Indoor Air Quality Update

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

NEWS & ANALYSIS

Federal Indoor Air Legislation Still Possible

Sen. George Mitchell's proposed $58 million indoor air legislation (S. 1629) was coldly received by the administration when hearings were held on it late last year, but it is still possible that some significant increase in federal funding of indoor air research, technical assistance, and public information will emerge during the current Congressional session. Senator Lautenberg was expected to introduce ammendments: 1) Testing and monitoring child care and other non-residential environments, 2) Requiring HUD to set forth its policy, and 3) Establishing regional training centers for radon control professionals.

Rep. Claudine Schneider has drafted alternative indoor air legislation. Schneider committed to introducing a bill during the EPA's Policy Forum last September. Her staff has been working with EPA staff and other groups to compromise between the Mitchell bill and EPA staff's suggestion of a $15 million package. At press time Schneider's staff was still working on details of the bill and it was "moving slowly." However, sources close to the process expect it to maintain many of the features of the Mitchell bill while eliminating some of the increased work load imposed on EPA.

Public interest groups are working to support most of the provisions of the Mitchell bill in spite of EPA's public opposition. Many sources within or close to EPA privately support most of the Mitchell bill.

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ASHRAE Ventilation Standard Approaches Final Approval

After several months of comment review, ASHRAE Standard 62-1981R, *Ventilation for Acceptable Indoor Air Quality,* should finally be approved later this year.

To avoid the difficulties created by objections to recommended maximum pollutant levels in the standard, such as those raised by the *Formaldehyde Institute* after adoption of the current standard, the guidelines for most contaminant levels will be moved from the standard itself to an appendix. *ASHRAE does not consider appendices as part of the standard and, therefore, they are not subject to public review.* Guidelines for radon (EPA's 4 picocuries/liter), chlordane (5 $\mu g/m^3$), ozone (0.05 ppm), and carbon dioxide (1,000 ppm) are still in the Public Review Draft of the revised standard.

According to review committee Chairman John Janssen, the Public Review Draft specifies minimum outside air ventilation in some of the most important occupancy categories (such as offices) at *15 cfm/person,* three times higher than the 5 cfm/person in the current standard. Critics of the revision point out that the existing standard requires a minimum of 20 cfm/person where smoking is permitted, while the Public Review Draft does not propose separate ventilation rates for smoking and non-smoking areas.

The current draft of the standard is now being cleaned up for a mail vote, which according to Janssen will be affirmative. The next step will be consensus determination by the Standards Committee, followed by Technology Committee review and recommendation to the ASHRAE Board of Directors.

Table 1: Selected Outdoor Air Requirements for Ventilation from ASHRAE Standard 62-1981, Public Review Draft

APPLICATION	Estimated Max. Occupancy per 1,000 ft^2	Outdoor Air Requirements
Hotel Conference Room	50	20 cfm/person
Assembly Room	120	15 cfm/person
Office space	7	20 cfm/person
Office Conference Room	50	20 cfm/person
School Classroom	50	15 cfm/person
Residential Living Area	15	0.35 ACH
Residential Kitchen		
- intermittent mechanical vent		100 CFM
- natural ventilation		50 CFM

For more information, contact American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), 1791 Tullie Circle N.E., Atlanta, GA 30329; (404)636-8400.

Maryland Department of Education Issues Indoor Air Guidance for Schools

Alan Abend of the Maryland Department of Education has produced an IAQ guidance document for school district facilities staff. The report, "Indoor Air Quality, Maryland Public Schools," is the first of its kind that we know about. A committee of state, federal, and private individuals participated in writing and reviewing the document.

The document contains a detailed table of pollutant descriptions, sources, standards and guidelines, comfort and health effects, measurement methods, and control methods. It provides advice on assessing IAQ problems, including detailed suggested forms to be used by school facilities personnel. Suggestions are made for building planning and design. The report also provides guidance on avoiding IAQ problems in school buildings through building maintenance and operations.

Another detailed table identifies potential contaminants and control methods for specific educational programs such as visual arts, industrial/vocational shops, science labs, etc. District and site facilities personnel should find the report informative and useful. We applaud Abend and his department for their work and hope that other states will follow Maryland's lead.

Available from Office of School Facilities, Maryland State Department of Education, 200 West Baltimore Street, Baltimore, MD 21201-2595; (301)333-2508.

Chlordane Is Out for Now

In light of growing concern about the health effects of chlordane, a widely used termiticide, it was removed from the market by recent EPA action. However, the action would have allowed continued use until pest control operators' supplies of the chemical were used up. Public interest and environmental groups recently went to court, successfully challenged the delayed implementation, and won an immediate ban on the further use of chlordane.

Field Test: Building "Bake-out" to Reduce VOC

Considerable attention has been given to building "bake-out" as a potential means of addressing IAQ complaints and building problems. A bake-out (or "bake-off") is a process of simultaneously or alternately applying heating and ventilating to increase the emissions of volatile organic compounds (VOC) from building materials and to remove them from indoor air. It has been recommended and employed in many problem buildings. Yet very little is known to date about the actual effect of a bake-out, how best to conduct one, and whether there are any undesirable side effects or by-products of the process.

John Girman and co-workers at the Indoor Air Quality Program, California Department of Health Services, have conducted field experiments to determine the potential effectiveness of bake-out strategies to reduce airborne VOC. Girman reports that a 13°Celsius (23°F) increase in temperature will result in a 200% increase in vapor pressure for VOC. Thus, theoretically, heating a building should drive off lots of VOC quickly, although the building environment is complex and dynamic, and the effectiveness of the bake-out will be a function not only of the emission rate but also of the ventilation or removal rate within the enclosed space.

To investigate the bake-out process, Girman and his colleagues performed their work in a newly renovated San Francisco office building. The building was baked out for 24 hours at temperatures between 32°C and 39°C (90° and 102° F). The ventilation rate before and during the bake-out was 1.59 ACH and after the bake-out it was 1.24 ACH, reflecting 20% and 16% outside air respectively.

Table 1. VOC concentrations ($\mu g\ m^{-3}$) in an office cubicle
before, during and after bake-out at 32°C to 39°C for 24 h with ventilation of 1.59 ACH

COMPOUND	BEFORE	DURING	AFTER
Formaldehyde	34	67	28
Methylcyclopentane	16.5	T	6.0
Benzene	T	T	T
Heptane	1.7	42.2	1.9
Methylcyclohexane	T	12.1	BD
Toleune	71.7	236	22.7
Octane	T	4.9	T
Ethylbenzene	T	4.2	T
m, p-Xylene	5.4	97.0	19.7
o-Xylene	BD	24.8	T
Ethylmethylbenzene	BD	47.6	T
1,2,3-Trimethylbenzene	BD	31.4	T
Decane	49.7	191	53.7
1,3,5-Trimethylbenzene	BD	10.1	T
Dodecane	35.4	110	21.0
TOTAL	214.4	878.3	153.0

T - Trace; BD - below detection

During the bake-out procedure, VOC measurements tracked the temperature, rising as temperature rose and falling as it decreased. The concentrations of various VOC are shown in Table 1. Measured levels rose during the bake-out and fell afterward. In most cases the after levels were lower than the before levels, which indicates that the process does achieve a reduction in VOC levels, at least in the short run.

The total VOC levels were 29% lower after the bake-out than before. However, since the initial measurements were made shortly after completion of the installation of many finishes, we do not know whether the decrease was the result of the bake-out or the normal decay due to aging that might occur during the week between the measurements. And the levels were low to begin with, perhaps because the ventilation system was run during the installation period. Furthermore, we do not know whether this effect persisted or was transitory.

The investigators report that the bake-out procedure did demonstrate potential as a means to reduce VOC levels in new or renovated buildings. They suggest that since the decrease in levels after the bake-out was modest, it may be necessary to employ longer bake-out periods to achieve more significant effects.

A Word of Caution

Concerns have been raised about the possible negative consequences of the bake-out process. Damage could occur to HVAC components or to moisture-sensitive objects (such as art work, wood furnishings) or building components. IAQU welcomes your comments if you have had experience with bake outs.

For more information contact: John Girman, Indoor Air Quality Program, Air Industrial Hygiene Laboratory, California Department of Health Services, 2121 Berkeley Way, Berkeley, CA 94704; (415)540-2469.

Factors in Sick Building Syndrome: The Danish Town Hall Study

The causes of sick building syndrome (SBS) are elusive. Several hypotheses have been put forward, including the ideas that volatile organic compounds (VOC), microorganisms, thermal factors, psychosocial factors, institutional factors, and others are responsible individually or in combination.

A major study of SBS has been conducted by a team of Danish researchers. A study of 14 town halls in Greater Copenhagen confirmed work done elsewhere regarding SBS. While reported symptom levels were high for mucosal irritation (28%) and for general symptoms in the form of headache, abnormal fatigue, or malaise (36%), the measurements of environmental factors did not identify a single causal agent. However, clusters of factors were associated with higher rates of reported symptoms.

Results

The research team measured indoor climates in the 14 town halls. A questionnaire study and a clinical study of 4,369 employees in the town halls and 14 affiliated buildings were also conducted. While none of the measurements indicated the cause of the complaints, the very large range found for most variables (see Table 1) provided the basis for a multifactorial analysis, which led to these findings:

1 *Elevated rates of mucosal irritation were associated with the size of the allergenic fraction of floor dust, the length of open shelves per cubic meter of air, the area of fleecy material per cubic meter of air, the number of work stations, and air temperature.*

2 *Symptoms correlated strongly with job category, with the highest prevalence found in subordinate job categories. Jobs involving photoprinting, working at video display terminals, and handling carbonless paper correlated with the reported frequency of mucosal irritation and of general symptoms; the number of weekly working hours of women also correlated with reports of these two symptom categories, although less strongly.*

3 *As in several other studies, symptoms were more prevalent among women than men* *and they complained more frequently about indoor climate.*

4 *Symptom prevalence rates varied significantly among buildings, supporting the notion that the symptoms are building-related. The lowest prevalence of symptoms was found in the oldest town halls (the buildings were mostly less than 30 years of age, with one almost 50 and another 80 years old).*

5 *The difference between mechanically and naturally ventilated buildings was not significant for this study. This is in sharp contrast to the results of a large-scale British study.*

These results have practical implications for controlling indoor air quality in problem buildings.

These are described in "Practical Tips for Indoor Air Quality Control" on page 7 of this issue.

References

Peder Skov, Ole Valbjϕrn, and the Danish Indoor Climate Study Group. "The Sick Building Syndrome in the Office Environment: The Danish Town Hall Study." *Environment International*, Vol. 13, pp. 339-349, 1987.

Ole Valbjϕrn and Peder Skov. "Influence of Indoor Climate on the Sick Building Syndrome Prevalence" *Indoor Air '87; Proceedings of the 4th International Conference on Indoor Air Quality and Climate* (Vol. 2). Berlin, August 17-21, 1987. Berlin: Institute for Water, Soil and Air Hygiene. pp. 593-597.

Table 1: Indoor climate measurements in 14 Danish town halls (Valbjϕrn and Skov 1987).

		Mean	Minimum	Maximum
Mean external temperature	(24 hours)(°C)	2.4	-1.2	11.4
Average daily sunshine	hours	2.3	0	6.4
Air temperature	(°C)	22.7	20.5	24.1
Person-weighted air temperature	(°C)	23.0	22.0	24.4
Temperature rise during a work day	(°C)	2.5	1.0	8.0
Vertical temperature gradient	(°C/m)	0.9	0.4	2.0
Air velocity	(m/s)	0.15	<0.15	0.20
Relative humidity	(%)	32	25	40
CO_2	(%)	0.08	0.05	0.13
Formaldehyde	mg/m^3	0.04	0	0.08
Static Electricity: Observer	(kv)	1.4	0	4.8
Occupants max.	(kv)	1.7	0	4.0
Airborne dust	(mg/m^3)	0.201	0.086	0.382
Dust particles: >0.5 µm	(l^{-1})	48x10^3	19x10^3	119x10^3
>2.0 µm	(l^{-1})	25x10^2	8x10^2	116x10^2
Airborne microfungi	(col/m^3)	32	0	111
Airborne bacteria	(col/m^3)	574	120	2,100
Airborne actinomycetes	(col/m^3)	4	0	15
Vacuum cleaned dust^a	(g/12m^2)	3.67	0.32	11.56
Vacuum cleaned dust^b	(g/12m^2)	6.14	0.66	17.04
Macromolecular content in the dust	(mg/g)	1.53	0	5.24
Macrofungi in the dust^a	(col/30 mg)	33	11	90
Macrofungi in the dust^b	(col/30 mg)	32	6	192
Bacteria in the dust^a	(col/30 mg)	199	41	380
Bacteria in the dust^b	(col/30 mg)	296	160	680
Man-made mineral fibers in air MMMF	(f/m^3)	5	0	60
Not MMMF (<3 µm) in the air	(f/m^3)	33.2x10^3	18.5x10^3	59.1x10^3
Not MMMF (>3 µm) in the air	(f/m^3)	3.1x10^3	0.7x10^3	5.0x10^3
VOC (charcoal)^c	(mg/m^3)	1.56	0.43	2.63
VOC (Tenax)^d	(mg/m^3)	0.5	0.1	1.2
A-weighted equivalent noise level, $L_{A,eq}$	(dB)	56.7	51.3	60.3
A-weighted background noise level, L_{95}	(dB)	36.2	28.2	44.1
Reverberation time	(s)	0.41	0.28	1.05

Notes:
a = In the office where all the measurements were performed. b = In an office with a considerable loading of clients during the day.
c = Mean of readings in 6 buildings d = Mean of readings in 13 buildings, in one building measured 32 mg/m^3.

TOOLS & TECHNIQUES

Landmark Document on Residential IAQ from Canada

Health and Welfare Canada has published Exposure Guidelines for Residential Indoor Air Quality, prepared by the Federal Provincial Advisory Committee on Environmental and Occupational Health. This is a landmark document for Canada, and provides those interested in guidance with extremely useful information.

Published in April 1987, the guidelines divide contaminants into carcinogens and noncarcinogens. The health effects of many contaminants are described and recommended values are given for airborne concentrations (see Table 1). Noncarcinogens included are aldehydes, carbon dioxide, carbon monoxide, nitrogen dioxide, ozone, particulate matter <2.5 microns, sulphur dioxide, and water vapor. *The only listed carcinogen is formaldehyde.*

Several *additional substances* are identified for controlled exposures but *recommended levels are not provided.* They include biological agents,

Summary of Exposure Guidelines

Contaminant	Acceptable Exposure Ranges	
	Short-term	Long-term
Aldehydes (total)	$\Sigma c_i/C_i \leq 1^{(a)}$	—
Carbon Dioxide	—	$\leq$6 300 mg/m^3 ($\leq$3 500 ppm)
Carbon Monoxide	$\leq$11 ppm — 8 h$^{(b)}$ $\leq$25 ppm — 1 h$^{(b)}$	— —
Formaldehyde	(c)	(d)
Nitrogen Dioxide	$\leq$480 μg/m^3 ($\leq$0.25 ppm) — 1 h	$\leq$100 μg/m^3 ($\leq$0.05 ppm)
Ozone	$\leq$240 μg/m^3 ($\leq$0.12 ppm) — 1 h	—
Particulate Matter $^{(e)}$	$\leq$100 μg/m^3 — 1 h	$\leq$40 μg/m^3
Sulpher Dioxide	$\leq$1 000 μg/m^3 ($\leq$0.38 ppm) — 5m	$\leq$50 μg/m^3 ($\leq$0.019 ppm)
Water Vapor	30-80% R.H. — summer 30-55% R.H. — winter$^{(f)}$	— —

[a] C_i = 120 μg/m^3 (formaldehyde); 50 μg/m^3 (acrolein); 9,000 μg/m^3 acetaldehyde), and c_i are respective concentrations measured over a 5 minute period.

[b] Units given only in parts per million so that guidelines are independant of ambient pressure.

[c] See Aldehydes (total).

[d] See page 26.

[e] $\leq$2.5 μm mass median aerodynamic diameter — MMMD.

[f] Unless constrained by window condensation.

Table 1
Landmark Document on Residential IAQ

Table 2 — Landmark Document on Residential IAQ: Summary of Exposure Control Recommendations

Contaminant	Recommendation
Biological Agents	In order to prevent many of the common indoor problems due to biological agents, measures should be taken to ensure that: • excess humidity and condensation are not present • surfaces are kept clear of dust • stagnant water sources, such as humidifier tanks, are kept clean and occasionally disinfected • a high standard of appropriate personal hygiene is maintained
Consumer Products (chlorinated hydrocarbons, pest control aerosols)	It is recommended that exposures resulting from the use of consumer products be kept to a minimum by ensuring adequate ventilation and observing any other precautionary measures described on the product label and in any accompanying information. Pesticides should be used only when absolutely necessary.
Fibrous Materials	Precautions should be taken to minimize inhalation of, and skin contact with mineral fibers during home renovations and installation operations. Materials and products containing fibers should be examined periodically for signs of deterioration. Advice should be sought before removing or damaging any materials thought to contain asbestos.
Lead	In order to minimize the exposure of people, and especially children to lead of airborne origin, it is recommended that surfaces which may be contaminated be cleaned frequently and that a high standard of overall cleanliness be maintained.
Polycyclic Aromatic Hydrocarbons (PAHs)	Exposure to PAHs indoors should be kept to a minimum by: • ensuring that combustion systems, for example wood- and coal-burning stoves, are properly installed and maintained and operated under conditions of satisfactory ventilation. • adhering to the guidelines and recommendations given in this document for particulate matter and tobacco smoke
Tobacco Smoke	In view of the carcinogenic properties of tobacco smoke, any exposure to tobacco smoke in indoor environments should be avoided.

pest control products, aerosol products, fibrous materials, lead, polyaromatic hydrocarbons (PAHs), and tobacco smoke. Discussions of health effects are presented, and recommendations for reducing exposures are described, although many of these are vague and not particularly useful (see Table 2).

Copies of the guidelines may be obtained from Communications Directorate, Department of National Health and Welfare, 5th Floor, Brooke Claxton Building, Ottawa, K1A OK9, Canada.

Practical Tips for Indoor Air Quality Control

We can derive some practical tips for problem buildings from the Danish Town Hall Study and IAQ Diagnostics articles (as well as the "bake-out" article) in this issue.

Causes of SBS

The results of the Danish Town Hall Study support the prevailing wisdom that high levels of "sick building syndrome" complaints cannot be linked to a *single* indoor environmental variable. Even where many measurements are made of many variables, they will not necessarily reveal "the cause" of the complaints. But this does not mean that the complaints are unrelated to occupancy of the building in question.

A *cluster* of factors will probably be associated with a complaint building. These may include the following:

- a large allergenic fraction of dust (or airborne particles)
- large "fleecy" surface area
- large ratio of open shelf area to building volume
- a large number of work stations
- elevated air temperature

Newer buildings are more likely to have problems than older ones.

Both "fleecy" material and large open shelf area mean large amounts of surface area. Thus, dust and volatile organic compound reservoirs may be large, and under certain conditions may result in elevated levels of detached dust or desorbed VOC. Higher temperature will also increase volatization of organic chemicals (this is clearly demonstrated by the bake-out research). It may, in certain types of ventilation systems (such as variable air volume), be accompanied by systematic reductions in ventilation.

Type of Ventilation System

The Danish study did not find a correlation of complaint levels with the type of ventilation system — mechanical or natural. Thus the ventilation system question, which has been raised elsewhere, remains open at this time. Other recent investigations, particularly by the Honeywell IAQ Diagnostics group, have found inadequate HVAC design capacities and equipment in every problem building. Engineering evaluation of system design and installation are likely to reveal deficiencies.

Ventilation System Deficiencies

In three-fourths of the buildings Honeywell IAQD investigated, inadequate supply air was found. Two-thirds had inadequate supply air distribution. Together, these problems indicate that occupied spaces simply are not getting enough outside air. This is easy to evaluate, and sometimes easy to remedy. Carbon dioxide measurements or tracer gas measurements can qualitatively and quantitatively verify these deficiencies.

Tips

Investigation of problem buildings or design of new buildings should include careful consideration of the conditions in the building. Particularly important are the following:

- ◆ The total amount of exposed surface area in occupied spaces. Use hard surface flooring and wall coverings, where practical, and limit open shelving.
- ◆ The scheduling and set points for operation of the HVAC system. Increase hours of operation after periods of non-operation such as weekends, or after periods of low outside air ventilation rates (warm weather), to remove accumulated VOC and particles.
- ◆ Supply air temperatures. Keep them as low as occupants will tolerate, to reduce VOC emissions, immediately prior to and during occupancy periods. During extreme weather periods, supply air should be cooler than room air to improve mixing within the space — warm supply air is more likely to stratify or short circuit.
- ◆ Outside air fraction and supply air distribution. Be certain that adequate outside air is supplied during the minimum flow conditions, usually extremely warm or cold weather. Verify that this air is reaching occupants by using tracer gases (carbon dioxide will work at levels far below toxicity).
- ◆ The quality of housekeeping related to dust control on floor, wall, and storage-shelf surfaces. Use and properly maintain high-efficiency filters (>70% ASHRAE dust spot rating).

FEATURE

IAQ Diagnostics for Problem Buildings

With growing recognition of indoor air quality problems in buildings, the opportunities for engineering and other consulting firms to provide services have increased rapidly in recent years. New firms have been established and older firms have expanded their capability and their marketing to capture some of the growing market.

One of the beacons in the IAQ field is James E. Woods, Jr., a former professor of mechanical engineering, who now directs a multidisciplinary team of engineers and scientists at Honeywell Indoor Air Diagnostics in Golden Valley, Minnesota. Woods chaired the ASHRAE committee that developed Standard 62-1981 and served on the National Academy of Sciences Committee on Indoor Pollutants. His current efforts are applying his broad knowledge and experience to resolving air quality problems in buildings.

In this article we will first present Honeywell's data on the causes of air quality problems in buildings. Woods presented this information while testifying before a U.S. Senate subcommittee hearing last fall on Sen. George Mitchell's indoor air quality bill (see page 1 of this issue). This is followed by a description of a practical, systematic approach to diagnosing these problems, which was developed by Woods and his colleagues at Honeywell.

Causes of IAQ Problems

According to Honeywell IAQ Diagnostics (IAQD) data summarizing 30 recent cases, 65% of IAQ problems in buildings investigated were diagnosed as "sick building syndrome" (SBS), and 35% were diagnosed as both SBS and "building related illness" (BRI). While SBS and BRI share many of the same flu-like symptoms, BRI is defined as a clinically verifiable disease entity (such as hypersensitivity pneumonitis, Pontiac fever, Legionnaire's disease, or allergic dermatitis) while SBS is diagnosed when complaints and symptoms are clearly associated with occupancy of the building but no causal agent can be positively identified.

Chemical contamination was found in 75% of Honeywell's reported investigations, with 55% having thermal problems, 30% humidity problems, and 45% microbiological contamination. Of the chemical contaminants, odors were detected in 70% of the cases, particulate matter (in excess of 50 $\mu g/m^3$) in 5%, and other chemicals in 5%.

Causes of the complaints and symptoms divide between operational factors and design factors. In all of the 30 cases, both system design and equipment design problems were detected. System design problems included inadequate outside air (75%), inadequate supply air distribution (65%), and inadequate return/exhaust air (70%). Other design problems included variable air volume (VAV) systems (25%), heat pump systems (10%), fan coil systems (10%), and induction unit systems (5%).

Equipment design problems were identified as contaminated internal duct lining (45%), contaminated humidifiers (20%), inoperable or inadequate drain pans and drain lines (60%), inadequate access panels to equipment (60%), and inadequate filtration (65%).

Most of the problems were determined to be caused by lack of sufficient maintenance (75%), changes in thermal contaminant loads since the time of initial occupancy (60%), and implementation of energy management strategies without evaluation of environmental impact (90%).

Looking for a less biased population than those in identified problem buildings, Honeywell IAQD conducted a national telephone survey. In a random stratified survey of 600 adult office workers, 24% were dissatisfied with office air quality, and 20% perceived that poor air quality hampered their performance. The concerns focused on by that 20% were lack of air movement (75%), too hot in summer (61%), stagnant or still air (55%), cigarette smoke (54%), too cold in winter (53%), and too humid in summer (50%).

Office workers' health and physiological responses due to air quality cited as "serious" or "very serious" included a tired/sleepy feeling (56%), congested nose (45%), eye irritations (41%), difficulty breathing (40%), and headaches (39%).

The Honeywell IAQD data points out that there are often many different sources of symptoms and complaints in problem buildings. Investigators (consultants, government officials, and researchers) need to be aware of the multiple sources of problems and develop investigatory procedures that are practical, economically feasible, and sensitive enough to detect the problems.

Building Diagnostics

Woods and his colleagues presented a paper on "Building Diagnostics" last year at the ASTM Symposium on Design and Protocol for Monitoring Indoor Air Quality; we have adapted the following description of procedures for problem building investigations from their presentation.

Building diagnostics is "a process in which a skilled expert draws on available knowledge, techniques, and instruments in order to predict a building's likely performance over a period of time." The process can be applied to an investigation of a building with a reported problem, to a "non-complaint" building as a preventive measure, or to the design for a new building or building remodel (diagnosis of the "virtual" building).

The process is divided into three major phases — consultation, qualitative diagnostics, and quantitative diagnostics. In many cases, problems can be identified and eliminated without the final phase. In some cases only the first phase is necessary. The phased approach can result in rapid and economic solution to many IAQ problems.

Phase 1

Consultation

The purpose of the consultation (diagrammed in Figure 1) is to identify the nature of existing or potential IAQ problems and to define the scope and objectives of the investigation. This begins with a site visit, which includes a meeting with a senior administrator and the health/safety officer (administrative meeting), a meeting with the facilities manager and staff (facilities meeting), and a tour of the facility (walk-through inspection).

Investigators obtain preliminary information on IAQ problems and complaints in a confidential discussion during the administrative meeting, and obtain additional information on systems characteristics during the facilities meeting. The walk-through inspection allows first-hand observation of the building interiors, the building equipment layout and performance, and interaction with occupants (if agreed to by all concerned parties). "Measurements" made during this phase are "professional observations" by the investigators rather than air sampling and other hardware-based approaches.

During this phase, the investigators formulate preliminary hypotheses to assist in developing a cost-effective diagnosis procedure. Hypotheses address suspected problem causes, their manifestations, and the system (building, equipment, operation) characteristics.

After briefly analyzing the information, the investigators hold a closing meeting with the senior administrator and health/safety officer to discuss the findings and to present preliminary recommendations. These usually include actions which can be taken by the client immediately, such as changes in ventilation system operational or maintenance procedures, changes in occupant activities which generate contaminants, or consideration of qualitative and quantitative diagnoses (phases 2 and 3).

Phase 2

Qualitative Diagnostics

The qualitative diagnostics phase is conducted on-site with subsequent analysis at the investigator's office. Figure 2 diagrams this phase of the work. The work is done principally through an engineering analysis, which includes establishment of performance criteria, characterization of problems and complaints, and preliminary evaluation of environmental control system design and performance. It may include medical evaluation of suspected health problems and bulk or air samples of suspected pollutants.

At this point, investigators establish air quality and thermal performance criteria for the particular building involved (see Tables 1 and 2). For offices, Honeywell IAQD recommends criteria for thermal performance and six air contaminants— toluene (a common ingredient of solvents used in construction materials and found in indoor air), total suspended particulates (TSP), carbon dioxide, pyridine and furfural (odiferous components of environmental tobacco smoke), and butyric acid (a human bioeffluent with a very low odor threshold). These contaminants are used because they each serve as surrogate indicators of the intensity of human activity and the adequacy of the ventilation system.

The investigators characterize occupant problems and complaints by interviewing the building health and safety officer or organizational medical staff.

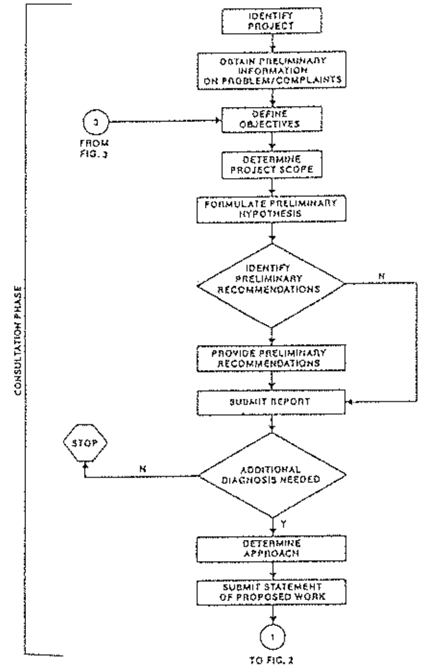

Figure 1 — Flow chart for Consultation Phase of Indoor Air Quality Diagnostics Protocol.

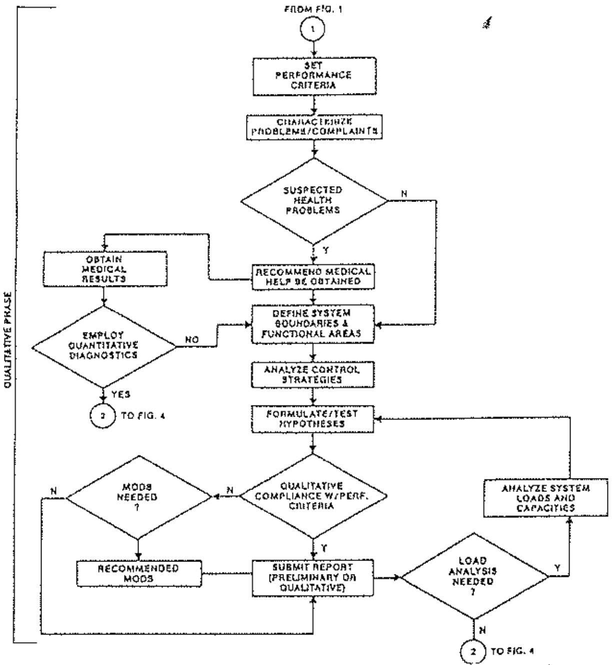

Figure 2 — Flow chart for Qualitative Diagnostics Phase of Indoor Air Quality Diagnostics Protocol.

At this point, if they believe BRI is present, they recommend immediate medical assistance along with appropriate microbiological or chemical sampling. If discomfort or SBS are suspected, they do an engineering system analysis. Even where BRI is found, the engineering systems analysis is usually necessary because the HVAC system may be the transmitter or source of the indoor air contaminant.

Table 1: Odor Recognition Thresholds, Threshold Limit Values and Recommended Air Quality Criteria.

Agent	Odor Recognition Threshold	Occupational TLV	Protection Factor Over TLV by Use of Odor Annoyance Threshold	Recommended Air Quality Standard Criteria
Butyric acid	0.001 ppm	N.A.	N.A.	0.002 ppm (C)
Carbon dioxide	N.A	5000 ppm	N.A.	1000 ppm (C)
Suspended particulate	N.A.	10,000 µg/^{3} (nuisance dust)	N.A.	50 µg/^{3} (Y) (≤10µm)
Pyridine	0.02 ppm	5 ppm	100	0.05 ppm (C)
Furfural	0.002 ppm	2 ppm	500	0.004 ppm (C)
Toleune	2 ppm	100 ppm	33	3 ppm (C)

N.A. = Not Applicable; C = Ceiling concentration; Y = Yearly Average

The engineering systems analysis is begun by defining the system boundaries (in large buildings it may be one or several zones or subsystems rather than the entire building). The investigators analyze control strategies in terms of the original design, the original installation, and the existing installation. Differences between these are often present and can account for IAQ problems. HVAC system capacities are examined in terms of the loads in the space, the design assumptions, changes in the space (loads) since design, and analysis of full and part-load capacities relative to design or modified loads. Tracer gas tests and simulations might be necessary to perform the load analysis. Since most simulations are not dynamic whereas building performance is, sophisticated simulation techniques might be required.

Finally, a written report is prepared describing the work, the findings and the conclusions, and recommending further actions.

Phase 3

Quantitative Diagnostics

If deemed necessary at the conclusion of qualitative diagnostics, the investigators perform quantitative diagnostics (see Figure 3). This phase consists of on-site investigations, laboratory analysis, and engineering analysis. These include objective measurements of chemical, physical, and microbiological parameters as well as subjective responses of occupants to their environments.

Frequently HVAC system operational parameters are upgraded or other building modifications are made according to phase 2 recommendations. Objective measurements may be necessary to determine

Table 2. Thermal Environmental Performance Criteria for Maintenance of Comfort Conditions

PARAMETER	GUIDELINE
Operative temperature (winter)	68.5 to 76°F (at 30% humidity)
Operative temperature (summer)	73 to 79°F (at 50% relative humidity)
Dew point	>35°F (winter): <62°F (summer)
Air Movement	≤30 FPM (winter); ≤50 FPM (summer)
Vertical temperature gradiant	Shall not exceed 5° Fahrenheit at 4 inch and 67 inch levels.
Plane radiant asymmetry	<18°F in the horizontal direction; <9°F in the vertical direction.

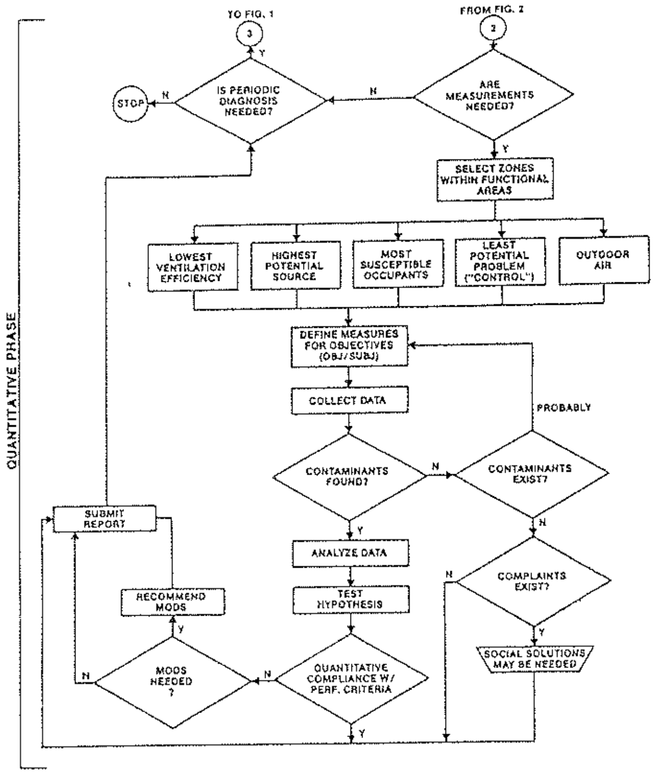

Figure 3 — Flow chart for Quantitative Diagnostics Phase of Indoor Air Quality Diagnostics Protocol.

levels of air contaminants because of potential litigation or to assess conformance to performance criteria. Site selection for sampling is critical for a cost-effective investigation. Five potentially different sites or functional areas of the building are recommended: 1) the room or zone with the most susceptible occupant; 2) room or zone with the lowest ventilation efficiency; 3) room or zone with the highest source of air contaminants; 4) indoor control zone (noncomplaint area); and 5) outdoor control site.

Phase 3 includes thermal, lighting, acoustic, and air quality measurements made within the occupied space and simultaneous thermal, air quality, and energy parameters measured within the HVAC system serving the space. Real-time measurements are important in order to correlate the indoor and the HVAC measurements. Selecting and correctly applying appropriate sampling methods are critical elements of the measurement program. And quality assurance/quality control procedures should be used to estimate the accuracy and precision as well as the reliability of the data.

The investigators make subjective measurements through use of a questionnaire administered simultaneously with the environmental measurements. The questionnaire covers occupant evaluation of the environment and demographic data necessary for analysis of the results. Questionnaire responses are confidential so that honest responses are obtained. The environmental evaluation includes rating acceptability of the environment in terms of four classes of chemical and physical parameters — acoustics, air quality, lighting, and temperature.

The measurement data is analyzed, interpreted, and reported to conclude the quantitative diagnostics and complete the investigation. The final report generally includes a series of recommendations for remedial actions, maintenance procedures, and building systems operations.

The quality of the building diagnostics investigation is largely a function of the knowledge, skills, and abilities of the investigatory team. Reliable, appropriate equipment is also an essential ingredient. The phased approach, with an emphasis on analysis rather than measurement, produces cost-effective, timely results which respond to the needs of building owners and occupants.

For more information:

"Building Diagnostics; A Conceptual Framework," Building Research Board, National Research Council. Available from Publications, National Academy Press, 2101 Constitution Ave. NW, Washington, DC 20418; (202)334-3113.

"Indoor Air Quality Diagnostics: Qualitative and Quantitative Procedures to Improve Environmental Conditions." Available from Honeywell Indoor Air Diagnostics, Golden Valley, MN 55422-3922; (612)542-7043.

Auro Organic Paints

Now available in the United States, AURO products are formulated with "natural" ingredients. The product line includes natural impregnations, varnishes, and waxes; natural resin lacquers; wall paints and glues; cleansers and polishes; and plant colors for painting and modeling.

The very useful product literature describes the composition and use of the products in detail. In fact, a table allows the potential user to determine the approximate composition of any AURO product. This is revolutionary. When do-it-yourselfers as well as architects and builders begin to demand such information from product suppliers, "clean" products will gain a competitive edge and alter the composition of the market. We applaud AURO for this enlightened marketing approach.

The literature also provides application, coverage, and price information from which the following examples were computed:

- The wood preservative, AURO Borax Wood Impregnation No. 111, covers 270 square feet per 1.5-kg tin and costs $37 per tin (approx. $0.137/sq ft).
- AURO offers a floor wax ointment (product 171) of beeswax and plant waxes to provide water repellancy on wood, especially floors. A 2.5-liter tin costs $78 and covers approximately 900 square feet (approx $0.086 sq ft).
- AURO natural resin interior wall paint (product 321) costs $110 for 15 liters and covers approximately 1,076 sq ft (approx. $0.102/sq ft).

These prices are high when compared to commercially available traditional products. Domestic interior paints sell for about $4 to $22/gal, average to good quality paints cost about $10 to $17/gal; the high end translates to about $67 for 15 liters (at the same coverage, this would be $0.06/sq ft). Note that the high-end products claim (and some are guaranteed) to cover with one coat.

We think these products will appeal primarily to the chemically sensitive or allergic homeowner or owner-builder. However, we also think they will stimulate American competition and perhaps result in development and marketing of new products from existing building products companies.

We have not yet tried AURO products, but we would like to hear from readers who have done so.

Contact: Martin Dunlap, Sinan Co., P.O. Box 181, Suisun City, CA 94585; (707)427-2325.

LIVOS PlantChemistry Offers Natural Products

LIVOS PlantChemistry of Santa Fe, New Mexico, also offers imported "natural" products with appeal to the residential market, particularly chemically sensitive individuals. One such product is Meldos Hard Sealer, a penetrating oil finish made from polymerized linseed oil and other plant oils, tree resins, and natural citrus thinner. It is reportedly nontoxic with a lemony odor. It is slower drying than conventional finishes due to the absence of chemical drying agents, particularly in humid weather. A five-liter container costs $49.50 and covers 500-600 square feet (approx. $0.09/sq ft.), according to LIVOS' literature.

LIVOS Natural Resin Wall Paint is described as fast drying, made from natural ingredients, and comes in flat white or off-white. (LIVOS sells eleven "earthen and mineral based concentrates" for tinting.) It contains no fungicides, which raises questions about its long-term resistance to mold and mildew, and it should probably not be used in kitchens or bathrooms. An 18-liter (4.5 gal) container costs $92 and covers approximately 990 feet (approx. $0.093/sq ft).

LIVOS products are also "pricey" but for particular applications or people, they might be worth the cost. It is conceivable that competition will bring the prices down as well as stimulate U.S. firms to develop domestically produced alternatives.

We have not tried LIVOS products but invite comments from readers who have done so.

Contact: LIVOS PlantChemistry, 614 Aqua Fria St., Santa Fe, NM 87501; (505)988-9111.

Natural versus Synthetic

The two product lines described above address a large potential market for "natural" products, and their product literature focuses on that theme. We caution readers to distinguish between "natural" and "nontoxic." Many naturally occurring substances are toxic: notable examples are lead, arsenic, asbestos, mercury, and formaldehyde.

Synthetics are not necessarily any more toxic than the natural products they replace. And many natural products such as cotton or wool carpets and rugs are more susceptible to attack by insects and microorganisms than are nylon fiber carpets. Chemicals are widely used to grow cotton, and most quality wool carpets are "moth-proofed."

There is no substitute for reliable information, which is not always available from the manufacturer or distributor. But purchasers are in the driver's seat when they are potential customers, and demanding detailed product information is always a good practice. Ask for the MSDS (manufacturer's safety data sheet) for any product that raises concerns in your mind. The MSDS is required (federal law) for any product that might result in exposure of workers to toxic substances.

Information on chemical hazards of building products is available from Hazardous Chemical Division, Consumer Products Safety Commission, Washington, DC; (301)492-6554.

INFORMATION EXCHANGE

Book on Monitoring Indoor Air Quality

Guidelines for Monitoring Indoor Air Quality presents the emerging methods and understanding applicable to monitoring indoor air, collected by three outstanding researchers in the field. It includes practical discussions of pollutants, factors affecting indoor air quality, and its measurement. A chapter on design describes in detail considerations for establishing a monitoring program. Another section on practical consideration will assist those without prior experience in air monitoring to develop a professional approach.

The book includes a section on information sources, and very useful appendices on "Commercially Available Instrumentation" and "Alternatives to Commercial Instrumentation: User-Configured Methods." For each available instrument, it gives information on physical characteristics of the device, its performance, operation, costs, manufacturers, and operations experience. Several instruments are covered for each of the following pollutants: asbestos and other fibrous aerosols, biological aerosols, carbon monoxide, formaldehyde, inhalable particulate matter, nitrogen dioxide, ozone, radon, and sulfur dioxide.

This is an extremely useful and complete reference for anyone involved in monitoring indoor air, and it is unique in the field today. It will also be a handy reference for those who retain the services of consultants to perform monitoring for investigation of problems, research, or compliance.

Guidelines for Monitoring Indoor Air Quality, by N. L. Nagda, H. E. Rector, and M. D. Koontz. New York: 270 pages. Available from Hemisphere Publishing Corporation, 79 Madison Avenue, New York, NY 10016. Price: $42.50 per copy. No shipping charges on prepaid orders.

NIBS Asbestos Model Guide Specifications

These specifications contain detailed model language for construction specifications for every conceivable situation where construction might involve dealing with asbestos containing materials (ACM).

Architects, engineers, and building owners requiring construction contract documents for construction, remodelling, or demolition in facilities containing asbestos can benefit greatly from the work of the NIBS Task Force which is currently updating and revising the document. The revised version will be available later this year.

The current version of the document is available for $75/copy from: NIBS, 1015 15th Street NW, Washington, DC; (202)347-5710.

Productivity and Indoor Air

Dave Mudarri at EPA in Washington is exploring the relationship between indoor air quality and productivity in the office workplace. Readers who have data or other helpful information can contact Mudarri at EPA, ANR 445, 401 M St. SW, Washington, DC, 20460; (202)475-8592.

READERS: If you have IAQ information to share with other IAQU readers, send it to our editor, Hal Levin, 2548 Empire Grade, Santa Cruz, CA 95060.

CALENDAR

North America

American Industrial Hygiene Conference and American Conference of Governmental Industrial Hygienists Joint Annual Meeting. May 15-20, Moscone Center, San Francisco, California, Contact: Ginger Styles, AIHC, 475 Wolf Ledges Parkway, Akron, OH 44311-1087; (216)762-7294; or Jack Heusser, ACGIH, 6500 Glenway Ave. Bldg. D-7, Cincinnati, Ohio 45211; (513)661-7881.

Consumer Federation of America. May 23-24, Washington, D.C. Contact: Erika Landsberg, Consumer Federation Association, 1424 16th St. N.W., Washington, D.C. 20036;(202)387-6121.

ASTM Subcommittee D22.05, Indoor Air. June 1-2, Royal York Hotel, Toronto, Ontario. Contact: Sharon Kauffman, ASTM, 1915 Race Street, Philadelphia, PA 19103; (215)299-5599.

APCA 81st Annual Meeting and Exhibition. June 20-24, Dallas, Texas. Contact: Lisa Zavacky, APCA, P.O. Box 2861, Pittsburgh, PA 15230; (412) 232-3444.

ASHRAE Annual Meeting. June 25-29, Ottawa, Ontario, Canada, Contact: Jim Norman, ASHRAE, 1791 Tullie Circle, N.E., Atlanta, GA 30329; (404)636-8400.

Asbestos: Measurement Research and Laboratory Accreditation ASTM Committee D22 on Sampling and Analysis of Atmospheres. July 10-15, Johnson College, Johnson, Vermont. Contact: Sharon Kauffman, ASTM, 1915 Race Street, Philadelphia, PA 19103; (215)299-5599.

Indoor Air Quality Symposium and Optional Workshop on Sampling and Analysis Techniques. September 20-23, Georgia Tech. Contact: Continuing Education, Georgia Tech, (404)894-2400.

EPA 1988 Symposium on Radon and Radon Reduction Technology. October 18-21, Sheraton Denver Tech Center, Denver, Colorado, Contact: Barbara Emmel, Radian Corporation, P.O. Box 13000, Research Triangle Park, NC 27709; (919)541-9100.

ASTM Subcommittee D22.05, Indoor Air. November 7-9, Atlanta Hilton & Towers, Atlanta, Georgia. Contact: Sharon Kauffman, ASTM, 1915 Race Street, Philadelphia, PA 19103; (215)299-5599.

TOPICS FOR COMING ISSUES:

Chamber Tests for VOC Emissions from Building Materials

VOC and Sick Building Syndrome

Computer Models for Predicting Indoor Air Quality During Building Design

Evaluating Building Materials for Indoor Air Impacts

Building Design Concepts to Improve Indoor Air Quality

Radon Mitigation Measures in Maryland School

LBL Reports that Energy Conservation Can Improve Indoor Air Quality

GEOMET Studies Pollutant Transport within Buildings

1989

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

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

International

Indoor and Ambient Air Quality, June 13-15, 1988, Imperial College, London, Contact: Prof. R. Perry, Department of Civil Engineering, Imperial College, London, SW7 2BU, United Kingdom.

Healthy Buildings '88. September 5-8, Stockholm, Sweden, Contact: Mrs. Gunilla Norbro, Swedish Council for Building Research, St Goransgatan 66, S-112 33 Stockholm, Sweden; 46 8 54 06 40.

1989

CLIMA 2000, the Second World Congress. September 1, Sarajevo, Yugoslavia. All topics related to HVAC&R will be covered. Emphasis on thermal comfort, energy use, computer modelling and applications, thermal envelope improvements, thermal storage, control theory and equipment performance. Abstracts, less than 200 words, due in English, French or German, by March 1, 1988. Send to CLIMA 2000, Massinski Fakultet, Prof. Dr. Emin Kulic, 71000 Sarajevo, Omladinsko Setaliste bb, Yugoslavia. Copies should be mailed to W. S. Comstock, ASHRAE, 1791 Tullie Circle NE, Atlanta, GA 30329.

Indoor Air Quality Update Indoor Air Quality Update Indoor Air Quality

Editor: Hal Levin

Publisher: Karen Fine Coburn
Business Manager: Charles Gibbs
Circulation Manager: Kim Gay
Reprint Manager: Ed Coburn
Production Staff: Ellen Bluestein, Barbara Shackelford, Sally Fine

Editorial Office: *INDOOR AIR QUALITY UPDATE*
2548 Empire Grade, Santa Cruz, CA 95060,
Phone: (408)425-3846

Circulation Office: CUTTER INFORMATION CORP.
1100 Massachusetts Avenue
Arlington, MA 02174, U.S.A.
Phone: (617)648-8700
Telex: 650 100 9891 MCI UW.