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Source Control Versus Ventilation: Is There a Choice?

Increasing attention to indoor air quality (IAQ) has stirred up controversy among professionals, regulators, and affected industries regarding how best to control IAQ. Some observers in the U.S. see the policy and professional IAQ control options as "source control versus ventilation." However, both are essential ingredients of an effective strategy.

This is true in the design of a building, the remediation of an IAQ-related complaint, and in the formulation of national policy and research directions. Source control is the first and most effective strategy and should be used as much as possible. Having done that, ventilation should be used to dilute and remove contaminants generated indoors.

As IAQ gains more attention from building owners, occupants, designers, and the construction industry, the providers of building products and services want to present their role in the most positive light. Manufacturers of products that are sources of indoor air contaminants have tried to focus attention away from their own products' contributions and towards other causes of poor IAQ. (See *Indoor Air BULLETIN*, May 1991.)

Many of these manufacturers stress ventilation over source control rather than acknowledging the need for both. This has led to the framing of the so-called "building systems approach" that focuses on ventilation both as the control option of choice and, at times, the very cause of IAQ problems. We discussed the "building systems approach" in the May 1991 issue of the *BULLETIN*. In this issue, we will focus on some of the efforts to assess sources of contaminants.

To Test or Not to Test

In Washington, D.C., controversy has recently arisen around provisions in the Indoor Air Quality Act of 1991 (HR 1066). Congressional committees are debating including emissions testing requirements for all construction materials, finishes, and furnishings used in buildings for federal government agencies. Such a provision would create a burst of testing activity.

Federal government construction constitutes a very important fraction of building construction in the United States. If manufacturers want their products used in government buildings, they will have to test them and report the results. This will make testing standard practice.

If the testing provisions are adopted and implemented, manufacturers will be responsible for the testing. Perhaps even more significant, we believe, manufacturers would become more accountable for the impacts of their products on IAQ. Designers and specifiers would gain access to testing results and could rely more completely on the manufacturers to ensure the suitability of their products. The testing requirement would leave manufacturers with no excuses of ignorance if harmful emissions from the products caused IAQ problems.

Inside This Issue:

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In this issue, we discuss several emission measurement studies. Some of these include both chamber testing and field studies. These and other studies show that chamber test data are useful to model concentrations in building environments. There are still many questions to answer before chamber testing can be standardized for the range of products used indoors and their results can be interpreted unequivocally. However, substantial progress has been made toward developing the necessary knowledge to perform the reproducible tests and to reliably interpret their results.

Chamber and Field Tests

Evaluating Paint Emissions of Mercury

Mercury emitted from latex paints is a hazardous indoor air contaminant; public health officials have documented poisoning from mercury emissions. In this article, we discuss a field study of mercury emissions and some laboratory measurements. The results, obtained by several different researchers, indicate that environmental chamber emissions tests can indeed produce reasonably accurate predictions of indoor air concentrations.

Until recently, many U.S. paint formulators added organic mercury to latex paint as an in-can preservative. In June, 1990, EPA made a voluntary agreement with paint manufacturers to allow the use of mercury only in exterior paints. While this should eliminate the hazards presented by mercury emissions from interior paint, products manufactured prior to the effective date of the ban (August 1990) are still on the shelf. Also, some individuals may apply exterior paints indoors.

Exterior latex paint may still contain mercury at concentrations up to 2,000 milligrams per liter (mg/L). The mercury kills mildew after application. Unfortunately, unaware painters and others sometimes use exterior paint indoors for its preferred performance qualities. It's also legal to sell and use consolidated recycled paints that contain less than 200 mg/L of mercury for interior applications.

Field Studies

Center for Disease Control and Ohio Department of Health researchers measured mercury in the air of 37 Columbus, Ohio, homes. (Beusterian et al., 1991) 21 of the homes had been painted within the preceding five months with paint containing more than 50 mg/L mercury. 16 were unexposed homes: not painted within the past 18 months. The measurements showed that even interior latex paint containing less than 2/3 of the EPA mercury concentration limit of 300 mg/L could produce mercury air concentrations exceeding the recommended maximum air level of 0.5 micrograms per cubic meter ($\mu g/m^3$). That level was established by the Agency for Toxic Substances and Disease Registry (ATSDR) in 1988. One home painted with paint containing less than 200 mg/L had an air mercury concentration of 1 $\mu g/m^3$.

The median mercury content of the paint used in the exposed homes was 210 mg/L (range 120-610 mg/L, P 0.0001). Three samples of a paint used in three of the homes contained mercury concentrations above 300 mg/L. The median measured air concentration was 0.3 $\mu g/m^3$ (range: non-detectable - 1.5 $\mu g/m^3$, P 0.0002). The median was non-detectable in unexposed homes (range: non-detectable - 0.3 $\mu g/m^3$). Six of the exposed homes had air mercury concentrations greater than 0.5 $\mu g/m^3$.

No correlation was found between paint mercury concentrations and total air concentrations. The time since a home was painted and air mercury concentrations had a negative correlation -0.37 (P = .06). Occupants reported the number of hours windows were open and the amount of paint used. However, researchers did not find these data significant predictors of air mercury concentrations. The authors speculated that the lack of correlation between mercury in air and open-window-hours might be because occupants' reports are poor substitutes for actual ventilation measurements.

CDC researchers also studied Michigan homes one month after painting. They measured a median mercury air concentration of 2.0 $\mu g/m^3$ (Agocs et al, 1990). The paints contained a median mercury concentration of 754 mg/L. These researchers reported that having windows open more hours daily reduced mercury air concentrations.

EPA Emissions Measurements

Bruce Tichenor of EPA's Office of Research and Development presented test results of mercury emissions from paints at the Annual Air and Waste Management Association (A&WMA) -EPA Symposium on Measurement of Toxics and Related Air Pollutants. The results provide emission factors and decay rates for mercury emitted from latex paints, the effect of light on mercury emission rates, and the differences between organic and inorganic mercury emissions. Tichenor's report showed

that emissions are complex processes and require much detailed study in order to be reliable predictors. He also showed that different measurement methods produce significantly different results, although they correlate well.

The Tests

The tests were conducted under dynamic conditions for 96 hours in the 53 liter electro-polished stainless steel chambers that EPA uses for many emissions tests. Five sheets of gypsumboard were each coated with one layer of a latex paint. Each paint contained one of four mercury additives. The four additives were PMA - phenyl mercuric acetate, PMDS - di(phenyl mercury) dodecenyl succinate, PMO - phenyl mercuric oleate, and CMPA - chloromethoxy propyl mercuric acetate. Researchers tested in both dark and light conditions in order to evaluate the effect of light on the mercury emissions.

To obtain total mercury values, vapor-phase mercury samples collected on hopcalite were analyzed as inorganic mercury by cold-vapor atomic absorption spectroscopy (AAS). Three of the paints were also tested for volatile organic and inorganic mercury using graphitized carbon collection. Researchers used AAS to determine mercury concentrations in liquid samples of the paints they collected at the same time the chamber tests were conducted. Chamber conditions for the tests were 25°C, 1 air change per hour (ACH), and 50% relative humidity (RH).

Results

Table 1 shows the test results. Mercury concentrations in the paints varied from 93 to 1060 ppm. Measured emissions varied from 3.7 to 112 mg/m^2 representing an emitted fraction ranging from 12 to 57%.

Figure 1 shows the decay curve Tichenor and Guo fitted to the mercury concentration data from sample #6 above, a CMPA-containing paint. The data show that for a paint containing only 114 mg/L mercury, several hours are required to reduce a concentration below the recommended level. The mercury emissions followed a pattern of high initial emissions followed by slow decay. These authors compared the data from the Detroit study to predictions based on their measurements of paint #1 (744 mg/L mercury) in Table 1 below. The comparison is shown in Figure 2. (Note the logarithmic scale for mercury concentration.) It took nearly a year for the measured air concentration, and somewhat less for the predicted air concentration, to decrease to the ATSDR maximum recommended concentration (0.5 μg/m^3) in the painted room. Even the rest of the house required several weeks, according to the prediction, to decrease to the ATSDR-recommended level.

Conclusions

Tichenor and Guo concluded that light did not appear to affect emissions in any except one case; emissions were predominantly inorganic mercury; and, emission rates did appear to be affected by the type of mercury additive used.

Sample	Mercury additive	Mercury in paint (ppm)	Paint Applied (g/m^2)	EF$_0$**	Mercury emitted (mg/m^2)	Mercury applied (mg/m^2)	Mercury fraction emitted(%)
1D*	PMA	744	201	2670	53	149	36
1L*		744	205	2810	51	153	33
2D	PMA	1060	201	177	62	213	29
2L		1060	207	179	66	219	30
3D	PMA	1011	190	140	99	192	52
3L		1011	193	126	112	195	57
4D	PMDS	93	176	68	9.0	16	56
4L		93	187	70	9.7	17	57
5D	PMO	839	140	80	14	117	12
5L		839	133	119	14	112	13
6D	CMPA	114	177	45	3.7	20	19
6L		114	204	74	6.7	23	29

* D = tested in the dark L = tested under lights ** EF = emission factor (in μg/m2-hr)

Table 1 - Mercury Concentration Test Results

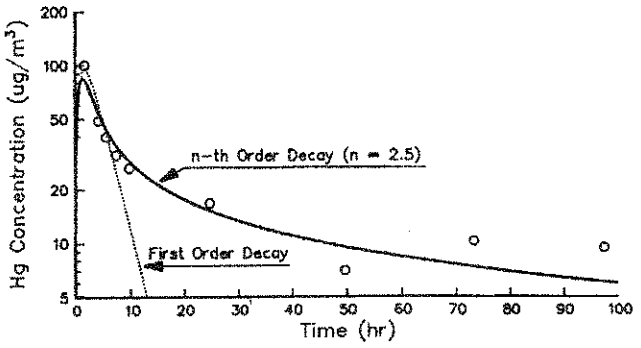

Figure 1 - Source Emissions Models Fit to Small-Chamber Mercury Concentration Data

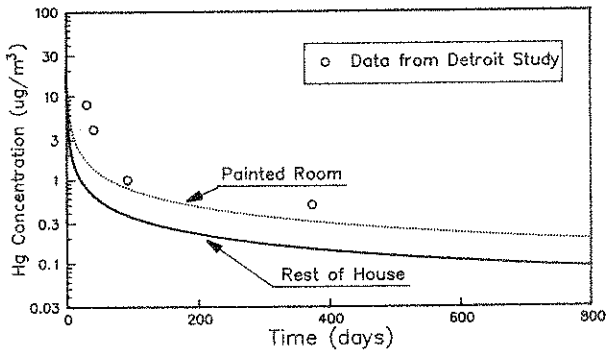

Figure 2 - Predicted Concentration in 3 Bedroom House
One bedroom painted with paint #6; air exchange = 0.5 ACH

He also concluded that, although the data are limited, the results are useful in predicting exposure to mercury vapors indoors.

Figure 2 shows that emissions tests in chambers are useful in predicting concentrations in real world situations. We believe the results demonstrate the value of emissions testing for reasonably accurate modeling of chemical concentrations in buildings. Data developed from emission testing can be used for various other purposes; these include calculating ventilation requirements when planning construction or renovation activities to be followed closely by occupancy and when considering the need for remedial or regulatory actions.

References:

M. M. Agocs et al, 1990, Mercury exposure from interior latex paint. *New England Journal of Medicine,* Volume 323, pp. 1096-1101.

K. M. Beusterien, R. A. Etzel, M. M. Agocs, G. M. Egeland, E. M. Socie, M. A. Rouse, and B. K. Mortensen (1991) Indoor Air Mercury Concentrations Following Application of Interior Latex Paint. Archives of Environmental Contamination and Toxicology, Volume 21, pp. 62-64.

Bruce A. Tichenor and Zhishi Guo, Small Chamber Determinations of the Emission Rates of Mercury From Latex Paints, presented at the annual A&WMA-EPA Symposium on Measurement of Toxic Pollutants and Related Air Pollutants, Durham, North Carolina, May, 1991.

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Chamber Tests

European Researchers Measure Emissions from Household Products

Researchers at the Joint Research Centre, Commission of the European Communities, Ispra, Italy, have tested the emissions of five household products. They used the tests to develop temporal emission profiles that will help in calculating emission characteristics both for total VOC and for individual compounds.

They report that they could characterize relatively complex emissions and their time dependence using an empirical mathematical model with relatively few parameters. The five products they tested were as follows:

1) Liquid cleanser/disinfectant applied to ceramic paving tile.
2) Liquid floor detergent applied to ceramic paving tile.
3) Carpet spray cleaner applied to carpet.
4) Furniture spray polish applied to wood.
5) Floor wax paste applied to ceramic paving tile.

They tested the five products in environmental test chambers at 23 ±0.5°C with 0.507 air changes per hour. Some of their results are summarized in Table 2 below.

Calculated times for concentrations to reach one-half (0.5_{max}) and one-tenth (0.1_{max}) their maximum values

Product number	Initial mass (g) (m^2/m^3)	Loading ratio area (cm^2)	Emitting surface	Initial emission rate (mg/h)	Emission factor mg/m^3-h	Calculated maximum concentration (model) mg/m^3	time (h)	Decay time (hours) 0.5_{max}	0.1_{max}
1	1.1	0.072	328	34.9	1064	6.51	0.31	1.9	5.7
2	4.2	0.29	1312	2.20	16.8	0.577	0.39	1.7	5.8
3#	1.5	0.10	462	50.4	1091	20.16	0.53	1.7	4.0
4	*	0.20	900	27.1	301	2.49	0.19	2.3	8.0
5	0.072	0.072	328	1.88	57	0.19	0.19	1.5	6.4

Emissions of total VOC by FID quantified as toluene equivalents.
Results for product 3 are for only one compound, 1-methoxy-2-propanol.
* Weight change through evaporation too rapid for measurement.

Table 2 - Chamber Test Conditions, Results Summary, and Calculations

help determine ventilation requirements and vacancy times for minimizing occupant exposures after product applications. All of the individual VOC compound concentrations were calculated to reach 0.5_{max} in 1.2-4.1 hours and 0.1_{max} in 3.2 to 11.9 hours; the time for only one compound exceeded 7.4 hours. The calculated time to reach 0.5_{max} and 0.1_{max} respectively for TVOC concentrations ranged from 1.5-2.3 hours and 4.0-8.0 hours. These calculations suggest that one day will generally result in factor-of-ten reductions in concentrations. This assumes that the test conditions adequately reflect the application, environmental conditions, and behavior of the tested products in actual use.

Conclusions

The researchers conclude that an empirical model, using data from small environmental chamber tests, can perform well in characterizing emissions from household products applied to surfaces (whose emissions decay rapidly). The model they have developed allows description of total emissions and/or emissions of single compounds with five parameters. They report that they can obtain these five important parameters "at least approximately... without any model by visual inspection of the data and simple calculation." The five parameters are the following:

1) The initial emission rate ($mg/h\text{-}m^2$).
2) The maximum concentration (mg/m^3).
3) The time (hour) at which the maximum occurs.
4) The time needed to reduce the concentration to one-half of its maximum value.
5) The time needed to reduce the concentration to one tenth of its maximum value.

They caution that their chamber experimental conditions may result in underestimates of peak exposures or maximum concentrations "...because real life loading factors may be higher and air change rates lower than used in the chamber experiments for reasons of analytical convenience."

Reference:

Angelo Colombo, Maurizio De Bortoli, Helmut Knöppel, Herbert Schauenburg, and Henk Vissers, (1991) "Small Chamber Tests and Headspace Analysis of Volatile Organic Compounds Emitted from Household Products" *Indoor Air*, Volume 1, Number 1, pp. 13-21.

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The Importance of Sampling Location and Timing

Why do so many studies and investigations fail to associate indoor air contaminant levels and occupant responses? Three North Carolina researchers have written a literature review that suggests a reason. The article, published in the July 1991 *Indoor Air*, Vol. 1, No. 2, shows how results from inappropriate sampling can confound indoor air studies. The problems are improper sampling locations and timing relative to the occupants and their activities.

Most studies and investigations use one sampling location to obtain exposure data for all the occupants of a single space or ventilation system zone. Some studies use samples from only one location to characterize the exposure of an entire building population. However, even area sampling a few feet away from an occupant may significantly misrepresent exposures if sources are close to the occupant's breathing zone.

Understanding the relationships between indoor air contaminant concentrations and occupants' responses requires accurate characterizations of both. Many indoor air studies greatly misrepresent exposure on the basis of collected samples. The article clearly shows that such misrepresentation may result from relying on micro-environmental monitors (MEM) rather than personal-environmental monitors (PEM). Sample-collection timing relative to occupant exposure may also affect (and distort) the representation of exposure.

Personal-environmental versus Micro-environmental Monitors

A personal-environmental monitor (PEM) is worn on a subject's body, usually with the sample collection inlet located as close as practical to the lower front of the face: the breathing zone. Micro-environmental exposure monitors (MEM) may be placed in any location within the space considered convenient for both the investigator and the study subjects. This often means locating the sampling inlet(s) away from the occupants to avoid interference from or with their activities. Yet the activities themselves may be associated with significant releases of contaminants.

Cooking, office or school work, cleaning, application of personal hygiene products, hobby activities, and even passive exposure from a nearby smoker during conversation are examples of common personal activities that place occupants in close proximity to air contaminant sources. Such activities "...can generate spatially localized concentrations of pollutant gases and aerosols..." in both residential and occupational settings. These sources are characteristically within an arm's length (60-80 cm).

Analyzing Contaminant Plumes in Two Dimensions

Figure 3 illustrates a hypothetical two-dimensional situation where a PEM worn on a body will be likely to differ significantly from an MEM intended to characterize a room. According to the authors, the differences may be especially large "...for low velocity situations and for the shorter duration exposures common for personal activity sources." Yet the MEM sampling approach is generally used to reduce study costs and encumbrance of subjects, or to "...attempt to generalize measurements to a larger area."

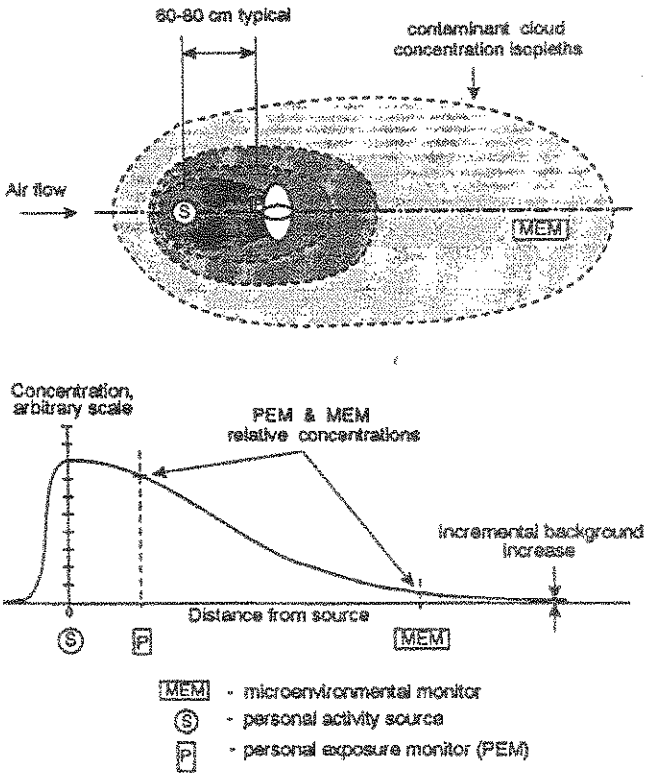


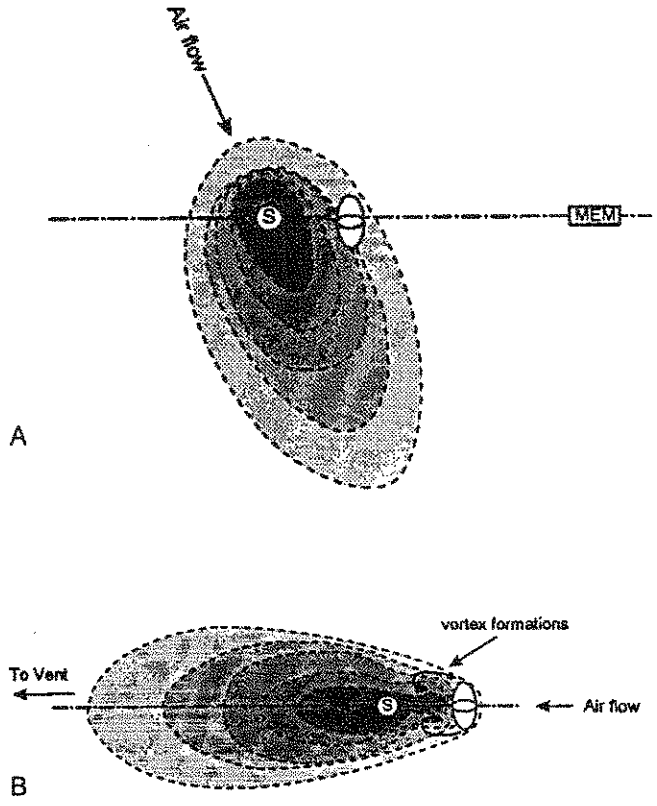
Figure 3 - Proximity effect on concentration with a personal activity source.
(Reprinted with permission from Indoor Air, Vol. 1, No. 2.)
Hypothetical short-term concentration isopleths following contaminant release from a personal activity source. Note the relative concentration differences between the PEM and MEM. The background increase is dependent on the duration of the source release and the magnitude of the sinks (e.g. total dilution volume, wall losses).

Figure 4A shows what happens in a hypothetical two-dimensional situation with the air flow perpendicular to the source-receptor axis. This produces a potentially greater skew in the PEM-MEM ratio depending on the relative distances of the source, PEM, and MEM.

Figure 4B shows a hypothetical two-dimensional situation with the air flow from the subject toward a nearby source. In this case, vortex formation is likely in the trailing wake from the subject's body. Research has found that this can create "significant low pressure areas within 0.5-1.0 meters of the body that draw part of the contaminant plume back into the breathing zone. This situation can occur when an exhaust vent is used to pull the contaminant away from the source.

Temporal Differences Are Also Important

Residential activities in a daily routine generally vary more frequently than occupational activities. Occupational activities tend to have a structured schedule and are more repetitive and predictable. Source strengths are generally stronger, and workers are more likely to be close to localized sources for extended periods. These factors combine to make the impact of personal activity sources on exposure far more apparent in the industrial setting and the related research.



Figures 4A and 4B - Effects of air flow direction on contaminant plume.
(Reprinted with permission from Indoor Air, Vol. 1, No. 2)
Shedding of vortices from flow around bluff body can draw contaminants back into breathing zone from sources up to 1m away. Typically caused by higher air flows from local exhaust ventilation.

Researchers Report Large Differences

The researchers' review of the literature on personal exposure monitors (PEM) and micro-environmental exposure monitors (MEM) showed that very large differences in measured concentrations can and often do exist. Reported differences range from only a few percent up to factors of 30 and 40 with typical values from 3 to 10 for occupational settings and 1.2 to 3.3 for residential settings. Table 3 summarizes the results from various studies reviewed in the article.

When individuals are close to a contaminant source, their exposure will typically be far larger than is indicated by an area sample. This is especially true when the contaminant source is related to an occupant activity such as cooking, painting, or other work and household tasks. The factors that influence actual exposure are "...proximity of the source, magnitude and direction of convective air movements from the source and around the body, the character of the air turbulence in the parcel [of air immediately surrounding the upper body, usually termed the breathing zone], and the presence of obstructions in the flow field."

In a perfectly mixed environment, the contaminant concentrations in a breathing zone are the same as that in the rest of a space. "In a less-than-ideal mixed situation [i.e., almost all non-industrial indoor environments], contaminant concentration gradients may be large in close proximity to the source, even though the general area concentration at some distance away may change insignificantly. Arbitrary area sampling at a single location, even for long integration intervals, will not necessarily provide a representative measure of inhalation exposure."

The authors argue that the use of "...integrated exposure models, relying on activity pattern information and compartmental average concentration data, may give results that are unacceptably inaccurate and produce estimates that are often biased low."

According to the authors, a combination of close proximity and high source strength produces the greatest distortion. They base this conclusion on a review of numerous published studies. The studies mostly concerned particles but also included vapors and gases. While most of the published studies were in industrial occupational settings, both residential and laboratory studies have confirmed the general findings. The authors write: "Although the influence of spatial concentration gradients on measurements of exposure is intuitively obvious, such

Micro-environmental type	Study type	Contaminant type	Expected source-PEM proximity	Source strength	PEM/MEM Ratio	
					Range	Typical
Occupational	In-plant	Aerosol	Various	High	3-35	7.7
Occupational	In-plant	Aerosol	Distant	Moderate	n/a	1.0
Occupational	In-plant	Aerosol	Close	High	5.1-40	13.4
Occupational	In-plant	Vapour	Close	Moderate	1.3-4.5	2.2
Occupational	In-plant	Gas	Close	Moderate	1.75-2.8	1.8
Controlled	Test chamber	Aerosol	Close	High	1.2-17.6	5.7
Residential	In-home	Aerosol	Various	Low	n/a	1.6(est)
Residential	In-home	Aerosol	Various	Low	n/a	2.0

Table 3 - Ratio of PEMs to MEMs Reported in the Literature

influences have seldom been noted, and [when noted] almost always in the occupational literature."

With respect to particulate matter measurements, "[t]he authors postulate the influence of proximity to indoor sources and/or perhaps the influence of body cloud aerosols on the PEM data." They base this on some preliminary studies in Southern California residences. Other investigators found that while indoor MEM-to-outdoor PM_{10} concentration ratios were often less than 1.0, breathing zone PEM concentrations in non-smoking residences were higher than outdoor concentrations 86% of the time. This further suggests the improbability that "... data from a single ... MEM location could adequately represent ... personal exposures."

Conclusions

Assumptions of well-mixed room air should be carefully examined when strong local sources or episodic sources could cause significant variations in spatial and temporal contaminant concentrations. In most field studies, measurements should validate such assumptions. Sensitivity analysis should be conducted to determine the possible impact of errors on the results.

Sample collection should be as close as practical to an occupant's breathing zone in order to analyze the relationship between exposure and effects or occupant response.

Sample collection should be spaced over time in order to assess the changes that occur. Efforts should be made to understand the occupant activity patterns that will result in contaminant generation and to characterize concentration patterns over time.

Reference:

Charles E. Rodes, Richard M. Kamens, and Russell W. Wiener (1991) "The Significance and Characteristics of the Personal Activity Cloud on Exposure Assessment Measurements for Indoor Contaminants." *Indoor Air* Volume 1, Number 2, July 1991. pp. 123-145.

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Reviews

Healthy Buildings

In September, ASHRAE will sponsor the second international "Healthy Buildings" conference to take place in Washington, D.C. Papers from the first conference, held in Stockholm in September, 1988, are presented in a special issue of *Environment International*, a scientific journal that has published papers from the international indoor air and climate conferences from 1978 to 1987.

The issue features a pair of guest editorials prepared by Birgitta Berglund, Thomas Lindvall, and Alan Moghissi. Berglund and Lindvall were key to the organization of the conference and Moghissi, the publisher of the journal, also presented a paper at the conference. The two editorials are outstanding statements on healthy buildings; we quote liberally from them below (with permission from Pergamon Press).

The first editorial describes the purpose of the conference as not only teaching "... the status of 'sick buildings' but also understanding what constitutes a healthy building. During the preparation of this conference," they write, "it became clear that sufficient scientific information was available to avoid most of the problems related to sick buildings." The authors describe a shift in focus from solving "sick building" problems to measures that could provide a comfortable and high-quality building environment. It meant, according to the authors, considering many new topics not normally included in assessing indoor air: topics like thermal comfort, functional requirements, noise, and lighting. They write that "...the ultimate goal of environmental protection is not only to avoid adverse effects but to promote the positive qualities of the various environmental components."

In the second editorial, the same three authors discuss "strategy options for the development of healthy buildings." Excerpts follow:

"Much of the success in energy conservation has resulted from the recognition by industry, car manufacturers and producers of appliances, that consumers and governments are expecting energy efficiency and, within limits, are willing to pay for it. An area where energy conservation has had a less than perfect performance is in building heating and cooling. Poor design of buildings and equipment, installation and maintenance of equipment by less than qualified workers, and inadequate source control have led to occurrence of poor indoor climate and, in some cases, adverse health effects, including the Sick Building Syndrome (SBS).

A basic requirement for a healthy building is that the room air must not cause illness or discomfort during normal use. The building must also be able to withstand a reasonable misuse by its occupants without giving rise to adverse health effects. Basically, indoor air quality can be controlled by a combination of 1) adherence to guidelines or standards for air pollutant concentrations, 2) source control of emissions, 3) prescribed outdoor air flow requirements, and 4) specific design requirements.

For commonly encountered and well-researched pollutants, concentration limits should be specified. However, there is a need for more toxicological knowledge about many pollutants at low levels and indicators of their presence. An area of considerable importance is adverse effects of the mixture of indoor air pollutants. There is ample evidence that these effects are not necessarily additive.

For healthy buildings, it is essential to choose building materials with minimum pollutant emission to the indoor air. These should be expressed in quantitative requirements.

It appears logical to develop a strategy for healthy buildings. The following parameters need to be considered:

1. Design, construction, and management of healthy buildings require a combination of proven experience and scientifically founded information.

2. Priority should be given to adverse health effects of major concern, such as building-related cancer and hypersensitivity reactions including allergy. Sensory reactions, discomfort, and annoyance reactions are frequent, widespread, and are early signs of adverse health effects. They are important parts of the health assessment.

3. Should a conflict arise between energy conservation and health, the health goal should prevail.

4. The target is to control human exposure and should be reached primarily by source control.

5. A ranking system is needed for buildings and consumer products. Fast-screening procedures should be developed for appropriate end points of health and comfort. Test facilities are needed to assist governments, manufacturers, builders, and consumers.

6. Microorganisms are important as allergens and causes of diseases including Legionnaire's disease. Ideally, the presence of microorganisms must be kept to a minimum, yet avoiding exposures to hazardous biocides.

7. The physical planning is critical. If buildings are erected on poor grounds or close to sources of hazardous or annoying emissions, specific requirements must be met.

8. Feedback of experience must not be neglected. Inadequate design, poor materials, and actions during the construction that may cause problems for the users are examples of the experience which must be evaluated.

9. Technical systems in the built environment should either be simple and self-explanatory or automated in order to reduce the need for maintenance and control.

10. A national strategy must be realistic and must accept and compensate for occurrence of failures in design, manufacture, installation, maintenance, and use of buildings and building components."

References:

B. Berglund, T. Lindvall, and A.A. Moghissi (1991), "Editorial: Healthy Buildings" and "Strategy Options for the Development of Healthy Buildings," Environment International, Vol. 17, pp. 183-184.

Fungi

Air Humidity and Fungal Growth In Cold Climates

Finnish researchers report that in cold climates, fungal growth on surfaces depends on surface moisture and can occur without elevated air relative humidity. Moisture leaks and condensation on cold surfaces produce sufficient surface moisture to support fungal growth. They report their findings in the special "Healthy Buildings" issue of *Environment International.* (See the article starting on page 8 of this issue of the *BULLETIN.*)

The researchers say that previous investigators of indoor fungal growth in warm and humid climates have not distinguished between air and surface moisture. However, in Scandinavia (and other cold-climate areas), "...intake air must be heated by 20 - 50 °C [36 - 90 °F] which reduces its relative humidity (RH) to <10-20%." Thus, indoor air relative humidity is very low in the winter. Fungal growth observed on surfaces in Finnish homes during the winter led to a study to determine the relative importance of surface and air moisture content.

Fungi germination and growth rates chiefly depend on three factors: 1) temperature, 2) availability of water, and 3) availability of nutrients at the surface. However, it is difficult to distinguish the effect of one factor from the others. Building materials are often substrates for fungal growth; these materials are not nutritionally optimal, yet fungi can grow on nutritionally marginal substrates. And, the low winter humidity in Finnish homes indicates that high humidity is not essential.

The Study

To accurately assess the three factors, the Finnish researchers ensured the homogeneity and availability of nutrients by studying culture media rather than building materials. Using two fungal strains commonly found indoors, *Aspergillus fumigatus* and *Penicillium* sp., the researchers showed that fungal growth could start with just a short period of favorable conditions.

Effect of Time and Temperature

Figures 5 and 6 show the rates of germination and colony size of the two fungi studied at 92-96% RH. *A. fumigatus* did not germinate at 4 °C and it took 7 days for *Penicillium* sp. to germinate. At 9-10 °C both germinated within 3-4 days and at 19 °C both germinated within 1-2 days. Neither fungi grew at 4 °C, but both fungi grew at 9-10 °C.

Table 4 shows growth rates at various temperatures relative to growth rates at optimum temperatures. Growth rates increased with increasing temperature but were different for the two fungi. *Penicillium* sp. grew fastest at 19-22 °C: right in the range of typical indoor air temperatures except in warm climates or during summer. *A. fumigatus* grew fastest at 30 °C: a temperature that persists indoors only in warmer climates.

Effect of Air RH on Fungi Growth

Figures 7 and 8 show the effect of five relative humidities on the growth rates for the two fungi at their optimum growing temperatures. The figures show that "the growth of both fungi was independent from air humidity as long as the moisture content of the medium remained above some critical level. The drier the air, the faster this level was achieved." This is logical, since drier air will be associated with more rapid evaporation from surfaces.

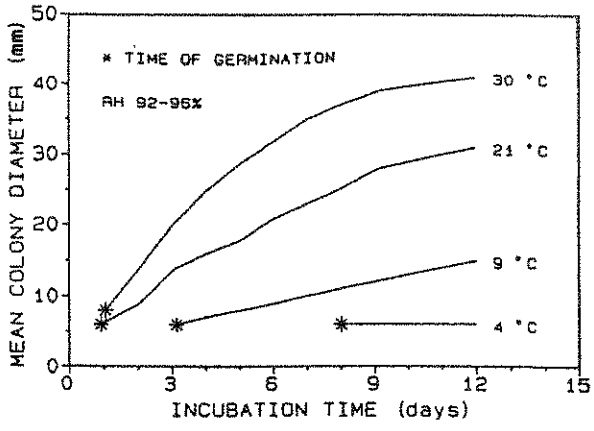

Figure 5 - Germination and Colony Size of Aspergillus fumigatus as a Function of Time and Temperature at RH 92-96%.
(Reprinted by permission.)

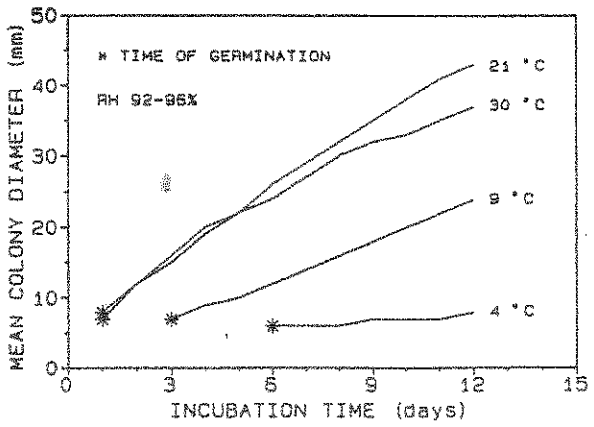

Figure 6 - Germination and Colony Size of *Penicillium* sp. as a Function of Time and Temperature at RH 92-96%.
(Reprinted by permission.)

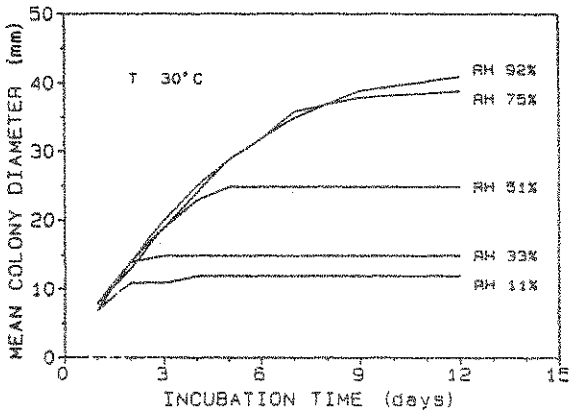

Figure 7 - Colony Size of *Aspergillus fumigatus* at Five RH-Levels at 30°C.
(Reprinted by permission.)

T (°C)	Growth Rate at T Relative to Growth Rate at the Optimum T	
	A. fumigatus (%)	*Penicillium* sp. (%)
4	0	0
9-10	18	52
21-22	40	100
30	100	85

Table 4 - Initial Growth Rates of *Aspergillus fumigatus* and *Penicillium* sp. at Various Temperatures Relative to the Optimum Temperature.

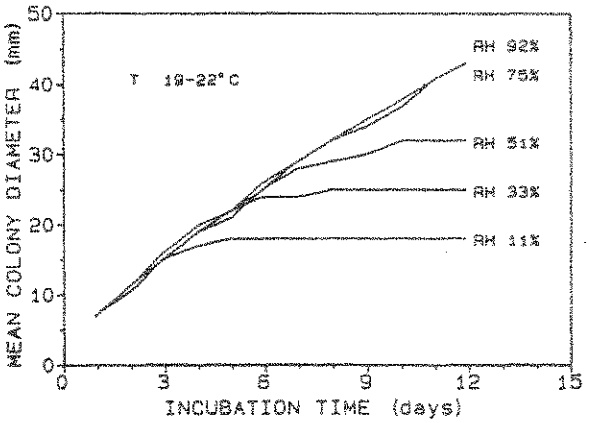

Figure 8 - Colony Size of *Penicillium* sp. at Five RH-Levels at 30°C.
(Reprinted by permission.)

Below the critical level, the fungi require high humidity to grow.

Conclusions

The authors caution against applying their results directly to field conditions since the growth medium used in the study assured that enough nutrients were present. This would not always be the case in field conditions. Also, the fungi in the study did not have to compete for living space with other microbes.

The study does demonstrate that fungi can grow under winter conditions as observed in Finnish houses. Both the low temperatures and RH found in houses are able to support fungal growth. While this growth may be slow under winter conditions, a significant accumulation of fungi can build up during the years and decades of a building's life.

Reference:

A.-L. Pasanen, P. Kalliokoski, P. Pasanen, M.J. Jantunen, and A. Nevalainen, 1991, "Laboratory Studies on the Relationship Between Fungal Growth and Atmospheric Temperature and Humidity." *Environment International* Vol. 17, 225-228.

Letters

In the May ***BULLETIN*** we wrote about the book published last year as a result of an ASTM symposium, "Biological Contaminants in Indoor Environments," held in 1989. We received a letter, reprinted below, from Dr. J. David Miller, Ph.D., from Agriculture Canada, commenting on our review.

Miller's plenary lecture at Indoor Air '90 in Toronto last year was well received by many of the more than 1,200 attenders. In it he raised some important questions about the role of fungi and mycotoxins in indoor air. He also discussed the conditions conducive to microbial growth in a paper presented at the NATO meeting in Quebec following the Toronto meeting.

In his letter to the ***BULLETIN***, Dr. Miller takes issue with what is generally accepted guidance in the United States. Therefore, we sent his letter to two leading aerobiologists for comment. They each replied, and their letters follow Miller's below. The first is from Dr. Harriet Burge, Ph.D., widely regarded as one of the foremost U.S. authorities on microbial contaminants, their sample collection, culture, and analysis. Each fall, at the University of Michigan where she is a research scientist in the School of Medicine, she teaches a course on assessing bioaerosols. The one-week course is open to the indoor air community and usually fills up well in advance. Contact information is provided at the end of this article.

The second response letter is from Philip R. Morey, Ph.D., CIH. Morey is also a recognized leader in the U.S. indoor air research and consulting community. He is widely known for his investigations of problem buildings: especially where biological contamination is suspected. Both he and Burge are members of the ACGIH Bioaerosols Committee which is responsible for an outstanding guidance document on investigating biological contamination. (Please see the reference at the end of this article.) Morey has worked for NIOSH, the Honeywell Indoor Air Diagnostics group, and now is with Clayton Environmental Consultants in Norristown, Pennsylvania.

J. David Miller On Sampling for Fungi

June 19, 1991
Dear Mr. Levin:

I read with interest your review of Biological Contaminants in Indoor Environments ASTM STP 1071 in *Indoor Air **BULLETIN***. I agree that this book is a valuable contribution. The common microbial problems - *Legionella,* endotoxin-containing bacteria and molds are fairly well considered. My comment concerns your sentence "Like the ACGIH guide, most of the book chapters' authors do not recommend air sampling for the occurrence of the organisms." I do not share this view with respect to fungi.

Your excellent analysis of the NIOSH investigations results in the same issue of ***Indoor Air BULLETIN*** pointed out a useful fact. Any rigorous analysis of a building with air quality problems should be as inclusive as possible. Mold contamination of HVAC systems in large buildings has been reported in a large percentage of so-called sick buildings. Recently, Dr. R. M. Rylander (University of Göteborg, Sweden) has reported some very high quality analysis of fungal biomass in indoor air. He determined the airborne concentrations of β1,3 glucan which is a component of fungal cell walls. Unlike traditional air sampling methods, this provides a quantitative assessment of mold concentrations. Increasing β1,3 glucan concentrations correlated with several common sick building symptoms. The large-scale studies of Dr. Robert Dales (Ottawa University, Canada) with respect to the occurrence of fungi in homes in relation to respiratory symptoms indicated non-allergenic mechanisms for the correlation observed. The role of spore-borne low molecular weight compounds as effectors of health is just being appreciated.

As you report in the above-noted analysis of the NIOSH investigation results, fungal contamination is apparently rather common and has been under-reported. The health effects that can be associated with exposure to fungal propagules are not completely known. However, from the above information, it can be taken that these too are under-reported.

Committees in Japan, Canada and of the European Economic Community are in the process of developing indoor air quality investigation protocols. Between these groups there is a broad opinion that some investigation for mold contamination should be routinely made. There is the view that this should involve some kind of air sampling followed by species determination. The length of time to collect samples, viable versus non-viable propagules as well as appropriate culture media are questions that have not been resolved. These pose formidable challenges. For example, Drs. A. Mouilleseaux and F. Squinazi (Lab. d'Hygiène de la Ville de Paris) have reported that concentrations of fungal propagules can vary in an irregular pattern over 4 orders of magnitude in a classroom over a school day. Researchers in Holland, U.K., Japan, Finland and Canada find that a quantitatively important group of molds in indoor environments are xerophillic species. Many of these do not grow on, for example, the culture media recommended in the 1989 ACGIH protocol for fungi.

Despite the difficulties in obtaining competent mycological expertise and the unresolved sampling questions, I believe that it is essential that investigations of a complaint building involve some protocol for determining fungal contamination. There are a surprising number of circumstances where such contamination is not obvious. It is possible to detect a significant difference in the indoor versus outdoor mycoflora by several means. The standard that must be used is that fungi should not be permitted to grow in or on building materials, surfaces and systems. This reflects ordinary common sense.

Sincerely,
J. David Miller, Ph.D.
Senior Research Scientist, Agriculture Canada

Harriet Burge Comments

Dear Hal:

In response to the letter from J. David Miller regarding your article in *Indoor Air BULLETIN*, May 1991: I agree entirely with Dr. Miller that fungi should not be permitted to grow in or on building materials, surfaces and systems and, in fact, always include air sampling (both for culturable fungi and for fungus spores) as well as careful visual observation and (often) bulk sampling in my building investigation protocols. I agree that Dr. Rylander (and others, ourselves included) are doing excellent research that has promise for characterizing health effects as well as prevalence patterns for bioaerosols.

However, I also feel strongly that, in inexperienced hands, air sampling for bioaerosols is counter-productive. It is commonly the case that industrial hygienists (who are virtually never trained in mycology, microbiology, or aerobiology) sample for bioaerosols in ways that are most likely to yield false negatives results. This is often because they are provided with inadequate funding to do the extensive sampling necessary to characterize bioaerosols. The equipment is expensive, sample analysis is skill-intensive, and data interpretation often impossible. A false negative bioaerosol result is far worse than not having sampled at all. For example, false negative air samples allow building managers to justify the continuation of poor maintenance practices. The ACGIH Bioaerosols Committee was formed to guide *inexperienced industrial hygienists* in evaluating indoor complaints that are potentially related to bioaerosols. It has been a continuing challenge for each committee member (all of whom are or have been engaged in bioaerosol research) to remember this fact. We would all like to see accurate, easy to use methods for bioaerosol sampling available to the industrial hygiene community, as well as guidelines for data interpretation based on solid epidemiologic and field sampling evidence. At present these do not exist. Until they do, the Committee will continue to recommend that air sampling be considered a last resort in investigations of individual problem buildings.

With respect to research efforts, the USEPA (as you are well aware) is also beginning to develop guidelines and protocols for the investigation of large building air quality problems. It is my understanding that, at present, the protocol does not include bioaerosol sampling. I personally feel that bioaerosol investigations should be a part of such research designs. I neither agree nor disagree with Dr. Miller with respect to the extent of the biological contamination in buildings or the extent of related health because I don't believe we have enough evidence to come to any kind of conclusion. If we continue to omit bioaerosol investigations from major research efforts, we will remain open to the criticism that we are overlooking major, preventable health effects related to bioaerosol exposure.

Thanks for the chance to comment,
Harriet A. Burge, PhD.

Phil Morey Comments

Dear Hal:

I agree with much of what Dr. Miller writes. However, I disagree on making air sampling for fungi routine in "sick building" investigations.

In the Practitioner's Approach to IAQ Investigations I offer the following suggestions (Morey 1990) for helping to interpret bioaerosol sampling data:

#1 Rank order comparison of the kinds or taxa of microorganisms present indoors and outdoors is often useful especially for fungi.

#2 Medical or laboratory evidence that allergic respiratory illness is caused by a specific taxon of microorganism is useful in narrowing the scope of sampling.

#3 Comparison of indoor and outdoor fungal concentrations is a useful interpretation guide. A high ratio of indoor to outdoor fungi during quiescent sampling shows that a strong indoor amplifier is present.

#4 The investigator must understand the concepts of microbial reservoir, amplifier, and disseminator. Thus, fungi may accumulate in reservoirs such as a filter, fungi may amplify in filters that become moist, and allergic respiratory illness or toxic effects may manifest when fungi in sufficient amount are transported to the workplace housing a susceptible occupant.

Thus, comparison of indoor versus outdoor fungal concentrations (#3 above) is but one of several parameters (#1 - 4 above) that must be considered when microbial sampling data is evaluated. Reliance on detection of "..a significant difference in the indoor versus outdoor mycoflora.." without a thorough investigation of building operation and performance may lead some investigators to *false negative conclusions* — in other words fungi are not a problem in this building.

The table below, from an article I wrote several years ago with Jim Feeley, Sr. (Morey and Feeley, 1988), illustrates how simple indoor versus outdoor air sampling alone can lead to *false negative conclusions* in a building with extensive fungal growth in the HVAC system.

Sample Location	Total cfu/m^3	Rank Order Taxa
Outdoor air	175	1) *Cladosporium*
		2) *Aspergillus*
Indoor air	16	1) *Cladosporium*
		2) *Penicillium*

Table 5 - Airborne Fungal Concentrations Indoors and Outdoors (Morey and Feeley, 1988).

The indoor to outdoor fungal ratio is 16/175 or 0.09. Does this air sampling data mean that the building in question is mycologically typical? Absolutely no! The porous insulation which lines the air supply system of the building is covered with a *Penicillium* and *Cladosporium* biomass which is visually evident. Indoor to outdoor fungal ratios rise to at least 200 to 1 in offices when the liner is disturbed. This data illustrates how routine air sampling alone as suggested by Dr. Miller can and will lead to *false negative results.*

My point is that a thorough visual inspection of the building including its HVAC system plus source sampling will identify most fungal problems in sick buildings. I have advocated this approach for years (Morey 1988) and basically this is the type of investigative method recommended by the ACGIH Bioaerosols Committee (ACGIH 1989). My own experience is that if there is a fungal reservoir or amplifier present in a building, this will be detected by visual examination and a thorough understanding of HVAC system design, operation, and maintenance. Routine air sampling is not required.

I do absolutely agree with the last two sentences in Dr. Miller's letter. "The standard that must be used is that fungi should not be permitted to grow in or on building materials, surfaces and systems. This reflects ordinary common sense."

Sincerely,
Phil Morey, Ph.D., CIH
Clayton Environmental Consultants
Norristown, PA 19403-3365

The *BULLETIN* Comments

We asked Morey and Burge if either of them was familiar with the European and Japanese protocols that recommend routine air sampling, but neither had seen them. We have asked Dr. Miller to send copies to us and Morey suggested that Miller forward copies to the ACGIH for its review.

We also asked Morey to comment on the issue of agar selectivity. He said that the use of malt extract agar as a screening agar for fungi does not preclude the use of other media. He offered the opinion that the debate on which media is best is likely to continue as long as there are mycologists to debate the point.

References:

P. R. Morey (1990), "Boaerosols in the Indoor Environment: Current Practices and Approaches." in, D. M. Weeks and R. D. Gammage (Eds.) *Practitioner's Approach to IAQ Investigations.* Akron, Ohio: American Industrial Hygiene Association, pp. 51-72.

ACGIH (1989), *Guidelines for the Assessment of Bioaerosols in the Indoor Environment.* Cincinnati, Ohio: American Conference of Governmental Industrial Hygienists. Available for $20. from ACGIH, 6500 Glenway Ave., Bldg. D-7, Cincinnatti, OH, 45211-4438, (513) 661-7881.

P. R. Morey (1988), "Experience on the Contribution of Structures to Environmental Pollution," in R. B. Knudson (ed.) *Architectural Design and Indoor Microbial Pollution*, Oxford: Oxford University Press, pp. 40-80.

Philip Morey, James Feeley, James Otten, (Eds.), 1990. *Biological Contaminants in Indoor Environments, ASTM STP 1071.* Philadelphia: American Society for Testing and Materials. 244 pages. Available from ASTM Publications, 1916 Race Street, Philadelphia, PA 19103. 215-299-5400. Price is $49 per copy ($39.20 for members).

Philip Morey, James Feeley, 1988, "Microbiological Aerosols Indoors," *Standardization News*, Vol. 16, No. 12, December.

For further information:

Dr. Harriet A. Burge, Associate Research Scientist, University of Michigan Medical Center, R6621 Kresge I, Box 529, Ann Arbor, MI 48109-0529. (313) 764-0227.

J. David Miller, Ph.D., Senior Research Scientist, Agriculture Canada, Plant Research Centre, Central Experimental Farm, Ottawa, Ontario, K1A 0C6. (613) 995-3700.

Dr. Philip R. Morey, Director, Indoor Air Quality Services, Clayton Environmental Consultants, Inc., 1729 Christopher Lane, Norristown, PA 19403-3365. 215 630 4657 fax 215 630 4684.

Letters

"Ventilation During Construction," June 1991

Dear Hal,

Since you specifically requested comments on your article "Ventilation During Construction" in the June issue, I have decided to comment before my impending vacation wipes the slate clean.

There are two possible effects at work that you did not mention, one on any attempt to do a "bake-out" and a more general one on shielding.

There is a very considerable thermal inertia in most building constructions. Therefore, it may be quite important that the rate of increase of air temperature be quite low during the heat-up phase. This is so that hotter surface materials (in good thermal contact with the air) do not boil off volatiles that would then plate out on more thermally slow-moving structural items: especially concrete that is behind finishes.

The whole problem of the release of chemicals from concrete has been too little studied for our own good. Loading it up with volatile chemicals originating in other materials seems to be a very poor idea indeed. I would suggest that allowing the air temperature to rise by no more than 0.2°C per hour would significantly help prevent this process, since the surface temperatures of even massive materials may slave quite well to [track closely with] the air temperature at that rate. Some simple calculations and tests could determine the degree of the temperature lag effect, but I have not yet done them.

Shielding carpets, drapes, room dividers, furniture and paper products from direct contact with the indoor air, say by use of 6 mil polyethylene sheets (or equivalent), could significantly slow the ad- and absorption rate of volatiles away from the sinks. Also, the volatiles will be removed from the space - not just adsorbed onto sink surfaces. This approach would probably not work well when a high concentration of volatiles occurred for an extended period of time; the storage would only be slowed, not prevented or reduced. However, many high pollution episodes are short-term and could benefit from the shielding.

The work by Wadden and Scheff on the "apparent" ventilation rate effect of reactive surfaces could possibly translate into very high "apparent or equivalent" ventilation rates for storage as a removal process. Theoretical considerations would then indicate that adding a reasonably effective barrier into the flow path may be quite useful, even if it is not a perfectly sealed layer. As with many processes, the first layer of added resistance may be by far the most effective, even changing the decimal order of the response rate. Here, too, I have not yet done calculations or tests, but the processes are likely valid, and the effects far from insignificant.

Jim H. White
Senior Advisor - Building Science
Canada Mortgage and Housing Corporation

Call for Papers

1992 Radon Symposium

The U.S. Environmental Protection Agency and the Conference of Radiation Control Program Directors, Inc., has issued a Call for Papers for its 1992 International Symposium on Radon and Radon Reduction Technology. The symposium will take place September 22-25, 1992, in Minneapolis, Minnesota.

Papers are invited on all facets of radon reduction technology in the indoor environment, both residential and large buildings. The topics of greatest interest, according to the announcement, are radon control, measurement methods (for air and soil), health issues, program and policy issues, public information and education, radon surveys, and radon in the natural environmnet.

Abstracts of 150 words or less should be submitted by November 1, 1991, to Timothy M. Dyess, Radon Mitigation Branch, MD 54, U.S. Environmental Protection Agency, Research Triangle Park, NC 27711. (919) 541-2802, fax (919) 541-2157.

Registration information is available from Diana at Conference of Radiation Control Program Directors, Inc., (502) 227-4543, fax (502) 227-7862.

Calendar

September 4-8, 1991. **CIB - ASHRAE Healthy Buildings - IAQ '91.** CIB International Council for Building Research Studies and Documentation. Washington D.C. Contact ASHRAE Meetings Department, 1791 Tullie Circle N.E., Atlanta, GA 30329 (404) 636-8400. *This is shaping up to be a very interesting conference with more of a design and problem-solving focus than most indoor air conferences. Details will be available in next month's BULLETIN.*

September 16-20, 1991. **Ventilation '91.** Sponsored by the American Conference of Governmental Industrial Hygienists (ACGIH). Omni Netherland Plaza, Cincinnati, Ohio. Contact: ACGIH, 6500 Glenway Avenue, Bldg. D7, Cincinnati, OH 45211-4438. (513) 661-7881.

October 3-4, 1991. "Diagnosing and Mitigating Indoor Air Quality Problems," Chicago, Illinois. *Contact: AEE Energy Seminars, P. O. Box 1026, Lilburn, GA 30326 (404) 925-9633, fax (404) 381-9865. Instructor Francis J. Offermann provides hands-on demonstrations for using IAQ measurement equipment. Fee is $750, AEE Member $650.*

October 9-11, 1991. **Fifth National Meeting, American Assocation of Radon Scientists and Technologists.** Crown Plaza Holiday Inn, Rockville, Maryland. Contact: Harry Rector, 1991 Radon conference, MAC AARST, P. O. Box 1272, Germantown, MD 20575. (301) 428-9898. *Technical sessions and panel discussions to cover practical, scientific, and policy issues related to the discovery, investigation, and control of radon in buildings. A full program of continuing education and professional development courses will be offered October 8-9 and 12.*

October 28-November 1, 1991; January 6-10, 1992; March 2-6, 1992; May 4-8, 1992. **Improving Indoor Air Quality in Non-Industrial Buildings.** Sponsored by EOHSI/CET, University of Medicine and Dentistry of New Jersey-Robert Wood Johnson Medical School and Rutgers, The State University of New Jersey. Contact: Centers for Education and Training (CET), 45 Knightsbridge Rd., Piscataway, NJ 08854-3923. (908) 463-5064. Course fee is $700 for five days.

November 4-7, 1991. **ASTM Subcommittee D22.05 on Indoor Air.** San Diego, California. Contact: George Luciw, ASTM, 1916 Race Street, Philadelphia, PA 19103

November 14-16, 1991. **"Blueprint for a Healthy House Conference."** The Urban Center, Cleveland State University. Sheraton City Centre, Cleveland, Ohio. Contact: Barbara Benevento, The Urban Center, Cleveland State University, Cleveland, OH 44115. (216) 687-6947.

November 18-19, 1991. **"How to Meet New Ventilation Standards: Indoor Air Quality and Energy Efficiency.** Sponsored by the Association of Energy Engineers. Atlantic City, New Jersey. Contact: AEE Energy Seminars, P. O. Box 1026, Lilburn, GA 30326 (404) 925-9633, fax (404) 381-9865. *Instructors are Francis J. "Bud" Offermann, and Thomas Gilbertson. Registration fee $750; $650 for AEE Members.*

December 10-12, 1991. **Indoor Air Quality Course,** Harvard School of Public Health, Boston, Massachusetts. Contact: Mary F. McPeak, Office of Continuing Education, Harvard School of Public Health, 677 Huntington Avenue, Boston, MA 02115. (617) 432-3515, (617) 432-1969. *This course focuses on the health hazards of various indoor air pollutants, their physiological, toxicological, and perceptional aspects, and in-field monitoring strategies and instrumentation. Enrollment is limited to 50. Fee is $750.*

September 22-25, 1992. **International Symposium on Radon and Radon Reduction Technology.** Minneapolis, Minnesota. Contact: For registration information, Diana, Conference of Radiation Control Program Directors, Inc., (502) 227-4543, fax (502) 227-7862. For Call for papers or to submit abstracts: Timothy M. Dyess, Radon Mitigation Branch, MD 54, U.S. Environmental Protection Agency, Research Triangle Park, NC 27711

International

August 30th - September 4, 1991. **9th World Clean Air Congress & Exhibition: Towards the year 2000: critical issues in the global environment.** Montreal, Province of Quebec, Canada, Queen Elizabeth Hotel. Sponsored by the International Union of Air Pollution Prevention Association. Contact: The air pollution control association in your country.

September 9-13, 1991. **Clean Air At Work; New Trends in Assessment and Measurement.** Luxembourg. Sponsored by the Commission of the European Communities. Contact: Mr. D. Nicolay, Commission of the European Communities, DG XIII/C3 TMO B4/087 L-2920 Luxembourg. Fax: (352) 4301-4544.

September 22-28, 1991. **Fifth International Symposium on the Natural Radiation Environment,** University of Salzburg, Austria. Sponsored by the Commission of the European Communities, the U.S. EPA, and the U.S. Department of Energy. Contact: Dr. Martial Olast, DG XII D-3 (ARTS 3/51), rue de la Loi. 200, Brussels, Belgium. 32-2/235 07 23, Fax 32-2/236 20 06.

November 5-8, 1991. **1991 Far East Conference.** Sponsored by ASHRAE. Hong Kong. Contact: ASHRAE, Meetings Department, 1791 Tullie Circle N.E., Atlanta, GA 30329 (404) 636-8400.

September 2-4, 1992. **Roomvent '92, The Third Internation Conference on Air Distribution in Rooms.** Aalborg, Denmark. Sponsored by Danish Association of HVAC Engineers. Contact: Danish Association of HVAC Engineers, Ørholmvej 40B, DK-2800 Lyngby, Denmark.

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