.

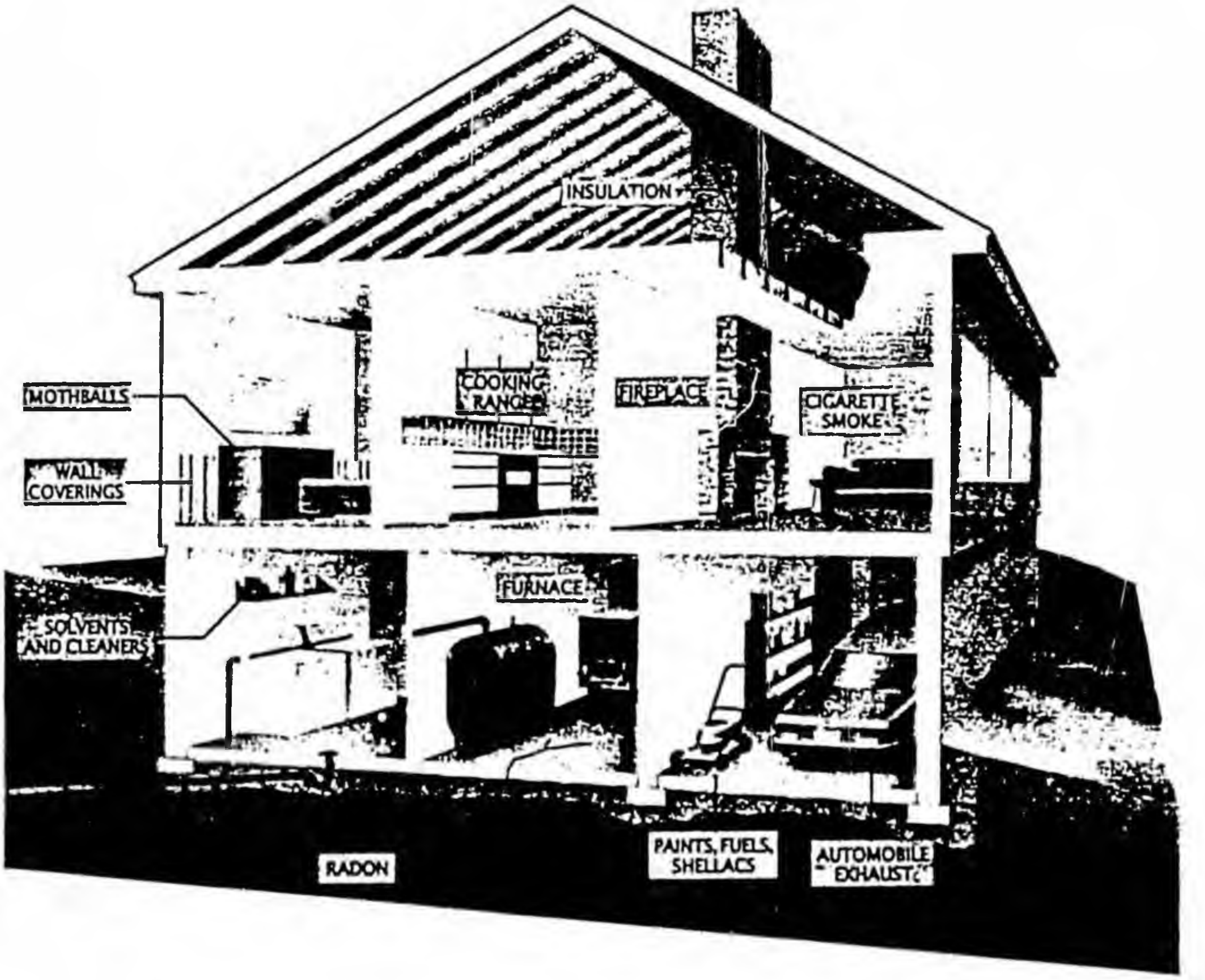
Studying the behavior of indoor pollutants also helps in the development of a methodology by which to identify buildings that have or are likely to have excessive pollutant levels. For example, knowledge that certain materials or appliances are often associated with high levels of organic pollutants or combustion emissions can lead to monitoring in buildings containing those products. Similarly, analysis of the general geologic, architectural and meteorologic factors affecting indoor radon concentrations might serve to identify regions where excessive levels are likely to occur.

Once a building has been identified as needing remedial action (whether it is already constructed or still in the planning stages), control techniques can be implemented. A number of control techniques have already been developed, corresponding roughly in both design and effectiveness to the fundamental factors affecting indoor concentrations. Given that the emission or entry rate is the primary determinant of concentration levels, measures to reduce pollutant sources provide the primary control—assuming that ventilation rates are in the normal range. Emissions of formaldehyde and other volatile organic substances, for instance, can be lessened by changing the way particle board, adhesives and other products are manufactured. Good burner and exhaust designs in heaters and cooking appliances can decrease the concentration of combustion products. Entry of radon from the ground can be diminished markedly by means of simple systems of pipes and fans that draw air from (or blow air on) the soil or gravel immediately under the substructure of a house.

If it is determined that neither infiltration nor opening windows is sufficient to ensure an adequate ventilation rate, mechanical systems can be installed. In large buildings these systems can be quite complex, designed to meet performance criteria that are often incorporated into building codes. In houses with little infiltration much simpler systems can be employed, such as a single exhaust fan. (To save energy the system can be designed so that exhaust and intake airstreams exchange heat.) Although infiltration and mechanical ventilation can provide a basic level of protection, they cannot be relied on to reduce pollutant concentrations substantially: the required increase in ventilation rate would ordinarily be more difficult and more costly to achieve than eliminating or reducing the source of the pollutants.

An alternative means of control might be to physically clean the air of airborne gases or particles. This approach suffers some of the same limitations as ventilation, namely that marked reductions in pollutant concentrations would require high rates of processing the air. In fact, many of the less expensive and popular tabletop air cleaners provide only very low and generally inadequate cleaning rates. Of more concern is the fact that better devices may not even reduce the overall exposure. For example, in drastically reducing the total concentration of radon's decay products, filter systems and electrostatic precipitators (which remove particles suspended in air by imparting an electric charge to them) increase the fraction of the decay products that are not attached to airborne particles. Unfortunately the free decay products appear to cause the greater radiation dose to the lung. Hence in spite of the fact that air cleaning may reduce the total concentration of radon's decay products, it does not necessarily reduce the exposure to radiation.

Air cleaning may find a role in control of biologic particles, such as bacteria, fungi or residue from house mites, that do not behave like chemical or radioactive pollutants. In particular these organisms actually multiply given the right conditions, requiring a different perspective on control. The most effective approach



SOURCES OF AIRBORNE POLLUTANTS in a typical house are myriad. Combustion products (*green*) are traced to cigarette smoke, heating and cooking appliances and perhaps automobile exhaust. Organic chemicals (*blue*) are given off by substances in paints, plywood, solvents and adhesives. Radon (*orange*) is drawn into a house by small differences between outside and inside air pressure: the gas seeps through cracks in the house's foundation and through openings around loose drainage pipes.

in their case would be to combine air cleaning or increased ventilation and a reduction in indoor humidity.

Current efforts to control indoor air quality have in fact followed the two basic approaches: setting specific concentration limits and modifying the design and manufacture of buildings and their contents. The Netherlands has adopted standards limiting indoor formaldehyde concentrations to 120 micrograms per cubic meter, and Canada has set a limit of 150 becquerels per cubic meter for indoor radon in uranium-mining communities. West Germany and the U.S., on the other hand, have set standards that limit formaldehyde emission from wood products, such as plywood, and have considered regulating the emissions from unvented fossil-fuel heating appliances. Policymakers, however, have come to acknowledge their naiveté in adopting concentration limits as the primary basis for control: emission and ventilation standards have been found to be more workable.

Attempts have also been made in recent years to include optional concentration limits for identified classes of pollutants as part of the ventilation standards incorporated into building codes. This illustrates a dangerous tendency to expand each of the approaches in an overall control strategy to include the other, leading to an overt or implicit confusion of objectives. A self-consistent and comprehensive strategy would rely on the factors that determine ventilation and emission rates as "handles" for keeping concentrations within (implicitly) acceptable ranges in most new buildings and adopt explicit concentration limits mainly as criteria for reducing truly excessive levels found in existing structures.

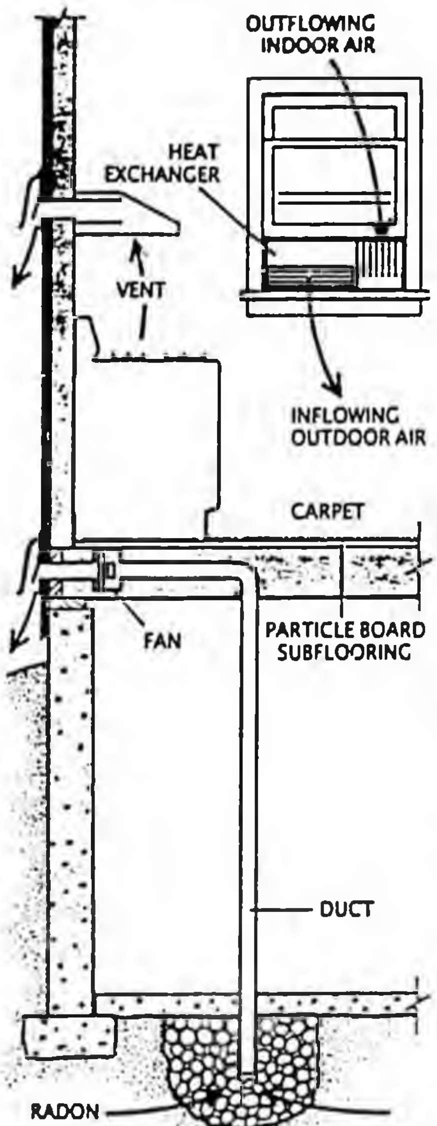
In spite of the confusion in objectives, there at least is some consensus on where the major responsibilities lie for implementing control strategies. This consensus is important, because many actors are directly involved. They include national and local government agencies, professional organizations, manufacturers of building materials and household appliances, builders and contractors. For that matte[illegible] anyone who is active in issues of hea[illegible]h, environment, housing, energy and consumer products as well as in related areas such as demography, meteorology and geography should necessarily be involved.

Yet the success or failure of a program to control indoor air quality ultimately hinges on the behavior of the owners and occupants of buildings. At present occupants are often not aware of potential health problems caused by the way they use certain appliances or substances—or for that matter of the effect they have on others by smoking cigarettes in enclosed spaces. Even building managers may not know for what activities the building was originally designed or how the ventilation equipment in the building is meant to be operated.

For this reason some local governments are considering requiring every manager of a building to conform to the assumptions made in its design. In this way a chain of responsibility from the engineer, architect and builder to the owner and occupants can be maintained. An important element in such a system might be a supporting document associated with a building, much like a deed, that describes the design assumptions relevant to indoor air quality and records changes in the building's occupancy or ventilation equipment. In the case of office buildings the document could list a building's smoking areas and indicate the extent to which furnishings that emit organic chemicals can be used.

A simpler document for private houses could maintain a record of radon measurements and of any remedial techniques and maintenance procedures that may be needed. It would be similar to the document required in many areas that certifies a house for sale is free of termites. Indeed, in areas where high radon concentrations have been reported real-estate transactions are already including this information. Such a document would be one of the more visible manifestations of a comprehensive control strategy.

The control of indoor air pollution goes beyond the conceptual basis of current regulatory structures, which were built for controlling exposures to pollutants in industrial or outdoor settings. The fact is that the health risks posed by indoor pollutants have to be considered in their own right, and the objectives and approaches for a rational pollution-control strategy must be thought out anew. Such rethinking depends on science to evaluate the health risks, elucidate the correlation between pollutant concentrations and the factors that influence them, develop methods for measuring pollutant concentrations and determine the effectiveness of control techniques. The resulting science and policy of indoor air quality might even change how we think about other pollutant exposures, leading to a more realistic perspective on environmental risks in general.



CONTROL MEASURES seek to lower concentrations of pollutants by lowering the rate at which they enter the indoor atmosphere or by increasing the rate at which outdoor air replaces indoor air. The amount of formaldehyde released from particle board and carpets can be reduced by changing the resins and binders used in their manufacture. Venting a cooking range usually results in a marked drop in the concentration of combustion products. The rate at which radon enters a house can be lowered by reducing the air pressure under the building. This can often be done by means of a single fan and a duct. Finally, heat exchangers can improve a house's general ventilation rate without significantly increasing energy costs, since they heat or cool inflowing outdoor air with outflowing indoor air.