

## Controlling Sources of Indoor Air Pollution

People are devoting more and more attention and resources to controlling indoor air pollution sources. Architects, engineers, interior designers, and facility managers are increasingly trying to specify healthier materials. Manufacturers are creating new, lower-emitting products and are eliminating carcinogenic chemicals from their products. Government agencies in the United States and other countries are funding programs to improve measurements and understand source emissions. They are also developing or using guidelines, standards, and even regulations to control sources.

However, large differences of opinion exist about some important indoor air pollution source control questions: is source control more effective than ventilation; is source control practical; and, is source control cost effective? Even if people decide to focus efforts on source control, a critical question remains: what sources are important to control?

This article explores three aspects of source control:

- Control Options - why source control is critical to controlling indoor air pollution.
- Understanding Sources and their Significance - the important sources, their emission patterns, and their effects on humans.
- Building Material Emission Factors - how factors such as quantities and physical properties of different materials affect a source's significance.

### Control Options

There are, essentially, three indoor air pollution control options: reducing or eliminating emissions from sources; ventilating to dilute or exhaust the pollutants; and, filtering or air cleaning.

It seems obviously less efficient to allow contaminants to disperse in air and then try to collect the contaminated air in order to exhaust or filter it. However, many manufacturers and sellers of indoor air contaminant sources argue vehemently against source control. Instead, they advocate a so-called "building systems approach." By this they mean we should focus control efforts on ventilation systems rather than building materials, furnishings, appliances, consumer products, tobacco smoking, and other sources of contaminants. They claim that inadequate ventilation causes most indoor air quality (IAQ) problems. Many supporters of this argument are chemical manufacturers, tobacco companies, and consultants who are aligned with manufacturers of ventilation and air-cleaning equipment. (See *IAB*, Vol. 1, No. 1, pp. 1-5.)

By directing attention away from source control, these advocates diminish the likelihood that their product or their client's product will be restricted or removed from the marketplace either by regulation or by market forces. Furthermore, they decrease, at least in the short run, the risk of legal and financial liability associated with the manufacture, sale, installation, and use of the products. They influence policy-makers as well as building designers, builders, and operators.

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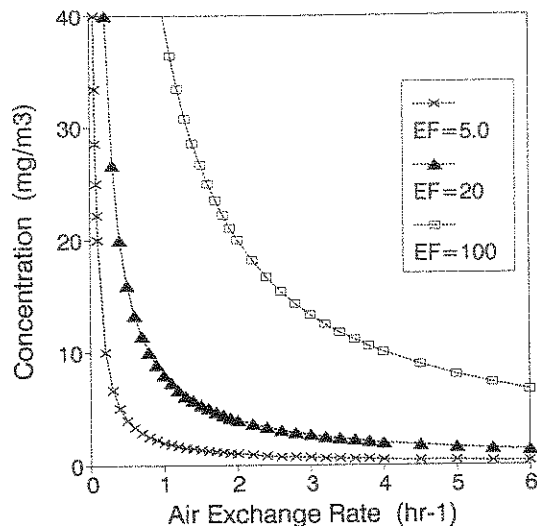
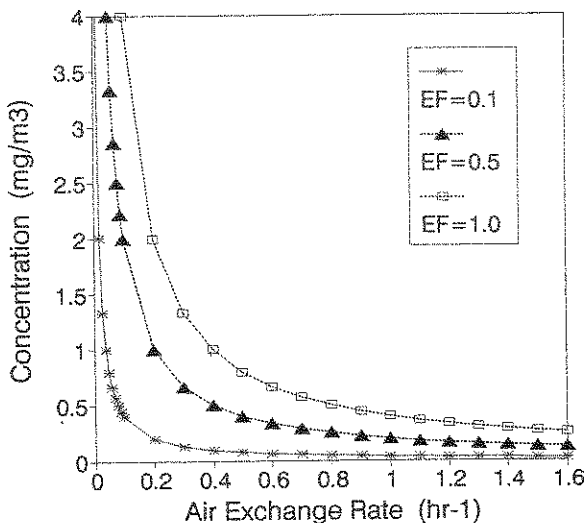


Figure 1 - VOC Concentrations as Functions of Ventilation and Emission Rates.  
EF (Emission Factors) in  $mg \cdot m^2 \cdot hr^{-1}$

### "An Ounce of Prevention..."

While the well-funded advocates of the so-called "building systems approach" lobby against it, most public health authorities promote source control. This is the case not only in the United States and Canada but also in several European countries active in the indoor air field.

From a comprehensive perspective, source control is the most effective general means to improve IAQ. It is the primary thrust of most public health and environmental protection programs. Examples are abundant in preventive medicine programs, hazardous materials programs, water pollution control programs, and ambient air pollution control programs. By eliminating or reducing sources of indoor air contaminants, requirements for exhaust or dilution ventilation and air cleaning can be minimized. Generally it turns out to be more cost effective to control pollution at the source than to try to remove it once it has been disseminated into the environment or dispose of it once it has been collected.

Indeed, some authorities promote a general strategy of minimizing source strengths without special regard for the composition of emissions or the knowledge of their particular impacts on occupant health. This is sometimes called "pollution prevention," and it has become a major U.S. EPA program. It sidesteps the deficiencies that result from failing to determine health effects (a costly and time-consuming process). Absent more detailed information on various characteristics of most sources, pollution prevention may be a reasonable approach.

### Source Control and Ventilation

Figure 1 shows the relationship between source VOC emission rate, ventilation rate, and indoor air VOC concentrations. Clearly, the stronger the source, the more

ventilation required to lower the VOC concentration to a given level. Note that for the "typical" source strength shown here, when outside air ventilation rates are above about one air change per hour, increasing ventilation a little produces very little reduction in concentration. However, as ventilation rates decrease, small changes have larger effects on concentrations. When ventilation rates are less than one-half an air change per hour, small reductions in ventilation produce significant changes in VOC concentrations. The same general relationships hold for specific VOCs and for other contaminants.

Note that with the very common variable-air-volume ventilation supply, the design of many building types such as offices, stores, and residences frequently produce low air-exchange rates. They operate at air-exchange rates less than one per hour when outdoor air temperatures approach or exceed the indoor air temperature if cooling is required indoors. That is the case for many buildings, especially larger ones, much of the time. Also, when heating is required for most of these same buildings, outdoor air-exchange rates also tend to be low when outdoor air temperatures are below the indoor temperatures. Thus, for these buildings, indoor air concentrations are extremely sensitive to the source emission rates.

Of course, either ventilation or filtration/air cleaning is necessary whenever people occupy buildings. This is true no matter how extensive or effective source control programs may be. Filter and adsorbent manufacturers believe that filtration and air cleaning could be effectively used more than they are currently; some HVAC system designers have favored air dilution and exhaust of contaminants rather than air cleaning and filtration for most non-industrial indoor air applications. Both viewpoints are often valid. However, good IAQ cannot be achieved in an

economically, socially, and environmentally responsible fashion without an effective source control program that minimizes the amount of ventilation and filtration required.

**Building Owners' Perspective** From the perspective of the developer, building owner, or operator, effective source control can often be accomplished without excessive costs. Sometimes design changes or product substitutions that minimize emissions cost little or nothing; some can even save money, energy, or other resources. In many cases it is more economical to control emissions at the source than to provide extra ventilation, filtration, or air cleaning. Source control is often a one-time, front-end action while increasing ventilation requires increased first costs for up-sizing HVAC systems and on-going operating costs that reflect energy costs.

**Product Manufacturers' Perspective** In many instances, marketing pressures are forcing source control through creation of "healthier," low-emitting products or withdrawal of high emitters and those with carcinogenic or very toxic emissions. In other instances, some government intervention has occurred before effective action was taken. (See articles about the EPA Carpet Policy Dialogue in *IAB* Vol. 1, Nos. 4 and 5.) Some source improvements can actually reduce manufacturing costs, and they certainly reduce potential product liability while increasing market appeal. However, many manufacturers

fear that product modifications will increase their manufacturing and marketing costs, diminish their sales, or require them to abandon their investments in existing product manufacturing processes or marketing programs.

## Understanding Sources and Their Significance

Lacking detailed and extensive health-effect information, we might select control options that yield the greatest reductions in exposure, that are most feasible, and that are practical in new construction and retrofit applications respectively. We might also restrict the use of products that emit known carcinogens. However, the number of sources is extremely large and source strengths vary greatly over time; the task of evaluating products available for a particular use (e.g., paints, adhesives, floor covering) is considerable. Therefore, it is important to prioritize target sources for mitigation strategies. To do this, we can categorize products of concern in terms of their generation, timing, and effective control strategy; consider source emission patterns; and, evaluate the sources' health effects.

### Danish Strategies

In Denmark, efforts to understand, categorize, and control sources and their emissions have been on-going since the mid-1970s. There, particleboard and other composite wood products using cheap formaldehyde-resin based binders became very popular materials for building construction and for furnishings. Also in the '70s, energy conservation efforts were undertaken due to the high cost of fuel. Ventilation rate reductions combined with the increased use of formaldehyde and other contaminant sources resulted in indoor air pollution. A heightened awareness of IAQ problems and greater government efforts to address them followed.

Ib Andersen (1982) of the Danish National Institute of Occupational Health presented a framework for understanding sources in relationship to their generation category, timing, and effective control strategies. This framework is described in Table 1.

Andersen's scheme shows the need for dilution ventilation to control human metabolic products and the need for dilution and exhaust ventilation to control the emissions from many processes that occur indoors. Removal or restriction is the preferred control strategy for chemical releases from materials, products and tobacco smoking. Although Andersen's scheme is more than a decade old, it is still basically sound.

Emission Source Category (emission)	Control Strategy
Human metabolism	Ventilation
Water vapor	Dilution
Carbon dioxide	Dilution
Odors	Dilution
Particles	Dilution
Processes	Ventilation
Food preparation	Local exhaust and dilution
Work (school, office, retail)	Local exhaust and dilution
Laundry	Local exhaust and dilution
Personal hygiene	Local exhaust and dilution
Chemical release	Source control
Tobacco smoking	Removal or Restriction
Household products	Removal or restriction
Furniture, textiles	Removal or restriction
Building materials	Preventive measures

**Table 1 - Emission Sources and Control Strategies (Based on Andersen, 1982).**

## Emission Patterns

A growing awareness of IAQ problems also occurred in the US in the mid-1970s. A large research group at the University of California's Lawrence Berkeley Laboratory (LBL) under the direction of the late chemist, Craig Hollowell, investigated ventilation and IAQ with funding from the U.S. Department of Energy. They adapted ambient air and industrial hygiene sampling and analytical methods to study IAQ in residences and in public buildings. Many of their studies, published in the early 1980s, are valuable sources of information today.

**Types of Emission Time Patterns** Robert Miksch, Hollowell, et al. (1982) from LBL have presented a simple description of three types of temporal emission patterns. Using the ventilation model of Turk (1963), they plotted the different behavior patterns of mean pollutant exposure levels for different source generation patterns. The three types of generation patterns they examined are 1) constant, 2) workday, and 3) episodic. Figure 2 shows these patterns. We would substitute the word "workday" with the word "periodic" to extend the applicability to non-workplace environments.

**Location Pattern Variations** Sources also have locational patterns depending on whether they are point sources or distributed sources. Examples of point sources are gas-fueled combustion appliances, burning cigarettes, and photocopiers. Distributed source examples include thermal insulation materials, furnishings, and floor coverings. Combining the temporal patterns with the spatial patterns yields a two-by-three matrix with six total cells. Table 2 shows this matrix.

Charles Rhodes and his colleagues discussed the importance of sources resulting from occupant activities in

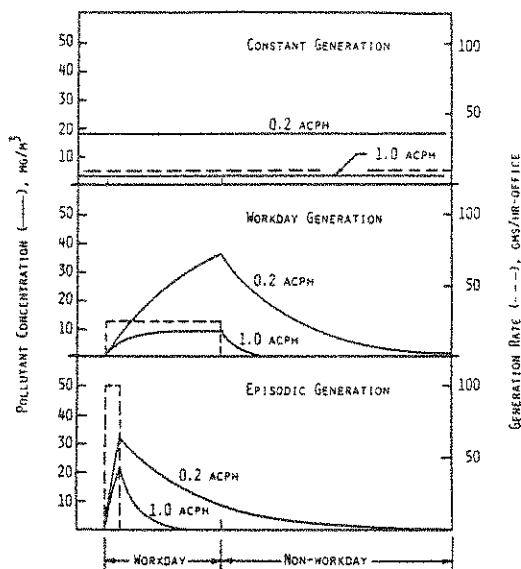


Figure 2 - Three Types of Temporal Emission Patterns.

	Constant	Periodic	Episodic
Point	Gas pilot light	Copier operation	Hobby activities
	Moth crystals	Showers, laundry	Tobacco smoking
Distributed	Carpeting	Vacuum cleaning	Carpet shampoo
	Insulation	Pest control	Painting

Table 2 - Matrix of Source and Generation Characteristics.

an article in *Indoor Air*, Vol. 1, No. 2. (See *IAB* Vol. 1, No. 3, pp. 6-8.) The emissions from these sources are either irregularly or periodically episodic. They are point sources located close to occupants so that the exposure of an occupant performing the activity may be quite large compared to other occupants in the space or building.

Important determinants of the timing of emissions include the useful life and replacement frequency of a material or materials in an assembly; the total embodied emittable constituents of the materials; the physical configuration of the product itself and of its use in the building; the environmental exposure of the material as installed in the building; and, the quality of maintenance of the installed material(s). These factors are discussed in the "Building Material Emission Factors" section of this article.

**Nature and Quantity of Emissions** The elements of the emission process are chemical transport through the material and into the air (diffusion and evaporation), environmental factors (temperature, air movement, air-exchange rate, humidity), sinks (for adsorption and subsequent re-emission), and removal. See Table 3.

Test results for chemical emissions are available for at least a few products in most of the major product categories. However, these test results are not necessarily comparable due to the use of a wide range of test methods, product acquisition, test specimen preparation, and other procedures. Furthermore, some investigators report emission factors or emission rates at a given point in time or averaged over some defined sampling period. Others provide emission factors at multiple time points. If enough is known about the emission patterns for a product or material type, an emission decay rate can be defined that will allow calculation of the emission rate at any given point in time. (See the charts on pages 7-10.)

Nearly all materials' emissions decay until eventually they reach a relatively constant rate, although the time required to reach this stable period is very different for different types of products. We need to know both how long it will take to reach the stage, what the emissions will

be until this stage is reached, and what the rate will be over the long term at this quasi-steady state emission rate.

### Importance of Various Sources

The importance of emissions from a given source is a function of the following:

- Human Exposure (average, peak, and distribution in population)
- Health and Comfort Effects Expected from Exposure
- Source Control Options Available in New Construction/Renovation/Remediation

**Human Exposure** Exposure from a source depends on the concentrations in the air and the time people spend in that air space. In general, the nature and quantity of emissions are determined by area, mass, and emission factor over the life of a product in a building. For less volatile compounds, condensation or adsorption on surfaces and subsequent human contact will also be an important determinant of health effects. For the sake of simplicity, we will not address the separate concerns raised by semi-volatile compounds (such as human body odor, some combustion by-products, pesticides, and fire retardants) in this article.

Transport
Diffusion: movement through a solid or liquid medium
Evaporation: movement from liquid, solid to vapor (gas) phase
Environmental Factors
Temperature
Humidity
Air movement
Air concentration (dependent on air-exchange rate)
Direct insolation (incident solar radiation) or other thermal radiation
Sinks
Capacity as function of surface area, material characteristics
Re-emission
Mass of substance in sink
Air concentration of substance
Removal
Ventilation
Filtration or air cleaning
Chemical reaction

Table 3 - Factors that Determine Emission Rates.

**Health and Comfort Effects** The importance of a source is a function of the health effects of its emissions; however, not enough is known about these effects. Even the strength of source emissions is not well understood for most products, although some generalizations can be made based on emissions testing, chemical compositions, and physical characteristics. Unfortunately, we are unlikely to have a great deal more information about health effects in the foreseeable future.

The Danish National Institute of Occupational Health publishes lists classifying chemicals as carcinogens, irritants, and odorants. The listings represent qualitative identifications but do not provide data on thresholds, effective doses, or significant exposure levels. The lists are used as the basis for regulatory actions when emissions tests reveal the presence of regulated substances.

Researchers in the U.S. and Denmark have used a mouse bioassay to assess the potential irritancy of emissions. The Danes use it as part of a comprehensive panel of emissions tests including human subjective response and odor evaluation, examination of changes in the eye, and chemical measurement of emissions. (See *IAB*, Vol. 1, No. 2, pp. 5-9.) The mouse bioassay method has been standardized as ASTM E981. (See *IAB* Vol. 1, No. 1, pp. 5-8.) In the next few years, it is certain that far more research will be done in this area.

**Source Control Options** Source control options for building materials and furnishings include the following:

*Chemical substitution or product reformulation:* Danish researchers have identified hazardous ingredients in some paints and created reformulations with substitution of less hazardous ingredients. U.S. carpet adhesive manufacturers have developed low-VOC products that do not use solvent carriers for the resins. U.S. paint manufacturers have been reducing the VOC content of their products to meet California standards. These standards are designed to minimize VOC emissions into ambient air as precursors to smog. Low-formaldehyde emitting particleboards have been available for several years in Europe and North America.

*Product substitution:* An example is the use of an exterior-grade plywood instead of particleboard to minimize formaldehyde emissions. Another is the use of baked-enamel coatings on furnishings such as office work stations or the use of steel rather than wood kitchen cabinets.

*Product encapsulation:* Completely laminating particleboard-based work surfaces on all six sides radically reduces emissions of formaldehyde. Wrapping asbestos pipe insulation material minimizes the fiber release from incidental contact.

## Building Material Emission Factors

There are hundreds to thousands of products used to construct and furnish buildings. It is virtually impossible to obtain and evaluate enough information in a timely way to carefully select every product in a building. Furthermore, products are being reformulated all the time, so data may not be relevant if it does not specifically apply to the product being considered. Building designs are often completed months and even years before certain elements are completed. Many product formulations will change between the design and the construction. Others will leave or enter the market. Since there is such a growing concern about IAQ, manufacturers are evaluating their own products' emissions and many are modifying them voluntarily. Others will be forced to do so by regulatory action or market forces brought about by their competitors.

Much of the attention to source control has focused on building materials and furnishings, yet a particular material may contribute relatively little to total occupant exposure to indoor air contaminants over the life of a building. This section discusses the following factors that determine the actual emissions from building materials:

- Useful Life or Replacement Frequency
- Total Quantity of Embodied Emissable Constituents in a Unit or Volume
- Chemical and Physical Properties of the Embodied Chemicals
- Physical Configuration of the Product Itself
- Quantity Used in the Building
- Environmental Exposure of the Material as Installed
- Quality of Maintenance

Pages 7 to 10 contain an extensive compilation of emissions data — most of it on building materials and furnishings. We have drawn from 9 published studies. Although a few other data sources are available, these are the more extensive ones that have been published in the open literature to date. Reported emission rates vary enormously — by more than  $10^6$ . Some of the variation is due to the timing of the test, but large differences exist among product types.

### Useful Life or Replacement Frequency

The useful life of a building material ranges considerably depending on the product: from as little as two to five years for some surface coverings and coatings to up to twenty or thirty years or more for products such as struc-

tural components. Even so, there is an enormous range among the useful lives.

Useful life is an important factor because emissions typically decrease over time; a long-lived, durable material may not be a significant emitter after a short, initial curing period. In terms of net emissions over the life of a product, durability is an important consideration. By having a long-lived component, a building is spared the emissions of a fresh, replacement material. A single application of a 10-year paint that, when new, releases a large burst of VOC may be better than two applications of a 5-year paint that releases, when new, a slightly smaller burst of VOC.

### Total Quantity of Embodied Emissable Constituents in a Unit or Volume

All materials emit chemicals, albeit stone emits (radon) less than wood (resins), and hardwoods generally emit less than softwoods. The quantity of embodied chemicals that are potentially emitted is a function of the volatility of the ingredients of the product as it is installed in the building and the physical characteristics of the installed product. The composition of a product changes over its life, and these changes are generally much larger for products that are installed wet, such as paints, adhesives, and caulks, compared to those installed dry. They are likely to be larger for soft or flexible plastic materials than for rigid ones, although there are notable exceptions to this rule.

### Chemical and Physical Properties of the Embodied Chemicals

The relative location of the volatile components in the installed product to the air at its surface(s) and the characteristics of the chemicals themselves will determine the emission rates. Thick solid materials such as composite wood products may have very slow emission rates because chemicals must migrate by diffusion from deep within the material to the surface before they can evaporate into the air. This is the case with formaldehyde in

Initial burst and surface drying (usually a matter of hours, sometimes only minutes, others a matter of days).
Reservoir depletion (sometimes)
← Molecular movement through the drier material closer to the surface and to the surface of the reservoir of liquid-phase material which may be contained by a skim coat on the surface.
Long-term evaporation
In this phase, formerly wet products behave more like materials that may have been installed as dry, solid materials.

Table 4 - Major Emission Phases of Wet Products.

Product type	Material or product description (Time sampled during chamber test)	Emission rate TVOC (ug/m2-hr)	Acquisition age, description Comments	Ref
FLOOR COVERING				
Carpet	Floor and wall covering, textile	83	New	1
Carpet	Floor covering, synthetic fibers/PVC	120	New	1
Carpet	Carpet, UF backing (1 h)	411	No seam	9
Carpet	Carpet, UF backing (1 h)	62	New, direct from manufacturer	9
Carpet	Carpet, UF backing (1 h)	98	Aged	9
Carpet	Carpet, UF backing (24 h)	202	No seam	9
Carpet	Carpet, UF backing (24 h)	35	New, direct from manufacturer	9
Carpet	Carpet, UF backing (24 h)	26	New, direct from manufacturer	9
Carpet	Carpet, UF backing (140 h)	20	New, direct from manufacturer	9
Carpet	Carpet, UF backing (140 h)	111	No seam	9
Carpet	Carpet, UF backing (140 h)	6	New, direct from manufacturer	9
Carpet	Felt carpet	80	New	1
Carpet	Latex-backed carpet (336 hrs) 4-PC	80		2
Carpet	Carpet, SBR latex backed (144 hr)	45	New, direct from manufacturer	7
Carpet	Carpet	36	<92 days	3
Carpet	Felt carpet (Synthetic fibers/plastic backing	11	New	1
Carpet assembly	Carpet, adhesive3 on concrete (24 h)	153000	Single stick, new products	7
Carpet assembly	Carpet, adhesive1, pad1 on concrete (24 h)	145000	Double stick	7
Carpet assembly	Carpet, adhesive1, on concrete (24 h)	98000	Single stick, new products	7
Carpet assembly	Carpet, adhesive2 on concrete (24 h)	88300	Single stick, new products	7
Carpet assembly	Carpet, adhesive4 on concrete (24 h)	783	Single stick, new products	7
Carpet cushion	Carpet, pad3 on concrete (24 h)	775	No adhesive, new materials	7
Carpet assembly	Carpet, pad1 on underlayment (24 h)	549	No adhesive, new materials	7
Carpet assembly	Carpet, pad1 on concrete (24 h)	136	No adhesive, new materials	7
Carpet cushion	Cushion P-3 (144 hr)	8110	New from factory	7
Carpet cushion	Cushion P-3 (24 hr)	3360	New from factory	7
Carpet cushion	Cushion P-2 (24 hr)	240	New from factory	7
Carpet cushion	Cushion P-1 (24 hr)	123	New from factory	7
Carpet cushion	Cushion P-1 (144 hr)	59	New from factory	7
Carpet cushion	Cushion P-2 (144 hr)	12	New from factory	7
Vinyl	Vinyl floor covering	22280		5
PVC	Central European PVC	7034	1-3 yrs, subject of complaint	6
PVC	Floor covering, homogeneous PVC	2300	New	1
PVC	Finnish PVC-covering	2192	0.5 yrs, unused from roll	6
PVC	Finnish PVC-covering	1629	1 yr, unused, from roll	6
PVC	Finnish PVC-covering	1443	<0.5 yrs, unused 2nd quality from roll	6
Rubber	Floor covering, rubber	1400	New	1
PVC	English PVC-covering	1122	1 yr, unused, taken from roll	6
PVC	Finnish PVC-covering	273	2-3 yrs, subject of complaint	6
PVC	Swedish PVC-covering	91	1-2 yrs, subject of complaint	6
Vinyl	Vinyl tile	45	Age < 98 days	3
Soft plastic	Floor covering, soft plastic	590	New	1
Linoleum	Linoleum floor covering	220	New	1
Linoleum	Linoleum	64	30 yrs, subject of complaint	6
Linoleum	Floor covering (linoleum)	22	New	1
Wood	Pine, industrial (1 mo.)	682	0.1 yrs, experimental surface coating	6
Wood	Birch, industrial	272	0.1 yrs, experimental surface coating	6
Wood	Pine	264	1 yr, UF-lacquered on site	6
Wood	Pine, untreated	216	New, in plastic wrapping	6
Wood	Birch, industrial	157	0.1 yrs, experimental surface coating	6
Cork	Cork	805	0.3 yrs, new material	6
Cork	Cork	7	2 yrs, subject of complaint	6

Chart 1 - Emission Rates for Floor Coverings.

Product type *WET* PRODUCTS	Material or product description (Time sampled during chamber test)	Emission rate TVOC (ug/m2-hr)	Acquisition age, description Comments	Ref
Adhesive	Wall and floor glue (24 hr)	271000	Water-based EVA	1
Adhesive	Adhesive, wall and floor (24 hr)	270000		1
Adhesive	Floor adhesive	220000		2
Adhesive	Carpet adhesive (24 hr)	99000		7
Adhesive	Carpet adhesive (24 hr)	90000		7
Adhesive	Carpet adhesive (24 hr)	76600		7
Adhesive	Carpet adhesive - Low VOC (24 hr)	698	Low VOC formulation	7
Adhesive	Carpet adhesive (144 hr)	17200		7
Adhesive	Carpet adhesive (144 hr)	11900		7
Adhesive	Carpet adhesive (144 hr)	3950		7
Adhesive	Carpet adhesive - Low VOC (144 hr)	76	Low VOC formulation	7
Adhesive	Carpet adhesive (7 d)	234		3
Adhesive	Cove adhesive, (7 d)	5000	Methanol based vinyl adhesive	3
Adhesive	Primer/adhesive (7 d)	6.1	Wall primer/adhesive	3
Adhesive	Floor adhesive (10-100 hrs)	<5000		2
Adhesive	Texture glue, PVA, water-based (24 hr)	2100		1
Seam sealant	Carpet seam sealant (1 h)	2960	Seam sealant only	9
Seam sealant	Carpet seam sealant (24 h)	249	Seam sealant only	9
Seam sealant	Carpet seam sealant (144 h)	10	Seam sealant only	9
Caulk	Silicone caulk (<10 hrs)	13000		2
Caulk	Silicone caulk (10-100 hrs)	<2000		2
Caulk	Filler, PVA, glue-cement (24 hr)	10200		1
Caulk	Filler, sand, cement, hardener (24 hr)	730	Water based hardener	1
Caulk	Latex caulk (7 d)	637	Interior/exterior latex caulk	3
Caulk	Sealing agent - putty strips (24 hr)	340	New	1
Caulk	Tightening fillet (24 hr)	160	Neoprene/polyethylene	1
Caulk	Caulk - plasticized PVC/polyethylene (24 hr)	56	New	1
Caulk	Heat-expanding neoprene (24 hr)	17	New	1
Caulk	Tightening fillet, heat-expanding neoprene	16	New	1
Paint	Paint, acrylic latex	430		1
Paint	Latex paint, "high profile" (7 d)	249		3
Paint	Latex paint, "vinyl flat white" (7 d)	3.2		3
Stain	Wood stain (<10 hrs)	10000		2
Stain	Wood stain (10-100 hrs)	<100		2
Varnish	Polyurethane wood finish (<10 hrs)	9000		2
Varnish	Floor varnish, 2-part isocyanate (24 hr)	4700		1
Varnish	Floor varnish, clear epoxy (24 hr)	1300		1
Varnish	Floor varnish, acid hardener (24 hr)	830		1
Varnish	Polyurethane wood finish	<100		2
Sealant	Sealing agent plastic compound (24 hr)	72000		1
Sealant	Sealing agent silicone compound (24 hr)	26000		1
Sealant	Urethane sealant	0.13		3
Polish	Spray polish for furniture	27100		4
Wax	Floor wax (<10 hrs)	80000		2
Wax	Floor wax ((10-100 hrs)	<5000		2
Wax	Floor wax paste (initial emission rate)	1880		4

Chart 2 - Emission Rates for "Wet" Products.

Product type VARIOUS MTLs.	Material or product description (Time sampled during chamber test)	Emission rate TVOC (ug/m <sup>2</sup> -hr)	Acquisition age, description Comments	Ref
Fiber board	Woodfiber board (12 mm)	120	New	1
Fiber board	Fiber board, glass fiber polyester reinforce	17	New	1
Gypsum board	Calcium Silicate board	64	New	1
Gypsum board	Plaster board	26	New	1
Gypsum board	Plaster board (12 mm, paper coated)	26	New	1
Gypsum board	Gypsum board	26	Age unknown	2
Gypsum board	Water repellent mineral board	1.5	Age unknown, from construction site	3
Insulation	Insulation foam, polystyrene	1400	New	1
Insulation	Polystyrene foam A	260		5
Insulation	Insulation foam, polyurethane	120	New	1
Insulation	Polystyrene foam B	30		5
Insulation	Polystyrene foam insulation	22	Purchased retail, age < 76 days	3
Insulation	Insulation batt (mineral wool)	12	New	1
Insulation	Fibrous glass insulation	0.8	From construction site	3
Insulation	Duct insulation	0.28	Purchased retail	3
Laminated board	Laminated board (plastic)	0.4	New	1
Particleboard	Particleboard (new) formaldehyde	2000		2
Particleboard	Particleboard (24 hr)	952		7
Particleboard	Particleboard (144 hr)	837		7
Particleboard	Particleboard	200	2 yrs	2
Particleboard	Particle board	140	New, from manufacturer	1
Particleboard	Particleboard (urea-formaldehyde glued)	130	New, from manufacturer	1
Particleboard	Particleboard	130	New, from manufacturer	1
Particleboard	Particleboard (urea-formaldehyde glued)	120	New, from manufacturer	1
Particleboard	Particle board	120	New, from manufacturer	1
Particleboard	Particle board	28	Age < 98 days	3
Plywood	Plywood B	1450		5
Plywood	Plywood A	900		5
Plywood	Plywood C	725		5
Plywood	Plywood D	215		5
Sheathing	Exterior mineral board	0.03		3
Chipboard	Chipboard (age unknown)	130		2
Panelling	Plywood paneling HCHO	100	nEW	2
Panelling	Plywood panelling (teak)	44	New	1
Wall covering	Vinyl and fiberglass wall paper	300	New	1
Wall covering	Wall paper, PVC foam	230	New	1
Wall covering	Wall covering, PVC	100	New	1
Wall covering	Wallpaper (age unknown)	100		2
Wall covering	Vinyl coated wallpaper B	95		5
Wall covering	Vinyl wall paper	40	New	1
Wall covering	Printed wall paper	31	New	1
Wall covering	Vinyl coated wallpaper A	20		5
Wall covering	Wall covering, Hessian	5.4	New	1

Chart 3 - Emission Rates for Various Building Materials.

Product type MISCELLANY	Material or product description (Time sampled during chamber test)	Emission rate TVOC (ug/m <sup>2</sup> -hr)	Acquisition age, description Comments	Ref
Cement block	Cement block	0.54		3
Cement flag	Cement flag	73		1
Cable	Small diameter telephone cable (new)	60	Standard wall to telephone	3
Cable	Large diameter telephone cable (new)	38	Bundled wire, computer or network	3
Pipe	PVC pipe	0.53		3
Vapor barrier	Tar paper	6.3		3
Subfloor	Concrete subflooring	<5		7
Trim	Black rubber moulding	103	Age < 124 days, from construction	3
Cove base	Vinyl cove moulding	46	Age < 98 days	3
Cove base	Vinyl edge moulding	30		3
Textile	Floor and wall covering, textile	1600		1
Cleanser	Spray cleanser for carpets	50400	Initial emission rate	4
Cleanser	Liquid cleanser/disinfectant	34900		4
Cleanser	Liquid floor detergent (initial)	2200		4
Pesticide	Moth cake (p-DCB) @ 23 C.	14000000		2
Dry-cleaning	Dry cleaned clothes ((0-1 day)	100		2
Dry-cleaning	Dry-cleaned clothes (1-2 days) Perc	50		2
Office chair	High back chair with arms (1 h)	1060	1 h	8
Office chair	High back chair with arms (981 h)	100	981 h	8
Office furniture	Tackable acoustical partitions (HCHO) (1 h)	158	1 h	8
Office furniture	Tackable acoustical partitions (2.5 h)	74	2.5 h	8
Office furniture	Tackable acoustical partitions (HCHO) (48	37	48 h	8
Office furniture	Tackable acoustical partitions (581 h)	6	581 h	8
Workstation	Workstation	3200	1 h	8
Workstation	Workstation	10	912 h	8
Workstation	Workstation (HCHO)	1470	1 h	8
Workstation	Workstation (HCHO)	830	336 h	8

#### References used in charts:

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- 9) Davidson, J.L., M.S. Black, W.J. Pearson, L.M. Work, D.P. Miller, (1991). "Carpet Installation during Building Renovation and Its Impact on Indoor VOC Concentrations." in *IAQ '91 - Healthy Buildings*, Atlanta: American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., pp. 299-303.

Chart 4 - Emission Rates for Various Materials and References.

particleboard. The processes are very different for "wet" and for "dry" products.

Wet products go through two or three fairly distinct phases as follows: initial burst, reservoir depletion, and long-term emissions.

### **Physical Configuration of the Product Itself**

A dense material presents a greater barrier to migration (diffusion) of gas phase molecules. Thicker products take longer to emit their ingredients than thin ones. Also, the amount of surface area of the material creates more or fewer pathways for a molecule to evaporate. Thus, a rough, textured surface, such as in textiles and insulations, is associated with higher emissions than a smooth one.

### **Quantity Used in the Building**

The total quantity (mass and surface area) of a material or product is a major determinant of life cycle emissions. We must not neglect large mass materials even though their emissions may be far lower than some materials whose mass may be a tiny fraction of the large one.

### **Environmental Exposure of the Material as Installed**

Higher emissions generally occur from materials that are exposed to the circulating air in the building as opposed to an enclosed space (e.g. inside a wall or floor cavity, or in a furred-out column). This is because the air

adjacent to the material surface is replaced more frequently with air that has a lower concentration of the chemicals being emitted. This results in a higher rate of evaporative flow from the material to the air.

Materials that are fully encapsulated will have relatively low emission rates. An example is that completely sealing particleboard can reduce its formaldehyde emissions by more than 90%. Sunlight striking a material can cause significant surficial heating and raise the vapor pressures of the chemicals at and near the surface.

### **Quality of Maintenance**

Maintenance materials and procedures can inhibit or increase emissions. For example, wetting the surface of formaldehyde-emitting materials is likely to increase emissions because formaldehyde is readily soluble in water. Vacuuming carpets may encourage evaporation by agitating and repositioning the fibers, thus creating more direct paths to the atmosphere.

### **References:**

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## **Formaldehyde**

# **Formaldehyde Irritation Found at Lower Levels**

A group of researchers at the Indoor Air Program of the State of California Department of Health Services (DOHS) has published convincing evidence that formaldehyde causes irritation at concentrations lower than previously believed. Researchers evaluated formaldehyde exposure and irritation symptoms for over 1000 individuals in mobile homes. The study, covering the entire State of California, included mobile homes of all ages. Given that over 10,000 mobile homes are sold annually in California alone, the affected population may be substantial.

### **Formaldehyde Concentrations Were Higher Than Expected**

This was by far the largest random mobile-home formaldehyde survey; the only previous random sample of mobile homes involved only 65 non-complaint mobile homes in Wisconsin. Other studies have either been small,

not randomized, or restricted to complaint homes. Because non-complaint mobile homes were part of the sampling, researchers expected the formaldehyde concentrations to be lower than those reported in studies of complaint homes.

The measured formaldehyde levels were, however, higher than expected. Concentrations ranged from below the detection limit (0.01 ppm) to 0.46 ppm. No significant differences were found between kitchen measurements and bedroom measurements.

The average formaldehyde concentrations in the study were 0.089 ppm in the summer and 0.088 ppm in the winter. The researchers determined exposure by multiplying the week-long average formaldehyde concentration by the number of hours the participant spent in the home.

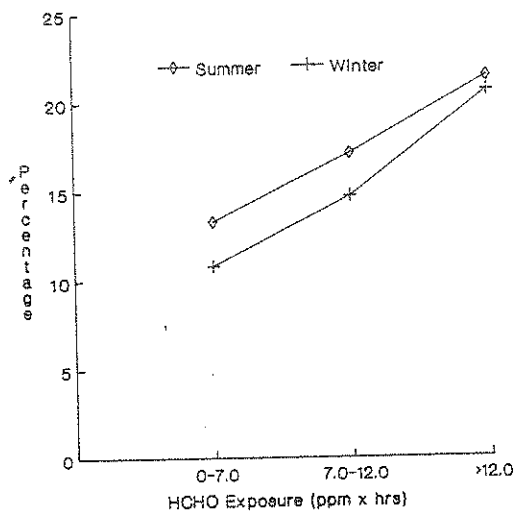


Figure 3 - Formaldehyde Exposure and Eye Irritation.

The average exposures in the study were 9.8 ppm-hr and 9.9 ppm-hr for summer and winter respectively.

### Irritation Rates Related to Exposure

Overall there was a positive correlation between formaldehyde exposure and irritation symptoms. Figure 3 shows the relationship between formaldehyde exposure and eye irritation for participants aged 20 to 64. It shows a clear association between the symptom rate and formaldehyde exposure.

Even for non-complaint participants chronically exposed to relatively low levels of formaldehyde, the researchers found positive associations between week-long average formaldehyde exposure and several irritant effects after controlling for potential confounding variables (age, gender, smoking status, and status of chronic respiratory/allergy problems). They concluded that "...[formaldehyde]-related irritant symptoms exist among residents of mobile homes who have not formally complained to government agencies." This, they say, suggests that "...effects occur at lower formaldehyde levels than previously thought."

The researchers also found a "...synergistic effect between formaldehyde exposure and chronic respiratory/allergy problems." Thirty-three percent of the study participants said they have "chronic respiratory diseases and/or allergy problems." The prevalence rates for symptoms among people with these chronic health problems "...were generally higher than for those without chronic problems. Further, for some symptoms, these rates were even higher than would be expected if the effects of [formaldehyde] exposure and chronic health problems were only additive." See Table 5.

There was a positive exposure-response relationship between levels as low as 7 ppm-hr and burning/tearing eyes. For 24 hour/day, 7 day/week occupancy, that means that symptoms occurred at a week-long average concentration of 0.042 ppm which is less than half the study's overall average formaldehyde concentration. At the study's winter average concentration of 0.088 ppm, this would mean that a significant exposure occurs after spending only 47% of a person's time inside the home.

### Formaldehyde Concentrations In Indoor Air

Manufacturers produce billions of pounds of formaldehyde annually. More than half is used in the wood-products industry. An article published in the December 1988 *Environmental Science and Technology* reported average measured indoor-air formaldehyde concentrations of 0.049 ppm and median concentrations of 0.042 ppm. The fourth-quartile formaldehyde concentration was .019 ppm, and the first quartile concentration was 0.072 ppm. Although the article did not report the distribution of locations where measurements were made, a conversation with an EPA researcher suggests that the majority were in non-residential environments. Thus, together with formaldehyde data from the California Air Resources Board (CARB) and the mobile-home study, these data suggest that population exposure to formaldehyde in all indoor environments may be substantial and of larger significance than previously thought.

### State of California Recommends Lowering the Target Level

The CARB believes that more than half the homes in California have formaldehyde levels above what CARB recommends. A recently released guideline from the CARB Research Division recommends that formaldehyde concentrations be kept below a "target level" of 0.05 ppm inside conventional homes. This is a reduction from the "action level" of 0.10 ppm that the California Department of Health Services and other public health agencies previously recommended. The guideline says typical formaldehyde levels in California are about 0.07 to 0.08 ppm in mobile homes and about 0.05 ppm inside conventional homes.

Pressed-wood products made with urea-formaldehyde resins dominate the formaldehyde sources identified in the guideline and accompanying supplemental report. These sources include hardwood plywood, particleboard, and medium-density fiberboard. The report identifies other important sources including furnishings, fabrics, clothing, paper products, and fingernail hardeners. Formaldehyde is also emitted by combustion sources such as cigarettes, gas appliances, and kerosene heaters.

CARB justifies the guideline recommendation on the basis of cancer risk. The guideline says that "...no concentration of formaldehyde can be considered absolutely safe. Therefore, you should try to reduce indoor formaldehyde to the lowest practicable level."

## Implications

Birgitta Berglund and her co-workers in Sweden have found higher occupant reporting rates of SBS-type symptoms when exposed to air containing low formaldehyde concentrations compared to similar exposures without measurable formaldehyde present. This finding and the California study finding of a synergistic effect in people with chronic health problems suggest that formaldehyde may still be an important indoor air contaminant in many environments where occupants complain.

Time spent indoors is probably greater and ventilation rates are probably lower in climates more adverse than California's. Therefore, formaldehyde may be an even greater concern elsewhere. The findings and recommendations of the two California agencies and the probable carcinogen status of formaldehyde reinforces our concern.

## Recommendation

We recommend that efforts to control formaldehyde concentrations indoors be intensified. This means eliminating or minimizing the use of formaldehyde emitting products wherever practical; specifying low-emitting products whenever they are available; completely and effectively sealing or encapsulating formaldehyde emit-

ting products whenever they are used; and, monitoring indoor concentrations of formaldehyde in newly constructed or remodeled facilities, especially where occupants have chronic respiratory problems or allergy.

## Copies of CARB Guideline

CARB made the formaldehyde recommendation in its first IAQ Guideline, "Formaldehyde in the Home." Copies of the Guideline and the Supplement are available from California Air Resources Board, Research Division, Indoor Exposure Assessment Section, P. O. Box 2815, Sacramento, CA 95812, (916) 323-5043.

## References:

Kai-Shen Liu, Fan-Yen Huang, Steven B. Hayward, Jerome Wesolowski, and Ken Sexton, 1991. "Irritant Effects of Formaldehyde Exposure in Mobile Homes." in *Environmental Health Perspectives*, Vol. 94, pp. 91-94.

Ken Sexton, Myrto X. Petreas, Kai-Shen Liu, 1991. "Formaldehyde Exposures inside Mobile Homes." in *Environmental Science & Technology* Vol. 23, page 985-988.

Jitandra J. Shah and Hanawant B. Singh, 1988. "Distribution of Volatile Organic Chemicals in Outdoor and Indoor Air; A National VOCs Data Base." *Environmental Science & Technology*, Vol. 22, No. 12, pp. 1381-1388. [Note: We called Dr. Shah when the article first appeared in *ES&T*, and asked how to obtain a copy of the database. He told us the cost for a copy, and we thought it too expensive for our needs. According to Lance Wallace at EPA, much of the indoor air data was taken from the TEAM studies of Wallace and others at EPA. Wallace said the TEAM studies measurements had been averaged in ways that actually reduced the value of the data for purposes of characterizing indoor air concentrations.]

Symptom	Gender		Smoker		Respiratory/Allergy	
	Female	Male	Yes	No	Yes	No
Abdominal pain	4.5	2.0	4.0	3.1	5.3	2.3
Asthma attack	1.6	1.0	0.4	1.6	3.9	0.0
Burning eyes	14.8	10.8	13.3	12.8	22.2	8.2
Burning skin	2.5	2.2	3.2	2.1	3.7	1.7
Chest pain	6.1	3.2	7.2	4.0	9.0	2.6
Cough	4.6	21.2	31.7	20.2	34.8	17.0
Diarrhea	6.4	3.4	6.4	4.6	8.7	3.1
Dizziness	7.3	4.0	5.2	5.9	8.4	4.4
Fatigue	11.2	6.6	14.1	7.5	12.1	7.5
Headache	25.5	14.4	24.1	19.1	33.4	13.6
Nausea	5.9	1.8	3.2	4.1	7.6	2.1
Sleeping problem	16.6	10.0	12.9	13.4	21.1	9.6
Rashes	3.4	5.0	4.4	4.1	9.3	1.6
Running nose	22.5	20.6	24.1	20.7	30.6	17.0
Sore throat	14.1	11.4	11.7	13.1	17.7	10.3
Wheezing	7.8	6.4	11.2	5.9	16.6	2.4

Table 5- Symptom Rates in California Mobile-home Survey.

## EPA Releases Major IAQ Publications

EPA recently released two IAQ documents we think will be valuable to our readers. The first, a guide for building owners and facility managers, emphasizes non-residential buildings such as offices, schools, stores, and public assembly buildings. The second, a two-volume self-paced study course, emphasizes residential environments but contains lots of valuable information for those interested primarily in the non-residential environment.

EPA's Indoor Air Division (Office of Air and Radiation), in collaboration with others, was responsible for both documents. Each publication is extremely useful individually, and together they make excellent library additions for anyone working frequently on IAQ.

### **"Building Air Quality: Guide for Building Owners and Facility Managers"**

This guide is intended primarily for office building operators, but it will also be very useful for people responsible for schools, stores, large residential buildings, and many other building types. We think most of our readers will find it useful: if not for personal use, than as a recommendation or gift to a client or colleague.

Major section titles in the guide include: "Basics," "Preventing IAQ Problems," and "Resolving IAQ Problems." The appendices include chapters on IAQ Measurements; HVAC systems; Moisture, Mold, and Mildew; Asbestos; Radon; a Glossary; and, Resources. Finally, there is a section of forms including management checklists, IAQ complaint forms, pollutant pathway investigation forms, chemical inventory, and others.

**Pollutant Pathways** The guide emphasizes the importance of pollutant pathways and the driving forces that move pollutants in a building. A dominant theme is that pressure differences cause pollutants to flow between and among spaces. The concept is developed both theoretically and in practical terms; the guide includes techniques for identifying and characterizing pollutant pathways using simple devices like smoke tubes (some people call them smoke pencils).

**Occupant Complaints** There is extensive information on handling occupant complaints. The guide includes forms to collect individual complaints, occupant interviews, diaries, or logs, and provides advice on information management in the event of an air quality problem.

**Production of the Guide** This 229-page guide is EPA's most ambitious IAQ guidance document to date. Co-sponsored by NIOSH, the work was originated by the

Indoor Air Division under the direction of Robert Axelrad with project management by Elizabeth Agle. Comprehensive, well-illustrated and referenced, and handsomely assembled, it is the product of almost two years of hard work by a team of consultants, an army of reviewers, and EPA staff.

**To Obtain A Copy** Copies of the "Building Air Quality: Guide for Building Owners and Facility Managers" are available for \$24.00 each (\$30.00 to international customers) from the Superintendent of Documents (part of the Government Printing Office). A discount of 25% is available on orders of 100 copies or more. Include the publication number S/N 055-000-00390-4 with your order. Use the order form included with this issue of the *IAB*, or write to New Orders, Superintendent of Documents, P.O. Box 371954, Pittsburgh, PA 15250-7954. You can fax your order to (202) 512-2250.

### **"Introduction to Indoor Air Quality"**

The second recent publication from EPA is the two-volume "Introduction to Indoor Air Quality." The first volume, "A Self-Paced Learning Module," is "designed to provide a first level understanding of basic IAQ principles," according to a letter sent by EPA with our copy. This document may not be as valuable as the second volume, "A Reference Manual." It is intended to be a companion to the first document, but it is extremely useful and stands by itself.

The "Reference Manual" is a general encyclopedia on indoor air with detailed information on selected subjects. It contains tables of indoor air measurements for many compounds, a guide to commercially available monitoring equipment, an overview of measurement technology, and lots of other useful tables for the practicing IAQ professional or industrial hygienist. It may be the most comprehensive such document available since the release of EPA's Report to Congress.

The 297-page Reference Manual was prepared by Ingrid Ritchie for EPA and the National Environmental Health Association (NEHA) which initiated the project and is distributing copies from their office in Denver, Colorado. Copies cost \$47.50 (\$40 for NEHA members). It bears an EPA publication number, EPA/400/3-91/003.

**To Obtain a Copy** Send your order to the National Environmental Health Association, 720 South Colorado Boulevard, South Tower, Suite 970, Denver, CO 80222. Tel. 303-756-9090.

## Publications

### Swedish Building Research Reports

There is lots of building research in Sweden given the relatively small population. It is funded through a tax on construction and is operated by the Swedish Council for Building Research, a government agency. The Council publishes a summary with extended abstracts of published reports in *Synopses*, a free newsletter issued eight times per year. The reports themselves are sold either

through the Council or through other publishers listed in the *Synopses* summaries.

While only a small fraction of the funded research relates directly to indoor air topics, we think *IAB* readers will find many of the other reports interesting as well. For a free subscription to *Synopses*, write: AB Svensk Byggtjänst, S-171 88 Solna, Sweden. (Tel. 08 734 50 00)

## Conference Announcement and Call for Papers

### Eco Logical Architecture European Congress 92

The first International Union of Architects (UIA) "Congress on Eco Logical Architecture" will be held in Stockholm, Sweden, and Helsinki, Finland, August 19-21, 1992. According to an announcement in the Newsletter of Swedish Building Research, the Congress will provide "...an overview of the present possibilities, a glimpse of the future, in-depth knowledge in some fields, newly awakened interest in others."

The Congress will focus on global environmental concerns, species diversity and preservation, individual preferences and lifestyles, and organizing for "responsible societies." Planned topics include "socio-ecological planning, architecture, and design." Participants will present examples of their own work.

Indoor air concerns will be addressed directly and indirectly through presentations of "the latest building

materials...[and]...building techniques." Other planned "eco-logical" architecture topics are recycling of water and waste, traffic, energy, urban vegetation, horticulture, and wildlife.

The Congress wrap-up will be an attempt to sum up the present situation, determine the best approach to create a responsible society, and develop actions architects and planners can take to bring change about.

#### **For more information:**

The Congress is being organized by the National Association of Swedish Architects and The Finnish Society of Architects. The preliminary program and call for papers will be issued in January. If you would like a copy, contact The Congress Secretariat, CONGREX, P.O. Box 5619, S-114 86 Stockholm, Sweden. Tel. +46 8 612 00, Fax +46 8 612 62 92.

## New ASHRAE Project

### ASHRAE Announces New Guideline Project: "Achieving Acceptable Indoor Environments"

Many building occupant complaints are blamed on IAQ; however, other environmental as well as socio-psychological and personal factors may produce symptoms of poor IAQ. These include symptoms of sick building syndrome. ASHRAE has announced the solicitation of applications to form a "Guideline Project Committee" to be designated "GPC 10P" to address the complete indoor environment and its effect on humans.

According to ASHRAE's press release, the committee's work will address "interactions among ther-

mal comfort, indoor air quality, sound and vibration, and non-ionizing electromagnetic radiation. It will apply to office, light-industrial and high-rise residential buildings, and to specifying indoor environmental criteria that minimize the potential for adverse health effects in human occupants."

Individuals interested in participating should request a biographical data form from the Manager of Standards, ASHRAE, 1791 Tullie Circle NE, Atlanta, GA 30329.

## Calendar

January 26-29, 1992. **ASHRAE Winter Meeting and Exhibition**, Anaheim, California. Contact: ASHRAE Meetings Department, 1791 Tullie Circle N.E., Atlanta, GA 30329 (404) 636-8400.

March 2-6, 1992. **"Improving Indoor Air Quality in Non-Industrial Buildings,"** Sponsored by EOHSI/CET, University of Medicine and Dentistry of New Jersey-Robert Wood Johnson Medical School and Rutgers, The State University of New Jersey. Contact: Centers for Education and Training (CET), 45 Knightsbridge Rd., Piscataway, NJ 08854-3923. (908) 463-5064. Course fee is \$700 for five days.

April 26-28, 1992. **Symposium on Modelling**, Sponsored by ASTM Subcommittee D22.05 on Indoor Air, Pittsburgh, Pennsylvania. Contact: George Luciw, Staff Manager, ASTM, 1916 Race Street, Philadelphia, PA 19103-1187, (215) 299-5571 Fax (215) 299-2630. *There will be a workshop on Sunday, April 28, with tutorials and hands-on demonstrations of models by many of the presenters at the symposium. Symposium papers will be on Monday and Tuesday. Registration fee is always reasonable for ASTM D22 symposia, and includes a copy of the proceedings. Fee for the workshop is included in the symposium registration fee and only a nominal charge when separate from the symposium.*

April 28, 1992. **ASTM Subcommittee D22.05 on Indoor Air; Spring Meeting**. Contact: George Luciw, Staff Manager, ASTM, 1916 Race Street, Philadelphia, PA 19103-1187, (215) 299-5571 Fax (215) 299-2630.

April 30 - May 2, 1992. **The First Annual IAQ Conference and Exposition, "Indoor Air Quality: Service & Technology,"** Tampa Convention Center, Tampa, Florida. Sponsored by the National Coalition on Indoor Air Quality. Contact: National Coalition on Indoor Air Quality, 1518 K Street, NW, Washington, DC 20005

July 12-17, 1992. **"Asbestos Measurement, Risk Assessment, Laboratory Accreditation."** Johnson State College, Johnson, Vermont. Sponsored by ASTM Committee D-22 on Sampling and Analysis of Atmospheres. Contact: George Luciw, ASTM, 1916 Race Street, Philadelphia, PA 19103, (215) 299-5571.

August 30 - September 5, 1992. **"Achieving Technical Potential: Programs and Technologies that Work!"** ACEEE 1992 Summer Study on Energy Efficiency in Buildings, Asilomar Conference Center, Pacific Grove, California. Sponsored by The American Council for an Energy-Efficient Economy. Contact: ACEEE 1992 Summer Study Office, 2140 Shattuck Avenue, Suite 202, Berkeley, CA 94704.

September 22-25, 1992. **International Symposium on Radon and Radon Reduction Technology**, Minneapolis, Minnesota. Contact: For registration information, Diana, Conference of Radiation Control Program Directors, Inc., (502) 227-4543, Fax (502) 227-7862. For Call for papers or to submit abstracts: Timothy M. Dyess, Radon Mitigation Branch, MD 54, U.S. Environmental Protection Agency, Research Triangle Park, NC 27711.

October 18-20, 1992. **ASHRAE IAQ '92 - Environments for People**, San Francisco, California, Contact: ASHRAE Meetings Department, 1791 Tullie Circle N.E., Atlanta, GA 30329 (404) 636-8400.

## International

January 20, 1992. **Workshop Environment: Indoor Air Quality**, 5th International Winter Cities Biennial, Montreal, Quebec, Canada. Contact: Winter Cities Biennial, 770 rue Sherbrooke Ouest, Bureau 1000, Montreal, (Quebec) Canada H3A 1G1. Tel. 514/872-2773.

March 23-27 1992. **"Chemical, Microbiological, Health and Comfort Aspects of Indoor Air Quality"** - State of the Art in SBS, Commission of the European Communities, Joint Research Centre, Ispra, Italy. Contact: EUROCOURSES Secretariat, Joint Research Centre, I-21020, Ispra (Varese) Italy. Tel. +39-332-789308, Fax +39-332-789839. *Organized with the scientific coordination of the EC Joint Research Centre Environment Institute and the Danish National Institute of Occupational Health, in collaboration with the EC Concerted Action "Indoor Air Quality and its Impact on Man." "[For those] with an interest in identifying causes of complaints about indoor air quality of the SBS type and their remedy." Deadline for enrollment is February 25, 1992. Students and university teachers may apply for a discount of 50%. Accommodation expenses are additional.*

April 28-30, 1992. **"Quality of the Indoor Environment,"** Sponsored by The International Association for Indoor Air Quality, Athens, Greece. Contact: Conference Secretariat, Quality of the Indoor Environment, Unit 6, 2 Old Brompton Road, London SW7 3DQ, UK.

July 22-24, 1992. **1992 International Symposium on Ventilation Effectiveness**, Tokyo, Japan, sponsored by the Institute of Industrial Science, The University of Tokyo. (co-sponsored by ASHRAE).

September 2-4, 1992. **Roomvent '92, The Third International Conference on Air Distribution in Rooms**. Aalborg, Denmark. sponsored by Danish Association of HVAC Engineers. Contact: Danish Association of HVAC Engineers, Ørholmvej 40B, DK-2800 Lyngby, Denmark.

October 12-16, 1992. **Second International Course on Sick Building Syndrome**, sponsored by the Nordic Institute of Occupational Health (NIVA). Hotel Oranje Boulevard, Noordwijk aan Zee, The Netherlands. Contact: Gunilla Ahlberg, NIVA, Topeliuksenkatu 41 a A, SF-00250 Helsinki, Finland. Tel +358 0 474 498. Telefax +358 0 414 634. *Enrollment limited to 50.*

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Hal Levin, Editor and Publisher

Subscription Manager: Gina Bendy

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