Indoor Air Quality Update™

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

Vol. 3, No. 1 Hal Levin, Editor January 1990

ACGIH Publishes *Guidelines for Assessing Bioaerosols*

The American Conference of Governmental Industrial Hygienists (ACGIH) has just published the most helpful document to date on bioaerosols in indoor air. The publication, *Guidelines for the Assessment of Bioaerosols in the Indoor Environment*, is presented in a loose-leaf notebook to allow updating as new information is developed.

It was prepared by the Committee on Bioaerosols of ACGIH, chaired by Dr. Harriet Burge of the University of Michigan School of Medicine. It contains free-standing chapters with the following titles (page lengths of the current version of each section are in parentheses):

Preface (1); Introduction (3); Step One: Medical Preassessment (9); Step Two: On-site Investigations (8); Step Three: Recommendations (1); Air Sampling (6); Remedial Actions (6); Biocides (7); Viruses (10); Bacteria (7); Endotoxin (6); Fungi (10); Protozoa (6); Antigens (7).

The 87 pages in the current version are comprehensive in scope. But a lack of detailed guidance in some areas reflects the paucity of information on some important subjects. While the guide is thoroughly referenced, the practitioner in the field typically will not have the time or the ability to pursue the references when dealing with a problem building.

Advice on Air Sampling

In general, the committee does not recommend air sampling, particularly if no apparent sources of biological contaminants are found in the medical and on-site investigations. The medical and on-site investigations are considered sufficient to exclude bioaerosol contamination unless the evidence indicates otherwise. These investigations are always recommended prior to air sampling, if air sampling is to be done at all. Those situations where air sampling is required may include the following:

1. When building management wants evidence that bioaerosols are being disseminated from an identified source.
2. When building management or occupants insist on air sampling in spite of the absence of evidence implicating potential sources.
3. When building occupants believe bioaerosols are present and want evidence that there is no air contamination.
4. In research projects requiring air sampling.

Where air sampling is done, its purpose is to identify sources rather than to provide evidence that the bioaerosol is causing the complaints. Identification and quantification of bioaerosols is difficult, at best, and a "highly skilled, labor-intensive task" at least. The committee asserts that acceptable levels or guidelines for bioaerosol concentration have not been established.

The committee also says that while positive air sampling results "may document the presence of a specific source," negative findings cannot be used to conclude the absence of sources.

After all of these caveats, the committee presents a summary of the available instrumentation and the operational features relevant to indoor air sampling. This includes the principle of operation, sampling rate, and recommended sampling time for each device.

Table 1 — Samplers commonly used for collection of indoor bioaerosols

Sampler type	Principle of operation	Sampling rate (lpm*)	Recommended sample time
1. Slit impactor	Impaction on rotating or stationary plate	30-700 continuous	1-60 min or 7-day
2. Sieve impactor			
a. single-stage portable	Impaction on agar; "rodac" plate	90 or 185	0.5 or 0.3 min
b. single-stage impactor	Impaction on agar; 100 mm plates	28	1 min
c. two-stage impactor	Impaction on agar; 2-100 mm plates	28	1-5 min
3. Filter cassettes	Filtration	1-2	15-60 min or 8 hr
4. High volume filtration	Filtration	140-1,400	5 min-24 hr
5. High-volume electrostatic	Electrostatic collection into liquid	up to 1,000	variable
6. All-glass impingers	Impingement into liquid	12.5	30 min
7. Centrifugal impactor	Impaction on agar; plastic strips	40??	0.5 min

*lpm = liters per minute

This information is presented in Table 1.

The ACGIH bioaerosols committee is composed of the most knowledgeable people in the field, and as new information becomes available, it will be incorporated into revisions.

The *Guidelines* can be purchased for $20 from ACGIH, 6500 Glenway Avenue, Bldg. D-7, Cincinnati, OH 45211-4438; (513)661-7881. ♦

Tools and Techniques

IAQU Suggests Materials Evaluation Form

In the March and April 1989 issues of *IAQU*, we discussed evaluating the impacts of materials and furnishings on indoor air quality as part of the selection, design, or specification process. In this issue we present a one-page evaluation sheet that will assist you in considering materials for your building.

The evaluation sheet will not work magic. If important information about a product's chemical emission rates or the health effects of those emissions is lacking, then the sheet will be even less helpful. Filling out the sheet provides an outline of what we view as the important considerations in selecting materials and furnishings for your new building or renovation project.

The values for the ratings are solely based on our judgment about their relative importance. If you have comments or suggestions about the sheet, please do not hesitate to forward them to us. We will collect readers' comments and publish an accordingly revised sheet in a future issue of *IAQU*.

Materials that are most important to evaluate carefully during the selection process are listed below. This list of items came from an anonymous reader who we consider one of the most knowledgeable in the field. The comments are ours.

- Coatings: paints, varnishes, waxes.

[These materials go on wet and therefore by design contain volatile components expected to enter the air. Diverse products are available for each application, and tests have shown that their emissions can vary significantly among products.]

- Flooring or wall covering materials made of plastics, fibers, or fabrics.
- Furniture or furnishings with substantial amounts of pressed wood or fabrics.

Materials Evaluation Sheet

CRITERIA (Weighted):	SCORE High 3	Med 2	Low 1	High Score Factors	Weight Factor	Total Score
1. Product use:						
* The total amount of the product or material used	.....			Large quantity	9	.....
* The location of its use in relation to occupants	.....			Close proximity	6	.....
* The location of its use in relation to the air flow in the occupied zone and in the HVAC system	.....			High airflow	6	.....
2. Chemical emissions' health effects:						
* Are the emitted chemicals known irritants, odorants, or toxins?	.....			Low threshold	9	.....
* Are there any carcinogens, mutagens, teratogens (substances that cause birth defects), or fetotoxins (substances with adverse effects on an unborn fetus)?	.....			Yes	9	.....
* Are there any chemicals known to damage immune systems?	.....			Yes	7	.....
* How potent are the chemicals? Are the levels found in buildings, or likely to result from the use of the product, near or above the threshold for the adverse effects?	.....			Low threshold	9	.....
3. Source strength and emissions characteristics:						
* What are the emissions rates for the product?	.....			Large	9	.....
* Do they change slowly or rapidly after installation in the building?	.....			Slowly	6	.....
4. Installation and curing options:						
* Does the product require special ventilation during installation to protect installers?	.....			Yes	4	.....
* Can special ventilation during installation eliminate the majority of the residues prior to occupancy of the building?	.....			No	6	.....
5. Alternate products:						
* Are there similar products with better ratings on categories 1-3 above?	.....			Yes	2	.....
6. Material dynamic characteristics:						
* Does the product have a large surface area that can adsorb and re-release large quantities of VOC?	.....			Yes	3	.....
* Is the product hygroscopic or likely to support microbial growth?	.....			Yes	3	.....
7. Maintenance requirements:						
* Does the product require maintenance involving frequent or large-quantity applications of VOC?	.....			Yes	3	.....

- Nonmetallic materials used in ductwork of ventilation systems.
- Office machines and supplies (e.g., coated papers).
- Maintenance materials (e.g., floor waxes, rest room odorizers).

The same authority has recommended a standard for emission test reports. The report should:

- Identify and report emission factors for the five major organic compounds emitted (i.e., the five compounds with the largest emission factors). [Some researchers also report emission factors for any very toxic compounds — Ed.]
- Identify the presence (or absence) of and report emission factors for any specified compounds (for example, you may request data on 4-PC from carpet or data on formaldehyde from furniture and furnishings); if absence is claimed, the detection limit should be reported.
- Report emission factors for total measured organic compounds, in units of toluene equivalents.
- Report emission factors as milligrams/hour per m^2 for surface materials and coatings; milligrams/hour per kg for sealants and adhesives; and milligrams/hour per unit for furniture, machines, and other items.
- Report emission factors at three "ages" of the product:
  - for coatings, adhesives, and caulks: approximately 1, 10, and 100 hours after application to a surface.
  - for solid materials, approximately 0-1, 10, and 50 days after production.
- Report ozone emission rates for office machines in units of milligrams/hour/machine.
- Report chamber testing conditions (temperature, air exchange rate, humidity, product loading), and storage and handling procedures. ♦

4-PC Facts

4-PC has received more than its share of attention from building occupants, carpet manufacturers, and IAQ researchers recently. Bruce Tichenor at EPA was kind enough to send *IAQU* some technical information on 4-PC and its close relatives, 1-PC and 3-PC. The information comes from the EPA-NIST mass spectra library widely used by analytical chemists.

The official names listed below are clumsy and did not look right to us. They certainly are not used in common conversation or even in the several published papers dealing with carpet emissions. However, they are the names officially sanctioned by the International Union of Pure and Applied Chemistry (IUPAC). Analytical chemists trying to find information would find them as listed below.

4-PC (4-phenylcyclohexene)
Name: Benzene, 3-cyclohexen-1-yl-
Formula: $C_{12}H_{14}$
CAS #: 004994-16-5
Molecular Weight: 158.109

1-PC
Name: Benzene, 1-cyclohexen-1-yl-
Formula: $C_{12}H_{14}$
CAS #: 000771-98-2
Molecular Weight: 158.109

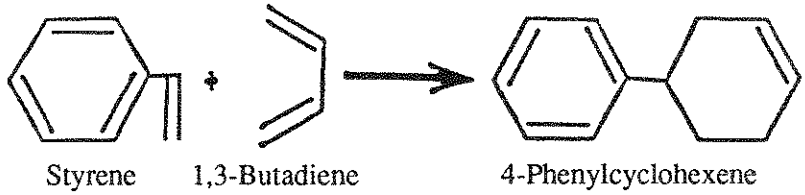
3-PC
Name: Benzene, 2-cyclohexen-1-yl-
Formula: $C_{12}H_{14}$
CAS #: 015232-96-9
Molecular Weight: 158.109 ♦

From the Field

French Canadian SBS Investigation Guide

A local community health clinic, CLSC Centre-Ville in Montreal, has produced a clever guide to investigating and resolving SBS problems. The guide, "Et Si On Prenait L'Air," presents a four-stage process intended to assist office occupants in investigating and understanding potential causes and cures of SBS-type problems. At a time when several guides have been produced, some of them from Quebec, this one stands out for two reasons: first, it is handsomely packaged; second, it emphasizes organizational and institutional aspects of solving IAQ problems.

The guide is formatted in an unusual and, we think, extremely practical and useful manner. The package includes lots of charts and checklists organized in separately



Diels-Alder Reaction of Styrene and 1,3-Butadiene to Produce 4-Phenylcyclohexene

bound guides and little notebooks for different aspects of the process.

The process followed in the guide is a variation on the widely recommended and generally accepted process. The major difference is that the new guide is focused not only on investigation but also on resolution of building-related health problems. It focuses on the technical issues first, but then it focuses on issues of responsibility and control over the conditions in the building. It is intended to provide workers and managers with assistance in developing a strategy to convince building owners and operators to make changes necessary to improve the indoor environment.

The publication is in two parts. The first part, "Elements d'information," is an informational document describing health problems related to indoor air quality in office buildings and the functioning of HVAC systems. It also discusses possible causes of SBS-type complaints. The second part, the "Action Plan," is summarized below.

Four Stages of the "Action Plan"

The four stages of the action plan at a glance are the following:

1. Identify occupant health problems: Administer an occupant questionnaire; compile the results; inform the occupants of the results.
2. Identify the causes of the problems: By means of a walk-through survey, inspection of the ventilation system, simple measurements, and discussions with key personnel; and report the results to the occupants.
3. Formulate the remedial plan: Identify the responsible parties for building management/operation; develop and present a prioritized list of corrective actions; present the information to the responsible parties; if accepted, monitor the correction of the identified problems; if not accepted, determine the reasons and develop appropriate means to rectify the problems;
4. Verify that the corrections are effective; Distribute the questionnaire to the occupants; and compare the results to those obtained previously. If the problem persists, repeat stages 2 and 3 to identify and obtain the necessary corrections.

CLSC Centre-Ville is a health clinic in Montreal. Workers there found themselves unable to respond to all the problems or SBS-type complaints in buildings. They developed the guide to provide assistance to office workers and their employers, who often are working together to resolve a building environmental problem. The clinic simply cannot provide assistance to all who need it, so they developed the publication to help people help themselves.

The guide is sold for $8 or $10 depending on whether it is to an individual or an agency. According to CLSC's Norman King, they have sold upwards of 300 in the first few weeks after publication. People in the second and third stages are now contacting CLSC and compiling the information. Then they call back for a little advice on the best way to organize it and present it to building owners and operators. In the near future, they expect to have considerably more information on the successes and failures of those using the guide.

King told *IAQU*, "Once you have done the survey, you have to develop the arguments to convince the building owner to make the changes. The real question is how you can take this information you have gathered and develop strategies to do this."

A drawback for some of our readers is that the guide is currently available only in French. King is actively seeking support for an English translation.

Copies of the guide (in French) can be purchased from CLSC for $12 including postage and handling in Canada; for the United States and other countries, $12 U.S. funds.

For More Information

Contact: Norman King, Research Consultant, CLSC Centre-Ville, 1199, de Bleury, Suite 200, Montreal, Quebec, Canada H3B 3J1; (514) 866-5761, ext. 144. ♦

News and Analysis

Congress Moves IAQ Bill

The Indoor Air Quality Act of 1989 (S657 in the Senate, also known as the Mitchell bill after its original author, Senate Majority Leader George Mitchell, D., Maine) has been amended in subcommittee and will go to the full committee (Environment and Public Works) for a vote early this year, according to *IAQU*'s sources in EPA. The Subcommittee on Superfund, Oceans, and Water Protection removed many of the features of the bill found most troubling by Bush Administration officials, as well as many critics in the private sector, before passing the measure and sending it to the full committee.

The bill, if passed, would authorize $48.5 million annually for IAQ programs for the next five years, a

rather large increase over current funding. While no one is willing to place a precise figure on the current level, our estimate is that between $4 million and $8 million in federal funds are spent on the type of activities addressed in the proposed legislation.

It is not yet clear what the House committee will do, but Washington insiders expect their marked-up version of the bill to be similar to the Senate's. *IAQU* presented a detailed summary of the bill in April 1989. A summary of the important changes in the Senate version of the bill follows below.

Section 5: Indoor Air Quality Research

The subcommittee transferred responsibility from EPA to OSHA for the comprehensive assessment of exposure of workers in non-industrial settings including resulting health effects, productivity, and claims. It also added new requirements for assessing indoor air pollution in public transportation and for designing control measures.

The revised bill deletes "Technology and Management Practice Assessment Bulletins" from paragraph (d)(2). Child care facilities were added to the school assessments and to the content of the required report to Congress on their progress.

Section 6: Management Practices and Ventilation Standards

(a) Technologies and Management Practices Assessment Bulletins

The new version requires bulletins on assessments of technologies and management practices for the control of indoor air contaminants. Bulletins are to be published "in a schedule consistent with the publication of health advisories."

(b) Model Building Management Practices Training

NIOSH, GSA, and EPA will develop indoor air quality training related to ventilation systems, maintenance of records regarding indoor air quality, health threats posed by indoor air pollutants, and identification of potential indoor air pollutants.

(c) Ventilation Program

The amended bill requires EPA to study the adequacy of existing standards and guidelines for ventilation. This is clearly aimed at ASHRAE Standard 62-1989, Ventilation for Acceptable Indoor Air Quality, and whatever provisions exist in model and local building codes. An important aspect of the mandate is evaluation of the extent to which buildings are operated in compliance with the standard. Additionally, the bill now requires assessment of the potential for ventilation control to "complement controls over specific sources of contaminants in reducing indoor air contamination."

EPA will report the results of its study in 36 months. Included in the report will be recommendations concerning the establishment of ventilation standards that protect public health while considering worker comfort and energy conservation, and "ensuring that adequate ventilation standards are being adopted and that buildings are being operated in a manner which achieves the standard." This is as close as the bill gets to mandating or instigating regulatory activity.

Section 7: Indoor Air Contaminant Health Advisories

This section was, perhaps, the most controversial in the earlier version of the bill. The required listed contaminants are now only those that occur in indoor air "at levels which may reasonably be expected to have an adverse impact on human health." This requirement replaced one calling for establishment of "no health effects levels" for the contaminants.

Several contaminants are explicitly listed; they are:

- benzene
- biological contaminants
- carbon monoxide
- environmental tobacco smoke
- formaldehyde
- lead
- methylene chloride
- nitrogen oxide[s]
- particulate matter
- asbestos
- polycyclic aromatic hydrocarbons (PAHs)
- radon

The preparation of the list will now be in consultation with the indoor air panel of the EPA Science Advisory Board.

Section 8: National Indoor Air Quality Response Plan

The EPA must now consult with the other relevant federal agencies in developing the national response plan, still under the authority of existing law. This is apparently a response to the unhappiness expressed by several other

agencies, specifically CPSC and DOE, at the degree to which the bill previously gave responsibility and control to EPA.

Technical Assistance and Training

A new section requires EPA to include in the national response plan specific plans for training seminars for state and local officials as well as private and professional firms dealing with IAQ.

The bill retains the requirement for planning the "development of model building codes, including ventilation rates, for various types of buildings designed to reduce levels of indoor air contaminants." We do not see this particular requirement surviving the legislative process in light of the building industry and code officials' successful efforts in the past to keep Congress out of their affairs.

Assessment of Private IAQ Services

EPA will assess the "indoor air monitoring and mitigation services provided by private firms ... including the range of such services, the reliability and accuracy of such services, and the relative costs of such services." This will include evaluation of the options for governmental oversight of such activities. Specifically, the bill mentions the possibility of registration, licensing, and certification of such firms.

Section 9: Federal Building Response Plan and Demonstration Program

The General Services Administrator will appoint or allow a lessee to appoint an indoor air quality coordinator for each federal building owned or leased by GSA. There will be one coordinator for each building, and coordinators shall serve as such for no more than one building. The coordinators must complete the IAQ training course required in section 6.

Other Amendments

NIOSH and OSHA have elevated roles in the revised bill. They will now have seats on the Council on Indoor Air Quality, and the Department of Labor is deleted. Funding levels were not changed. The bill still provides $48.5 million for each of the next five years.

The Future of the Bill

There has been some talk about appending the IAQ Act to the Clean Air Act; this might be an easy way to get it through since there seems to be agreement that the Clean Air Act will be passed this year. But the Senate has not scheduled hearings. None are scheduled in the House yet either, although there has been talk about early summer hearings.

The changes made in the Senate will surely make the bill more palatable to at least some Bush Administration officials. And the problems at Waterside Mall keep indoor air on many people's agendas there. Right now it is wait and see. We will keep you informed as things develop.

For more information or a copy of the current version of the Senate bill, contact Jeffrey Peterson, Senate Committee on Environment and Public Works, (202)224-6691. In the House of Representatives, some staffers involved with the bill include Wesley Warren (Rep. Claudine Schneider) at (202)226-6993 or Jeanne Gorman (Rep. James Scheuer) at (202)226-6980. ♦

California Issues Perchloroethylene Report

Tetrachloroethylene is commonly referred to as perchloroethylene (PCE). It is a volatile organic hydrocarbon with a chloroform-like odor used as a solvent in dry cleaning, a metal degreaser, a chemical intermediate in synthesis of fluorocarbons, and in coffee decaffination. Acute toxicity of "perc" is moderate; the principal target is the liver. Perc causes skin and eye irritation, but experts do not expect it to do so at the concentrations encountered in non-occupational settings.

The California Air Resources Board (CARB) has recently issued a two-volume draft report on perc. The final report is due out in July. It will be reviewed by the Scientific Review Panel before final regulatory action is effected.

The draft report says that mean ambient air levels measured in outdoor air in southern California were 0.43 ppb. Mean indoor air concentrations reported in the United States were 0.34 to 1.01 ppb, with maximum concentrations reported in some homes of 14.1 ppb. According to the report, concentrations in indoor air vary with the quantity released from water and consumer product sources, the time since release, and the size of the room.

The California risk assessment described PCE classification by EPA as a "possible human carcinogen based on animal studies" and "insufficient data to assess human carcinogenicity." The IARC (International Agency for Research for Cancer) made similar findings. Based on those findings and a risk assessment for lifetime exposure, the California draft report concludes that "PCE is an

air pollutant which may cause or contribute to an increase in mortality or in serious illness, or which may pose a present or potential hazard to human health."

Thus, the California Air Resource Board proposes to add perc to its list of toxic air contaminants.

Copies of the report are available from Robert Rood, Stationary Source Division, CARB, P.O. Box 2815, Sacramento, CA 95812. (916)327-5615. ♦

Information Exchange

How to Get European Community SBS Report

In the November *IAQU* we wrote about the Report No. 4, "Sick Building Syndrome, A Practical Guide," from the Commission of the European Communities. The information at the end of the article on obtaining the report was not sufficiently clear or detailed, and we have received a very large volume of calls from readers wanting to obtain the report. The full citation for the report is as follows:

EUR 12294 — European concerted action; Indoor air quality and its impact on man. Cost Project 613: Report No. 4, "Sick Building Syndrome, A Practical Guide."

Previous reports in the series (Nos. 1-3) include publications on radon, NO_2, and test chamber measurements of formaldehyde emissions.

Readers may obtain the report directly from Joint Research Centre, Commission of the European Communities, I-21020 Ispra (Varese) Italy.

Or you may call: Information Service, Commission of the European Communities, Washington, D.C.; Monday-Thursday, 10 AM-4 PM, (202)862-9500. ♦

EPA Releases IAQ Services Study/Directory

EPA has just released a report containing the results of its survey of over 7,000 IAQ firms nationwide. EPA selected the firms from the business-to-business yellow pages and other directories listing IAQ-related professional organizations. Each firm received a questionnaire inquiring about the firm and its IAQ services. About 1,200 responses were received and analyzed. The report, entitled "Survey of Indoor Air Quality Diagnostic and Mitigation Firms," contains the results of the survey conducted by EPA in the fall of 1988.

EPA intended the report to serve as a useful directory for those seeking professional assistance in dealing with indoor air quality problems. However, the report contains abundant (on every page of the listings) disclaimers. It states "EPA has not verified the accuracy of the information reported or evaluated the quality of the services provided." It states that "no approval, recommendation, endorsement, or accreditation of any kind is implied or intended."

On the front page of the report, the disclaimer concludes as follows: "Representation to the contrary by any individual or firm should be brought to the attention of the Indoor Air Division..." of EPA. There was concern that listed firms might use the listing in a misleading way in promoting or marketing its services.

The results of the study indicate the following, as reported in the Executive Summary:

- Many of the firms have provided industrial hygiene services for "several decades;" however, 47% have provided services in nonindustrial settings for ten years or less. The report's authors conclude that "the nonindustrial IAQ service industry is at an early stage in its development."
- Most of the responding firms are not primarily in business to provide IAQ services.
- The majority of the nation's nonindustrial IAQ service industry is in the eastern part of country. Sixty-six percent of the respondents are located east of the Mississippi River. However, 45% of the respondents said they serve a national client base.
- While IAQ service firms as a whole provide a diversity of services, individual firms tend to be "relatively specialized and geared toward diagnostic services." Very few of the firms provide a wide range of diagnostic and mitigation services.
- "The average national firm is relatively small, with an average of only 18 employees."

The last statement is not surprising in light of the way the lists were generated for distributing the survey questionnaire. The lists included names of radon and asbestos firms obtained from associations of those specialized firms.

The listing of the types of services provided by the various firms is contained in Table 2.

The types of buildings serviced by firms are listed in Table 3.

Formaldehyde is the pollutant monitored by the largest

Table 2 — Evaluation Services Performed by IAQ Firms

Evaluation service	Number of firms that provide service	Percent all firms
One or more evaluation services	769	80 %
Ventilation system evaluation	598	62 %
Temperature/relative humidity	591	61 %
Air exchange rates	541	56 %
Pollutant source characterization	519	54 %
Noise	509	53 %
Lighting	283	29 %
Occupant health status	238	25 %
Other[a]	188	19 %
Psycho-social factors	133	14 %

[a] There were no predominant responses to this question. The most frequent responses included asbestos-specific evaluation techniques (one percent), ergonomics (one percent), and health and safety (one percent).

Table 3 — Types of buildings serviced by IAQ firms

Type of building	Number of firms	Percent of all firms
Office buildings	849	88 %
Public buildings	795	82 %
Schools	766	79 %
Hospitals	726	75 %
Private residences	563	58 %
Multi-family residences	546	57 %
Other[a]	267	28 %
Did not respond	49	5 %

[a] Major entries under "other" include industrial buildings (12 percent), commercial buildings (three percent), and military buildings (two percent).

percentage of firms — 65%. Runners-up were carbon monoxide and airborne particles at 60% each, followed by asbestos, other VOC, lead, carbon dioxide, nitrogen dioxide, and others. 26% of the firms said they monitor for biological agents, a number we find surprisingly high. 84% of the firms said they monitor "one or more pollutants."

The majority of the firms appear to have begun providing IAQ services during the last ten years, and most of those within the last five years.

For More Information

"Survey of Indoor Air Quality Diagnostic and Mitigation Firms," EPA 400/1-89/004.

To obtain a copy; contact National Technical Information Service, 5285 Port Royal Rd., Springfield, VA 22161; (703)487-4650. At press time no price information was available. ♦

WHO Issues Organic Chemicals Report

The World Health Organization Office for Europe has issued another in its series of highly respected and frequently cited reports on indoor air quality. Typically, a group of European and North American experts prepares the reports following an international meeting. The report on organic chemicals in indoor air was prepared by a working group that met following the 4th International Conference on Indoor Air Quality and Climate in West Berlin in August 1987.

The report covers the exposure, health effects, levels of knowledge, levels of concern, and needs for further research on most of the important (in terms of health effects or frequent occurrence) organic chemicals in indoor air.

Exposure Measurements

The report provides exposure data for 74 organic compounds based on several European and North American studies. It lists in a table the 90th and 98th percentile measured concentrations, where available, for each compound, available known effect levels, unit carcinogenic risk, and TLVs (or the German counterpart, MAK levels), outdoor concentrations, and important health effects. The data from this table are presented here in Table 4.

Health Effects

The WHO report divides the discussion of the health effects of organic chemicals into three broad categories:

1. Odor and other sensory effects such as irritation;

Table 4 — Organic air pollutants for which health effects have been shown

Pollutant	Exposure ($\mu g/m^3$) 90th %ile	98th %ile	Effect level Type	mg/m^3	Unit risk[a]	TLV mg/m^3	MAK mg/m^3	Remarks
Aliphatic hydrocarbons								
n-hexane	20	—	—	—	—	180	180	Odour detection threshold 230 mg/m^3
hexane (isomers)	—	—	—	—	—	1800	—	
n-heptane	15	—	—	—	—	1600	2000	
octane	10	—	—	—	—	1450	2350	
nonane	20	—	—	—	—	1050	—	
Cycloalkanes								
cyclohexane	100	—	—	—	—	1050	1050	
methylcyclohexane	100	—	—	—	—	1600	—	
Aromatic hydrocarbons								
benzene	20	30	—	—	4	30	16 (TRK)[b]	Can cause: leukaemia (non-lymphatic), aplastic anaemia, polycythaemia (bone marrow) (TLV for last 2)
toluene	150	250	NOEL[c]	187	—	—	380	AQG value 7.5 mg/m^3 (24 hr); sensory limit 70 mg/m^3; odour detection threshold 1 mg/m^3; neurotoxic; data on cancer (animals) inadequate; mutagenicity negative
m,p-xylene	40	—	—	—	—	435	440	Odour detection threshold 0.6 mg/m^3
o-xylene	10	—	—	—	—	—	—	
ethylbenzene	20	—	—	—	—	435	440	
trimethylbenzene	—	—	—	—	—	125	—	
isopropylbenzene	—	—	—	—	—	—	245	
styrene	5	10	LOEL[d]	210	—	215	85	Odour detection threshold 0.07 mg/m^3 (sensory AQG value, 30 min); AQG value 0.8 mg/m^3 (24 hr); neurotoxic; mucous membrane irritant; limited evidence of carcinogenesis (IARC)
Chlorinated hydrocarbons								
chloroform	15	—	—	—	—	50	50	Suspected carcinogen, sufficient animal evidence (ACGIH)
tetrachloromethane	5	—	—	—	—	30	65	Suspected skin carcinogen (ACGIH)

Table 4 — Organic air pollutants for which health effects have been shown, continued

Pollutant	Exposure ($\mu g/m^3$) 90th %ile	98th %ile	Effect level Type	mg/m^3	Unit risk [a]	TLV mg/m^3	MAK mg/m^3	Remarks
Chlorinated hydrocarbons								
trichloroethylene	20	—	NOAEL[e]	189	—	270	270	Suspected carcinogen, IARC Group 3; neurotoxic; liver and kidney toxic; genotoxic; teratogenic; AQG value 1 mg/m^3 (24 hr); AQG occupational limit 135 mg/m^3
1,2-dichloroethane	—	—	—	—	—	40	80	Carcinogenic in animals (oral); mutagenic; AQG value 0.7 mg/m^3 (24 hr)
dichloromethane	—	—	NOAEL	173	—	350	360	COHb formation; AQG value 3 mg/m^3 (24 hr); neurotoxic; odour detection threshold 3 mg/m^3; low mutagenicity; sufficient evidence of carcinogenicity in animals
vinyl chloride	—	—	—	—	10	—	5 or 8[f]	IARC Group 1 (liver and other cancer)
tetrachloroethylene	20	70	NOEL	136	—	335	345	AQG value 5 mg/m^3; CNS effects 136 mg/m^3; odour detection threshold 8 mg/m^3 (30 min); carcinogenic in animals, IARC Group 3
bromoform	—	—	—	—	—	5	—	
chlorobenzene	10	—	—	—	—	350	230	
o-dichlorobenzene	5	—	—	—	—	300	300	
p-dichlorobenzene	20	—	—	—	—	450	450	
1,2,4-trichlorobenzene	15	—	—	—	—	40	40	
1,1,1-trichloroethane	20	—	—	—	—	1900	1080	
Alcohols								
ethanol	—	—	—	—	—	1900	1900	
Esters and ketones								
ethyl acetate	—	—	—	—	—	1400	1400	
butyl acetate (isomers)	—	—	—	—	—	710	135	Odour detection threshold 0.03 mg/m^3
butanone	—	—	—	—	—	590	590	Odour detection threshold 5.8 mg/m^3

Table 4 — Organic air pollutants for which health effects have been shown, continued

Pollutant	Exposure (µg/m³) 90th %ile	Exposure (µg/m³) 98th %ile	Effect level Type	Effect level mg/m³	Unit risk[a]	TLV mg/m³	MAK mg/m³	Remarks
Aldehydes								
formaldehyde	—	—	—	—	—	1.0	0.6	Short-term AQG value 0.1 mg/m³ (30 min)
acetaldehyde	—	—	—	—	—	180	90	Irritation; odour
acrolein	—	—	—	—	—	0.25	—	Eye irritation
butanal	5	—	—	—	—	—	300	Odour detection threshold 158 mg/m³
Other compounds								
naphthalene	5	—	—	—	—	50	50	Odour detection threshold 0.3 mg/m³; animal toxicity at 2500 mg/m³
PAH								
mixture	—	—	—	—	$9x10^4$	—	—	Carcinogenic in lung (AQG), IARC Group 1
benzo[*a*]pyrene	—	—	—	—	—	—	—	Suspected carcinogen, sufficient evidence in animals
sodium dodecyl sulfate	—	—	—	—	—	—	—	Irritation in sensitive individuals (carpet shampoos)

[a] Lifetime excess risk of cancer from exposure to 1 µg/m³ per million people.
[b] No MAK values have been set for confirmed human carcinogenic compounds. For some of these, technical guidance concentrations (TRK in German) are set, taking into account technical and socioeconomic considerations.
[c] NOEL = no-observed-effect level.
[d] LOEL = lowest-observed-effect level.
[e] NOAEL = no-observed-adverse-effect level.
[f] 8 (TRK for polyvinyl chloride/vinyl chloride production);
5 (TRK for other cases).

2. Mucosal irritation and other morbidity due to systemic toxicity;
3. Genotoxicity and carcinogenicity.

Sensory Effects

A review of the sensory effects of the important indoor chemicals listed in the report suggests that there is little reason for concern for most or all of them at the levels found in indoor air. Typically, the thresholds for irritation are many times the concentrations found in indoor air. The exception to this generalization is the case of formaldehyde.

The report says that for many chemical compounds having both odorant and irritant properties, human beings cannot readily differentiate the two effects. Research techniques available today cannot separately determine the odor and irritant potency of chemicals. Odor detection thresholds reported by various laboratories can vary by as much as five orders of magnitude due to the differences in their exposure and measurement methods.

Due to the absence of reliable data for modeling and predicting responses to VOC, some researchers have recommended the concept of total VOC to indicate or predict indoor air quality. However, the ability of such an indicator to perform reliably has not been demonstrated. The concept has some merit since all sensory information is processed into a total

signal, according to the report. But present knowledge is limited on the processing of the exposure into this total signal.

Detection and recognition of odors also vary greatly, according to reported research. Individual sensitivities to a compound may vary by a factor up to 1,000. And the distribution of sensitivities seems to be skewed rather than normally distributed. These things make prediction even more difficult.

For these and other reasons, the report recommends against using recognition thresholds as the only measure for assessing the importance of a particular chemical for indoor air quality. In spite of this, for many indoor chemicals, this is the only measure available.

For nonodorous indoor air contaminants (such as ozone and carbon monoxide, the report says), measurement of sensory effects are not adequate to protect human health. (We have heard other authorities disagree with respect to the odor and health effects thresholds for ozone.)

Derived effects

The derived effects of irritation may include subjective symptoms and objective signs — for example, conjunctivitis, sneezing, coughing, hoarseness, and others. Airway functioning and nasal resistance can be affected. Not enough is yet known about the dose-effect relationships between various indoor air contaminants and the derived effects of sensory irritation.

The report's authors conclude that the most important derived effects of odors in relation to indoor air quality are sensory irritation symptoms and the triggering of hypersensitivity reactions.

Sensory Effects of Mixtures

In discussing the odor impact of mixtures, the report points out that both "vector summation" and "hypo-addition" models have been presented to explain human perception of odor intensity from complex mixtures. Both of these models mean that the perceived intensity of the odor is less than the sum of the perceived intensities of the individual constituents. The rule of thumb is that the perceived odor intensity of a mixture can be estimated within 50% accuracy from the odor intensity of the strongest-smelling constituent.

The authors reported no studies on the irritation interactions of mixtures. Without being specific, they suggested using a team of panelists to evaluate test mixtures and field samples.

Systemic Toxic Effects

Apart from sensory irritation and carcinogenic effects, the authors identified benzene (which is also carcinogenic) as the compound of greatest concern. The other compounds reviewed, including toluene, styrene, trichloroethylene, and tetrachloroethylene, have been found indoors at concentrations many times the levels of concern. The report says that organic compounds do produce mucosal irritation and other morbidity, but this usually occurs at orders of magnitude above the measured concentrations indoors.

Other Potential Hazards

This section of the report deals with organic compounds that are not classified as volatile. These include pesticides, nitrosamines, and polynuclear aromatic hydrocarbons (PAHs). In general, the authors believe that these compounds had not been adequately evaluated in indoor air. There were many such compounds the authors considered important, and a general discussion is provided for each.

One of the reasons some of these compounds are considered important is because exposure occurs not only through inhalation but also through ingestion and skin absorption. For this reason, the authors recommend assessment of total dose and the relative contribution of indoor air.

Other WHO Indoor Air Reports

The other reports by the WHO Europe office are described below. The manuscript for a recent meeting on biological contaminants in indoor environments is in preparation and should be available in the next few months. Watch these pages for notice of price and publication date and availability.

"Health aspects related to indoor air quality," EURO Reports and Studies 21, Regional Office of Europe, WHO, Copenhagen (prepared after a meeting in April, 1979, in Bilthoven, The Netherlands).

"Indoor air pollutants: exposure and health effects," EURO Reports and Studies 78, (prepared after a meeting at Nordingen, June 1982).

"Indoor air quality research" EURO Reports and Studies 103 (prepared after a meeting in Stockholm, August 1984, following "Indoor Air '84, The 3rd International Conference on Indoor Air Quality and Climate").

"Indoor air quality: organic pollutants," EURO Reports and Studies 111 (prepared after a meeting in West Berlin, August 1987, following "Indoor Air '87, The 4th International Conference on Indoor Air").

We have spoken with Michael Seuss from the Copenhagen WHO Office about communicating information on new publications to our readers as they become available.

The publications are available in the United States through the World Health Organization Publications Sales Office, 49 Sheridan Avenue, Albany, New York, 12210; (518)436-9688.

European readers can obtain them from the Copenhagen office of WHO, 8 Scherfigsvej, DK-2100 Copenhagen, Denmark.

The publications are individually priced. Call or write the office for the latest prices and availability of the reports. ♦

On the Horizon

IAQ Jobs Go Begging

Yet another sign of the rapid growth in indoor air activities, not enough qualified people are available to fill job opportunities. Positions are open nationwide with both industry and consulting firms developing and marketing IAQ services.

According to Patricia Eagle with Management Recruiters of Austin, Texas, there is a need for professionals with one to two years of experience in IAQ. The most desirable backgrounds are in chemistry or industrial hygiene. Management capability is an added plus because many firms are planning to open IAQ branches. Prior IAQ experience can range from sick building syndrome investigations to building-related illness diagnosis in office buildings or to radon measurement in homes.

Eagle says the available IAQ positions involve comprehensive evaluations and thorough assessments followed up with solutions and development of on-site, ongoing relationships with client IAQ programs.

Eagle told *IAQU* that there is a real shortage of candidates and an abundance of job opportunities. Many colleagues have told us they are having lots of trouble finding qualified people to expand their firms' IAQ staff.

Contact: Patricia Eagle, Management Recruiters of Austin, 1250 Capital of Texas Highway South, 1 Cielo Center, Suite 200, Austin, TX 78745; (512)327-8292. ♦

Readers' Forum

Carpet Emissions and Vapor Pressure

To the editor,

As an avid and appreciative *IAQU* reader, I would like to comment on the December 1989 article on carpets, where you pointed out that a 9% increase in the Kelvin temperature caused an "unusual" 500% increase in carpet VOC emissions.

VOC emission rates might be expected to vary with temperature approximately as the vapor pressure of the individual components varies. For many pure organic compounds, VP varies according to the following expression*:

$$\log_{10}P = \frac{0.05223A}{T} + B$$

where:
P = vapor pressure (VP), in millimeters of mercury (mm Hg)

A = constant (= 39,198 for toluene)

B = constant (= 8.330 for toluene)

T = temperature, in degrees Kelvin

(* *CRC Handbook of Chemistry and Physics*)

Using the above equation, the vapor pressure of pure toluene at 24°C (297.1°K) is 27.5 mm Hg, and at 50°C (323.1°K) is 98.5 mm Hg. The VP ratio of 98.5 mm/27.5 mm is 3.58, or 358%.

Since the VOC emissions almost always consist of many components, the overall VP of these mixtures could be expected to deviate from the simple sums (Raoult's Law) based on contributions from the fractional composition of each component.

Since the boiling point (BP) of a mixture is the temperature at which the total VP is 760 mm Hg, an idea of the magnitude of the deviation in VP for a mixture can be obtained by comparing the mixture BP to the BP of the pure individual components.

For example, in a heterogeneous mixture consisting of 80.4% toluene and 19.6% water, the boiling point of the "azeotrope" (i.e., constant boiling mixture) is 84.1°C. This temperature is 26.7°C lower than the boiling point of pure toluene, and 15.9 °C lower than the boiling point of water. Thus, it might be expected that under identical environmental conditions, a single cloth dampened with a mixture of toluene and water would dry faster by evaporation than the same cloth dampened with separated pure components.

Low boiling "binary" (two component) and "ternary" (three component) azeotropes exist for numerous combinations of organic compounds, both with and without water.

In view of the temperature dependence of VP, and the sensitivity of component VP to the presence of

other components in a mixture, it is not unusual that the VOC emission rate from carpet increases by 500% for a relatively small temperature increase.

Yours truly,
Jeffrey May, President
J. May Home Inspections
Cambridge, Massachusetts

Editor's reply:
We are grateful to Jeff May for correcting the impression we gave in the carpet article and for taking the time to share his knowledge. Based on our mail and phone calls, the phenomenon in question, the change in emissions as temperature increases, is of very great interest to many of our readers. Specifically, readers have inquired about bake-outs and their efficacy.

To date, far too little research has been reported (or done) on bake-outs. What little we know of was done by John Girman and his colleagues at the California Department of Health Services. We reviewed his published papers in past issues of *IAQU* (December 1988 and July 1989).

Last July we described Girman's paper presented at the 1987 international meeting in West Berlin. The paper was revised slightly and published in the new volume of *Environment International* cited below.

In that paper Girman reported an increase in airborne VOC concentrations of 400%. It was about double the increase calculated for the effect of temperature on vapor pressure. He also noted that the increase was much larger than the 10% increase calculated for increased diffusion of solvents through building materials because of the temperature increase. However, note that Girman was comparing airborne concentrations, not emissions rates.

On the other hand, Girman's calculations for formaldehyde air concentration changes based on temperature and humidity differences (the formaldehyde concentration is sensitive to moisture in air) predicted an increase of 3.2, whereas the measured concentration increased only by a factor of 2.0 during the bake-out.

In conclusion, we offer the following observations:

The processes occurring during bake-outs (or any emissions from typical building materials and furnishings) are complex. They are affected by several factors, including the following:

- (temperature) vapor pressure
- air movement at the surface
- air concentrations of the chemicals being emitted
- adsorption phenomena (sink effects)
- ventilation rate of the space (and concentration of the compounds of interest in the outside air)
- for some materials, moisture content in the air.

While the results of bake-outs reported to date are encouraging, more research needs to be done on the behavior of materials and their chemical emissions in carefully controlled environmental studies. We need to learn more about the optimum combinations of ventilation and temperature, the duration of an effective bake-out, and the potential adverse effects on buildings and their contents.

Bake-outs can materially affect the building and its contents by extreme thermal effects, by removing moisture from sensitive objects like wood, art objects, caulks, sealants and filler compounds, and by affecting metals or other materials subject to significant thermal expansion.

For More Information

J. Girman, L. Alevantis, G. Kulasingam, M. Petreas, and L. Webber, "The Bake-out of an Office Building: A Case Study." *Environment International*, Vol. 15, pp. 449-453, 1989.

Contact: John Girman, Indoor Air Quality Program, California Department of Health Services, 2151 Berkeley Way, Berkeley, CA 94704; (415) 540-2469. ♦

Calendar

February 6-8. **Georgia Tech. Research Institute Indoor Air Quality Symposium.** Atlanta, Georgia. Contact: Ann Harbert, GTRI, O'Keefe Bldg., Rm. 146, Atlanta, GA 30332; (404)894-7430.

February 8-9. **Indoor Air Quality Seminar.** Atlanta, Georgia. Contact: Education Coordinator, ASHRAE, 1791 Tullie Circle NE, Atlanta, GA 30329; (404)636-8400, Fax: (404)321-5478. *ASHRAE Topics for this seminar include "causes of poor indoor air quality, their impact on health and comfort of occupants, and strategies for alleviating difficulties." Also included are discussions of the "provisions and status of ASHRAE Standard 62-1989" and "HVAC systems design to assure superior air quality while keeping energy and construction costs in check."*

February 9. **Georgia Tech. Research Institute Sampling and Analysis Workshop.** Atlanta, Georgia. Contact: Ann Harbert, GTRI, O'Keefe Bldg., Rm. 146, Atlanta, GA 30332; (404)894-7430.

February 10-14. **ASHRAE Winter Meeting.** Atlanta, Georgia. Contact: Judy Marshall, ASHRAE, 1791 Tullie

Circle NE, Atlanta, GA 20239; (404)636-8400.

February 12-14 1990. **International Air-Conditioning, Heating, Refrigeration Exposition.** Sponsored by ASHRAE and Air-conditioning and Refrigeration Institute (ARI). Atlanta, Georgia. Contact: ASHRAE, 1791 Tullie Circle NE, Atlanta, GA 30329; (404)636-8400, Fax: (404)321-5478.

February 19-23. **The 1990 International Symposium on Radon and Radon Reduction Technology,** Atlanta, Georgia. Contact: Robert Page, Radian Corporation, P.O. Box 13000, Research Triangle Park, NC 27709; (919)541-9100.

April 4-6. **Excellence in Housing '90** — Eighth Annual International Energy Efficient Building Conference and Exposition. Denver, Colorado. Sponsored by Energy Efficient Building Association, University of Southern Maine, Technology Center, Gorham, ME 04038; (207)780-5143, Fax: (207)780-5129.

April 23-27. **Improving IAQ in Non-Industrial Buildings.** Piscataway, New Jersey. Contact: Registrar, Robert Wood Johnson Medical School, 45 Knightsbridge Rd., Piscataway, NJ 08854. Fee is $700.

April 24-26. **ASTM Subcommittee D22.05 on Indoor Air.** San Francisco, California. Contact: George Luciw, ASTM Headquarters, 1916 Race Street, Philadelphia, PA 19103; (215)299-5571.

April 26-27. **Blueprint for A Healthy House Conference.** Cleveland, Ohio. Contact: Al Wasco, Housing Resource Center, 1820 W. 48 Street, Cleveland, OH 44102; (216)281-4663.

April 30-May 4, 1989. **Measurement of Toxic and Related Air Pollutants.** Raleigh, North Carolina. Contact: Sandy Riley, Meetings Department, Air & Waste Management Association, P.O. Box 2861, Pittsburgh, PA 15230; (412)232-3444.

June 24-29, 1990. **Air & Waste Management Association 83rd Annual Meeting.** Pittsburgh, Pennsylvania. Contact: A&WMA, P.O. Box 2861, Pittsburgh, PA 15230; (412)232-3444. *A&WMA is a non-profit technical and educational organization with nearly 10,000 members in more than 50 countries. Founded in 1907, the association provides a neutral forum where all viewpoints of an environmental issue (technical, scientific, economic, social, political, and health-related) receive equal consideration.*

August 26-September 1, 1990. **ACEEE 1990 Summer Study on Energy Efficiency in Buildings.** Asilomar (Monterey) California American Committee for an Energy-Efficient Economy. Contact: ACEEE Summer Study Office, c/o Ed Vine, Building 90H, Lawrence Berkeley Laboratory, Berkeley, CA 94720.

October 1-5. **International Conference on Environmental Ergonomics IV.** Austin, Texas. Contact: Dr. Eugene H. Wissler, Department of Chemical Engineering, The University of Texas at Austin, Austin, TX 78712-1062; (512)471-7213, Fax (512)471-7060; or, Dr. Sarah A. Nunneley, USAF School of Aerospace Medicine, USAFSAM/VNC Brooks Air Force Base, San Antonio, TX 78235; (512)536-3814.

October 16-19. **Indoor Radon and Lung Cancer: Reality or Myth?** 29th Hanford Symposium on Health and the Environment. Richland, Washington. Inquiries should be addressed to Fred T. Cross, Symposium Chairman, Battelle PNL, P.O. Box 999, Richland, WA 99352; (509)375-2976.

October 29-31, 1990. **ASTM Subcommittee D22.05 on Indoor Air.** San Antonio, Texas. Contact: George Luciw, ASTM Headquarters, 1916 Race Street, Philadelphia, PA 19103; (215)299-5571.

INTERNATIONAL

April 24-26. **Indoor Air Quality and Ventilation in Warm Climates.** Lisbon, Portugal. Conference registration: Secretariat International Indoor Air Quality & Ventilation Conference, British Occupational Hygiene Society, 1 St. Andrews Place, London NW1 4LB, UK.

June 13-15. **Roomvent '90.** Second International Conference on "Engineering Aero- and Thermodynamics of Ventilated Room," Oslo, Norway. Contact: Room Vent, c/o Norsk VVS Teknisk Forning, P.O. Box 5042, Maj N-0301 Oslo, Norway.

July 29-August 3. **5th International Conference on Indoor Air Quality and Climate.** Toronto, Ontario, Canada. Contact: Dr. Douglas S. Walkinshaw, Canada Mortgage & Housing Corp., 682 Montreal Road, Ottawa, ON K1A OP7, Canada; (613)748-2714.

September 3-6. **Energy, Moisture, Climate in Buildings.** Rotterdam, The Netherlands. Contact: Mr. G. de Vries, Bouwcentrum, Weena 760, P. O. Box 299, 3000 AG Rotterdam, the Netherlands.

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Indoor Air Quality Update,
2548 Empire Grade
Santa Cruz, CA 95060;
Phone: (408)425-3846

SUBSCRIPTION OFFICE:
Cutter Information Corp.,
1100 Massachusetts Avenue,
Arlington, MA 02174, U.S.A.;
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Fax: (617)648-8707
Telex: 650 100 9891 MCI UW,

Subscriptions: $207 per year for single subscription (U.S. and Canada); $247 outside North America. Published monthly by CUTTER INFORMATION CORP.

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