Indoor Air Quality Update™

A Guide to the Practical Control of Indoor Air Problems, from Cutter Information Corp.

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EPA RELEASES LANDMARK STUDY

Most *IAQU* readers accept the idea that building materials, furnishings, and consumer products emit chemicals to indoor air and that they are responsible for a significant fraction of indoor air pollution. We also know that indoor air levels of many volatile organic compounds (VOC) are higher than outdoor levels, sometimes 10 to 100 times higher. EPA has just released a two-volume, 1,221-page report that provides ample evidence supporting these ideas. The EPA report helps us understand the role that selected building materials and products play in contributing to the levels of various VOC found indoors. It also gives clear evidence of the dramatic changes that occur in building air over time, from construction and finish work to initial occupancy and during normal use patterns.

EPA released the massive report on November 10, reporting on a pair of indoor air studies. The studies focused on VOC and other air pollutant measurements in 10 buildings and on measurements of emissions from building materials, maintenance, and consumer products used in some of the buildings.

Research Triangle Institute in North Carolina prepared the report, which describes work under two separate contracts over a period of about three years. The whole two-part project is the largest and most comprehensive survey of its type ever done in the United States.

We are extracting the important findings and interpreting them for practical application to indoor air problems in buildings. This is the first *IAQU* article on the report, and we plan to examine details of the study in future articles.

Summary

Researchers investigated 10 public access buildings: three offices, a school, a combined university school/office building, two homes for the elderly, two nursing homes, and a hospital. The buildings were monitored for about three days on each site visit, and the number of visits ranged from one to three for each building, usually with several weeks or months between visits. The researchers measured new buildings immediately after completion and again after occupancy; they were thus able to compare air pollution levels and determine the effects that may be attributable to either emissions from new materials or to occupant activities.

Separate monitoring was done during daytime and nighttime periods. For most visits, the four sample locations included three indoors and one outdoors. And at each location during the second study (six buildings), triplicate samples were collected for VOC using different flow rates. Thus, multiple measurements are available for any given location during each trip.

On each visit the researchers measured indoor air concentra-

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tions of various chemicals and particles, and on most visits they measured ventilation rates at the same time. They collected and tested a variety of building materials from some of the study buildings and tested the emissions of VOC from those materials. The results of the emissions tests were compared to the levels found in the buildings.

Study Methods

For those of you interested in air sampling for research or investigations, here's a brief description of how the EPA studies were performed:

VOC: Air samples were collected in Tenax cartridges, thermally desorbed, and analyzed by GC-MS (gas chromatography-mass spectrometry). Sample volumes were 20 liters during the first study (four buildings) and triplicate samples of 10, 15, and 20 liters for the second study (six buildings).

Particles: Dichotomous samplers, using virtual impaction, collected air samples for particles in both fine (0.5μ) and coarse (2.5-10μ) fractions.

Emissions from materials: In the first study, several materials were studied by headspace vapor collection from samples in heated bell-jars, using Tenax adsorption and GC-MS analysis. Based on these results, several materials were then studied in a room-sized chamber. In the second study, 31 materials collected from a new office building were studied using headspace sampling. Based on these results, nine materials were selected for detailed study in 12-liter glass chambers. Again, Tenax and GC-MS were used for VOC collection and analysis.

Ventilation: SF_6 (sulfure hexafluoride), an inert gas, was released into the building air supply and allowed to mix and equilibrate; air samples were collected using sequential syringe samplers. Analysis was by GC-ECD (gas chromatography-electron capture detection).

Study Objectives and General Results

The objectives and summary results for the two studies included the following:

Identify all VOC that could be collected from the air by the Tenax adsorbent, and perform GC-MS detection on a subset of samples.

Of the 500 chemicals identified, half occurred only once. Thus, many small VOC sources are probably present in a typical building rather than a few dominant ones. Aliphatic hydrocarbons predominated, followed by aromatic hydrocarbons and chlorinated (halogenated) hydrocarbons (see Table 1). Alcohols, acids, ketones, aldehydes, and esters were also present. However, the chemicals observed were limited by the collection and analysis methods, and represent only a portion of all VOC present. The triplicate samples showed extremely small differences; this indicates that the method was reliable and that sample volume is not a critical factor.

Quantify the indoor and outdoor levels of a subset of the organic compounds, selected on the basis of potential health effects, production volume, and ease of collection on Tenax. These compounds were selected using information from previous EPA studies of indoor and outdoor VOC.

Indoor concentrations exceeded outdoor concentrations for all of the target compounds (see Table 2 for a typical case). These VOC were emitted by one or more of 19 materials studied in chamber tests during the first study.

Determine the effect of building aging on the concentrations of VOC in newly constructed buildings.

Newly installed or applied finishes in the new buildings resulted in VOC air levels 10 to 100 times higher than those measured in the same buildings months later. And new buildings had generally higher levels than older buildings. The effect of building aging on the VOC concentrations appeared to be dramatic, and there was a shift in the predominant types of VOC found from new to aged buildings.

Measure emissions from building materials and processes used in some of the buildings.

The results showed clearly that most of the VOC found in building air are emitted from common building materials. This should not be interpreted to mean that the only source of the VOC were building materials.

Measure concentrations of other air pollutants, including inhalable particles, metals, radon, formaldehyde, pesticides, PCBs, carbon monoxide, nitrogen dioxide, polynuclear aromatic hydrocarbons, and asbestos.

The studies found fine (inhalable) particle air levels to be significantly higher in smoking than in nonsmoking areas, and they were clearly related to the number of

Table 1: Most Common Organic Compounds at Four Buildings

Class/Compound	N[a]	Class/Compound	N[a]
Aromatic Hydrocarbons		**Aldehydes**	
benzene	16	n-nonanal	13
toluene	16	n-decanal	10
xylenes	16		
styrene	16	**Miscellaneous**	
ethylbenzene	16	acetone	16
ethyl methyl benzenes	16	acetic acid	10
trimethyl benzenes	16	dimethylphenols	6
dimethylethylbenzenes	15	ethylene oxide	4
napthalene	15		
methyl napthalenes	15	**Aliphatics**	N[b]
propylmethylbenzenes	14	undecane	10
n-propyl benzene	13	2-methylhexane	9
diethyl benzenes	12	2-methylpentane	9
		3-methylhexane	9
Halogenated Hydrocarbons		3-methylpentane	9
tetrachloroethylene	16	octane	9
1,1,1-trichloroethane	15	nonane	9
trichloroethylene	14	decane	9
dichlorobenzenes	12	dodecane	9
trichloroflouromethane	12	tridecane	9
dichloromethane	11	methylcyclohexane	9
chloroform	10	heptane	8
		tetradecane	8
Esters		2-methylheptane	8
ethyl acetate	8	cyclohexane	8
m-hexyl butanoate	4	pentadecane	7
		4-methyldecane	7
Alcohols		2,4-dimethylhexane	7
2-ethyl-1-hexanol	9	pentane	6
n-hexanol	8	hexane	6
2-butyloctanol	7	eicosane	6
n-dodecanol	6	3-methylnonane	6
		1,3-dimethylcyclopentane	6

[a] Number of samples (of 16) with compound present
[b] Number of samples (of 10) with compound present

cigarettes smoked. Other measured variables were not remarkable.

Characterize ventilation in order to relate chemical air levels to air exchange.

Ventilation rates were generally low (less than one air change per hour [ACH]) in all visits to all ten buildings, except during one visit to an elderly home during extremely cold outdoor temperatures. VOC levels did not appear to be affected strongly by ventilation rates.

Other Discoveries

VOC

All 10 buildings had higher concentrations of VOC indoors than outdoors. In the newly constructed buildings, indoor-outdoor (I/O) total VOC concentration ratios measured shortly after construction were 50 to 1. For some VOC, the I/O ratios were as high as 400 to 1. After two months the I/O VOC ratio dropped to about 10 to 1, and several months later was closer to 5 to 1. The older buildings had I/O ratios of 2 or 3 to 1. The concentrations measured in one new office building fell from 1,300 $\mu g/m^3$ to 326 $\mu g/m^3$ in two months and to 150 $\mu g/m^3$ in another three months. (See Tables 2 and 3.)

Average VOC concentrations for the six buildings in the second part of the study for all samples (except the very high, post-construction levels at the new office building) ranged widely, from about 18 $\mu g/m^3$ to 220 $\mu g/m^3$, with the levels distributed rather evenly over that range. (See Table 4.)

Ventilation Rates

Typical average three-day ventilation rates were from 0.3 to 0.9 ACH, and the range was from about 0.14 (mostly at night in buildings with HVAC turned off for most of the night) to 1.7 ACH. The high level was in the elderly home mentioned above, when the indoor/outdoor temperature dif-

Table 2: Volatile Organics in a New Office Building

	Concentration ($\mu g/m^3$)			
	Indoors[a]			Outdoors[b]
Chemical	**July**	**Sept**	**Dec**	**All Trips**
Aliphatics				
decane	380	38	4	2
undecane	170	48	13	1
dodecane	47	19	5	0.2
Aromatics				
m+p-xylene	140	19	9	2
o=xylene	74	8	4	1
ethylbenzene	84	6	5	1
benzene	5	7	7	3
styrene	8	7	4	1
Halocarbons				
1,1,1-trichloroethane	380	100	49	6
tetrachloroethylene	7	2	3	1
trichloroethylene	1	38	27	0.3
carbon tetrachloride	1	1	1	1
chloroform	1	2	18	6
p-dichlorobenzene	1	1	1	ND
Total of 14 organics	**1,300**	**326**	**150**	**25**

[a] Mean of six 12-hour averages at five indoor locations
[b] Mean of 18 12-hour averages at one outdoor location

ferences were very large and caused high infiltration air exchanges.

In Table 4 we see the VOC concentrations and air exchange rates for all trips to the six buildings in the second study. There does not appear to be any consistent relationship between air exchange rates and VOC concentrations, while the age of buildings does appear to be related to VOC levels. The age of buildings and the activities within them seem to be better predictors of VOC levels than does ventilation rate.

The lowest air exchange rates were at a new hospital, where some measured day and night values fell below 0.1 ACH, many were below 0.5 ACH, and only one location exceeded 1.0 ACH (for one day) during all three 3-day visits. The measurements were made in July, October, and the following August. The spaces monitored were a visitors lounge, a nurses station, and a patient's room. These rates seem rather low, especially for the nurses station and the visitors lounge.

Typical daytime ventilation rates ranged from 0.7 to 1.0 ACH. Nighttime rates were usually slightly to significantly lower than daytime rates, depending on the building. Some buildings were not used at night, so ventilation system operation might have been unusual in order to provide researchers with the distribution and mixing of the tracer gas needed for the ventilation rate measurements.

We would expect considerable differences in air concentrations of VOC at different ventilation rates, but the measurements were made during the first few hours of the twelve-hour periods they reflect. Actual spot rates or average rates might have varied more than is indicated. In fact, ventilation rates could and normally would vary even more than the measured and reported range during typical daily operation of many building types under normal climate conditions.

Generally, ventilation rates above 1.0 ACH significantly reduce air levels of most contaminants, with the reduction increasing as the ventilation rate approaches the typical building maximum around 5 or 6 ACH. Rates below 1.0 ACH and down to the usual minimum around 0.2 tend to less dramatically affect air levels.

Materials Emissions

The quantities and types of chemicals emitted from the building materials tested varied enormously. The VOC emissions were consistent with what was found in the building air. Total VOC emission rates for a cove adhesive, as measured in the study, exceeded 5,000 $\mu g/m^2$ per hour! Rates above 600 $\mu g/m^2$ per hour were found for one latex caulking compound, while emission rates of 200 to 300 $\mu g/m^2$ per hour were found for a latex paint and a carpet ad-

Table 3: Concentration Data for Volatile Organic Compounds Summarized by Class and Compound

Building	Time since completion (weeks)	Concentration (μg/m³) aromatic HC	aliphatic HC	chlorinated HC	oxygenated HC	Total Indoor	Total Outdoor	I/O Ratio
Hospital (new)								
Trip 1 (7/84)	34	18	7.0	8.1	1.3	34	9.1	3.7
Trip 2 (10/84)	48	11	4.7	6.0	ND	21	10	2.1
Trip 3 (8/85)	1.5 yr	26	5.1	26	ND	57	9.4	6.1
Office (new)								
Trip 1 (1/85)	1	270	810	13	ND	1,100	17	65
Trip 2 (4/85)	14	54	98	56	8.5	220	16	14
Office (old)								
Trip 1 (8/84)	1 yr	74	5.1	46	4.3	130	58	2.2
Office/School (old)								
Trip 1 (2/85)	2 yr	30	18	26	1.5	75	16	4.6
Nursing Home (new)								
Trip 1 (4/85)	4	93	173	9.9	9.6	286	11	26
Trip 2 (8/85)	23	22	7.3	3.9	1.2	34	20	1.7
Nursing Home (old)								
Trip 1 (7/84)	8 yr	12	1.9	4.1	ND	18	9.1	2.0

HC = Hydrocarbons
ND = Below the quantifiable limit

hesive. About one-third of the materials emitted between 20 and 100 μg/m^2 per hour, and another third emitted from 6 down to less than 1 μg/m^2 per hour.

Some of the emitted chemicals (such as benzene, styrene, p-dichlorobenzene, carbon tetrachloride, and trichloroethylene) are suspected or believed to be toxic or carcinogenic, and many of them are known irritants and odorants.

Comments on the Methodology

VOC measurements were made continually during twelve-hour periods. Building ventilation systems normally cycle through the daytime hours, and average ventilation rates or the integration of twelve-hour VOC measurements can give a misleading picture of the contaminant levels present at any point in time. Sampling was usually conducted separately for day and night periods for two or three days. This gave a large number of samples, but they are still twelve-hour averages. Aggregating them for the three days is, however, useful for determining total exposure of the occupants in the hospitals and nursing homes, and the purpose of the project was to characterize human exposure to indoor air pollutants.

Looking at the day and night VOC levels separately and in relation to ventilation rates is also useful, although ventilation rates could not be measured using tracer gas injection into the air supply when ventilation systems were turned off. So, either systems were run when they might not be in normal practice, or no ventilation rate data was collected. In either case, the data needs to be looked at carefully and in detail to determine the true meaning of the results. This has not yet been done.

While the researchers collected a very large (and therefore costly) set of VOC samples, many of them were for quality control purposes rather than for additional locations and sampling times. Typically they sampled only three indoor locations and one outdoor location in each building. Significant variations in ventilation rates, source

Table 4: Total VOC and Air Exchange Rates for Six Buildings in Study Phase 2

Building	Time since completion (weeks)	Total HC (µg/m³)			Air Exchange Rate ACH (±S.D.)[a]		
		Indoor	Outdoor	I/O Ratio	Overall	Day	Night
Hospital (new)							
Trip 1 (7/84)	34	34	9.1	3.7	0.94 (0.73)	0.93 (0.86)	0.95 (0.64)
Trip 2 (10/84)	48	21	10	2.1	0.14 (0.12)	0.19 (0.14)	0.08 (0.08)
Trip 3 (8/85)	1.5 yr	57	9.4	6.1	0.44 (0.12)	0.50 (0.12)	0.37 (0.08)
Office (new)							
Trip 1 (1/85)	1	1,100	17	65	0.60 (0.08)	0.58 (0.08)	0.61 (0.08)
Trip 2 (4/85)	14	220	16	14	0.30 (0.10)	0.38 (0.07)	0.21 (0.03)
Office (old)							
Trip 1 (8/84)	1 yr	130	58	2.2	0.44 (0.19)	0.49 (0.14)	0.39 (0.23)
Office/School (old)							
Trip 1 (2/85)	2 yr	75	16	4.6	0.50 (1.10)	0.57 (0.08)	0.45 (0.08)
Nursing Home (new)							
Trip 1 (4/85)	4	286	11	26	0.54 (0.14)	0.65 (0.10)	0.43 (0.08)
Trip 2 (8/85)	23	34	20	1.7	NC	NC	NC
Nursing Home (old)							
Trip 1 (7/84)	8 yr	18	9.1	2.0	0.43 (0.27)	0.54 (0.33)	0.35 (0.19)

HC = Hydrocarbons
NC = Not calculated
[a] = air changes per hour ± standard deviation

strengths, and air concentrations typically occur in going from one space to another within a building, especially in large buildings with diverse activities and spatial characteristics, so the samples may not reliably represent average or peak levels for the whole building.

The results indicate the "tip of the iceberg" of what is going on in the particular buildings tested; based on our experience, variations from the measured levels could easily reach a factor of two or greater during any particular time period for different spaces within the buildings. And during different time periods in a given day, you could find differences even greater than a factor of two.

All of the above notwithstanding, we think that the exact levels are not as important as the general nature of the conclusions that we can reach from the reported results.

Implications

1. Comparing VOC air levels in new buildings as they age provides a picture of the changes that occur over time. *Air levels of VOC emitted by new building materials appear to decrease between one and two orders of magnitude (10 to 100 times) in the first few weeks or months after construction is completed.* This reinforces the importance of aggressive ventilation during that period of time.

2. Comparing emission results from headspace tests and chamber tests is important. Headspace tests are considerably easier, quicker, and cheaper. They are currently used primarily for screening purposes prior to chamber testing. Headspace tests allow the investigator to determine the types of compounds and the general magnitude of the emissions from a suspect material.

The results from headspace tests are not reliable enough for predicting indoor air levels, but they may be adequate for comparing two or more products within a generic class, or for comparing differing classes of products. *Designers, contractors, and building owners could find this very useful in selecting products and materials for their buildings.*

As we learn more from headspace and chamber testing, headspace testing will become an adequate evaluative tool for most practical

Table 5 : Summary of Emission Results

Sample [a]	Emission Rate (μg/m² h) Aliphatic and Oxygenated Aliphatic Hydrocarbons	Aromatic Hydro-carbons	Halogenated Hydro-carbons	All Target Compounds
Cove adhesive	a	a	a	5,000
Latex caulk	252	380	5.2	637
Latex paint (Glidden)	111	52	86	249
Carpet adhesive	136	98	-b	234
Black rubber molding	24	78	0.88	103
Small diameter telephone cable	33	26	1.4	60
Vinyl Cove Molding	31	14	0.62	46
Linoleum tile	6.0	35	4.0	45
Large diameter telephone cable	14	20	4.3	38
Carpet	27	9.4	-	36
Vinyl edge molding	18	12	0.41	30
Particle board	27	1.1	0.14	28
Polystyrene foam insulation	0.19	20	1.4	22
Tar paper	3.2	3.1	-	6.3
Primer/adhesive	3.6	2.5	-	6.1
Latex paint (Bruning)	-	3.2	-	3.2
Water repellant mineral board	1.1	0.43	-	1.5
Cement block	-	0.39	0.15	0.54
PVC pipe	-	0.53	-	0.53
Duct insulation	0.13	0.15	-	0.28
Treated metal roofing	-	0.19	0.06	0.25
Urethane sealant	-	0.13	-	0.13
Fiberglass insulation	-	0.08	-	0.80
Exterior mineral board	-	0.03	-	0.03
Interior mineral board	-	-	-	-
Ceiling tile	-	-	-	-
Red clay brick	-	-	-	-
Plastic laminate	-	-	-	-
Plastic outlet cover	-	-	-	-
Joint compound	-	-	-	-
Linoleum tile cement	-	-	-	-

[a] Emission rate for cove adhesive is a minimum value; sample was overloaded. It is estimated that cove adhesive is one of the highest emitters of volatile organics.

[b] No detectable emissions.

purposes. We think this type of testing will be dramatically increased in the next year or two, and architects, interior designers, engineers, product manufacturers, and regulators will increasingly rely on this type of testing. (See "Saskatchewan Developing Materials Emissions Testing Standard" on page 8 in this issue.)

3. The air measurements collected during or shortly after interior finishing work indicate that *people in buildings where renovation or refinishing work is occurring can be exposed to very elevated levels of toxic chemicals. This may be one of the most dramatic implications of the study.*

Many complaints from occupants in remodeled buildings come during the application of paint, carpet, or cove molding, probably near the end of the process. The emissions measured from those products in this study show that some of them are very strong emitters of VOC, and some of the chemicals are extremely hazardous. Products are available that have much lower emissions than others in the same category. *It is essential that you carefully select products, ventilate during their application, and isolate occupied areas from work areas to control this problem.*

In the field we are strongly recommending that air from areas being finished, renovated, or furnished not be circulated into occupied spaces of the building. If possible, directly exhaust such work areas to the outdoors during installation and for several days afterwards. We have recommended this in previous issues of *IAQU*, but we are now even more convinced of the importance of this measure.

4. *Ventilation rates can vary considerably from one building to another,* although their designs and ventilation requirements might appear similar. Only measuring ventilation in the field can provide

reliable information on system performance.

The Report

The two volumes are not organized in very readable fashion, though they are full of descriptive details and data. The authors have focused much of their presentation, discussion, and analysis on the methodologies for future research and on numerical results rather than on the implications or for efforts to control indoor air pollution in public access buildings. However, a separate summary for each of the two volumes was prepared by Lance Wallace at EPA, and the summaries are far more readable than the report itself. Each summary consists of six pages of text and several pages of references, selected tables, and figures. We encourage readers to obtain these summaries, particularly for more details on the study methods and results.

We encourage you to submit comments or questions about the EPA report. We will share your thoughts and our responses with readers in future issues. There is plenty of substance in the study to merit further attention in future issues of *IAQU*.

To Obtain the Report or Summaries:

The reports are titled ***Indoor Air in Public Buildings, Volume I and Volume II***, and are numbered EPA/600/6-88/009A and EPA/600/6-88/009B, Aug. 1988. The summaries are numbered EPA/600/S6-88/009A and EPA/600/S6-88/009B, September 1988. All of the documents are available from the Center for Environmental Research Information, EPA, 26 Martin Luther King Drive, Cincinnati, OH 45268. You can call the Center at (513)569-7562 to request the reports or summaries, while the supply lasts. After the published supply runs out, they will be available through the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, VA 22161. ♦

News and Analysis

Washington Scene: Legislative Update

With Senator George Mitchell's election as Senate majority leader, the future of his 1988 major indoor air legislation is up in the air. However, we expect that his increased visibility and authority bode well for the future of indoor air legislation. He was strongly committed to effective legislation during the 1988 session, and his bill was voted out of committee. In case you have not had an opportunity to hear or see Sen. Mitchell, he is an impressive speaker, extremely intelligent, and one of the best stand-up comedians we have heard.

The committee bill contained almost $50 million in new funding for indoor air quality research, technical assistance, investigations, and demonstrations. This would be a dramatic increase in funding for federal indoor air activities, mostly at EPA. A similar bill was introduced in the House by Rep. Joseph Kennedy, and Sen. Mitchell testified there strongly urging favorable action.

According to Senate Environment Committee staff, no decision has been made about what — if anything — to introduce in the coming session. However, authoritative sources told us that something is anticipated; it simply is impossible to say what right now.

On the House side, it is not clear whether Rep. Kennedy will reintroduce his clone of Mitchell's bill, whether Rep. Schneider will become active in developing legislation again, or whether Rep. Scheuer will be a key player in the 1989 session. ♦

On the Horizon

Saskatchewan Developing Materials Emissions Testing Standard

Under a grant from Energy, Mines and Resources Canada, the Saskatchewan Research Council is studying the use of caulks, sealants, and weatherstrip products for energy conservation. That study includes the examination of toxic hazards from caulks and sealants used in residential sealing work. Although the focus of the study is residential applications, the work has important implications for nonresidential construction as well.

The work not only provides a preliminary model for materials evaluation, it indicates that products can be rated for safety based on measurements and on toxicity data currently available.

The study used charcoal adsorption and carbon disulfide desorption for the chemical sampling and analysis. This limits the number and type of compounds that can be collected and runs counter to sampling method trends among most researchers in the U. S. during the past several years. However, many European investigators favor this method.

But even with its limitations, the work developed some significant findings and demonstrates a workable model for materials evaluation. It moves us one giant step closer to a time when building materials and consumer products can be systematically and effectively screened and selected according to their potential IAQ impacts.

The researchers used a three-part process, which they believe may be universally applicable to the evaluation of building materials:

1. Test the product to determine the emissions rate.
2. Analyze the results in an IAQ model that predicts the indoor air levels under realistic use conditions.
3. Compare the predicted levels to acceptable levels established for indoor air.

Determining guidelines or standards for permissable levels is fraught with scientific, political and economic problems. However, even before such standards are developed, testing and analysis can allow formulators to improve their products' performance and designers to select products based on relative performance. If the differences are great among different products within a generic category, designers can specify the use of the lowest or lower emitters. This can be done now and does not require any further standards or research.

The Research

The study had the following main objectives:

- Develop a method for measuring VOC emissions from sealants.
- Develop a method of translating experimental results into safety ratings for caulks.
- Test the procedures by applying them to a representative range of caulks and sealant products.
- Use the results to describe procedures (draft standards) for consideration by the Canadian General Standards Board.

The purpose of the work was to develop the methodology and not to actually do the ratings of products. Preliminary results appear satisfactory, and the work is being refined and finalized currently.

To test every product of each type would be an exceedingly time consuming and costly effort. In order to conduct the work practically, one randomly selected product was tested from each of 20 generic groups of sealants identified by the researchers. The list of generic sealants indicates the large number of distinct product types:

- Oleoresinous
- Polysulphide
- Butyl rubber
- Acrylic emulsion
- Acrylic solvent
- Polyvinyl acetate
- Vinyl acrylic
- Asphaltic 1-part
- Neoprene
- Hypalon
- Polyurethane 1-part
- Silicone
- Polybutene
- Bitrile
- Neoprene blend
- Silicone 1-part
- Styrene butadiene
- Styrene butadiene rubber (SBR)
- Styrene butadinene styrene
- Styrene ethylene butylene styrene (Styrene elastomer)

The report presents its description of the outgas process as a "simple, preliminary working hypothesis...crude and over-simplified...[which gives] a fairly good account of the observed phenomena." We summarize their description below.

The VOC Emission Process

Generally, sealants are mixtures of solids, liquids, and gases. The solid component is a rigid matrix

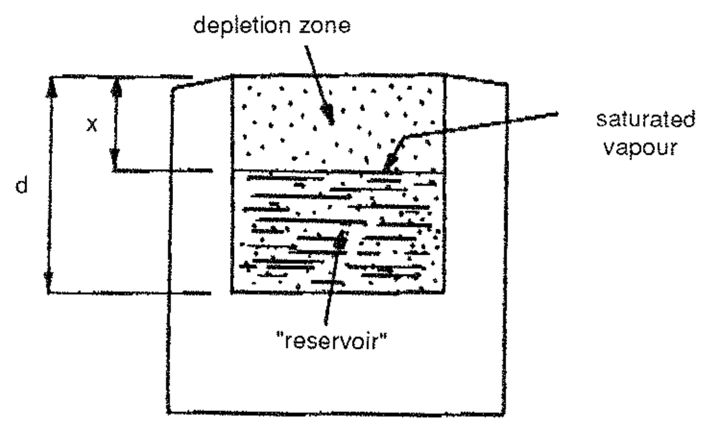

Figure 1: The assumed model of sealant diffusion

containing voids filled by a mixture of liquids and gases. The liquids are usually volatile. The volatiles at or near the surface of a newly installed sealant bead will evaporate and escape. While this occurs a surface skin is formed, creating a barrier to the further escape of volatiles more distant from the surface.

At the end of the initial period a resistive skin is formed and the voids close to the surface are depleted of liquid volatiles. Volatiles in liquid form deeper within the sealant evaporate and diffuse through depleted voids toward the outer surface skin. As the process continues, remaining VOC must travel an increasing distance to reach the surface. (See Figure 1.)

Thus, the profile over time consists of high initial emissions, decreasing rapidly as the skin forms. Then emissions continue to decrease but more slowly, as the diffusion path increases in length. Air movement at the surface strongly affects emission rates. Stagnant air results in high VOC air levels close to the surface, which tend to inhibit further evaporation. If air movement is rapid and continuous at the surface, resistance to emissions is lowered and evaporation increases.

This model is generally applicable to emissions from materials other than caulks and sealants. The emission rate for a material will depend on its chemical makeup, physical structure, and the environmental conditions to which it is exposed.

Results of the Study

1. The VOC identified were:

- xylene,
- aliphatic hydrocarbons (typical of retail solvents and "mineral spirits," consisting of nonane, decane, etc. and their alkenes and impurities),
- petroleum hydrocarbons (typical of paint thinners, consisting of gasoline, diesel, kerosene, naphthas, and sometimes a range of aliphatic hydrocarbons),
- hexane (only in one case),
- methyl ethyl ketone (MEK), and
- toluene.

2. Weight loss of the dried sealant ranged from about 4.5 to almost 60 percent of the original compounds. Drying times (end of outgassing period) ranged from as low as 55.5 hours for styrene butadiene to as high as 8,269 hours (almost a year) for polyurethane 1-part.

3. The slowest dryer was deemed safe for indoor use.

4. Safety ratings were provided for the six products. Three were judged "safe," one was judged "unsafe," and two were rated "caution." A seventh was rated "probably safe." Those containing petroleum hydrocarbons were not rated due to the absence of acceptable guidelines for exposure limits or toxicity values.

A rating of "caution" indicates that at least one VOC constitutes a hazard if the maximum amount of sealant (3.6 kg) is used in a residence. Therefore, the sealant should only be used in prescribed (limited) quantities and according to procedures outlined for safe application.

A "safe" rating means that the VOC analysis was deemed successful and no hazardous compounds were detected.

The Researchers' Opinions

Dave Eyre of the Saskatchewan Research Council told us that he feels the general principles developed and used in the study are sound. He said that they are currently developing final findings of safety. He warned we should not try to use these preliminary product tests as a way of deciding what type of sealant or caulk to use since only one product from each generic group was tested. Eyre said that the quantity of each chemical given off in the short time period of the tests can be used reliably to predict concentrations indoors. Therefore, with adequate standards for airborne concentrations of the chemicals involved, we can develop guidelines for product selection and use.

Implications

1. If you are seeking guidance for material selection from careful laboratory testing, be aware of the great magnitude of the task due to the number of products involved in any class of products. Also, products vary from manufacturing batch to batch, formulations are changed over time, and products change as a result of the storage and handling conditions prior to and during use. Thus, even test results can only indicate what might be expected within reasonable limits.

2. Recognize that temperature and air movement vary greatly during construction and afterwards, and these factors affect emission rates and airborne VOC concentrations. Higher temperatures increase evaporation rates, as do increases in air movement. And air movement can vary enormously between a sealed, low-ventilation building and a very well-ventilated

indoor location or an outdoor location.

Thus, the conditions under which sealants and caulks are installed and exposed to the atmosphere during the hours and days immediately after installation will have important effects on their long-term performance and emissions.

3. We are tremendously optimistic about the potential usefulness of emissions testing for evaluating the indoor air effects of building products. Information from such tests will soon be available to designers and builders, to assist them in careful selection of products to minimize indoor air pollution.

4. Studies of VOC from building materials are leading to a more complete understanding of the emissions process. With this knowledge and a market interest in cleaner, safer products, formulators will be able to develop products that will cause less harm to building occupants.

For More Information

Contact the office below or Dave Eyre, Energy Program Manager, Buildings & Energy Technology Program, Saskatchewan Research Council, 15 Innovation Blvd., Saskatoon, Saskatchewan, Canada S7N 2X8; (306)933-6925.

D. Jennings, D. Eyre and M. Small. "The Development of a knowledge base relating to indoor use of caulks, sealants and weatherstrip products; Volume 4, The safety categorization of sealants according to their volatile emissions." Ottawa: Energy, Mines and Resources, Government of Canada. August 1988. Available from Residential Energy Management Division Distribution; Energy, Mines and Resources Canada; Ottawa, Ontario K1A OE4. ♦

ASTM Standards for Emissions Studies

The increased interest in the use of test chambers to quantify emissions from building materials, furnishings, and products has spawned the need for some standardized test methods. Standards would allow comparing results from different laboratories.

ASTM Subcommittee D22.05 on Indoor Air is preparing a guide to chamber testing based on the chamber used by EPA at its Research Triangle Park laboratory. Bruce Tichenor at Research Triangle Park is preparing the document. If you are interested in commenting on it, call Tichenor at (919)541-2991. ♦

Practical Research Briefs

Indoor Air and a Whole Lot More

Indoor air quality problems are often blamed for building occupant's complaints or health problems, but IAQ may not always be the cause of the problems. *The human body integrates all of the environmental forces acting upon it, and its physiological and psychological responses may not be attributable to a* **single** causal factor. Lighting, acoustics, seating, computer equipment, and furnishings (among other things) also can cause many of the symptoms that lead to indoor air quality investigations. This complicates those investigations.

The following three articles look at office environments and occupant health, safety, and comfort in terms of a variety of environmental factors besides indoor air. Documented sick building syndrome investigations have revealed that mechanical vibration from HVAC systems, glare from lighting, or noise contributed to or caused the complaints. Therefore, we want you to appreciate the diversity of environmental factors that you must consider when investigating complaints (or designing buildings).

Quality of Work Environment: Factors in SBS?

In "Quality of Work Environment (QWE): Effects on Office Workers," Professor Franklin D. Becker of Cornell University reviews the literature on the quality of the work environment as a facet of what he calls the "Quality of Worklife (QWL)" movement. The purpose of the article is to characterize office quality to "help guide the search for design solutions that genuinely promote individual health and well-being as well as organizational effectiveness."

Becker says that reducing accidents and environmentally induced illness is necessary but insufficient for greatest productivity. Work environments can only contribute to individual and organizational welfare if they support different "workstyles" and respond to how employees want to be supervised and do their jobs.

QWE varies among different interest groups (developer, investor, manager, employee). In effect, Becker says, office quality is the result of a political process involving each interest group "to determine the allocation of the scarce resources of space, furniture, equipment, and location." While different interest groups might define office quality differently, employee responses to different work environments provides clues to the essential building blocks.

Office Automation

Health and satisfaction among VDT (video display terminal) users appears related to the quality and type of support furniture and to work scheduling. Lighting problems of glare and contrast are common, especially when workers perform multiple tasks including non-VDT work. Some problems may be linked to the VDT, but the majority stem from seating, equipment and furniture adjustability, poor lighting, and other qualities of the surrounding environment. Becker suggests that the reported increased incidence of miscarriages among VDT users may be related to the stress of VDT use and perhaps to the increased use of drugs and alcohol to relieve that stress. (See the article below, "Miscarriages, Birth Defects, VDTs, and Indoor Air.")

Furniture

Backaches and circulatory problems have been associated with sitting for long periods, and over half the population experiences backaches at some point in their lives. Especially for VDT operators, adjustability has become a major consideration in furniture design.

Air Quality

Becker cites a number of effects familiar to most ***IAQU*** readers. He focuses on energy conservation as a source of increased indoor air quality problems. The negative effects of indoor air problems he mentions include decreased performance, memory problems, eye and respiratory irritation, cancer risk, depression of the central nervous system, irritation of tissues, and neurological damage.

Temperature

Most temperature effects in offices are discomfort or mild stress, although some research indicates that behavioral changes could be caused by temperature problems. Small temperature variations during the day may actually be beneficial by promoting increased awareness and improved performance.

Illumination

Lighting requirements depend on task difficulty and duration. Employees may prefer lighting levels several times higher than that required to do the job without eyestrain. Direct and reflected glare are major sources of office workers' health-related problems, including annoyance, discomfort, and temporary loss of good vision or visibility. Perceived color quality also affects workers' responses. However, there is little evidence that "full-spectrum" lighting helps performance.

Workers prefer natural lighting and views outside. Windows provide visual relief and relaxation, connect the worker to the outside world, and may reduce a sense of crowding.

Sound

Acoustic privacy is generally a greater concern to office workers than is visual privacy. "Meaningful noise" such as overheard telephone conversations are most bothersome.

Noise provokes more stress as it increases in intensity and unpredictability. Noise can also have a bad effect on social behavior, task performance, and evaluative judgments of other people.

Density and Enclosure

Open office plans cause problems due to lack of auditory and visual privacy and impaired inter-worker communication. Improved sound masking systems and acoustic separations have effectively reduced many of these problems. Some research suggests that higher "social density" (not necessarily less space per person) may improve performance among professional staff where interaction is valued.

Design

Workers tend to respond positively to any indication that the people responsible for their environment care about their needs and preferences. Thus, newness or cleanliness take on symbolic as well as physical significance in shaping workers' attitudes and responses. Office workers prefer muted color tones to bright colors or stark black and white decor.

Participation in Change

Office workers like to participate in the planning and design of their work environment, but they are rarely allowed to do so. Such participation increases job satisfaction, environmental satisfaction, and job performance.

For More Information

Contact Franklin D. Becker, Department of Design and Environmental Analysis, College of Human Ecology, Cornell University, Ithaca, NY 14853.

Franklin D. Becker, "Quality of Work Environment (QWE): Effects on Office Workers" in A. Wandersman and R. Hess, eds., ***Beyond the Individual: Environmental Approaches and Prevention.*** The Haworth Press, 1985. ♦

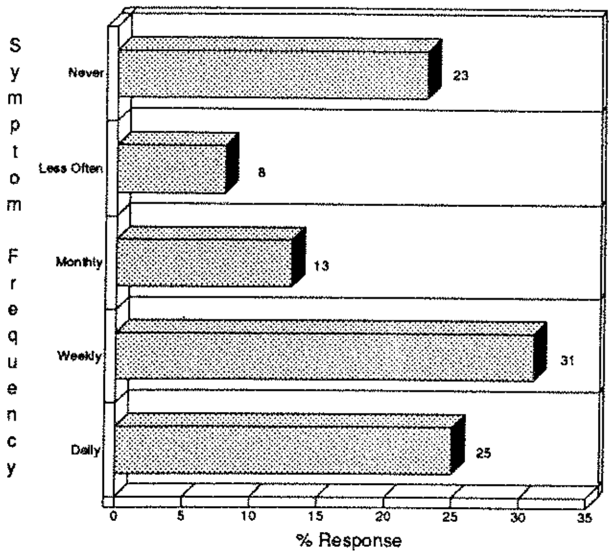

Figure 2: Prevalence of work-related symptoms

Job Stress, Job Satisfaction, and SBS

A study in the United Kingdom found that reported work-related illness among office workers was not associated with self-reported job stress or negative perceptions of the office environment.

Alan Hedge, now of Cornell University, conducted the study while still at Aston University in the U.K. He distributed a questionnaire which 486 office workers (85% of the sample given the questionnaire) in six buildings completed. Three of the buildings were occupied by government agencies, three by private firms. They had various types of HVAC systems, although the descriptions of the systems are limited, and no other information about the buildings is included in this report.

The prevalence of work-related symptoms is shown in Figure 2. Lethargy, headache, stuffy nose, and dry throat were the most commonly reported symptoms. (A positive answer indicated that the symptom was experienced at least twice during the prior year and that it abated when the employee was away from work.)

At least one work-related symptom was reported as occurring daily in 25% of the respondents, weekly in 31%, monthly in 13%, less often in 8%, and never in 23%. (See Figure 3.)

Hedge found that job satisfaction was not significantly associated with symptom reporting. He states that "workers are not reporting illness as a way of expressing dissatisfaction with their work." He also concludes that satisfaction with work does not compensate for symptoms attributable to the office environment.

Hedge did find that symptom reports correlated strongly with "negative perceptions of office environmental conditions, i.e., dissatisfaction with ventilation, temperature, humidity, and noise, and with self-reported job stress."

For More Information

Contact Professor Alan Hedge, Department of Design and Environmental Analysis, College of Human Ecology, Cornell University, Ithaca, NY 14853.

Alan Hedge 1988. "Job Stress, Job Satisfaction, and Work-Related Illnesses in Offices." ***Proceedings of the Human Factors Society 32nd Annual Meeting***, Anaheim, California, October 24-28, 1988. Santa Monica: The Human Factors Society (P. O. Box 1369, Santa Monica, CA 90406). ♦

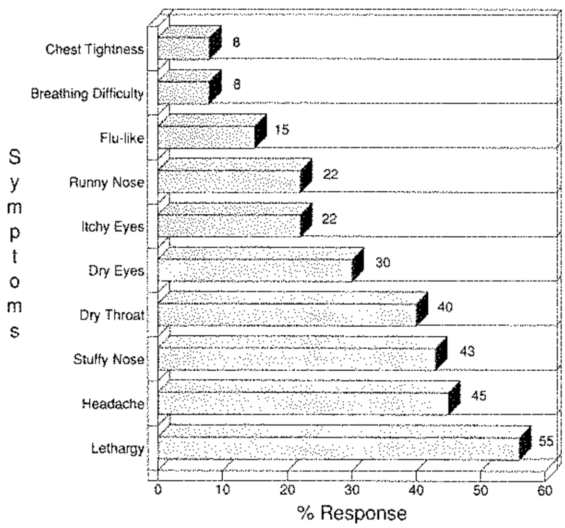

Figure 3: Frequency of reporting at least one work-related symptom

Miscarriages, Birth Defects, VDTs, and Indoor Air

There has been substantial concern about the possible harmful effects of VDTs on pregnancy, but we have not seen similar interest in the impact of indoor air quality on pregnant women. A recent study found a strong correlation between high (more than 20 hours per week) VDT use and miscarriages among clerical workers. We think it could be related to air quality in clerical areas, and this should be investigated.

The Study

9,564 pregnant women at three Kaiser Permanent Medical Clinics in Northern California were studied to determine the possible relationship between VDT use at work and pregnancy outcome. The researchers divided the women into groups of working and non-working women, and divided the workers into two groups — VDT users and non-VDT users.

Results

The researchers found that women with any VDT exposure during the first trimester had a risk of miscarriage 1.2 times higher than non-VDT working women. The relative risk of ending in birth defect was similar.

However, with more than 20 hours per week VDT exposure during the first trimester, the estimated relative risk of miscarriage was significantly elevated at 1.8. No statistically significant elevated risk of birth defects was found.

The researchers observed a dose-response trend for miscarriages in administrative support/clerical workers — that is, the greater the exposure, the more likely a miscarriage in this occupational group. This was not observed in working women in other occupational categories including managers/professionals, technical/sales, and service/blue collar.

In the nonclerical groups, an increased relative risk compared to nonworking women was found, but it was not related to VDT use. However, the number of women in these other categories with high (20 hr/wk) VDT exposure was too small to form reliable conclusions.

Previous Studies

While four previous studies had not concluded that VDT use is unsafe during pregnancy, in all studies in which high VDT use was examined separately, relative risks above 1.0 (1.0 = no elevated risk) were found. The risk ratios for these other studies ranged from 1.1-1.2 for miscarriages and 1.2-2.3 for birth defects. While excess risks were small in all but one (2.3 for birth defects), the consistently elevated risk ratio in all the studies suggests that excess risk could be real.

There are a number of reasons why some or all of the studies may have built-in biases, mostly dealing with self-reporting of VDT use.

Causal Theories

Theories linking VDT use to pregnancy problems have included radiation, ergonomic environment, and stress. Several investigations have ruled out ionizing radiation on the basis of the very low levels emitted.

Studies are underway to examine the effect of low-frequency magnetic radiation, and preliminary results from one lab animal study indicate increased risk of fetal death, fetal reabsorption, and malformations.

Actual use patterns are different for women who use VDTs intermittently and those who work at them most of the day. Ergonomic factors, work patterns, sitting postures, and psychological stress have been suggested as possible contributors to reproductive risk.

Indoor Air Could Be a Factor

To the list of potential contributors to reproductive risk, we would like to add air quality parameters of two sorts. Emissions from the VDTs themselves may result in chemical exposure. And the air quality in the types of environments where VDTs are used may be different from that in office environments where VDTs are used intermittently or not at all.

Indoor air quality can vary significantly among locations within buildings. One study has found that air quality variations among spaces were greater in a sick building than in an identically constructed healthy building (we will report on this in next month's issue). Clerical workers are often more crowded together, and they are frequently in interior air supply zones. The interior air handling zone usually receives less air supply and less outside air than those located in perimeter offices or air supply zones. Interior zones tend to go through less temperature variation and tend to stay near the warmer end of the design or operating thermal range.

Clerical workers might also be exposed to airborne chemicals from clerical materials and equipment other than the VDTs, including carbonless copy paper, copier machines, printers, and other office devices. Some of these chemicals are known toxins.

Recommendations:

1. Any future comprehensive study of VDT exposure and pregnancy outcome should include indoor air in clerical and nonclerical areas, along with other possible causes .

2. Meanwhile, office workers and managers should be aware of potential risks and implement any measures at their disposal to minimize them until more evidence is available on this important issue. Conventional wisdom indicates the need for good lighting, adjustable computer furniture, and frequent breaks; *we would add a sufficient supply of good air.*

For More Information

Marilyn K. Goldhaber, Michael R. Polen, and Robert A. Hiatt, "The Risk of Miscarriage and Birth Defects Among Women Who Use Visual Display Terminals During Pregnancy," ***American Journal of Industrial Medicine*** Volume 13, pp. 695-706 (1988). ♦

Readers' Corner

To Bake-out or Not to Bake-out?

We have had several inquiries recently from readers interested in bake-out procedures for newly constructed buildings. Several are from designers involved in new hospital construction.

Many of the articles in ***IAQU*** have provided strong evidence for the value of a properly conducted bake-out in reducing VOC levels in new buildings. The EPA study reported in this issue gives strong evidence of this need.

No simple or universally applicable answer is available. As is the case in any good design decision, *the nature and details of a bake-out depend on the particular circumstances.*

Following are some questions which must be answered in order to determine whether a bake-out will succeed and how to conduct it. If you are contemplating a bake-out we strongly urge you to retain qualified professionals with knowledge and experience related to the procedure. They can help answer these questions and advise building owners and operators on the use of a bake-out.

- What is the reason for the bake-out, and can it be achieved in the particular building with the available time, weather conditions, and HVAC capacity?
- What temperatures can be reasonably achieved while maintaining at least some ventilation, and are they sufficient to increase emissions significantly in the time available?
- How much time is available for the bake-out, and is it sufficient to thoroughly ventilate the building after the bake-out and prior to occupancy?
- Can manufacturers provide assurances that warranties of the HVAC components and other building elements will not be violated by a bake-out?

Meanwhile, if you are planning a bake-out, attempt to reach temperatures in excess of 90°F, hold the temperature high for as long as possible, maintain at least some ventilation during the bake-out, ventilate thoroughly before re-entry, and protect materials and building components from thermal stress.

We will continue to cover building bake-outs in upcoming issues of *IAQU*. Some good work is being conducted that will shed new light on the subject. ♦

From the Field

CO_2 and Detector Tubes

We have recently heard that high humidity can interfere with CO_2 readings on detector tubes. If you have any experience or information on the use of detector tubes for CO_2 air levels, please contact editor Hal Levin. (See back page for editorial office.) ♦

Products & Services

The Radon Industry Directory

Radon Press, Inc., of Alexandria, VA, is in the final stages of publishing *The Radon Directory*, an invaluable tool for consultants, state and local government officials, contractors, and others involved with radon control. We have had an advance view of the directory, and it appears to be a comprehensive and useful guide to the industry. It includes nonevaluative listings for detection companies, mitigation companies, product manufacturers, government agencies, seminars, conferences, and a glossary.

We have been promised a copy by the publishers and will prepare a more detailed review of the 535-page, softbound directory for the next issue of ***IAQU***.

Available from Radon Press, 500 N. Washington St., Alexandria, VA 22314. Phone (703) 548-2756 or (800) 548-1567 to order at the prepublication price of $49.95 plus $2.50 for shipping. The publisher's listed retail price is $75.00 . ♦

Calendar

January 11. **Radon: An Awareness Seminar,** Georgia Tech Research Institute, Atlanta, Georgia. Contact: Education Extension-R, Georgia Institute of Technology, Atlanta, GA 30332-0385; (404)894-2400, (800)325-5007.

January 22-25. **Annual Meeting Cooling Tower Institute,** New Orleans, Louisiana. Contact: CTI, P.O. Box 73383, Houston, TX 77273; (713)583-4087.

January 22-26. **Annual Meeting American Society of Mechanical Engineers,** Houston, Texas. Contact: Frank Demerest, ASME Petroleum Division, 13773 North Central Expressway, Suite 1314, Dallas, TX 75243; (214)437-0094.

January 28 - February 1. **ASHRAE Winter Meeting and Exhibition,** Chicago, Illinois. Contact: Jim Norman, ASHRAE, 1791 Tullie Circle, N.E., Atlanta, GA 30329; (404) 636-8400.

February 3-4. **Symposium on Architecture and Building Construction Issues with Consideration of Regional Climatic Conditions,** Baton Rouge, Louisiana. Contact: Dr. Jason Shih, School of Architecture, Louisiana State University, Baton Rouge, LA 70803.

February 13-18. **Housing for Cold Climate, Third Annual Congress and Exhibition,** St. Paul, MN. Contact: Minnesota Energy Council, Box 76070, St. Paul, MN 55175.

April 17-20. **IAQ 89: The Human Equation: Health and Comfort,** San Diego, California. Contact: Jim Norman, ASHRAE, 1791 Tullie Circle, N.E., Atlanta, GA 30329; (404)636-8400.

May 2-5. **EPA/APCA International Symposium on Measurement of Toxic and Related Air Pollutants,** Raleigh, North Carolina. Contact: Seymour Hocheiser, Environmental Monitoring Systems Laboratory, U. S. Environmental Protection Agency, Research Triangle Park, NC 27711

June 6-9. **ASTM Subcommittee D22.05 on Indoor Air,** Philadelphia, Pennsylvania. Contact: George Luciw, ASTM, 1916 Race Street, Philadelphia, PA 19103; (215)299-5400.

June 20-24. **ASHRAE Annual Meeting,** Vancouver, British Columbia. Contact: Jim Norman, ASHRAE, 1791 Tullie Circle, N.E., Atlanta, GA 30329; (404)636-8400.

June 25-30. **APCA 82nd Annual Meeting and Exhibition,** Anaheim, California.

July 16-19. **Symposium on Biological Contaminants in Indoor Environments.** Sponsored by the ASTM Subcommittee D22.05 on Indoor Air. Boulder, Colorado. Contact: George Luciw, Subcommittee D22.05 on Indoor Air, ASTM, 1916 Race Street, Philadelphia, PA 19103; 215-299-5400.

October 11-13. **Blueprint for a Healthy House Conference,** Cleveland, OH. Contact: Housing Resource Center, 1820 W. 49 St., Cleveland, OH 44102; (216)281-4663.

INTERNATIONAL

February 14-16. **"Present and Future of Indoor Air Quality,"** Brussels Congress Centre, Brussels, Belgium. Sponsored by the Belgian Ministry of Public Health, The World Health Organization, and the Belgian Ministry of Hygiene and Epidemiology. Contact: D. Shanni E.C.C.O.sprl, Rue Vilain XIIII, 17 A, B-1050 Brussels, Belgium.

June 19-22. **11th International Congress on Quality for Building Users,** Paris, France. Sponsored by the Council for Building Research, Studies and Documentation (CIB). Contact: Jean-Louis Feliz, Centre Scientifique et Technique du Batiment, Relations Exteriereurs, 4 avenue du Recteur-Poincare, 75782, Paris Cedex 16 France, Phone (1) 45 24 43 02.

June 23-24. **"Building Simulation '89: Technology Improving the Energy Use, Comfort, and Economics of Buildings Worldwide,"** Vancouver, British Columbia, Canada. Sponsored by the International Building Performance Simulation Association. Contact Dr. Marianne McCarthy Scott, MCC Systems Canada Inc., 30 Wellington Street East, #202, Toronto, Ontario, Canada M5E 1S3; (416)368-2959.

September 1. **CLIMA 2000, the Second World Congress,** Sarajevo, Yugoslavia. Contact: CLIMA 2000, Massinski Fakultet, Prof. Dr. Emin Kulic, 71000 Sarajevo, Omladinsko Setaliste bb, Yugoslavia.

October 16-20. **The Sick Building Syndrome,** Copenhagen, Schafergarden. Sponsored by the Nordic Institute of Advanced Occupational Environment Studies (NIVA). Contact: NIVA, c/o Institute of Occupational Health, Topeliuksenkatu 41 a A, SF-00250 Helsinki, Finland; tel +358-0-47471.

July 29 - August 3, 1990. **5th International Conference on Indoor Air Quality and Climate,** Toronto, Canada. Contact: Dr. Douglas S. Walkinshaw, Centre for Indoor Air Quality Research, University of Toronto, 223 College Street, Toronto, Ontario, Canada M5T 1R4.

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