Indoor Air Quality Update™

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

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Portland East Federal Office Building: A Case Study

Researchers studying indoor environments have published few comprehensive assessments of new office buildings. The EPA Public Access Buildings Study (*IAQU*, December 1988) is a notable exception. Now, the National Institute of Standards and Technology (NIST) is publishing the results of a comprehensive study of a new office building in Portland, Oregon. We think this is an extremely important piece of work, and therefore we are presenting the results in detail. They will interest designers, operators, consultants, researchers, and policy makers.

First-year monitoring results from the new federal building indicate that in some new office buildings, building materials and furnishings are far less important contributors to airborne levels of volatile organic compounds (VOC) than are occupant activities. Specifically, copy machines and plotters are major VOC sources. The results also show a strong correlation between ventilation rates and VOC levels: adequate ventilation controls VOC even where source strengths are large.

Background

Researchers from NIST studied the building for the General Services Administration. The study's purpose was to evaluate the building's thermal and environmental performance, and it included extensive documentation of ventilation rates. The building was constructed during 1986 and 1987 and first occupied in August 1987.

Researchers installed a central diagnostic center. They connected this center through an extensive network of tubes and wires to over 100 monitoring points throughout the building, and measured thermal performance, ventilation, and air contaminants over a one-year period. Another team of researchers from Lawrence Berkeley Laboratory (LBL) made additional VOC measurements on three occasions during early occupancy and again after one year. The NIST research team plans to monitor the building once a year for the next two years. This kind of follow-up will give a good, long-term view of environmental trends in new office buildings.

The results reported here are based on two separate papers (see the references at the end of the article) and on our discussions with the principal investigators for the two research organizations.

The Building

The Portland East Federal Office Building includes seven office stories with a basement and a two and one-half story underground garage. The occupied building area is about 500,000 square feet (~46,000 square meters), with a volume of about 6,356,000 cubic feet (~180,000 cubic meters). A dining room and kitchen attach to the building on the ground floor. The garage connects to the building by several stair and elevator shafts, and a loading dock is located on the first basement level. Figure 1 shows a schematic of the building.

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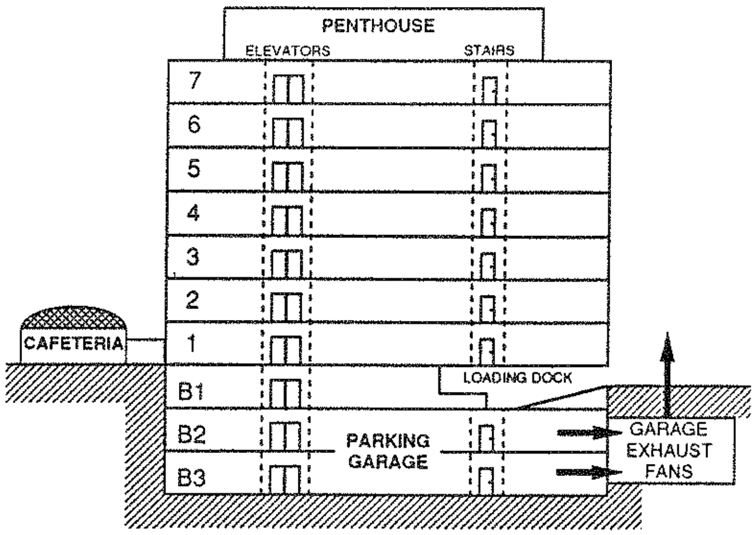

Figure 1 — Schematic of the New Federal Office Building

Three mechanical systems located in a rooftop penthouse serve the east, central, and west portions of the seven office floors. The HVAC systems are the variable air volume (VAV) type, and together they can provide three air changes per hour (ACH) — about 300,000 cubic feet per minute (cfm). Four air handling systems and four exhaust fans ventilate the garages and the loading dock. They activate when carbon monoxide levels exceed 50 ppm.

The offices are mostly open plan with five-foot-high partitions between work stations. Most floors have enclosed offices for supervisors and enclosed conference rooms. All enclosed areas lack separate air handling systems. The second floor contains a computer facility.

Ventilation Rates

Ventilation rates in the Portland building vary between 0.4 and 2.2 ACH when the building is occupied. The low of 0.4 ACH occurs during very hot or extremely cold outside conditions. The building would require 0.7 ACH to meet the new ASHRAE ventilation standard requirement of 20 cfm per occupant, based on 135 square feet of space per occupant. It would require 0.79 ACH based on federal government standards of 120 occupiable square feet (minimum) per occupant.

Building air leakage (uncontrolled ventilation when HVAC fans are off during unoccupied hours) ranges from 0.2 to 0.4 ACH. The building was designed to be energy efficient, but the exterior walls are not tight. The researchers comment that the leakage found in the Portland building can be considered typical of U.S. office buildings (see *IAQU* May 1988). They compared the building to a typical home that has an exterior surface to interior volume ratio of six to one. Using that ratio, they say the building walls would be equivalent to the walls of a house with an air leakage of 1.2 to 2.4 ACH.

Figure 2 shows measured air exchange rates for the building with fans on (open diamonds) and off (solid squares). The NIST team obtained these ventilation rates using an extensive set of tracer gas measurements similar to those described in *IAQU* May 1989. They injected an inert, buoyancy-neutral gas, sulfur hexafluoride

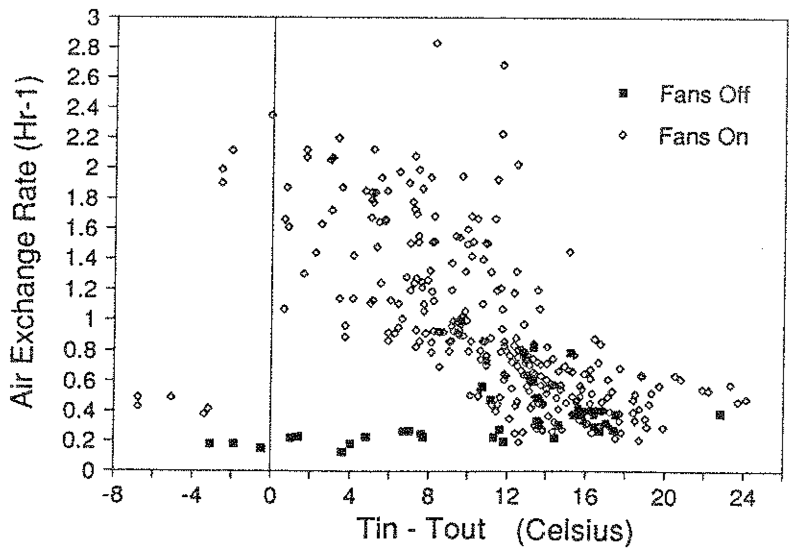

Figure 2 — Air Exchange Rate vs. Inside-Outside Temperature Difference

(SF_6), into the building air supply and allowed it to mix well. Then they collected samples and calculated the ventilation rate based on the decay rate of the tracer gas. This method provides a ventilation rate which includes both mechanical ventilation and air leakage through the envelope.

The researchers obtained another set of ventilation rate data by using carbon dioxide levels and occupant density. The results are consistent with tracer gas measurements and are shown in Figure 3. Analysis of these data show that the air in the building is well mixed and that short circuiting of the air supply is not occurring.

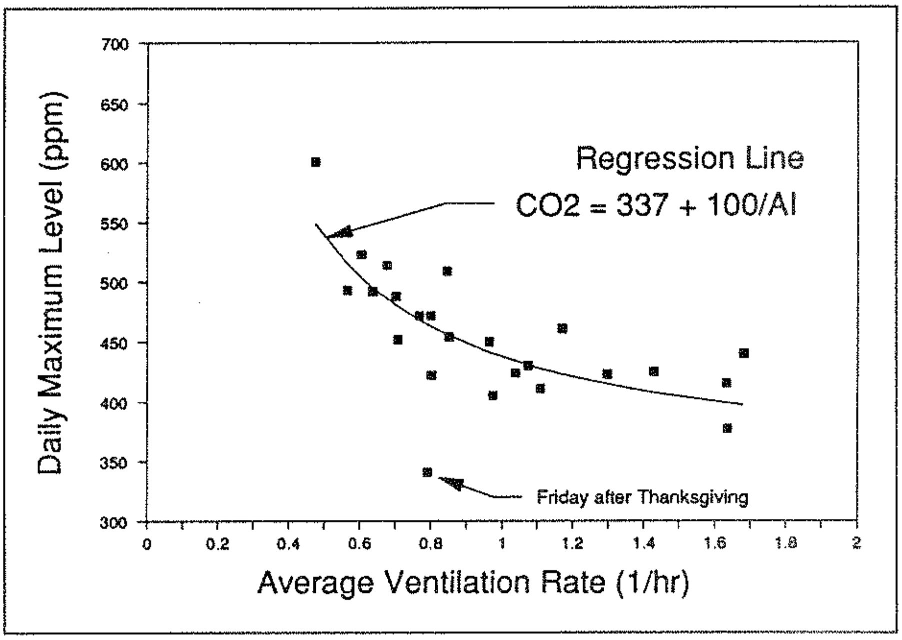

Figure 3 — Carbon Dioxide level vs. Ventilation

Contaminants

Contaminants that the researchers measured included:

- Respirable particles
- Carbon monoxide
- Radon
- Formaldehyde
- VOC

Respirable Particles

Respirable particle levels in six size ranges were measured during portions of September and October 1987 (see Figure 4). Researchers measured the particle levels by using a light-scattering instrument that counts particles in each size range. They found very large numbers of particles of the smallest size measured: 0.3 to 0.5 microns. Typical building media filters do not efficiently remove particles in this size range. These particles penetrate deep into the human respiratory tract, where they can cause serious long-term health problems. This characteristic of the Portland building is not unusual. It simply points out an area where indoor air quality has not been adequately considered when developing design criteria.

Carbon Monoxide

Due to air flow up the elevator shafts and stair towers from the underground parking garage, carbon monoxide (CO) levels in the upper parts of the building frequently exceeded 10 ppm during the fall and early winter. Figure 5 shows daily maximum CO levels in the sixth-floor elevator lobby.

The automated sensors in the garage work as designed, activating exhaust fans when garage CO levels exceed 50 ppm. However, this intermittent operation does not prevent CO transport up the elevator shafts and stair towers during extreme weather conditions when the stack effect is strongest. To remedy the problem, two of the four exhaust fans are operated continuously during building occupancy. The resulting CO levels in the office space did not exceed 5 ppm, the threshold for complaints.

Radon

Researchers measured radon concentrations by using charcoal canisters. They took three-day measurements at interior locations, and measured working levels of radon progeny. The results are shown in Figures 6 and 7.

The levels found in the building do not exceed EPA or ASHRAE guidelines. However, it is noteworthy that the levels in the upper floors of the building were almost as high as the levels in the basement.

EPA plans a radon survey of all federal office buildings. Richard Guimond of EPA's radon program recently told us that his agency plans a survey of commercial building radon levels in the near future. We have written about the potential for elevated radon levels in nonresidential structures (*IAQU*, September 1988), but we did not consider the potential for elevated radon in the upper portions of medium- and high-rise buildings due to the stack effect. The Portland building demonstrates that there is reason to measure radon in taller buildings.

Formaldehyde

The NIST team sampled formaldehyde using a passive monitor based on absorption onto a sodium bisulfite treated filter, and analyzed it by the chromotropic acid colorimetric method. They made ten measurements in August 1987, when furniture was being moved into the building. Carpet tiles had been installed from April to July in most parts of the building. The maximum formaldehyde level they measured was 0.056 ppm, with the remainder of the ten measuring levels less than 0.04

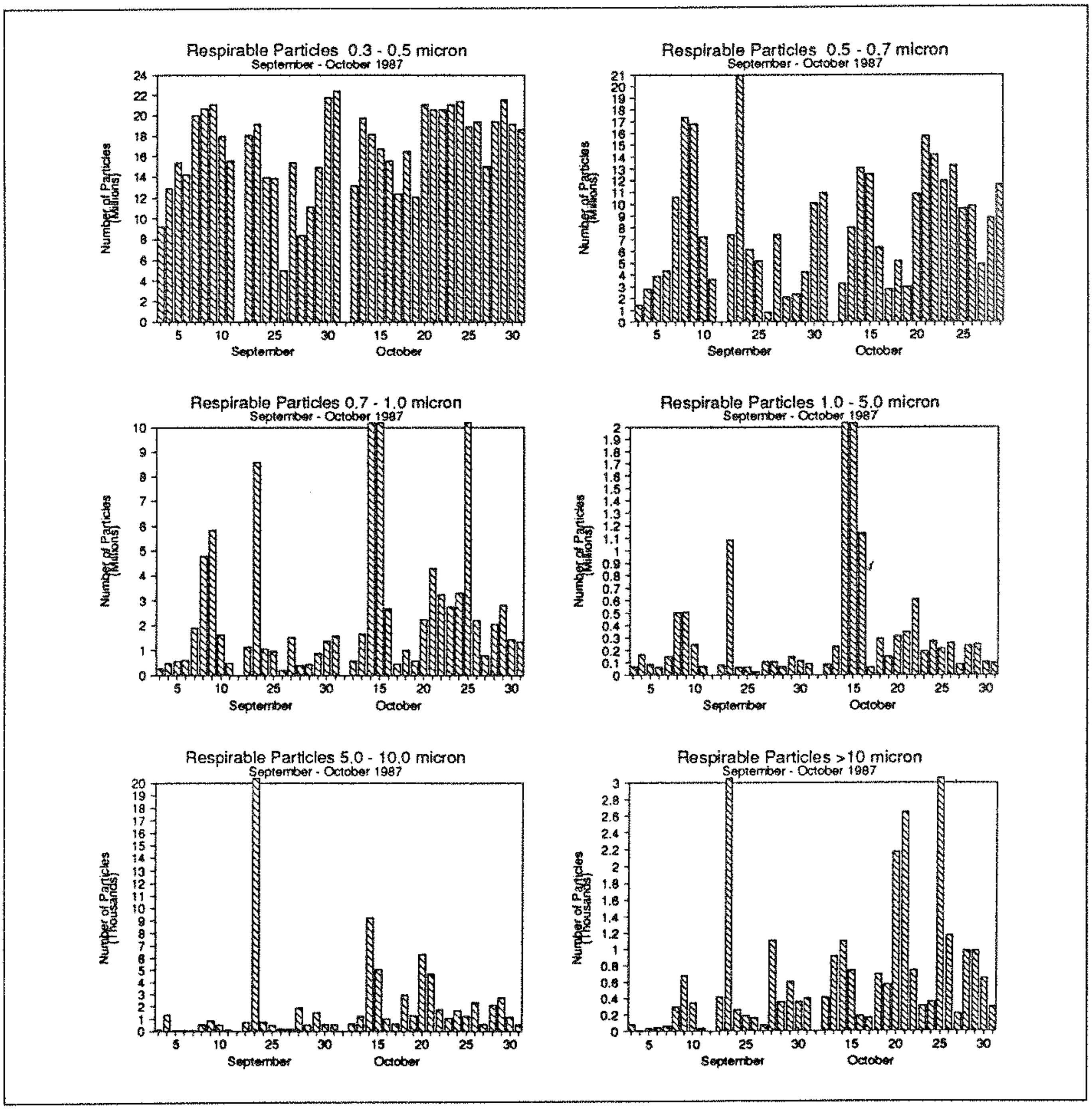

Figure 4 — Respirable Particles in Various Size Ranges for Months of September and October 1987

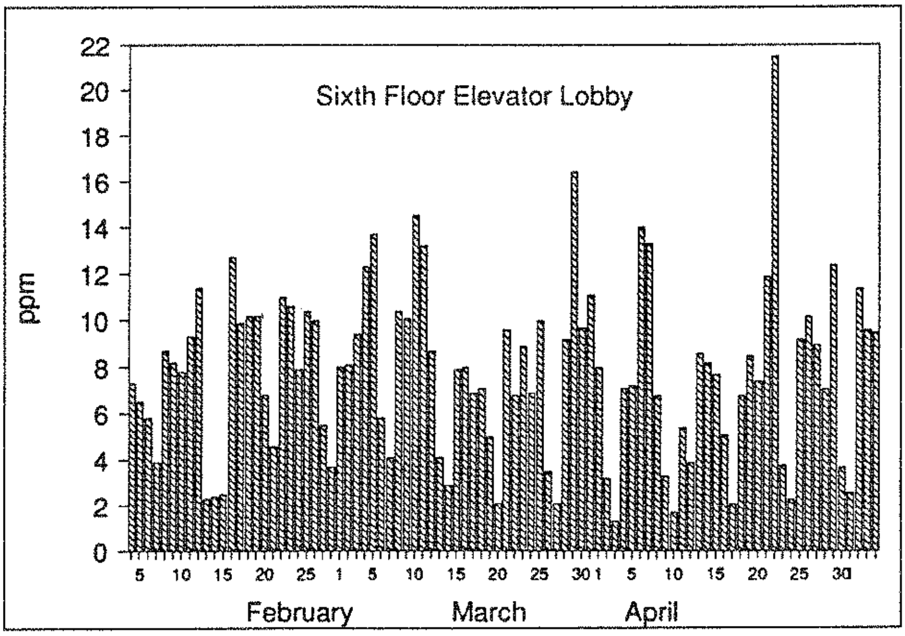

Figure 5 — Daily Maximum Carbon Monoxide Level in Sixth Floor Lobby for Months of February to May

ppm (see Figure 8). This compares to the ASHRAE guideline level of 0.1 ppm. The 0.056 ppm formaldehyde concentration indicates that formaldehyde emissions from building materials and furnishings were not excessive.

VOC

Volatile organic compounds measurements and modelling show clear relationships between source strengths, ventilation rates, and VOC air concentrations. The investigators conclude that occupant activity sources are greater than building material and furnishing sources. The relationships between ventilation rates and VOC concentrations were consistent.

VOC Measurements

LBL scientists measured VOC four times: during move-in (August 4, 1987), ten weeks later (October 14, 1987), 13 weeks later (January 13, 1988), and finally a year later (October 28, 1988). They measured VOC using a sophisticated multisorbent collection system.

VOC analysis was by thermal desorption and concentration, a capillary gas chromatograph equipped with an on-column cryogenic focusing device, and a mass-selective detector. Following thermal desorption, a portion of the sample was split for analysis by a flame ionization detector to measure total organic carbon.

The scientists collected samples (in duplicate or triplicate) from return air shafts at the penthouse level, office spaces, and outdoor air on the roof. Sample volumes were typically one to three liters collected at a rate of 100 cc per minute.

Source Strength Calculations

Researchers calculated source strengths based on measured air concentrations and ventilation rate information. They used a single-equation mass balance. It assumes

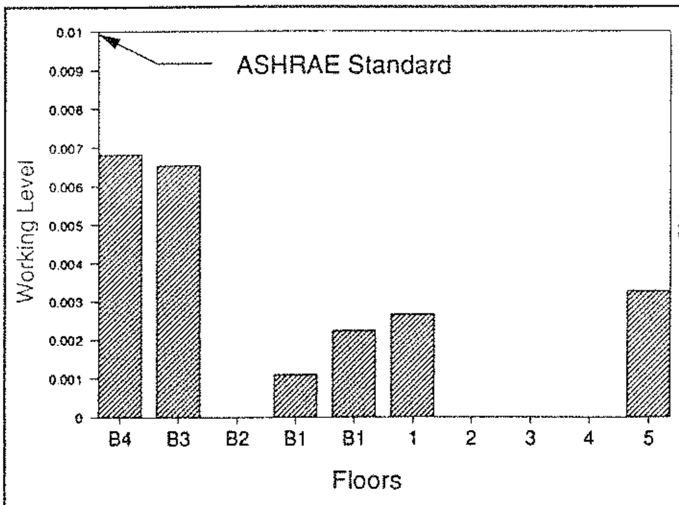

Figure 6 — Working Levels of Radon Daughters

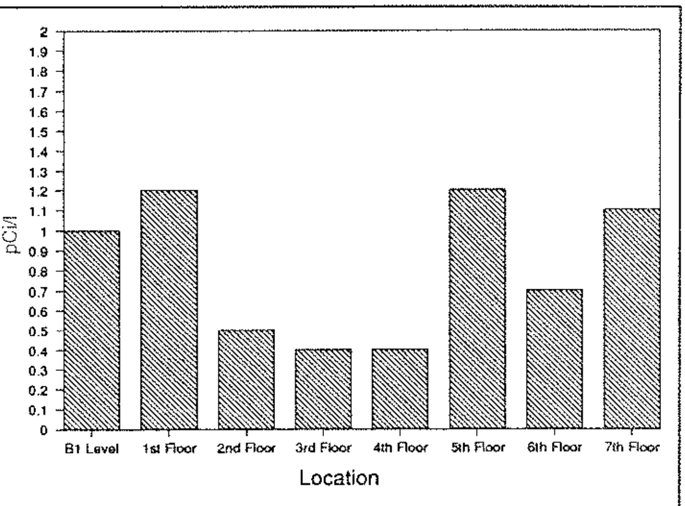

Figure 7 — Radon Levels as Measured with Charcoal Canisters

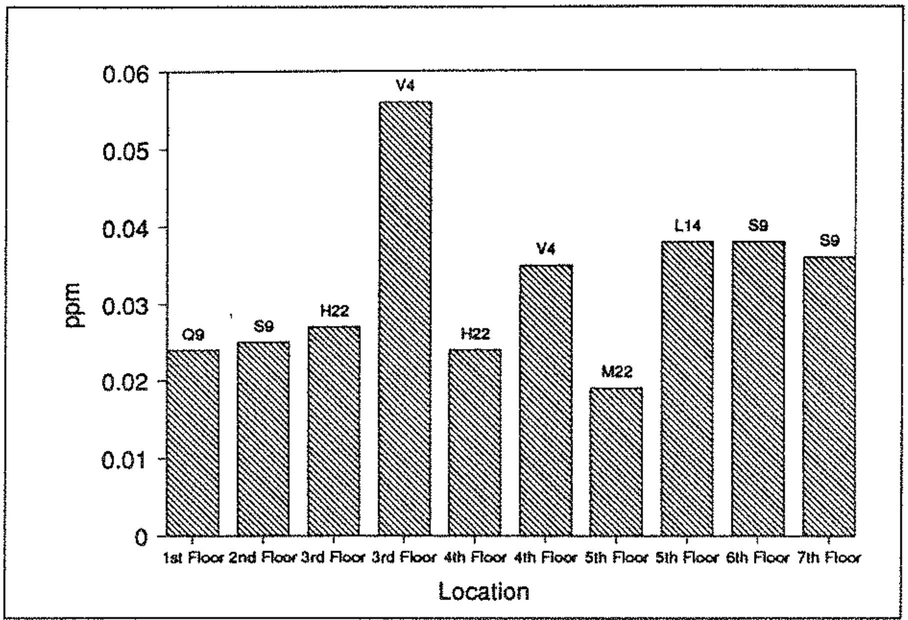

Figure 8 — Formaldehyde Levels in Building

that perfect mixing of air occurs in the indoor environment and that removal mechanisms other than ventilation are neglible. At near steady-state conditions, the source strength, S (mg/hr), of a contaminant equals the product of the ventilated volume (m^3) and the ventilation rate (ACH) times the difference between indoor and outdoor concentrations (C_i - C_o).

$$S = \text{Vol.} \times Q\,(C_i - C_o)$$

$$(\text{mg h}^{-1}) = M^3 \times AC\,H^{-1}\,(\text{mg/m}^3)$$

To facilitate comparison with other buildings, investigators expressed results as specific source strengths: S/V (mg/m^3-h).

Table 1 — Long-term variations in the concentrations and specific source strengths of individual VOC

	CONCENTRATION (ug/m3) *				SP. SOURCE STRENGTH (ug/m3-h)			
Date	8/4/87	10/14/87	1/13/88	10/28/88	8/4/87	10/14/87	1/13/88	10/28/88
Time	20:00	17-19:00	15-17:00	15-17:00	20:00	17-19:00	15-17:00	15-17:00
Vent. Rate	0.5	1.36	0.24	1.99	0.5	1.36	0.24	1.99
COMPOUND								
Oxygenated								
2-Propanol (acetone)	14.8	20.2	137.2	26.5	5.8	21.9	31.6	52.6
2-Propanone	50.1	28.8	66.6	32.4	22.1	27.0	14.9	49.7
2-Butanone	40.9	6.2	15.3	5.7	19.0	2.5	2.0	7.6
Chlorinated								
Dichloromethane	32.4	2.6	13.4	2.7	15.9	1.3	2.7	5.4
1,1,1-Trichloroethane	13.5	13.8	119.7	17.1	5.4	13.6	27.5	27.0
Trichloroethene	16.4	7.2	58.2	14.8	8.2	9.7	11.0	27.6
Aliphatic								
2-Methylbutane	31.9	53.8	81.6	26.2	13.1	31.7	16.1	44.7
n-Hexane	11.3	10.0	24.0	9.2	5.7	6.7	3.7	14.6
Cyclohexane	5.7			2.7	2.4			4.2
n-Heptane	4.8	3.1	12.6	3.6	2.0	2.7	0.2	5.5
3-Methylhexane	6.0	4.0	14.7	3.5	2.4	3.1	0.0	5.2
Methylcyclohexane	5.1			1.7	2.4			2.5
2,2,4-Trimethylpentane	2.4	1.8	8.0	3.0	1.0	1.3	0.7	6.0
1,4-Dimethylcyclohexane	3.1				1.6			
n-Nonane	39.6	10.6	149.1	33.9	19.7	11.4	35.3	63.0
2,2,5-Trimethylhexane	2.4				1.2			
Isopar 2 **	147.0	82.5	638.7	95.4	72.8	104.2	151.7	179.7
n-Undecane	115.6	57.3	831.3	48.3	55.2	71.3	196.8	85.7
n-Dodecane	49.1	10.6	280.8	10.9	21.8	5.9	67.0	17.6
n-Tridecane		6.0	111.9	8.5		5.8	26.2	13.8
n-Tetradecane		36.1	245.3	27.0		43.0	57.9	49.5
Aromatic								
Toluene	60.4	81.3	91.0	33.1	22.7	80.9	13.7	50.2
Ethylbenzene	11.8	7.0	18.7	7.5	5.3	4.9	2.3	11.4
1,2-Dimethylbenzene	17.2	8.7	25.8	8.1	7.6	5.8	4.1	12.0
1,3-,1,4-Dimethylbenzene		18.1	54.5	18.3		11.7	8.8	26.6
1,3,5-Trimethylbenzene	4.1				1.6			
TOTALS								
Sum of Individual VOC	685	470	2998	440	315	466	674	762
Total Organic Carbon	5200	1900	11000	2300	2500	2400	2500	4300

* Average concentration for return-air shafts
** Estimated concentration using n-decane as standard

Long-term VOC Variations

Table 1 shows the measured VOC levels and calculated source strengths by compound during each of the four sampling periods. Indoor levels were generally between five and twenty times outdoor levels. This is consistent with the work of many other investigators.

However, the oxygenated and chlorinated compounds often found at elevated levels in new office buildings were not found at significant air concentrations. And their concentrations did not vary greatly over time. This suggests that the building materials and furnishings were not significant sources of indoor air contaminants in the Portland building.

Investigators discovered that the dominant VOC were aliphatic hydrocarbons. These compounds are found in a common solvent used as a clear dispersant and toner premix for photocopiers and plotters.

The solvent, Isopar G (Exxon Corp.), consists of a mixture of branched alkanes (C_{10} and C_{11}). This chemical was analyzed by GC/MS (gas chromatography-mass spectrometry) and found to contain at least 20 major compounds. The solvent analysis was comparable to that from indoor air samples, although there were unexplained differences in peak areas in the two analyses.

The LBL investigators stated that the light hydrocarbons such as those in Isopar G are considered to have low toxicity. The occupational exposure threshold limit values for exposure to nonane and gasoline are 200 ppm (1050 mg/m^3) and 300 ppm (900 mg/m^3) respectively. The manufacturer's recommended exposure limit for Isopar G is 300 ppm (~1850 mg/m^3).

Table 2 — Concentration of VOC in mechanical system, indoor air and outdoor air on October 28, 1988

	CONCENTRATION (ug/m3)					
	Return Fans			Return		
	East	Center	West	Fan	Floor 5	Roof
Time	15:51	15:16	16:25	Avgerage	15:38	14:42
COMPOUND						
Oxygenated						
2-Propanol	38.8	19.1	21.5	26.5	13.1	0.0
2-Propanone (acetone)	33.9	31.2	32.2	32.4	27.9	7.4
2-Butanone	5.2	5.3	6.6	5.7	5.0	1.9
Chlorinated						
Dichloromethane	2.8	2.7	2.6	2.7	2.0	0.0
1,1,1-Trichloroethane	15.8	18.3	17.2	17.1	15.0	3.5
Trichloroethene	16.0	15.4	13.1	14.8	15.9	0.9
Aliphatic						
2-Methylbutane	30.2	30.2	18.3	26.2	35.8	3.8
n-Pentane	13.2	17.8	11.5	14.2	21.1	2.7
n-Hexane	9.4	9.7	8.4	9.2	10.9	1.8
Cyclohexane	2.8	2.8	2.4	2.7	3.2	0.6
n-Heptane	3.7	3.8	3.3	3.6	3.6	0.8
3-Methylhexane	3.6	3.5	3.3	3.5	5.1	0.9
Methylcyclohexane	1.8	1.8	1.6	1.7	2.0	0.4
2,2,4-Trimethylpentane	3.1	3.1	2.8	3.0	4.4	0.0
n-Nonane	33.2	40.4	28.0	33.9	37.2	2.2
Isopar 1 *	133.6	155.4	134.3	141.1	139.5	7.7
Isopar 2 *	94.5	110.5	81.1	95.4	98.0	5.1
Isopar 3 *	221.1	240.9	198.2	220.1	250.6	11.1
Isopar 4 *	278.5	297.6	248.1	274.8	306.1	13.9
n-Undecane	52.9	47.7	44.5	48.3	56.2	5.3
n-Dodecane	9.9	12.2	10.6	10.9	13.3	2.0
n-Tridecane	7.3	7.6	10.5	8.5	9.5	1.6
n-Tetradecane	28.3	27.4	25.2	27.0	62.3	2.1
Aromatic						
Benzene	15.3	15.0	15.0	15.1	18.7	4.7
Toluene	33.4	34.8	31.1	33.1	41.0	7.9
Ethylbenzene	7.3	7.8	7.3	7.5	7.8	1.8
1,2-Dimethylbenzene	8.2	8.2	7.9	8.1	10.0	2.1
1,3-,1,4-Dimethylbenzene	18.7	18.2	18.0	18.3	24.0	4.9
Methylethylbenzene	11.4	11.1	11.2	11.2	13.6	2.9
1,2,4-Trimethylbenzene	10.6	10.7	10.5	10.6	12.6	2.7
1,4-Diethylbenzene	8.6	8.7	8.5	8.6	9.1	2.1
TOTALS						
Sum of Individual VOC	1153	1219	1035	1136	1275	105
Total Organic Carbon	2348	2537	2061	2315	2163	143

* Estimated concentration using n-decane or n-undecane as standards

Table 2 shows the VOC levels in the mechanical system air, indoor air, and outdoor air on October 28, 1988. Indoor VOC air levels were generally five to twenty times higher than outdoor levels. The results show that aliphatic compounds dominate the measured hydrocarbons.

Investigation of VOC Sources

The researchers investigated copier dispersant and toner premix useage. During a 55-day period, 147 liters were used: an average use of about 2.7 liters or two kilograms per day. Twenty-six copiers and three plotters in the building use this solvent with at least three machines on each floor. While some of the machines are in separate spaces, many are in the open office areas without any special ventilation.

The measured air levels of the toner solvent compounds resulted in a calculated source strength of 2.6 to 4.6 kg/day. The source strength calculations for solvent are in reasonably close agreement with the estimated use of solvent: two kg/day.

It's important that there was close agreement between the results of the investigation into product use and the calculated source strength based on measured air levels. This demonstrates that modelling air levels based on known source strengths is a reasonable approach to predicting estimated air concentrations of VOC. It also suggests the importance and value of source inventories during problem building investigations or during routine building environmental audits.

VOC and Ventilation

Measurements of the total VOC levels (reported as "Total Organic Carbon") during the first few months of occupancy are shown in Figure 9. At the lowest measured ventilation rates of about 0.24 ACH, the VOC levels reached 11 mg/m^3. At 0.5 ACH, VOC air levels were 5.2 mg/m^3, and at 1.36 ACH the VOC concentration was 1.9 mg/m^3. More than a year after initial occupancy, at 1.99 ACH, VOC air concentrations were 2.3 mg/m^3 (not shown on the graph).

There is a direct relationship between ventilation rate and VOC levels when source strengths are constant. However, varying source strengths play an important role. With VOC concentrations dominated by occupant activity-related sources (rather than building materials or furnishings), occupant activity is far more important than ventilation.

At the time of the last sampling period, source strengths were calculated to be much greater than during the three previous VOC sample collection periods. Therefore, the VOC air concentration for the last period falls slightly above the curve plotted in Figure 9. Even so, at this high ventilation rate, the levels of VOC (total and as organic carbon) were still far below the levels when ventilation rates were much lower. This is evidence that adequate ventilation can control VOC even where source strengths are large.

The VOC/ACH Curve Inflection Point

Last month in ***IAQU*** we showed a theoretical curve for the relationship between VOC and ventilation. We said that the inflection point of the curve occurs when ventilation is between 0.6 and 1.2 ACH, depending on the source strengths and sinks. The inflection point is where the slope of the curve changes from a more vertical to a more horizontal line: the point where a tangent to the curve makes a 45° angle with the vertical and horizontal axes.

The results plotted in Figure 9 show a slightly lower inflection point for the Portland East Federal Office Building (around 0.5 ACH). Perhaps this is because the source strengths are fairly small.

The ventilation rate at which the inflection point occurs is important because it tells us when increasing or decreasing ventilation will have a more or less significant impact on VOC levels. At ventilation rates below (to the left of) the inflection point, a small increase in ventilation produces a larger decrease in VOC levels than at ventilation rates above (to the right of) the inflection point.

It is important for building owners and operators to know where their building falls on this curve. This knowledge will help them make economically sound decisions about increasing ventilation in response to complaints or decreasing ventilation to reduce energy consumption. Building designers must consider this factor in developing the design assumptions regarding ventilation system capacity and minimum outside air supply rates.

In many cities, it is important to know when outside air reductions are necessitated by high outdoor CO levels. Under the ASHRAE ventilation standard (62-1981 as well as 62-1981R), building

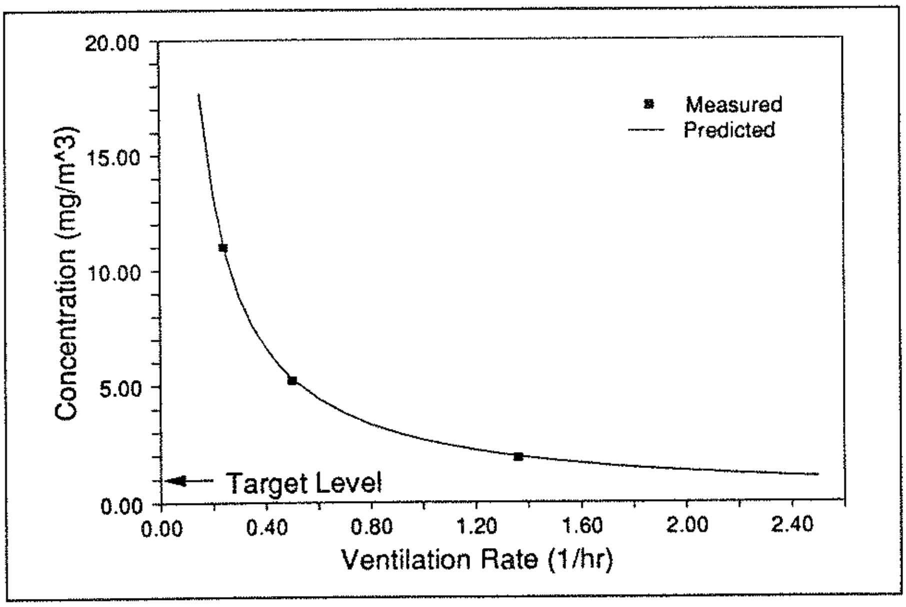

Figure 9 — Total Organic Carbon vs. Ventilation Rate

operators may reduce outside air ventilation during elevated CO periods in order to avoid contaminating indoor air. This is because the requirements to clean outdoor air supply to meet ambient air quality standards do not apply in cases where feasible technology is not available. In these cases, regulations allow reduced outdoor air supply instead.

VOC and Their Sources

Table 1 shows the "Total Volatile Organics" by chemical group and compound on four different days. It gives measured concentrations and calculated source strengths for each day with the measured ventilation rates.

Off-gassing of construction materials and furnishings do not appear to be a major source of airborne VOC. Even though researchers monitored the building within a few weeks after construction was completed and while move-in was still occurring, the VOC levels were not remarkably higher during the initial monitoring. According to Al Hodgson of LBL, liquid-process photocopiers and plotters are the most likely sources of the VOC measured there.

Table 2 shows VOC concentrations at various locations in the building and in outside air during the October 28, 1988 monitoring. For most compounds, air concentrations did not vary significantly from one location to another. This suggests that air was fairly well mixed throughout the building, at least when outside air supply was near its maximum level.

Figure 10 graphically illustrates that source strengths were fairly consistent throughout the four sample collection days and that differences in airborne concentrations were primarily a function of ventilation differences.

Conclusions and Implications

We are impressed with how much NIST's work tells us about building design, operation, and use effects on indoor air quality. Following are some of our conclusions about the implications of this work.

Design implications

Designers must separately ventilate and exhaust directly outside all liquid process copiers, plotters, and other devices which are known sources of indoor air contaminants.

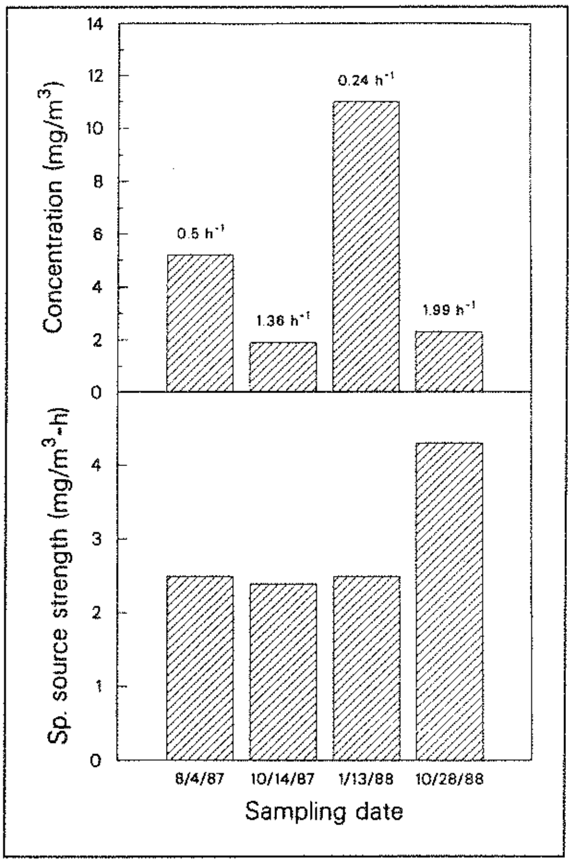

Figure 10 — Long-term Variations in the Concentration and Specific Source Strength of TOC. Ventilation rates are shown above the concentration bars.

If building materials and furnishings are reasonably well selected, conditioned, or treated to control their emissions, then the major challenges for designers will be the following:

- Controlling sources from outside the building (outdoor air quality sensors and control to initiate air cleaning when outdoor air becomes dirty);
- Cleaning and filtration where practical and as required, and modulating outside supply air volumes when outdoor contaminants exceed permissable levels for contaminants for which air cleaning is not practical;
- Developing methods to monitor and clean recirculated air when outdoor air supply is reduced;
- Designing ventilation system air distribution to effectively remove contaminants generated by occupant activities at the source;
- Developing methods and procedures for building management and occupants to identify and control contaminant sources related to occupant activities;
- Designing buildings, including parking garages, that carefully protect vertical shafts from vehicle exhaust fumes. Controlling garage CO levels may not

be adequate to protect occupants in office spaces from unacceptable levels.

Investigation implications:

- Identify all significant indoor activities involving the use of VOC sources. Determine the chemical composition of the sources and evaluate their potential toxicity or irritation effects on occupants.

- Locate sampling devices so they are not overly affected by known sources. Be sure to characterize worst-case and typical occupant exposures based on known sources. This involves both the proper location and timing of sample collections.

Investigating VOC Sources

Investigating source strengths is a valuable tool for characterizing indoor air contaminants. Based on copier and plotter solvent use, we can reasonably predict that air levels of the solvent compounds will be significant.

Analyzing of a liquid sample prior to an air sample would allow investigators to identify appropriate sampling methods and strategies for the expected compounds. Air samples would serve to confirm the source inventory. Control recommendations would be more fully justified because of the close relationships between solvent use, air levels, and ventilation rates.

- When investigators begin a study of an alleged air quality problem in an office building, we recommend that an inventory of major activities include all supplies regularly purchased for use in the building. This should include office products, printing, mailing, and duplicating materials, etc. It should also include any graphics materials including art supplies, photographic supplies, etc. Particular attention should be paid to any laboratory activities.

- Source strength calculations should be made and a simple air quality model should be used to predict indoor air concentrations. Such calculations will be accurate enough to provide first-order estimates of air quality.

For More Information

Contact: Richard A. Grot, NIST, Gaithersburg, MD 20899; (301)975-6431, or Alfred T. Hodgson, Indoor Environment Program, Lawrence Berkeley Laboratory, Univ. of California, Berkeley, CA 94720; (415)486-5301.

Richard A. Grot, Andrew Persily, Alfred T. Hodgson, and Joan M. Daisey, "Environmental Evaluation of the Portland East Federal Office Building Preoccupancy and Early Occupancy Results." Report NISTIR 89-4066. Gaithersburg, MD: National Institute of Standards and Technology. April 1989.

Available from National Technical Information Service (NTIS), Springfield, VA 22161. Price: $12.95.

A. T. Hodgson, J. M. Daisey, and R. A. Grot, "Source Strengths and Sources of Volatile Organic Compounds in a New Office Building." LBL-26950. To be presented at Air and Waste Management Association, 82nd Annual Meeting, June 25-30, Anaheim, California. Paper 89-80.7. ♦

News and Analysis

ASHRAE Ventilation Standard

ASHRAE Standard 62-1981R is expected to be adopted by the Board of Directors during its meetings in Vancouver this month. If that is the case, it will be in print by late this summer: probably about mid-August. Watch *IAQU* for news of the release and related events. ♦

Forum on IAQ Issues

Implementation of the new ASHRAE ventilation standard will be one of the featured topics at "IAQ Update '89," a forum on current issues in the practical control of indoor air quality to be held in Washington, D.C., September 25-26, 1989. See the insert in this issue, or call the publisher for more information: Cutter Information Corp., (617)648-8700. ♦

Lead Paint Law Suit: Another Asbestos?

On June 8, New York City sued five manufacturers of lead paint pigment. According to a story in *Indoor Pollution News*, the suit seeks $50 million in damages for abatement of lead paint in city-owned buildings. The city is trying to hold companies liable for lead paint removal costs and treatment of victims.

This sounds like many of the lawsuits concerning asbestos in schools and public buildings filed by public entities around the country in recent years. The theory is that the manufacturers knew of the hazards, yet they continued to produce and market the products. Cities, states, and school boards have individually and jointly filed law suits seeking damages related to the costs of abatement of asbestos hazards in schools and other buildings.

The article quoted a prepared statement from New York Mayor Ed Koch: "If we have the right to demand that Exxon pay the price for cleaning up the environmental disaster it caused in the Gulf of Valdez, we also have the right to demand that the lead pigment industry cleans up the environmental catastrophe they have caused in buildings throughout our city and other urban areas. As our landmark suit suggests, for years the industry knew of the dangers of lead paint and deceived and endangered the American public."

According to the suit, the industry knew of the hazards of lead paint, including those posed to children, as early as the mid-19th century. The suit also asserts that the defendants suppressed research, testing, regulation, and public dissemination of information on the paint's toxic properties. Nontoxic pigments such as zinc oxide were available as commercial substitutes by 1900. As early as 1933, the Lead Industries Association knew exposure to lead pigment was harmful and recommended that lead paint not be used on toys and children's furniture.

The city claims it has spent more than $15 million in the past six years dealing with lead paint hazards. The City Department of Housing, Preservation and Development spent more than $7 million abating lead paint hazards in publicly and privately owned residential buildings. The city Human Resources Administration has spent $1.6 million abating lead paint in its facilities that include children's programs.

This may be the first of many similar lawsuits around the country, particularly if New York has any degree of success in recovering some of the substantial expenditures related to lead hazards. It will also alert manufacturers of other building materials and products regarding information they may possess on the potential hazards of their products.

Reference: New York City v. Lead Industries Association Inc., New York Superior Court, New York City, NY, filed June 8, 1989. ◆

Conference Report

Bioaerosols in the Indoor Environment

At the American Industrial Hygiene Conference (AIHC) in St. Louis in May, Phil Morey shot down many popular myths about bioaerosols in indoor air. In presenting a comprehensive paper to an audience of nearly a thousand people, Morey summarized his years of experience investigating problem buildings with a special focus on bioaerosols. That presentation and his written paper are extremely useful overviews of the subject. With bioaerosols receiving more attention recently, his paper is timely and valuable.

Last month, we described Morey's paper (from ASHRAE's IAQ '89) on his recent office investigations. The most important finding from that paper was that airborne measurements alone are inadequate indicators of bioaerosol contamination indoors.

The Magic Number

Many people have used the number 1000 colony-forming-units per cubic meter (cfu/m^3) as a guideline for acceptable bioaerosol levels in indoor air. The article in last month's ***IAQU*** and his presentation at the AIHC meeting make it clear that Morey does not believe such numbers alone are reliable indicators of indoor air quality.

In particular, Morey criticizes those who, he alleges, have misquoted or misinterpreted his 1984 paper, "Environmental Studies in Moldy Office Buildings" (see reference at end of this article). He read a portion of his 1984 paper in an attempt to clarify the record on his views. Referring to a number of publications reviewed in that paper, Morey wrote:

"These literature citations collectively suggest that a level of viable microorganisms in excess of about 1×10^3 viable particles per m^3 indicates that the indoor environment may be in need of investigation and improvement. However, this is not to say that the air is unsafe or hazardous. Illness in the workplace can only be determined by medical or epidemiological studies."

Morey emphatically stated that 1,000 viable particles per cubic meter of air is not a guideline; it does mean that investigation is warranted. Morey believes that levels far lower than 1,000 cfu/m^3 can cause illness and that levels above that can be found without illness. He illustrated his view by citing a case study in which verified humidifier fever was diagnosed with less than 50 cfu/m^3. He believes that nonviable organisms can also cause discomfort or allergic reactions.

Bioaeresol Sampling Methods

Morey told the audience that sampling methods that use settling plates or surface sample collection

TABLE 3 — Potential Microbial Contaminants in Ventilation Systems that may be Associated with the Perception of Poor Air Quality

Mechanical System Component	Nature of Contamination
Outdoor air intake	Emissions from sanitary vents and bioaerosol sources such as cooling towers and decaying leaves. Occupants express dissatisfaction because of odor annoyance. Complaints may be sporadic because of variables such as wind direction and percent of outdoor air being used by the HVAC system.
Dust cake on filter bank of air handling unit	Organic materials in dust cake offer a substrate for growth of microorganisms if relative humidity exceeds 70 percent.
Manmade insulation in air handling units and fan coil units	The ventilation air in these units is exposed to microbial amplification sites especially where insulation is near or downstream of cooling coils. Potential source of "megaolfs."
Stagnant water in drain pans and sumps	The ventilation air passes over niches where microorganisms may amplify. The potential for emissions of odors from microorganisms and disinfectants is great.
Fan coil units and induction units	Dust and debris accumulate within these units. Microorganisms may amplify in these units when moisture is available (for example during the air-conditioning season).

are "almost worthless." For bioaerosol sampling, he suggests consulting the recently published review of sampling and analytical procedures by Burge and Solomon. These are especially applicable to IAQ studies (see references at end of this article).

For a review of the principles of sampling and analysis for microorganisms, he recommends the ACGIH Air Sampling Instruments Manual. For collection and analysis of microbial particulate, Morey recommends the protocol being developed by the ACGIH Bioaerosols Committee published in *Applied Industrial Hygiene* (see references).

Interpreting Bioaerosol Sampling Data

Morey says that at present there are no numerical standards or guidelines for bioaerosol exposure indoors. He also believes that none are likely to be available in the foreseeable future. In his paper, he presents a series of reasons for this.

Morey recommends that bioaerosol sampling data be interpreted using the following parameters:

1. Rank ordering of the kinds of microorganisms present in the indoor environment and in outdoor air.
2. Indoor/outdoor concentration ratios of microbial agents found in indoor and outdoor air.
3. Medical or laboratory evidence that an infection or allergy is caused by a kind or kinds of organisms.
4. The concept that microorganisms occur in reservoirs and "amplifiers" and must be disseminated to the occupants' breathing zone to cause illness.

Controlling Microorganisms in Indoor Environments

Morey said that the most effective way to control microorganisms indoors is to limit the availability of water and nutrients. The major causes of microbial contamination in office buildings include the following:

1. Inadequate maintenance of ventilation systems.
2. HVAC designs which ignore maintenance requirements.
3. Porous man-made insulation in HVAC systems.
4. Excessive humidity and floods in the occupied spaces.
5. Outdoor air intakes located near external bioaerosol sources.

Table 3 lists some of the major bioaerosol problems encountered by Morey. Cooling towers and evaporative condensers present special problems. They must be controlled through the application of biocides together with the use of corrosion and scale inhibitors.

Air washers or sump-type humidifiers require fastidious control strategies. Chemical biocides are not recommended because of the potential toxic effect on occupants. Therefore, great care must be taken: for example, the use of deionized water and daily cleaning.

For More Information

Contact: Phil Morey, Clayton Environmental Consultants, 151 S. Warner Road, Suite 235, Wayne, PA 19087; (215)688-4080.

Philip R. Morey, 1989. "Bioaerosols in the Indoor Environment: Current Practices and Approaches." Clayton Environmental Consultants, Wayne, PA.

P. Morey, et al, 1984. "Environmental Studies in Moldy Office Buildings," in *Evaluating Office Environmental Problems.* Annals of the American Conference of Governmental Industrial Hygienists (ACGIH), Volume 10. Cincinnati: American Conference of Governmental Industrial Hygienists. pp. 21-36.

H. Burge and W. Solomon, 1987. "Sampling and Analysis of Biological Aerosols." *Atmospheric Environment*, Vol. 21, pp. 451-456.

H. Burge et al, "Guidelines for Assessment and Sampling of Saprophytic Bioaerosols in the Indoor Environment." *Applied Industrial Hygiene*, Vol 2: R10-R16 (1987).

Reminder

Symposium on Biological Contaminants in Indoor Environments, July 16-19, 1989, Boulder, Colorado. Phil Morey is co-chairman (along with Jim Feeley of Atlanta) of this conference, which promises to be the benchmark for the subject for the near future. There may still be registration space available. See the Calendar listing at the end of this newsletter for details. ♦

On the Horizon

How to Measure CO_2

A debate is looming on the issue of CO_2 measurements for ventilation rate measurement. At the AIHC meeting in St. Louis last month, Gyan Rajhans of Canada presented the view that CO_2 measurements can be used to obtain ventilation rates when occupancy levels are known. Others are disputing the reliability of this method. Tracer gas advocates often claim that CO_2 cannot reliably measure ventilation rates.

The debate is complicated by the fact that while some researchers use detector tubes for the measurements, others consider them unreliable or inaccurate. We have asked readers for comments on the detector tubes versus direct-reading instrument methods but as yet have received none. If you have done surveys in which you have used both, either side-by-side or otherwise, we would like to hear from you. We would be especially interested in any comparison data or other light you can shed on the controversy.

Practical Research Briefs

Characterization of Environmental Tobacco Smoke

The respected research journal *Environmental Science & Technology (ES&T)* has published three assessments of the constituents of environmental tobacco smoke (ETS) in its May and June issues. Some of the results from the May article are summarized in Table 4.

We calculated the emissions of ETS for the U. S. population using the assumption of 50 million smokers smoking one pack of cigarettes per day. This results in one billion cigarettes smoked per day. Multiplying some of the yields reported in the *ES&T* article times one billion, we get 1.1 million pounds of benzene and 4.4 million pounds of formaldehyde.

Reference: Lofroth et al, "Characterization of Environmental Tobacco Smoke," *Environmental Science and Technology*, May 1989, Volume 23, pages 610-614. ♦

Table 4 — Selected Airborne Contaminant Yields from Cigarettes in Controlled Chamber Studies

Contaminant	Average airborne yield/ cigarette ($\mu g/m^3$)
ethene	1200
ethane	1600
propene	1300
propane	830
1,3-butadiene	400
isoprene	3100
benzene	500
formaldehyde	2000
acetaldehyde	2400
acrolein	560
total suspended particulates	10,000

Formaldehyde Levels in Fabric Stores

Researchers from the University of Houston and from NASA conducted a survey of formaldehyde levels in fabric stores for the Bureau of Occupational Health in Houston. They did the survey because they believed the formaldehyde levels in fabric stores might approach the OSHA action level. The mean formaldehyde level in all Houston area fabric stores sampled was 0.14 ppm with a standard deviation of 0.07 ppm. The ASHRAE guideline for formaldehyde indoors is 0.1 ppm.

There were differences in the levels found in various stores attributed to ventilation, cloth type, and air movement.

Formaldehyde is used in permanent press systems, which cross-link cellulosic fibers and impart rigidity to textiles. The dominant permanent press systems are methyloamides, which break down and release formaldehyde. Present levels of formaldehyde — about 300 µg of formaldehyde per gram of cloth — are approximately 10% of what they were in 1975. Nonetheless, formaldehyde levels can still be elevated in fabric stores.

Exposure and Symptoms

A symptom questionnaire survey was administered to employees in the surveyed stores. Two groups were established: those with exposures of 0.13 ppm or above and those with exposures less than 0.13 ppm. Employees in the higher-level group responded positively to 38 of 46 questions. Significant response differences were found for 18 of 46 questions. In all significant cases, the high-exposure group responded more symptomatically. These questions indicated a clear dose/response relationship.

In the high-exposure group, 27% of the employees reported eye irritation, while only 10% percent of the low-exposure group reported this symptom. Irritation of the nose or throat was reported by 26% of the high-exposure group and 20% of the low-exposure group.

For More Information

Contact: Matthew McGuire, City of Houston, Department of Health and Human Services, 7411 Park Place Blvd., Suite 200, Houston, TX 77087.

Reference: Matthew McGuire and Dennis Casserly, "Formaldehyde Levels in Fabric Stores." Presented at the American Industrial Hygiene Conference, St. Louis, Missouri, May 21-26, 1989. ♦

Perceived Air Quality and the Thermal Environment

The reactions of building occupants to indoor air quality are consistently influenced by temperature and humidity. Air is rated fresher and less stuffy with decreasing temperature and humidity. The effect of temperature is stronger than that of humidity within the comfort range normally encountered in conditioned buildings.

Researchers from John B. Pierce Foundation at Yale University studied 20 subjects in 27 different hour-long tests. The test conditions consisted of combinations of three temperatures, three humidities, and three metabolic rates. The experiment's purpose was to study small differences in responses.

The results reflected a remarkable set of consistent and repeated responses. Additionally, within the experiment, judgments of perceived freshness-staleness and stuffiness were nearly identical. The researchers considered them interchangeable.

Judgments about humidity were consistent with actual conditions, even when temperature was varied within the test conditions' range of 70 to 81° F. At RH 65%, occupants expressed strong dissatisfaction with air quality.

A one-degree change in air temperature had the same effect as a six degree change in the dew point temperature. The increase in dew point from 52°F to 68°F proved more salient than the increase from 36°F to 52°F.

Implications

We have frequently advised building owners and operators to run HVAC systems at the lowest comfortable temperatures to control IAQ problems. In newly constructed or newly renovated buildings, emissions of VOC from building materials and furnishings will be minimized at lower temperatures. Berglund and Cain have now shown that occupants' perceptions of air quality will improve as temperature decreases.

Of course, reducing temperature or humidity is no substitute for effectively controlling sources and providing outside air ventilation. Once those steps are taken, building operators can adjust temperature and humidity to improve occupants' perceptions of air quality and reduce occupant complaints.

For More Information

Contact: Larry Berglund, John B. Pierce Foundation Laboratory, Yale University, New Haven, CT.

Reference: Larry Berglund and William Cain, "Perceived Air Quality and the Thermal Environment." Presented at ASHRAE IAQ '89, San Diego, California, April, 1989. Available in the Conference Proceedings, when published. See following article for update. ♦

Information Exchange

IAQ '89 Conference Proceedings

ASHRAE had originally hoped to get the proceedings of this meeting into print by July 1. However, the publication has been delayed and is not expected until later this summer. Contact ASHRAE Publications in Atlanta for the latest projection, or watch *IAQU* for news of publication. ASHRAE, 1791 Tullie Circle NE, Atlanta, GA 30329; (404)636-8400. ♦

Significance of Fungi in Indoor Air

"Significance of Fungi in Indoor Air: Report of a Working Group," is the title of an article published in the March/April issue of the *Canadian Journal of Public Health.* Published in both English and French, the 14-page report is a comprehensive overview of the subject.

Topics include the following:

- Methods of collecting and quantifying of fungi;
- Toxigenic potentials of fungi;
- Volatile chemicals produced by fungi;
- Nonvolatile chemicals produced by fungi;
- Other indoor organisms (bacteria, mites);
- Health implications;
- Assays to test for potential to cause ill effects. ♦

Call for Papers

The American Association of Radon Scientists and Technologists (AARST) has issued a call for papers for The Third Annual AARST Radon Conference. The title of the conference is "The Radon Industry — A New Beginning." It will be held October 15-17, 1989, in Ellicott City, Maryland (just outside Baltimore).

The call for papers says: "Abstracts should convey in 150 words maximum the essence of the intended paper, indicating clearly the contribution it will make. Most papers should provide study results, but theoretical discussions of concepts and mechanisms may also be submitted. Abstracts will be screened by sessions chairpersons and specific papers will be solicited to cover areas of special concerns."

Abstracts are due July 1, 1989, which will give readers virtually no time to spare. If you wish to present a paper, you should contact AARST for details: AARST, Mid-Atlantic Chapter, 1916 Grayslake Drive, Silver Spring, MD 20906. (301)598-4008 ♦

Calendar

North America

September 25-26. **IAQ Update: '89: A Forum on Current Issues in the Practical Control of Indoor Air Quality**. Mayflower Hotel, Washington, D.C. Sponsored by ***Indoor Air Quality Update.*** Contact: Kim Gay, Cutter Information Corp., 1100 Massachusetts Avenue, Arlington, MA 02174; (617)648-8700, fax (617) 648-8707.

October 8-13. **American Association for Aerosol Research, Eighth Annual Meeting.** John Ascuaga's Nugget Hotel Casino, Reno/Sparks, Nevada. Contact: Ms. Chloe Smith, American Association for Aerosol Research, Center for Aerosol Technology, Research Triangle Institute, P. O. Box 12194, Research Triangle Park, NC 27709-2194; (919)541-6736. The program includes plenary lectures, symposia, technical sessions, and tutorials as well as an exhibit. The symposium on Indoor Air Quality and Radon has 50 papers in the fields of measurement, control, sources, transport and deposition of viable and nonviable particles in the indoor environment. Twenty-nine of the papers are on radon.

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

October 15-17. **Third Annual AARST Radon Conference: The Radon Industry -- A New Beginning.** Ellicott City, Maryland. Contact: AARST, MidAtlantic Chapter, 1916 Grayslake Drive, Silver Spring, MD 20906; (301)598-4008

October 16-19, 1990. **"Indoor Radon and Lung Cancer: Reality or Myth?" 29th Hanford Symposium on Health and the Environment.** Richland, Washington. Sponsored by the U.S. Department of Energy and Battelle, Pacific Northwest Laboratories. Inquiries should be addressed to Fred T. Cross, Symposium Chairman, Battelle PNL, P. O. Box 999, Richland, WA 99352; (509)375-2976.

November 6-7. **Radon in Buildings: Sources, Biological Effects, Monitoring, & Control.** Boston, Massachusetts. Contact: Harvard School of Public Health, Office of Continuing Education, Dept. A, 577 Huntington Avenue, L-23, Boston, MA 02115; (617)732-1171.

November 13-17. **Indoor Air Quality Diagnostics Professional Training Course.** Golden Valley, Minnesota. Contact: Honeywell Indoor Air Quality Diagnostics, MN10-1451, 1985 Douglas Drive North, Golden Valley, MN 55422-3992; (612)542-6488; or (800)232-4637.

November 27-30. **Total Exposure Assessment Methodology: A New Horizon.** Tropicana Hotel, Las Vegas, Nevada. Sponsored by U. S. Environmental Protection Agency, Air and Waste Management Association. Contact: Dan Denne, Air and Waste Management Association, P. O. Box 2861, Pittsburgh, PA 15230. *There will be training courses on "human sampling" and on "personal exposure monitoring and quality assurance." Technical sessions will include multi-media/multi-pollutant exposures, implications of exposure and dose in health effects studies, TEAM and microenvironmental field studies, and others. The conference is designed for scientists and regulatory managers.*

INTERNATIONAL

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

September 11-15. **Clean Air 89 — 8th World Clean Air Congress and Exhibition.** The Hague, The Netherlands. International Union of Air Pollution Prevention Associations (IUAPPA). Contact: 8th World Clean Air Congress, Netherlands Congress Centre, P.O. Box 82000, 2508 EA Den Haag, The Netherlands. *The theme of the congress is "Man and His Ecosystem." Three sessions are scheduled on the human aspects: health, psycho-social effects, and education. Two sessions are scheduled on indoor air: one on occupational health, the other on air quality in public buildings, the home, and the car. There are also sessions scheduled on monitoring, air pollution chemistry, instrumentation, policy issues, economic aspects, and several other topics. An extensive exhibition program is also planned.*

October 16-20. **The Sick Building Syndrome.** Nordic Institute of Advanced Occupational Environment Studies (NIVA), Copenhagen, Schafergarden, Denmark. Contact: NIVA, c/o Institute of Occupational Health, Topeliuksenkatu 41 a A SF-00250 Helsinki, Finland, tel 358-0-47471. *This course has very limited enrollment.*

June 13-15, 1990. **Roomvent '90, Second International Conference on "Engineering Aero- and Thermo- dynamics of Ventilated Room."** Oslo, Norway. Contact: Room Vent, c/o Norsk VVS Teknisk Forening, P.O. Box 5042, Maj N-0301 Oslo, Norway.

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

Watch your mail...

In a week you will receive a Conference Information Pack for ***IAQ Update '89: A Forum on Current Issues in Practical Control of Indoor Air Quality.*** *In it you will find complete details on the conference agenda and participants.*

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