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

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IAQ '89 Conference Papers

Past ASHRAE IAQ conferences (1986-1988) focused on engineering controls for IAQ, at least thematically. This year, ASHRAE invited the Society for Occupational and Environmental Health to co-sponsor IAQ '89 in San Diego. The announced theme was "The Human Equation: Health and Comfort."

In This Issue

We expected far more emphasis on health considerations and more presentations exploring the issues. But we heard a number of outstanding new presentations on engineering and other control issues and very little that was new or exciting regarding IAQ and health. There were many good papers, four of which we present in some detail in this extended feature article.

Typical Air Contaminant Levels

Phil Morey (Clayton Environmental Consultants) reported on many of the fungi, VOC, and NO_2 measurements made during investigation of complaint buildings. Morey reported on typical levels of air contaminants in office buildings investigated by Clayton. His findings regarding airborne fungi were quite different from many previous reports. His reported VOC levels were consistent with those reported previously by many other investigators, including the EPA's Public Access Buildings Study (see *IAQU*, December 1988). He found NO_2 levels were elevated where ventilation air intakes were poorly located and subject to high levels from motor vehicle exhaust.

Fiberglass and Moisture

Mike West (University of Florida) reported on studies of moisture uptake by fiberglass and other building materials studied in a moldy Florida veterinary school. West found that dirty fiberglass insulation absorbed far more moisture than clean fiberglass insulation. His findings suggest that fiberglass can be used safely in HVAC systems if proper precautions are taken.

Maintenance and SBS

Dean Rask (Honeywell Indoor Air Quality Diagnostics group) presented case studies of investigations into sick building syndrome (SBS) where maintenance played a critical causative role. Dirty HVAC system filters, coils, and drain pans figured in many of the complaint buildings. Poor housekeeping, lack of a comprehensive maintenance program, and nonexistent inspection and repair programs were also blamed for air quality problems.

Office Ventilation Rates

Andy Persily of the National Institute of Standards and Technology (NIST) reported his analysis of more than 3,000 ventilation rate measurements in 14 office buildings. His findings suggest that buildings do not necessarily function according to design expectation, that ventilation rates vary widely among buildings, and that typical ventilation rates are less than one air change per hour.

Other Important Papers

Other important papers presented at the conference but not reported on below include some interesting advancements in the development of PC-based models of IAQ. EPA and its contractor, Research Triangle Institute, both presented working versions of their models in the poster session. We expect that such computer-based presentations will be more common at future IAQ conferences as our understanding increases and is reflected in analytical tools.

British SBS Study

Alastair Robertson (Institute of Occupational Health, Birmingham, England) reported on follow-up work of a major British multi-building SBS study. He found that "water-based" and "all air" HVAC systems were associated with the highest complaint rates. Evaporative cooling was the worst; steam was not so bad. Complaint rates were higher in "large, mutli-occupier rooms," (open space office planning) than in private, single occupant offices.

In a follow-up of a study done a year earlier, symptom reports declined slightly. Robertson concluded that this shows that studying SBS (administering questionnaires) does not elevate the complaint rate. Robertson also stated that occupant's perception of control over their environment can be an important factor in reducing symptom reports.

Danish Town Hall Study

The Danish Town Hall Study (DTHS) involved 27 buildings and 4,369 office workers. (See ***IAQU***, May 1988.) Peder Skov (Clinic of Occupational Medicine, Copenhagen, Denmark) said that 53% of those surveyed reported no symptoms. Air levels of contaminants did not correlate with people's symptoms. Among the most important factors were the amount of dirt on the floor, the size of the organic fraction of the dust, the "fleece" factor, the "shelf" factor, and the age of the building. Skov said the fleece factor was based on the area of the carpet compared to the volume of the office. The shelf factor was the shelf area compared to the office volume.

There were many other fine papers at the conference. Space limitations do not permit us to report on them all. Interested readers should obtain a copy of the conference proceedings from ASHRAE in Atlanta. Publication is scheduled for early July; for more information, see the end of this article.

What Are Typical Levels of Air Contaminants in Office Buildings?

Phil Morey poses and answers that question in the paper he presented at IAQ '89. Morey is best known for his work on biological contaminants in indoor air. He presents important results which have not been previously published.

Results of Microbial Sampling

Table 1 presents the results of sampling for mesophilic fungi in seven buildings. The table expresses concentrations of indoor fungi samples as ratios of the average indoor level divided by the outdoor level. In most of the investigated buildings, the concentrations of indoor fungi collected by quiescent sampling were 10% to 25% of outdoor levels. "Quiescent sampling" means collecting samples under normal conditions of building operation and use but without unusual disturbance of potential or known fungi sources.

In a few buildings, levels were high in the immediate vicinity of active (wet) microbial amplification sites. Indoor concentrations in these buildings varied widely, and the researchers could not obtain a uniform interpretation of results by simply comparing indoor to outdoor levels (I/O ratio). This contrasts with the previously held conventional wisdom on the subject that I/O ratios greater than unity indicate microbial contamination. This new conclusion from Dr. Morey is an extremely important outcome of the study.

"Aggressive sampling" entails disturbing furnishings and HVAC system components. This involves light tapping or agitation, but not pounding. As a result of the agitation, concentrations of airborne fungi in the immediate vicinity became elevated relative to outdoor levels. Aggressive sampling increased indoor airborne concentrations dramatically; the increases ranged from a factor of three up to a factor of a thousand. Thus, disturbance of an airborne microbial contaminant source may be as important a factor in exposure as the simple presence of the source and the amplification site or conditions.

Morey collected viable fungi on malt extract agar using a sieve impactor. He did not do particle sizing, and he collected respirable as well as nonrespirable particulate matter on the same plate. The samples were collected at a flow rate of 6.4 cubic feet per minute (180 liters per minute). Incubation temperatures for fungi were 25°C.

Dr. Morey is a widely respected authority on indoor microbial contaminants and is probably the most widely published researcher on the subject. His writing on sampling and interpreting results is mandatory reading for all those interested in investigating microbial contamination in indoor environments.

Office Building Air Levels Database

Clayton Environmental Consultants is one of the largest environmental and occupational consulting firms in the country. Based in Edison, New Jersey, it has offices all over the country. When Clayton hired Phil Morey, it was a sign that Clayton would become an important firm in IAQ investigations. Morey has outstanding credentials, having worked at the National Institute for Occupational Safety and Health (NIOSH) and at Honeywell before joining Clayton.

Now, Dr. Morey has assembled results from a variety of office building investigations. His paper presents findings from 15 buildings investigated by Clayton. Besides the microbial levels, he presented data on VOC and NO_2 concentrations.

VOC Levels

Figure 1 shows the results of indoor and outdoor measurements performed by Clayton in 15 office buildings. Twenty percent of the samples exceeded 1 mg/m^3 and 6% exceeded 2 mg/m^3. Outdoor concentrations never exceeded 1 mg/m^3, and 35% of outdoor samples contained less than 0.1 mg/m^3. Total VOC concentrations were less than 0.1 mg/m^3 in only 12% of the samples.

The average indoor concentration observed by Clayton's investigators was 0.66 mg/m^3, while the average outdoor level was 0.232 mg/m^3. The indoor/outdoor ratio average was 2.84.

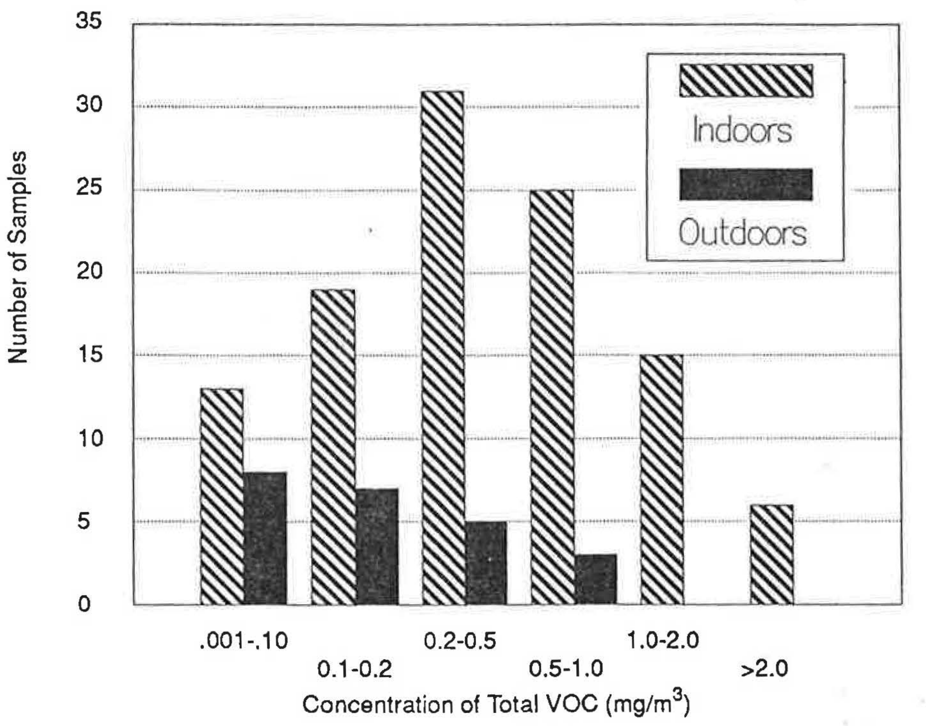
Clayton measured VOC in one New York City office building four times with minimum and

Table 1 — Ratio of Indoor/Outdoor Fungal Concentrations

Building, Time of year	Fungi in Outdoor Air (cfu/m^3)*	Quiescent Sampling in Offices	Quiescent Sampling in HVAC Systems	Aggressive Sampling in Office or HVAC System	Environmental Conditions in Building
A, January	36	0.21	—	5.5	Excessive moisture RH = 60 to 80% dewpoint 62 to 72°F
B, October	200	0.08	0.08	10 to 100	Dry, moldy insulation on inside of air handling units
C, June	200	0.1 to 1.0	—	—	Floors 1 to 4 RH = 30-40%, dewpoint 43 to 48°F
C, June	200	2.5 to 5	—	—	Basement; RH = 60 to70% dewpoint 62°F to 70°F
D, November	830	0.07	—	13.2	Ceiling tiles dry but damaged by previous floods; induction units poorly maintained
E, December	100	0.15	—	0.5	Induction units poorly maintained
E, September	75	0.13	—	0.5	Induction units poorly maintained
F, August	200	0.25	0.5	1.5	Excessive moisture on day before sampling; RH = 50% on date of sampling
G, May	85	0.16	—	2.0	Fan coil units poorly maintained

*cfu/m^3 means colony forming units per cubic meter of air.

Figure 1 — Total Volatile Organic Compounds in 15 Buildings



twice with maximum outdoor air (economizer cycle). The I/O ratio was significantly higher under minimum ventilation (see Table 2). Under minimum ventilation, the I/O VOC ratio ranged from 4 to 16. Under maximum ventilation, the I/O ratio was only slightly above one (1.4 to 1.7).

In another building, Clayton measured VOC with a passive charcoal monitor in the offices of one tenant. The tenant was bothered by fumes from the printing press operations of another tenant. Complaints were of eye, nose, and throat irritation. Average concentrations of VOC for three weeks were 22.5 mg/m^3. Outdoor concentrations six feet from the building were 1.45 mg/m^3, and at a site remote from the building they were less than 0.2 mg/m^3 (the limit of detection for the sampling technique).

NO_2 Measurements

Clayton collected NO_2 samples in seven New York City area buildings. In each case, landlords or tenants were concerned about the entry of combustion byproducts from garages, parking areas, or loading docks. The measured indoor concentrations never exceeded outdoor levels.

In one building, researchers conducted round-the-clock sampling for six days. The outdoor air inlet for the HVAC system was located at ground level near a loading dock. Nearly 40% of the occupants of one office reported periodic headaches, disorientation, nausea, burning eyes, and nosebleeds. They also complained of gasoline and diesel fume odors. The office had been evacuated pending outcome of the investigation due to sporadic disruption of productivity.

Samples collected in a protected rooftop location never exceeded 0.08 ppm. The National Primary Ambient Air Quality Standard limits NO_2 to 0.055 ppm annual average concentration. In the affected office, levels did not exceed 0.08 ppm except on two occasions, when they rose to 0.6 ppm and 0.7 ppm. During one of these occasions, air at the HVAC inlet contained almost 2.0 ppm. The researchers concluded that the building-associated problem was caused by the faulty location of the HVAC inlet.

Conclusions

Microbial Contaminants

Except for one building, quiescent sampling for fungi measured indoor levels that were 10% to 25% of outdoor levels. The probable removal mechanisms were HVAC filtration and sedimentation of large spores. Quiescent sampling will detect elevated levels indoors only in the immediate vicinity of active (wet) microbial amplifiers. Even where obvious but inactive sources exist, indoor levels are likely to be well below outdoor levels. You must perform a thorough visual inspection of the building, including the HVAC system, to detect microbial reservoirs and amplification sites. You can use aggressive sampling near the suspect sites to confirm your visual inspection findings.

Even where elevated indoor/outdoor microbial air concentration ratios exist (I/O ratios of 5 to 100), there may be no complaints suggesting hypersensitivity lung illness. In one case where such complaints were present, aggressive sampling revealed only slight-

Table 2 — Average Concentration of Total VOC

Time of Year	Outdoor Air Ventilation	Indoors	Outdoors	Indoor/Outdoor ratio
June	Minimum	1420	—	—
November	Minimum	1270	310	4.1
December	Minimum	445	93	4.8
September	Minimum	268	16	16.0
September	Maximum	71	48	1.48
October	Maximum	85	50	1.70

ly elevated fungi levels indoors. Morey writes, "These data suggest that interpretation of air sampling data for microorganisms should be made with caution.... The possibility that occupant problems are related to agents other than viable fungi should not be overlooked."

Air sampling for fungi should be carried out only after a visual inspection. It is much easier to carry out remedial actions than to prove a microbial agent is causing building-related illness.

Important factors in microbial contamination are the availability of water and nutrients, the number and kinds of fungi present indoors and outdoors, the HVAC system's operational status, and the occupant activities.

VOC

Wide variations in VOC concentrations reflect differences in building ventilation rates and VOC source strengths. Lars Molhave of Denmark suggests that VOC levels above 1 mg/m^3 exceed the threshold for sensory perception. Among 109 samples collected by Clayton, 20% exceeded that level and 6% exceeded 2 mg/m^3.

NO_2

Indoor NO_2 is well below prevalent outdoor levels unless HVAC air intakes are located near strong NO_2 sources. When intakes are poorly located, indoor levels can exceed the average outdoor standard by a factor of ten or more and occupant complaints can be expected.

For More Information

Contact: Philip R. Morey, Ph.D., 151 S. Warner Rd., Ste. 235, Wayne, PA 19087; (215)688-4080.

Moisture and Building Materials

Many investigators believe that wet fiberglass insulation or ductwork in ventilation systems, wet carpeting, and wet ceiling tiles cause SBS or building-related illness (BRI). Microorganisms thrive in the dark, damp, nutrient-rich environment provided by dirty, wet fiberglass ductboard or duct linings. Carpets and ceiling tiles, once wet, are so difficult to clean and disinfect that investigators usually recommend they be discarded. Current research is revealing some critical factors in how common building materials react to moisture.

Mike West, an engineering graduate student at the University of Florida, has written a paper of tremendous practical significance. He and other researchers studied moisture content and uptake by building materials in a microorganism-contaminated Florida building.

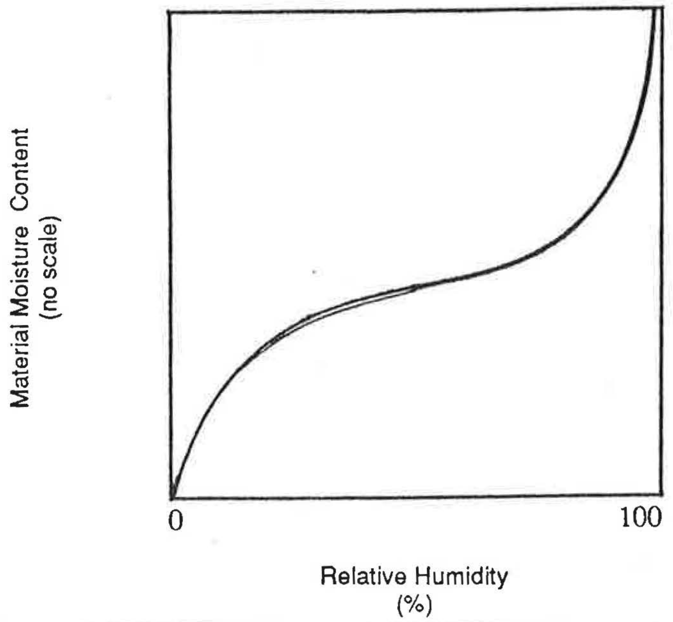
West reported on studies of material moisture content as a function of relative humidity, temperature, and time. The researchers examined fiberglass duct linings, polyester filters, cotton cloth, and jute-backed nylon carpet. They found that all of these materials were capable of absorbing sufficient moisture to support microbial growth.

Materials with moisture content less than 10% are unlikely to support microbial growth, according to West. Materials with more than 14% moisture are likely to support microbial growth.

Clean fiberglass does not take up much moisture even when partially submersed in water. However, after the same amount of exposure, dirty fiberglass will have a high moisture content. Once wet, the dirty fiberglass will take up even more moisture. It becomes difficult to dry out sufficiently to prevent microbial growth. West concluded that fiberglass duct liners are safe if kept clean and not wetted.

The generalized uptake of moisture of any material is described in Figure 2. It shows the relationship between relative humidity and material moisture content, and it applies to all materials that take up moisture. The figure shows that dry materials take up moisture

Figure 2 — Relationship of Material Moisture Content to Relative Humidity of Surrounding Air



slowly until they reach a critical moisture content. Then, they begin to take up moisture very quickly until they approach their saturation point.

Practical Implications

West's findings are very significant for indoor air quality control. The study shows that fiberglass used in HVAC ductwork must be kept clean and dry. Most applications require more effective filtration (and other air cleaning) and humidity control.

Since fiberglass ductwork is often used as a cost-saving measure, most designers or owners will probably not opt for the more expensive air cleaning and humidity-control measures required for safe HVAC ductwork.

In investigations of SBS complaints, many researchers and consultants have recommended removing wet, dirty, or contaminated building materials that support microorganism growth. Cleaning, drying, and disinfecting are not practical or economically viable. The research reported here supports those recommendations.

For More Information

Contact: Mike West, Department of Mechanical Engineering, University of Florida, Gainesville, FL; (904)392-0827.

Resolving Sick Building Syndrome: Maintenance

Simple, routine maintenance tasks are often neglected in more than half of the air quality problem buildings investigated by the Honeywell Indoor Air Quality Diagnostics (IAQD) group. Many of the neglected maintenance items involve the HVAC system; others involve the building envelope or structure, general housekeeping, and comprehensive building maintenance.

The Honeywell IAQD group, a major IAQ consulting team, has investigated over 50 buildings in response to IAQ complaints. The group found four major causes of IAQ problems:

- Lack of proper maintenance;
- Changes in thermal and contaminant loads occurring during the lifetime of the building;
- Changes in control strategies to meet new objectives (i.e., energy management, cost containment);
- Inadequate design of the original system or building.

We discussed some of their findings in the May 1988 issue of ***IAQU.***

At IAQ '89, Dean Rask, P.E., from the Honeywell group, presented case studies from six buildings where the group found maintenance problems. Descriptions of the six buildings follow. In five of the six buildings, investigators diagnosed the problems indirectly on the basis of interviews, discussions with key personnel, walk-throughs of the facilities, and reviews of building plans, engineering drawings, and maintenance records. They made measurements in only one of the six buildings, a hospital.

The most commonly neglected HVAC maintenance items were the routine changing of filters and the cleaning of cooling coils, drain pans, and perimeter induction units.

Building One

In one 300,000-sq ft building, the only routine HVAC maintenance was filter changing. Occupants complained of temperature problems and stuffiness. Some occupants experienced headaches, fatigue, and drowsiness. Reportedly, these symptoms went away when the occupants left the building, leading investigators to suspect sick building syndrome.

Each of the four HVAC systems lacked pre-filters. Old electronic air cleaners in the system had not operated for years and had collector plates caked with dirt. Two floor drains had dry traps, which allowed sewer gases to enter the mixed air plenums. The ductwork was dirty and rusty and the perimeter mixing-box units were very dirty. The mixing boxes did not work properly and contained moldy food.

Other than filter changing, maintenance was done on an "as needed" basis. The chief engineer and his assistant did not understand the system and were not trained to operate it. The lack of training helps explain the lack of a comprehensive maintenance program.

Housekeeping was also inadequate; years of dirt and dust covered the window sills. Lacking storage space, employees put things on top of the perimeter units, thereby blocking airflow. Due to overcrowding in some offices, file cabinets were put in front of some low sidewall return air grilles.

Building Two

In the second building, outdoor air intakes were located at ground level in an alley where transients urinated. Dumpster odors exacerbated the air quality problem. Maintenance crews cleaned the central HVAC units meticulously; however, they serviced the perimeter induction units only on an as-needed basis and rarely cleaned them. Office remodeling limited access to the induction units.

Building Three

The Honeywell group suspected both SBS and BRI in the third building, where an outside contractor performed a comprehensive maintenance program. Despite the program, Penicillium heavily contaminated the sound liner in the discharge air plenum of the variable air volume (VAV) systems. Investigators determined that maintenance personnel were not trained to look for evidence of fungal growth or to understand its potential risk. The investigators recommended removing the sound liner and disinfecting the plenum.

Building Four

The fourth building was a warehouse structure remodeled into offices. The building envelope was leaky, resulting in moisture penetration during wind-driven rain. Wet ceiling tiles along the windows created the potential for microbial growth, although none was observed during the investigation.

The mechanical equipment rooms functioned as mixed air plenums, and they were not clean. They served as storerooms for various janitorial and maintenance products that made them hard to clean. Panels were missing from the filter rack, allowing some air to bypass the filters.

Maintenance personnel did not keep records, and the engineering drawings were incomplete. Individuals who had been involved with the building for a number of years indicated that the only regular HVAC system maintenance was filter changing. Any other work was done on an as-needed basis.

Building Five

This 25-year-old hospital's HVAC system was approaching the end of its useful life. Condensate leaks or drain pan overflows rusted out plenums and ductwork around cooling coils. Some control functions had been disconnected or modified without regard for overall system performance. The plenums were very dirty and filter maintenance appeared erratic. Fan coil units around the perimeter showed signs of infrequent cleaning.

Housekeeping was very poor due to a lack of storage space and insufficient staff. No comprehensive maintenance program was in place. Some systems seemed completely neglected and only attended to on an emergency basis.

Investigators recommended an engineering study to determine whether to renovate or replace the HVAC system. Short-term recommendations include: cleaning all plenums, coils, and drain pans; replacing filters per manufacturers' schedules; and cleaning the perimeter fan coil units.

Building Six

The last building, built in 1971, contained 92,000 sq ft. Occupants had experienced nausea, dizziness, eye and throat irritation, numbness in the fingertips, and loss of depth perception. The affected occupants reported that their symptoms seemed to subside shortly after leaving the building.

Building envelope maintenance problems were roof-related. When a new elastomeric roof coating was applied one year prior to the site visit, some of the roof drains were inadvertently plugged. The resulting inadequate drainage caused a roof leak that wetted ceiling tiles. Although investigators observed no microbial growth during the site visit, the potential was present.

HVAC equipment maintenance was very poor. Coils and drain pans were dirty. Maintenance staff did not schedule or carry out regular filter changing; the building had no comprehensive maintenance program.

The Honeywell IAQD group recommended unplugging the roof drains, replacing filters in all air handlers, cleaning coils and drain pans, and instituting a comprehensive maintenance program.

Conclusions and Implications

Through October, 1988, Honeywell had investigated more than 50 building IAQ problems. The group cited maintenance deficiencies as factors in 75% of the cases. In descending order of importance, these deficiencies involved: HVAC systems, comprehensive maintenance programs, housekeeping, and building structures. Budgetary limitations and inadequately trained personnel were often part of the maintenance problems.

Budget and personnel cutbacks are often made without any immediately observable effects on IAQ. When problems develop, the connection to maintenance cutbacks may not be apparent.

The investigators concluded that "when care is taken to ensure that the HVAC equipment is properly maintained and operated, and that appropriate amounts of outdoor air enters the building and is properly distributed, complaints can be minimized and resolution of SBS is achievable in most buildings." Since most clients do not request follow-up diagnostics, the results of implementing recommendations are not usually known.

Recommended Actions

The Honeywell group recommends the following key maintenance actions as part of a comprehensive maintenance program:

- Repair all building envelope leaks.
- Schedule regular filter changing in all HVAC equipment.
- Schedule regular inspection and replacement (if necessary) of the air duct liner.
- Schedule regular coil and drain pan cleaning.
- Schedule regular maintenance of the mechanical equipment.
- Schedule regular maintenance and calibration of controls.
- Specify the cleaning agents to be used in the occupied space as well as the schedule for their use.

For More Information

Contact: Dean Rask, P.E., Principal Development Engineer, Honeywell Indoor Air Quality Diagnostics, 1985 Douglas Drive North, Golden Valley, MN 55422-3992; (612)542-6514.

Ventilation Rates in Office Buildings

In the NIST studies analyzed by Andy Persily, the mean air exchange rate measured in 12 office buildings ranging from low-rise (two story) to high-rise (15 story) and from small (39,000 sq ft) to large (714,000 sq ft) was 0.88 air changes per hour (ach). The median was 0.80 ach.

Table 3 summarizes the air-exchange measurements from 14 buildings studied. Buildings A and C are not in the second set of totals because they are atypical. Building A has some laboratory space resulting in abnormally high ventilation rates, and Building C always operates on 100% outdoor air supply. So, totals are given for all buildings and then for all buildings except A and C. The results are based on over 3,000 measurements made over a one-year period by researchers at NIST, formerly the National Bureau of Standards.

Table 4 shows ventilation rates per person and various air exchange rates for ceiling heights of 8, 9.75, and 11.5 feet. Assuming an occupant density of seven people per 1,000 sq ft (ASHRAE Standard 62-1981 assumes that density when the actual density is not known), a 20 cubic feet per minute per person (cfm/p) ventilation rate requires 0.72 ach for an 11.5-ft ceiling height (including plenum space) and 1.03 ach for an 8-ft ceiling height. For 15 cfm/p, the air exchange rates are 0.54 and 0.77 for 11.5-ft and 8-ft ceiling heights.

The NIST researchers noted that the most significant difference among buildings was the air exchange rate under minimum outdoor air intake conditions. This rate is interesting in relation to both the building's design specifications and the recommended levels of ventilation. While ventilation rates varied considerably among buildings and within individual buildings, about half the measured ventilation rates were below design ventilation rates during significant portions of the year.

The measurements were made using tracer decay rates. A harmless tracer gas, sulfur hexafluoride (SF_6), was released and mixed thoroughly in the building. The logarithm of the concentration decay rate is the ventilation rate.

Table 3 — Summary of Building Air Exchanges

	HVAC System Description from Design Specifications					Measurements		
	Supply Fan Capacity		Minimum Outdoor Air Intake			Number	Air Exchange Rate	
Building	ACH	cfm/ft^2	ACH	cfm/ft^2	Percent of Supply Air		Mean	Median
A	*	*	*	*	*	228	1.73	1.65
B	3.0	0.61	*	*	*	392	0.97	0.41
C	1.7	0.24	1.70	0.24	100	521	0.90	0.91
D	4.3	0.92	0.72	0.15	16	544	0.99	0.94
E	4.3	0.92	0.72	0.15	16	536	0.80	0.72
F	4.1	0.82	*	*	*	127	1.15	1.12
G	2.9	0.63	*	*	*	93	0.89	0.90
H	3.1	0.77	0.42	0.10	13	94	0.78	0.50
I	2.5	0.43	*	*	*	175	0.75	0.67
J	3.1	0.67	1.82	0.40	60	93	0.29	0.25
K	5.5	1.78	0.90	0.29	16	52	0.54	0.40
L	3.8	1.27	0.36	0.12	9	131	0.73	0.65
M	2.4	0.80	0.53	0.17	21	246	1.19	0.96
N	2.8	0.55	0.36	0.07	13	90	0.99	1.07
All buildings						3,122	0.94	0.89
All buildings except A and C						2,373	0.88	0.80

Tracer gas decay tests were done in each building during at least one month during each season of the year. In some buildings, the tests were made for even longer periods. More than 500 measurements were made in some buildings.

The results were adjusted to remove the biases from the variations in the number of measurements made in each of the buildings. The unbiased mean ventilation rates ranged from 0.29 to 1.73 ach. The high value was from a building with some laboratory spaces and a VAV air supply system. The next highest mean air exchange rates were 1.19 and 1.15 ach. The remainder of the buildings had mean values below 1.0 ach. The vast majority of all measurements in the unbiased frequency distribution were from 0.5 to 1.25 ach. Less than 10% of all measurements were outside that range.

Commentary: Ventilation Rates Affect VOC Levels

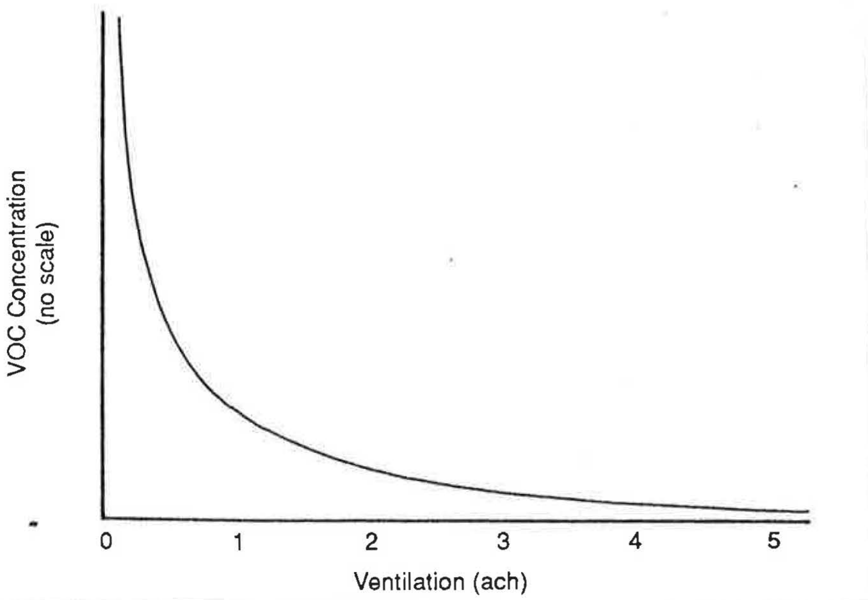
By reviewing data from our own and other studies, we have found that indoor air VOC concentrations tend to increase very quickly as ventilation decreases below a rate within the range of 0.6 to 1.2 ach, depending on the source strengths and sinks. The stronger the sources and larger the available sinks, the more ventilation required. Figure 3 illustrates the generalized relationship between VOC concentrations and ventilation rates.

As ventilation decreases below the critical value (the inflection point

Table 4 — Ventilation levels in air changes per hour

Ventilation per person		Air exchange rate (ach)		
		Ceiling height		
CFM	L/s	11.5 ft	9.75 ft	8 ft
35	17.5	1.26	1.52	1.80
20	10.0	0.72	0.87	1.03
15	7.5	0.54	0.65	0.77
10	5.0	0.36	0.45	0.52
5	2.5	0.18	0.21	0.26

Figure 3 — VOC Concentrations vs Ventilation Rates



in the curve), VOC concentrations increase dramatically. As ventilation increases above the inflection point, VOC concentrations decrease much less rapidly. *The key to economical IAQ control is to maintain ventilation just above the inflection point whenever possible.*

Most ventilation rates measured in the study fell within the critical band where the inflection point usually occurs. Unfortunately, VOC measurements were not made. However, the measurements show that variations above or below typical ventilation rates significantly affect airborne VOC levels in many buildings. From this crude, general analysis, it seems that measurement of VOC levels and ventilation rates provides substantial information to building operators on how to improve both factors. Efforts to control VOC through ventilation without measurements might result in excessive energy consumption (and costs) or not enough ventilation to maintain VOC concentrations at the lowest practical levels.

For More Information

Contact: Andy Persily, National Institute of Standards and Technology, Gaithersburg, MD; (301)975-2000.

References

P. R. Morey and B. A. Jenkins, "What Are Typical Concentrations of Fungi, Total Volatile Organic Compounds, and Nitrogen Dioxide in an Office Environment?"

M. K. West and E. C. Hansen, "Determination of Material Hygroscopic Properties Which Affect Indoor Air Quality."

Dean R. Rask and Charles A. Lane, "Resolution of the Sick Building Syndrome: Part II, Maintenance."

A. Persily, "Ventilation Rates in Office Buildings."

All are to be published in ***The Human Equation: Health and Comfort. Proceedings of IAQ '89.*** Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (in press). Expected availability is early July. Contact ASHRAE Publications, 1791 Tullie Circle N.E., Atlanta, GA 30329 (404)636-8400.

News and Analysis

EPA IAQ Report to Congress

EPA's long-awaited "Report to Congress on Indoor Air Quality" identifies nearly $100 million worth of research needs. However, the Office of Management and Budget (OMB) has not authorized release of the report. Inside sources told ***IAQU*** that OMB will submit the report to the President's Domestic Policy Council. The council will develop both a position on the report and the Bush administration policy on indoor air. OMB gave no indication when the council would formulate the policy.

Frustrated with the administration's slowness in coming to grips with indoor air issues, Senator Frank Lautenberg released the report at the May 3rd subcommittee hearing on the Mitchell IAQ bill. EPA prepared the report in response to Title IV of the Superfund Amendments and Reauthorization Act of 1986 (SARA). The report consists of an Executive Summary and two volumes as follows:

Volume I: Federal Programs Addressing Indoor Air Quality.

Volume II: Assessment and Control of Indoor Air Pollution.

Executive Summary

The Executive Summary of the report states that "sufficient evidence exists to conclude that indoor air pollution represents a major portion of the public's exposure to air pollution and may