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Ventilation Rates and Contaminant Measurements

Ventilation rates are very important factors determining IAQ because of the strong relationship between ventilation and indoor air contaminant concentrations. At low ventilation rates (typical of the majority of mechanically ventilated buildings), small rate changes can result in significant increases in occupant exposure to contaminants. At higher ventilation rates or lower source strengths, increasing ventilation rates may not significantly lower airborne contaminant concentrations.

Depending on the design and operation of a building's ventilation systems, ventilation rates vary greatly. Design maximum air exchange rates can vary by factors of ten or more in different mechanically-ventilated modern office buildings or even within the same building at different locations or times. A contaminant concentration can easily change tenfold or even one hundredfold under different, realistic ventilation conditions in the same building with the same source strengths.

Researchers and investigators almost always report contaminant measurement results, yet they infrequently report the associated ventilation rates. Because of the connection between contaminant levels and ventilation rates, contaminant concentrations without reference to the prevailing ventilation rates can be very misleading and easily misinterpreted. The absence of ventilation rate information may contribute to many investigators' failures to find links between contaminant concentrations and occupant health effects or discomfort reports. It can also mislead those who assess exposure on the basis of reported contaminant concentrations.

In most IAQ investigations and in some studies, investigators compare contaminant concentrations and other environmental variables to measured values obtained elsewhere or to guideline or legally-permissible concentrations. However, they simply cannot understand the significance of the measured concentrations without knowing how well they represent either typical or unusual occupant exposure. Exposure is a function of concentration times time, and a single measurement, whether a short-term or long-term average, cannot be generalized without considerable additional information. If measured values differ on different occasions, we must know ventilation rates to know whether the variation is due to different source strengths or ventilation. Source strengths are key.

Accurately Measuring Ventilation Rates is Difficult

Talking about ventilation rates is easy, but measuring them accurately is not. They cannot be reliably measured quickly, easily, or inexpensively. For example:

- Proper use of accurate instruments and methods requires skill and patience.
- Most of the reliable measurement devices are relatively expensive.
- Most reliable techniques can only characterize average ventilation rates for fairly long time periods, usually at least an hour. They cannot measure short-term ventilation rates or changes in rates over short time periods. The exception is continuous measurement of air speed in a duct which can capture time scales of interest.

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Reporting Ventilation Rates

There are three main ways to report ventilation rates:

Ventilation rate per person: Outside supply air flow rate per person, reported in volume per person per unit of time. Common units are cubic feet per minute per person (cfm/p) or liters per second per person (L/s/p). 1 cfm/p = 0.472 L/s/p. 1 L/s/p = 2.12 cfm/p. This rate is independent of the volume of the building itself but may vary within the building.

Building ventilation rate: Air changes per hour (ach), meaning the volume of outside air entering the building (or a portion of the building) each hour divided by the air volume of the building interior or portion of it being ventilated. Ach are sometimes expressed as units (h^{-1}). The building ventilation rate is independent of the number of people occupying the building.

Ventilation efficiency: The delivery or distribution of outside air to the spaces or ventilation system zones within a building, which may vary considerably. Measurement of outside air distribution is called "ventilation efficiency," defined as the percent of outside air entering the building that is delivered to an occupied zone.

- Measurements provide reliable information on individual spaces only under special conditions – conditions that may vary significantly from actual conditions during normal building occupancy. Specialized techniques are required to learn how ventilation air is distributed.
- Measuring ventilation rates in individual spaces within a building is seen as simply too labor-intensive, equipment-intensive, or expensive for use by all but the most serious researchers and investigators. Clearly, differences among spaces can be very large, and generalizing measurements from one space to a whole building or applying whole building measurements to individual spaces can produce significant distortions.

The factors above explain why so many researchers and investigators do not measure ventilation rates when they report the results of their air contaminant and other measurements. Another reason is that they just don't appreciate the significance of ventilation rates for interpreting contaminant measurements. Even when the significance is appreciated, poor-quality measurements can produce unreliable results and invalid conclusions. Unfortunately, many researchers measure by means that may be quick or economical but not reliable or useful for the particular application.

Measured contaminant concentrations should never be reported without at least some information on the ventilation conditions. At best, outside air supply rate per actual occupant (cfm/p or L/s/p), actual number of occupants (not an estimate or assumed design value), and building volume are determined. This will allow calculation of the air exchange rate. Descriptions of the ventilation system operational status and capacity – quantitative or semi-quantitative fraction of capacity and total capacity in ach – should also be included. Capacities can be observed from equipment labels and/or design documents, but the reliability of these indications is variable.

Measuring Ventilation Rates

There are several ways to determine ventilation rates. These methods depend on both measurements and calculations. The choice of methods depends on the purpose for making the measurements. The methods include measuring inert tracer gases released intentionally into the building, measuring carbon dioxide concentrations, and measuring air flows. In residences, ventilation is often calculated based on using a "blower door" and measuring pressure relationships between the building and the outdoors. CO_2 measurements made in various locations or at various times can provide information on different aspects of ventilation. Many people rely on CO_2 data to evaluate ventilation, but there are many problems involved. We discuss some of them in the following article.

Help Is Available and On the Way

The Air Infiltration and Ventilation Centre (AIVC) has many publications and a bibliographic database on ventilation and its measurement. Help is available free to citizens of member countries which include the US, Canada, and others where ***BULLETIN*** readers reside.

Andy Persily is writing a manual on ventilation assessment in mechanically ventilated commercial buildings. He is in the process of a serious revision and expects it to be available by the end of the year. We have seen the draft table of contents and expect it to be very useful. Meanwhile, the guide to characterization of HVAC systems described in last month's ***BULLETIN*** is still a good document to have along with several papers by Persily referenced at the end of the following article on "Determining Ventilation Rates with CO_2 Data."

Last month we wrote about Andy Persily's report, "Building and HVAC Characterization for Commercial Building Indoor Air Quality Investigations." Now Persily has transferred all the checklists and tables to WordPerfect 5.1 files, and a copy from Persily is available upon request. He still has a few copies of the report

Misinterpreting Ventilation Rates and Contaminant Concentrations: NEJM SBS Article Revisited

Last month we wrote about a highly-publicized study of SBS and ventilation. (Menzies *et al., New England Journal of Medicine*, in ***IAB***, Vol. 2, No. 10) The study has been widely misinterpreted to show that ventilation rates and contaminant concentrations do not affect occupant symptom prevalence in problem buildings.

In their article, the authors reported the concentrations of formaldehyde and VOCs at ventilation rates of 64 and 30 ft^3/minute/person (cfm/p) of outside air or 30 and 14.2 liters per second per person (L/s/p). The results of their measurements illustrate that concentrations vary with ventilation. For example, at the higher ventilation rates, mean VOC concentrations were only 36% of mean VOC concentrations at the lower ventilation rates (287 to 792 $\mu g/m^3$). And, mean formaldehyde concentrations at the higher ventilation rates were 62% of mean formaldehyde concentrations at the reduced ventilation rates (24 ppb and 39 ppb).

The accuracy of the reported ventilation rate measurements is, however, questionable. We can calculate contaminant source strengths from contaminant concentrations and ventilation rate measurements and we did so with the data reported by Menzies *et al.* The resulting source strengths for each contaminant at each of the two reported ventilation rates differed by factors of six and four for VOCs and formaldehyde respectively. Apparent or effective source strengths will vary somewhat as a result of changes in ventilation and, therefore, concentrations will not change linearly – but the changes calculated here for the Menzies study are just not plausible.

It may be that the source strengths did vary greatly under the different ventilation conditions, but this was not described by Menzies' article. Answering a direct question on the subject during Indoor Air '93, Dr. Menzies himself did not know whether source strengths might have changed. This discrepancy further underscores the need for accurately measuring contaminants *and* ventilation as well as characterizing potentially important sources so that results can be interpreted correctly. Unfortunately, it also further undermines the potential significance of Menzies' findings.

available as well. When they are gone, it will be on sale by the National Technical Information Service for $27., publication # PB 93-198844/AS. Send your requests to Andrew Persily, NIST, Bldg. 226, Room A313, Gaithersburg, MD 20899, 301 975-6418, fax 703 990-4192.

For more information:

In the UK and elsewhere: Martin Liddament, Air Infiltration and Ventilation Centre, (AIVC), U. of Warwick Science Park, Sir Williams Lyons Road, Coventry, CV4 7EZ, UK, 44 203 692 050, fax 44 203 416 306.

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Ventilation Measurements

Determining Ventilation Rates with CO_2 Data

During the past five years, measuring CO_2 to evaluate ventilation has become increasingly popular. However, like all methods of determining ventilation rates, it has inherent limitations. CO_2 is very often misused, producing extremely misleading estimates of ventilation. Why has the use of CO_2 to measure ventilation rates in buildings become such a controversial subject? Why are manufacturers of monitoring equipment developing and marketing CO_2 monitors more than for any other substance in indoor air? Why are manufacturers of ventilation system control equipment also incorporating CO_2 into their catalogs and marketing efforts?

- CO_2 can be relatively easy and inexpensive to measure. However, mismeasurement is quite common.
- CO_2 is always present in inhabited buildings because human metabolism produces CO_2 as a

byproduct. It is also present in outdoor air, so even unoccupied buildings have measurable CO_2 concentrations.

- Used properly, CO_2 measurements provide a convenient way to get an indication of the ventilation rates in buildings. Yet even ventilation rate calculations based on accurate CO_2 measurements can seriously overestimate ventilation rates.

The Difficulties in Using CO_2

According to a detailed study of ventilation published recently, there are serious problems in the use of CO_2 measurements for calculating ventilation rates. Stuart Dols and Andy Persily at the National Institute of Standards and Technology (NIST) compared the most common and practical methods available for determining ventilation rates in buildings. They conducted their study at the Bonneville Power Administration (BPA), also known as the Portland East Federal Building. This is a seven-story, four-year-old building of some 350,000 ft^2 (32,500 m^2)and a volume of 4,030,000 ft^3 (114,000 m^3). NIST investigators previously studied the building during and shortly after initial occupancy. The earlier investigations were reported in references listed at the end of this article.

After using air flow measurements, carbon dioxide measurements, and SF_6 tracer gas measurements, the researchers compared the results of each method. Furthermore, they measured CO_2 with detector tubes and a lab-grade NDIR monitor to compare their accuracy and reproducibility. They also compared different measurement locations and equipment for air flow measurements to determine the performance of these options. Using the measurements, they calculated supply air flow rate, outdoor air flow rate, and percent outdoor air. They also evaluated the accuracy of the measurement methods themselves and the accuracy of the calculated ventilation and air flow rates using the various types of measurements.

Some of the problems the researchers identified include:

- Relying on CO_2 to determine ventilation rates in buildings can result in very inaccurate results and can seriously mislead those who rely on them. CO_2-based ventilation rate estimates are likely to be high. CO_2 is a tracer gas, and its proper use to calculate ventilation rates depends on theory including equilibrium (steady state) conditions. But equilibrium is not often achieved in real buildings. The result of most CO_2 measurements to evaluate ventilation is a false sense that ventilation system design and operation is adequate for the loads present in the occupied space.
- Insufficient time for measurements is the most likely cause of significant overestimation of ventilation rates. Three to twelve hours of stable conditions of occupant population, occupant activity, outdoor CO_2 concentrations, and outdoor air supply rates are required, depending on the outdoor air supply rate. The higher the rate, the shorter the time required. Typical building ventilation rates require a minimum of three to four hours of stable conditions.
- Occupants are the indoor source of CO_2, and occupant generation rate of CO_2 depends on both the number and activity (metabolism) of the occupants. Variations in occupant populations or inaccurate counts of occupants can result in high or low ventilation rate calculations. Counting occupants, monitoring their activity levels, and estimating their CO_2 generation rate is difficult, if not impossible, in most situations. Estimates based on design assumptions cannot be considered valid unless confirmed empirically.
- Using detector tubes to measure CO_2 at typical indoor air levels can produce very unreliable results: both far higher and far lower than actual rates. Different brands and tubes with different sensitivities exist. They may be used for qualitative indications in screening applications.

Detector Tubes Not Reliable

One of the NIST researchers' most unequivocal findings was that CO_2 measurements made with one brand of detector tubes simply were not reliable. There were significant errors in the CO_2 values obtained and the calculated ventilation rates were inconsistent with the values obtained using the other methods.

The researchers evaluated the accuracy of the detector tubes for measuring CO_2 two ways: with three separate individuals each making simultaneous CO_2 measurements, and with a single individual making a single measurement. They used the measured CO_2 values to calculate two ventilation values: percent outside air at the air handler, and L/s/p based on equilibrium analysis. The results indicated significant errors in the data. The variations among the three individuals were extremely large, especially at low CO_2 values (<600 ppm in return air).

At higher CO_2 concentrations (>600 ppm in the return air), the measurements still yielded unacceptably large variations in the readings of the three individuals. When the ventilation values obtained with detector tubes were compared to values calculated using automated CO_2 or SF_6 measurements, the results were as much as several hundred percent different. For example, on one occasion, the automated SF_6 and CO_2 measurements gave outdoor air intake rates under minimum outdoor air intake conditions of approximately 10% while the CO_2 detector tube method gave results from -36% to 89%. (Automated measurements of CO_2 can give results of percent outside air (%OA) comparable to those given by measurements of SF_6 tracer gas. However, using CO_2 values in equilibrium analysis to get L/s/p is still unrealistic.)

The investigators explained the large variations between readings taken by individuals as resulting from the difficulty in reading the tubes consistently. This, they said, was because the line separating the reacted and non-reacted chemicals in the tubes is diffuse. Calculations of outside air based on tube readings magnify the errors in tube readings because the calculations are based on differences between the uncertain CO_2 concentrations.

A word of caution: the detector tubes used were from only one manufacturer, and they were not the most sensitive tubes available. However, previous investigators have also found detector tube performance for measurement of CO_2 at typical indoor concentrations unacceptable. See the references to Norbäck and Ancker at the end of this article.

Direct Reading CO_2 Measurement

There are many instruments available for measuring CO_2 that, if used properly, can produce accurate CO_2 values. Proper use includes frequent calibration, a time-consuming process too frequently neglected by careless investigators. Instruments are available ranging in price from around $400 up to $3000, and there are a variety of associated items such as data-loggers and computer software available to assist in handling and analyzing the measurement data.

The equipment varies greatly in portability, stability of the readings, and ability to withstand rough handling normal in transporting equipment from office or lab to a measurement site. We urge our readers to carefully evaluate the available equipment before purchasing a CO_2 analyzer, as there are many on the market, and the manufacturer's claims are not always accurate.

CO_2 Measurements Must Be Used Cautiously

Apart from problems in obtaining accurate CO_2 measurements with detector tubes, there are problems obtaining accurate estimates of ventilation rates using CO_2 values to calculate per person or building ventilation rates. In general, ventilation rate calculations based on CO_2 measurements over-predict ventilation because CO_2 concentrations are not at equilibrium at the time of the measurements.

Date	Hr.	SF_6 Decay L/s per person	Peak CO_2 Auto L/s per person
7/27/91	9	27	50
7/30/91	9	29	45
7/31/91	9	29	49
8/01/91	9	32	52
8/01/91	15	8	18
8/02/91	9	30	54
8/13/91	9	27	43
8/13/91	17	8	37
8/14/91	9	30	45
8/15/91	9	28	45
8/15/91	16	9	20
8/16/91	9	33	47
8/16/91	15	9	15
8/17/91	10	25	45
8/20/91	9	31	43
8/20/91	15	9	20
8/21/91	9	29	52
8/21/91	15	9	17
8/22/91	8	26	49
8/22/91	15	9	18
1/16/92	11	7	14
1/17/92	11	7	13

Table 1 - Comparison of ventilation rate per person measurements by method.

Table 1 shows ventilation rate per person determined from SF_6 decay and peak CO_2 concentrations (automated). This table clearly shows the over-prediction of ventilation based on peak CO_2 concentrations, even when CO_2 is measured well. At minimum ventilation rate conditions, the CO_2-based values are about twice those determined using SF_6 decay-based values (~16 versus 30 cfm/p, or 8 vs. 15 L/s/p). At higher air change rates, the difference is smaller, as expected. Under maximum outdoor air intake conditions the CO_2 values were still much higher than the tracer gas decay method (~100 vs. 60 cfm/p, or 50 vs. 30 L/s/p).

Calculating ventilation rates based on CO_2 concentrations requires that the CO_2 concentrations be at

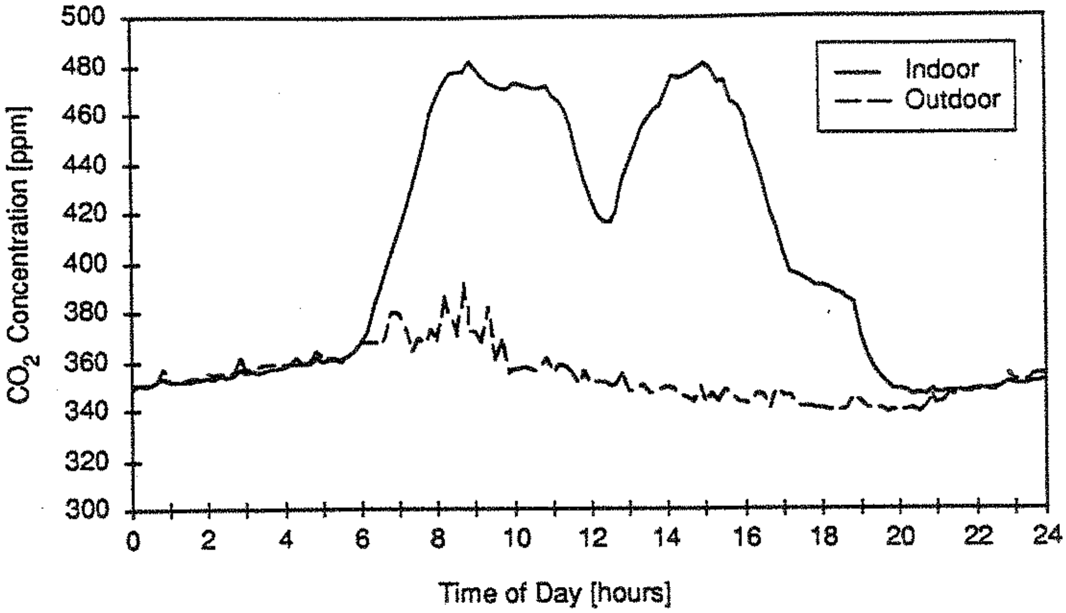

Figure 1 - Typical daily pattern of CO_2 concentration. Source: Dols and Persily, 1993.

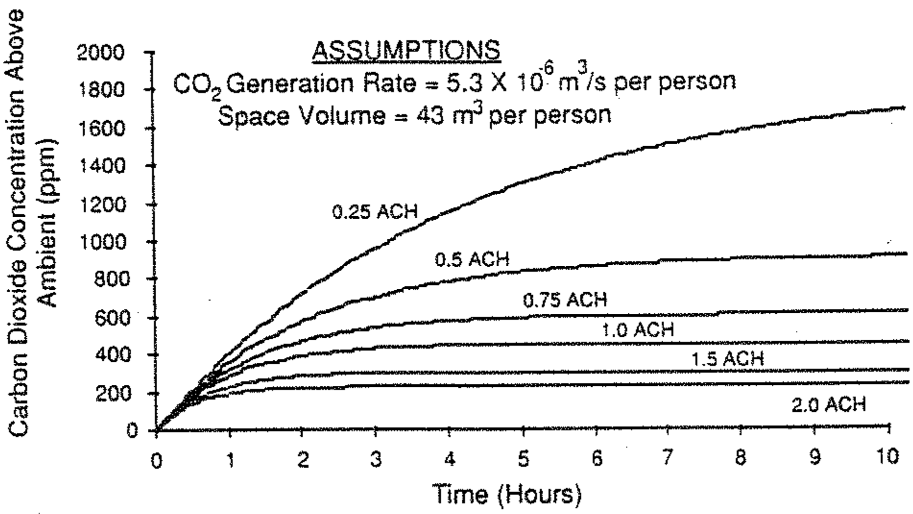

Figure 2 - Calculated buildup of CO_2. Source: Persily and Dols, 1990.

equilibrium (steady-state concentration): This can only occur when the critical variables are constant for a sufficiently long time for the concentrations to build up. It is easy to understand this by examining the typical daily pattern of CO_2 concentrations. Figure 1 shows that when people begin to enter the building in the morning, the CO_2 concentrations are close to those found in outdoor air. As more people enter, the concentrations rise fairly rapidly, although they tend to lag behind the occupancy rate somewhat.

If the number of occupants is constant and the ventilation rate is constant, then steady-state concentrations will be reached more or less quickly, depending on the air exchange rate.

The higher the air exchange rate, the more quickly steady state will be reached. At typical low building air exchange rates, 0.3 or 0.4 air changes per hour (ach), it takes as much as 12 hours to reach steady-state concentrations. Even at 0.5 ach it takes 6 hours. This means that the number of occupants and the ventilation rate must both remain constant for 6 hours before CO_2 values reach the steady-state concentration. At 1 ach, under constant occupancy, it takes 3 hours to reach 95% of steady-state CO_2 concentrations. Figure 2 shows the time required to reach steady state at various ventilation rates.

In the office building studied by Dols and Persily, as well as in most other office buildings, it is unlikely that the peak CO_2 concentration is an equilibrium value. In many cases, investigators do not even obtain peak values. In any case, most calculations of ventilation rates based on CO_2 are likely to over-predict actual per person ventilation rates.

Occupant Counts

Using peak CO_2 concentrations to calculate per-person ventilation rates requires knowing the number of occupants in the building. Our experience suggests that in many office buildings, occupancy varies considerably during the day and throughout the week. Depending on the type of organization, many office workers may move about within the building, or they may leave the building for part or even most of the day, even on a frequent basis. This uneven occupancy is very common in many types of government buildings. Since so many indoor air investigations are made in government buildings, it is extremely important to be aware of the variability in occupancy and account for it in estimating occupant density for purposes of calculating per person ventilation rates.

The *BULLETIN* Recommends:

- Never rely on peak CO_2 concentration measurements to estimate ventilation unless it is clear that the occupancy level and building ventilation system operation are constant. Steady-state conditions must have been achieved, and that usually takes between three and six hours, depending on the air exchange rate – the higher the rate, the shorter the time to reach steady state (equilibrium concentration).
- Do not use detector tubes to measure CO_2 for use in quantitative assessment of ventilation.
- If possible, use tracer gas decay rates to calculate building ventilation rates. Be specific about the time period and about the portion of the building covered by the measurements. Both CO_2 and SF_6 may be used, but CO_2 can only be used this way for unoccupied buildings.

References:

Stuart Dols and Andrew K. Persily, "A Study of Ventilation Measurement in an Office Building," (NISTIR 4905). National Institute of Standards and Technology, October 1992, 37 pages.

Richard A. Grot and Andrew Persily, "Environmental Evaluation of the Portland East Federal Office Building Preoccupancy and Early Occupancy Results," (NISTIR 89-4066), National Institute of Standards and Technology, April 1989, 28 pages.

Andrew K. Persily, "Ventilation Rates in Office Buildings," *Proceedings of ASHRAE/SOEH Conference IAQ '89, The Human Equation: Health and Comfort*, American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., Atlanta, 1989.

Andrew K. Persily and W. Stuart Dols, 1990. "The Relation of CO_2 concentrations to Office Building Ventilation," *Air Change Rate and Airtightness in Buildings*, ASTM STP 1067, M.H. Sherman, ed., Philadelphia: American Society for Testing and Materials, pp. 77-92.

Norbäck *et al.*, "Field Evaluation of CO_2 Detector Tubes for Measuring Outdoor Air Supply Rate in the Indoor Environment," *Indoor Air*, Vol. 2, No. 1, pp. 58-64.

Ancker *et al.*, "Evaluation of CO_2 Detector Tubes for Measuring Air Recirculation," *Environment International*, Vol. 15, pp. 605-608.

Radon

EPA Construction Standard for Radon Mitigation

In an April 12 Federal Register (FR) notice, the EPA proposed a model construction standard for radon mitigation in new construction. The EPA called for public comments, and it is now reviewing those comments. The EPA believes that all new construction in areas of "high radon potential" (using the Radon Potential Map) should include passive radon control systems. If high radon levels are found after construction, then the systems should be activated.

The recommendations for passive systems apply "all the construction techniques" that create physical barriers to radon entry, reduce the forces that draw radon into a building, and facilitate post-construction "active" radon removal if the passive barrier techniques prove to be inadequate. The EPA calls this approach a "passive system" and includes in its definition the provision of an open vent pipe stack to carry radon from the sub-slab area or crawl space floor to an open vent pipe stack exiting above the roof.

The so-called passive features include "...use of a coarse gravel or other permeable base material beneath slabs, and effective sealing of expansion joints and penetrations in foundations below the ground surface [to] facilitate post-construction installation of a sub-slab depressurization system, if necessary." The proposed model standard says that "limited mitigation experience has shown that some [of these techniques] can be scaled up ...to effectively reduce radon in larger buildings." This suggests the approach EPA might take if Congress mandates radon protection of schools or other buildings.

The FR notice says that the EPA's limited research indicates the passive techniques will reduce dwelling radon concentrations below the EPA's action level in "the large majority of homes where post-construction radon levels would otherwise have been *slightly* elevated." [Italics added.] It goes on to say that the EPA believes the passive techniques alone can reduce radon levels by 50%. In cases where soil radon levels are "greatly elevated," the proposed standard recommends an active system involving the addition of a fan in the passive stack that can easily improve the radon reduction to achieve EPA's prescribed guideline of 4 pCi/L.

The EPA estimates the costs of these improvements at $350 to $500 per home for a passive system and $600 to $750 for an active system. Where active radon control systems are used, the EPA estimates the annual maintenance and operational costs at $40 to $75.

The third mitigation method is known as "stack effect reduction." It involves features to prevent or reduce the flow of warm, conditioned air upward and out of the dwelling. The upward movement can draw soil gas into the dwelling. This method includes providing makeup air for combustion appliances, closing air passages around chimney flues and plumbing chases, and sealing openings around attic-access doors. These techniques simply represent good building practice for conserving energy and achieving comfort. According to the EPA, these techniques alone are not enough to significantly reduce indoor radon levels. When combined with the passive or active approaches, however, the EPA says these techniques can contribute to reduced radon entry.

According to limited EPA research, active systems have reduced radon levels to below 2 pCi/L in over 90% of new homes and below 4 pCi/L in nearly all new homes. Of course, there is no way of knowing what the levels would be without the systems in place, and the FR notice does not address this.

Radon Potential Map

Probably the most important news in the FR notice is the announcement of the "Map of Radon Zones." The EPA, with assistance from the US Geological Service (USGS), has mapped radon zones in the US to help state and local governments target data collection and outreach programs. The FR notice says it is also intended to help code officials "...determine where adoption of radon-resistant construction codes may be advisable." The map categorizes US counties in three zones. Zone 1 applies to areas with predicted indoor radon "average screening levels" above 4 pCi/L. Counties with predicted levels between 2 and 4 pCi/L are classified Zone 2. And counties with predicted levels below 2 pCi/L are classified Zone 3. It is important to stress that these zones are based on short-term screening measurements performed under closed-house conditions, and they are not reliable indicators of long-term radon exposures. They tend to err on the high side.

Implementation Approach

The EPA is proposing passive systems in Zone 1 only. Activation, if necessary, would be indicated by follow-up testing. The EPA estimates that 145,000 of the one-million new homes built each year are in Zone 1. However, the EPA's cost-benefit analysis led officials to conclude that the costs of requiring active systems in all new Zone 1 homes or passive systems in all new Zone 2 homes would outweigh the benefits. This, the FR notice says, is because of the large percentage of homes in Zones 1 and 2 that would have radon levels "...below 4 pCi/L without any radon-resistant features installed." The agency considered the costs of installing passive systems throughout Zones 1 and 2 "...too great because of the large number of homes that would receive no benefit in terms of radon risk reduction."

We think it is important to note that the majority of these 145,000 new homes expected to have levels above 4 pCi/L will be in the 4- to 8-pCi/L range. That's because the radon levels in homes follows a log-normal distribution. Thus, there are far more homes between 4 and 8 than there are above 8. There are roughly 7.4% homes with levels above 4 pCi/L and only 1.7% above 8 pCi/L. This helps explain why even the minimal mitigations involved in the so-called passive approach are sufficient to reduce concentrations below 4 in most of these homes.

Data Needs

The EPA specifically requested comments on several aspects of radon-resistant construction:

- Data on the effectiveness of passive systems in reducing levels below 4 pCi/L.
- Information on the effectiveness of mitigation techniques on radon reduction, building safety, and energy conservation.
- Information on the predictive ability of measurements made prior to occupancy of a new home regarding the exposure of future occupants to radon.

- Comments on how to address the problem of a small number of homes with elevated radon levels in areas of generally low radon levels.
- Comments on how to achieve early adoption of the model code provisions.

The *BULLETIN* Comments

The mitigations developed by the EPA may initially work as well and as inexpensively as claimed. However, it is important that the methods be demonstrated effective over time, and that there be some study of the maintenance and operation of installed mitigations where they are in place already. We believe such information should be available as part of the guidance provided by the EPA when it prepares and advocates adoption of model code provisions.

For more information:

Copies of the Federal Register Notice FR/Vol. 58, No. 68, Monday, April 12, 1993, and the supporting Cost Benefit Analysis (CBA) are available from the EPA. Contact David M. Murane, Environmental Protection Agency, Radon Division (6604J), 401 M Street, SW, Washington, DC 20460, 202 233-9442.

Radon

Scientists, Policy-makers Question EPA Radon Policy

A fundamental concern of many scientists and policy-makers is the appropriateness of the EPA's radon guideline of 4 pCi/L. After all, the basic issue is health, and there is not broad agreement in the scientific community regarding the health effects of radon at the EPA's guideline exposure level. In fact, a new book from AAAS Press (the publisher for the American Association for the Advancement of Science) raises the issues once again. In the book, *The Element of Risk; The Politics of Radon,* Leonard A. Cole discusses the views of various scientists including many who do not find the available evidence as convincing as the EPA does.

Cole cites studies in New Jersey, Canada, and elsewhere that contradict the conclusion that there is a linear dose-response relationship between radon and lung cancer. He points to one study that found an inverse relationship between general geographical region radon levels and lung cancer incidence. He describes another that found no significant elevation of lung cancer in high radon areas. In a Winnipeg, Canada study of 750 lung-cancer cases and 750 controls, not a single case occurred among non-smokers. This supports the view of many critics that there is no evidence that radon poses a risk for non-smokers. In two Canadian provinces, Manitoba and Saskatchewan, according to Cole, outdoor radon levels commonly approach 3 pCi/Liter without elevated lung cancer rates.

Regarding the distribution of elevated radon levels, Cole cites LBL Dr. Anthony Nero's estimates that something like 6 or 7% of US homes may have radon levels exceeding 4 pCi/L. This, Cole says, contrasts with the EPA's data implying that 30% of U.S. homes have levels above 4 pCi/L. Nero is also critical of the reliance on short-term tests, especially in basements where people spend far less time than in other parts of the home where levels are likely to be far lower. According to Nero, half the short-term tests are wrong when compared to long-term tests: some are too high, some are too low. Long-term tests cost no more, but they just don't work in the context of a real-estate transaction, which is the wrong time to deal with radon, Nero says. Other countries rely on long-term tests, somehow without the real-estate transaction problem.

Nero and others also criticize the EPA's approach from an economic perspective. They estimate the cost of mitigation following the EPA guidance at $20 to $100 billion, depending on the extent and vigor of its implementation. Nero would prefer a program that targets houses with levels above 20 pCi/L, 90% of which he says are in about 10% of the country. Such a program, he estimates, would cost about $500 million.

According to our conservative calculations, if every home in the US tested for radon at an average cost of $25., the total bill would be about $2.5 billion. This is a low estimate because many will do follow-up and repeat tests. If 6 or 7% of existing homes have levels above 4 pCi/L and they all perform retrofit mitigation at a cost of $1500 per home, the total cost would be more than $10 billion. Most other countries with radon guidance have adopted radon action levels of 10 or 20 pCi/L. Is it reasonable for the EPA to advocate testing in most parts of the US before there is more agreement regarding radon health effects, especially on non-smokers?

Policy Questions

Congress has held 11 hearings on radon, but the Department of Energy (DOE) has never been called to testify. Yet the DOE spends $10 million of the federal government's radon health-effects research moneys while the EPA spends less than $0.5 million. The public needs to hear all of what we do and don't know about the risks of radon exposure in homes, schools, and elsewhere.

Legislation now in Congress would require schools to test and mitigate following the EPA's current guidance. Critics say that children should not be used for political issues; there must be a scientific basis for such massive public expenditures. There is simply no evidence that they are at risk for lung cancer from radon in their schools' air, the critics say.

The EPA's research on radon in schools showed that most schools are not ventilated properly. This points to a problem with highly-probable health and economic consequences; schoolchildren are exposed to infectious airborne agents. With increased concern about tuberculosis and other infectious diseases transmitted through the air, it is even more important that schools be ventilated properly. See the letter from Shirley Hansen and the Editor's reply in the next issue of the ***BULLETIN***.

The EPA suggests that all new homes in all areas of the country should be tested to achieve "maximum risk reduction." However, the maximum risk reduction argument could more easily and unambiguously be extended to say no one should smoke. In spite of this, government anti-smoking efforts amount to a labeling program. Maximum risk reduction goals need to be interpreted in the context of public and private cost, scientific certainty, and personal freedom. Radon is a convenient pollutant since neither government nor interests represented by powerful lobbyists are being required to pay the cost of its control.

References:

Leonard Cole, *The Element of Risk; The Politics of Radon*, Washington, DC: AAAS Press, 1993. Order from Tasco at $29.95 per copy plus $4.00 shipping and handling, 301 645-5643, fax 301 843-0159.

Letters

Cammer on Increased Ventilation

Paul Cammer is president of the Business Council on Indoor Air (BCIA). Readers should be aware that the Chemical Manufacturers' Association and tobacco industry interests are among BCIA's largest supporters. (We do not know the exact composition of BCIA's board of directors, but the original board contained those and related groups. When we asked for a list of board members last year, we were not provided one.) These organizations represent producers of contaminant sources that might be affected by the proposed approach to the new Standard 62. We wrote about the BCIA in ***IAB*** Vol. 1, No. 1.

Dear Hal:

I was intrigued by the juxtaposition of articles on Gene Tucker's vision for a revised ASHRAE standard and the indoor air research recently completed by Menzies and others at McGill University in the most recent issue of your ***Indoor Air BULLETIN***. Your review of the McGill University research ("New England Journal of Medicine Ventilation Report — Good Research, Wrong Problem") provides a useful explanation for the effectiveness of ventilation rates below ASHRAE's recommended 20 cfm/person and the marginal benefit of rates greater than 20. In spite of this lucid analysis of the relationship between ventilation and IAQ, you show an unusual enthusiasm for Tucker's proposal for additional ventilation rates of greater than 20 cfm/person, based on contaminant emissions ("New ASHRAE Ventilation Standard Outline").

Such increased ventilation is important during temporary procedures such as renovation and installation. Tucker's proposal to specify that higher ventilation rates be generally imposed for VOC and other emissions (that occur for a relatively short period of time), however, runs directly counter to what we know to be the relationship between ventilation rate and contaminant levels. Moreover, to use the revision of ASHRAE Standard 62 as a means to encourage, or perhaps force, designers to specify low-emitting products, is an inefficient and largely ineffective means of addressing indoor air problems. At best, such an approach achieves minimal reduction in exposures to contaminants, most of which likely present little or no health concern. The proposal is particularly troublesome because Standard 62-1989 has been in place for such a relatively short period of time.

Another result of the McGill University study that has received far too little attention is the failure of the researchers to correlate a reduction in symptom reporting with measured reductions in contaminant levels. BCIA would not suggest that these data are conclusive, but we believe they indicate what many of us have been saying about the "lower must be better" philosophy. Before we embrace source reduction as a primary means of preventing IAQ problems, we need a far clearer idea of what benefits can be realistically achieved. The recent experience of carpet manufacturers (as part of its "Policy Dialogue" with the EPA and others) provides a useful example of what can happen when government and/or business attempts to find solutions without having identified a problem.

BCIA recognizes that many companies, including some BCIA members, have begun to offer products specifically directed at the market for low-VOC products. We are encouraged by this response to market demands, but question the wisdom of attempts to incorporate such an approach, either directly or indirectly, into standards and regulations without evidence that there are specific benefits to be gained.

Sincerely,
Paul A. Cammer, Ph.D.
President, BCIA

Editor's Reply

Our enthusiasm for the proposed approach to revising ASHRAE Standard 62-1989 is not "in spite of" but indeed because of our analysis (called lucid by Cammer) of the relationship between ventilation and IAQ. The analysis in last month's ***BULLETIN*** (Vol. 2, No. 10, Figure 4) showed that source strength is far more important than ventilation rate within the ventilation region where most buildings operate. This was especially true at the lower end of their operating range. Only at low ventilation rates, below 15 cfm/p (0.8 ach in typical cases), do virtually all realistic source strengths produce extremely high concentrations. Above that 15 cfm/p baseline, source strength is an extremely important determinant of contaminant concentration while ventilation varies. Additional ventilation is very beneficial for the emission rates shown in last month's article.

The drafters of the new ASHRAE standard are confronted with the impossible task of writing a standard for ventilation engineers that will be used (or abused) by everyone, at least in the US. Its existence has, in the past, reduced the incentives and needs for government and other professional societies to develop their own guidance. This will likely continue to be the case, and for that reason, we believe ASHRAE must address all topics relevant to making the standard an effective tool to achieve "acceptable" IAQ.

Ventilation alone cannot control IAQ adequately, yet the standard is fundamentally a ventilation standard. Since the amount of ventilation required is a function, among other things, of the contaminant loads that must be addressed, the standard can do nothing other than prescribe a process by which designers can address the loads they encounter. As in all pollution control arenas, prevention is the most cost effective and environmentally beneficial approach. To ignore source control would appear self-serving since it would place even more reliance on ventilation and would require unnecessarily high ventilation rates as margins of safety to address the relatively small number of situations where strong sources occur.

Note that Dr. Cammer's letter refers to an ASHRAE requirement for 20 cfm/p, one that applies to open office areas and some other occupancy types. The minimum ventilation rate called for by ASHRAE Standard 62-1989 is actually 15 cfm/p. Cammer does not mention that the ventilation rates reported by the McGill researchers were 2.0 and 5.3 times the 15 cfm/person required by Standard 62-1989.

Putting aside the concerns about the accuracy of Menzies *et al.*'s reported measurements, Dr. Cammer's comments miss a fundamental point: at the ventilation rates and contaminant levels studied by Menzies, there simply has not been any real concern about sick building syndrome. The formaldehyde concentrations reported by Menzies *et al.* were 24 and 39 $\mu g/m^3$ at 64 and 30 cfm/p respectively. We have not seen concern expressed about SBS symptoms at those concentrations. And, even the higher of the two reported VOC concentrations of 287 and 792 $\mu g/m^3$ is well below the lowest guideline or recommended value we have seen published anywhere.

The ASHRAE proposal certainly does attempt to encourage source control in order to accomplish its objective: to provide guidance for achieving acceptable IAQ. It is the only reasonable approach. The real question is how successful it will be.

Finally, Cammer's suggestion that there is no evidence of specific benefits from low-VOC products runs counter to both logic and the facts. Lars Mølhave found that 84% of the 52 most common VOCs found in his indoor air studies were known or suspected mucous-membrane irritants and 25% were known or suspected carcinogens. Reducing exposure to these substances must be considered beneficial absent evidence to the contrary. As Cammer indicates, meeting market demands must be considered beneficial to manufacturers, otherwise, why would they produce low-VOC products? Could they possibly believe it will also reduce their legal liability related to the toxicity or irritancy of the VOCs?

Letters

White on Vapor and Air Barriers

Jim White is the senior advisor on building science at the Canada Mortgage and Housing Corporation in Ottawa. He discusses a problem in Florida involving two large government buildings. Hot, humid outdoor air migrated through the walls and moisture condensed on the relatively cool surfaces near the inside; this resulted in massive microbial contamination. People are seriously ill, and the buildings now require major reconstruction. We are grateful to White (and all readers) who write or call to comment on our articles.

Dear Hal:

I received Vol. 2, No. 9 a few days ago and proceeded to devour it – as usual. This time I did not just want to comment on some of the content (nearly always do), I felt that I had to!

On Page 3, your article on Ventilation for IAQ in Hot, Humid Climates continues a misconception that is seriously affecting the health of these buildings and their occupants. You refer to vapor barrier instead of an air barrier, as though they were the same thing. While you are very much in line with many in the field, your article actually (and correctly) identifies both barriers, just confuses the terminology.

A vapor retarder (only welded stainless steel or glass might classify as a barrier) allows the flow of water vapor through the very materials themselves. It does not have to stop air flow to do its job, although flanking air paths can leak a lot of moisture, even without a net air flow. This process is a slow one, driven by the vapor pressure differences between humid air and drier air. In Canada we could quite likely get away with no vapour retarder (yes we spell it funny here) other than several coats of oil-based paint. The vapor pressures are too small for most of the time to cause serious mass flows of water. In places like Florida, however, the vapor pressure of the outdoor air can be very high, and the indoor vapor pressure quite low in air-conditioned buildings. Buildings in Florida (and other hot and humid states) may actually need a vapor barrier, if all moisture problems are to be avoided. The barrier, of course, must then be near the outdoor side of the structure, not the inside as we do it in colder climates.

If you want to avoid serious moisture problems in a hot and humid climate, you need an air barrier near the outside surface, to prevent the flow of that hot and moist air into (and often through) the structure. An air barrier is an assembly of materials that (almost completely) blocks air flow. It is not really sensitive to material properties (although fiber glass batts don't work), but connection method is important. How you put the materials together, and whether or not they stay tightly in contact, is what really matters. In the southeastern hotels that got into trouble, hot air was drawn into the walls, made its way into the rooms via a long and tortuous path, and was exhausted elsewhere. As it wended its way past and through the interior surfaces, it cooled below its dew point temperature, and condensation occurred on the back of wall materials. With a vinyl surface room-side, the moisture had a hard time leaving, so it accumulated until materials were saturated. The reverse problem often occurs in cold climates. No amount of attention to a vapor retarder will stop this problem, if the air barrier is not there, and/or the driving air pressure differences are not kept near zero, unless very sophisticated systems are used, at great construction and maintenance costs.

In cold climates we build tight, and then consider adding some depressurization to provide a second line of defense. In a hot and humid climate, you need a tight envelope (air barrier near the outside), and possibly a ventilation system that will pressurize the remaining leaks, so that the flow is outwards, supplying cool and dry air to warmer surfaces. This latter situation is drying, not wetting.

If you doubt any of this, please feel free to develop an example that you like, and track the amount of moisture that moves by diffusion through the materials, versus the amount that is transported by even a small air flow. There is usually a decimal order of magnitude difference in the two moisture flows, so that the vapor retarder should be considered secondary, until the air barrier is in place and working to an acceptable degree.

I hope that this does not sound too much like a lecture (I tend to do that), and that it is helpful. We cannot afford to keep building in a way that is sure to result in damage. This is more than a matter of terminology – the methods of solving an air leakage problem can and should be different than those used to slow diffusion. The first needs an air barrier assembly, while the second needs a vapor barrier materials. One does not replace the other!

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

Indoor Air '93

A Huge Success!

More than 1,100 delegates attended the Sixth International Conference on Indoor Air Quality and Climate, Indoor Air '93, in Helsinki, Finland, July 4-8. There were over 690 papers in the six-volume, 13-pound (5.9 kg) proceedings given to all participants. Attendance leaders were the USA, Germany, Scandinavia, Japan, and Canada; delegates came from 38 countries in all.

The conference was very well-organized and well-received by the attendees, although the schedule of three and one-half days was quite packed, and difficult choices had to be made. One long-time indoor air researcher said it was the best yet. Congratulations to Olli Seppänen, and thanks to all the members of the Organizing Committee: you did a great job!

Most of the papers continued work begun earlier, and many attendees felt that there were not a whole lot of new frontiers explored. We found that the presentations on design and materials selection issues did go a long way toward applying the research on materials emissions and the test procedures that have been developed. Many participants observed that they were more impressed with the importance of microbial contaminants than they had been previously, although we thought many had the same reaction after Indoor Air '90 in Toronto. Perhaps the word is really getting out that microbial contamination is a more widespread problem than has been recognized to date.

Conference Summary by Matti Jantunen of Finland

Dr. Matti Jantunen, Vice President of Indoor Air '93, summarized the conference at the closing session. Among his remarks were the following;

"Many session summaries... have stated explicitly that work is under way, expanding and developing, but no new breakthroughs have appeared since Indoor Air '90 in Toronto. I want to point out some areas where I think this is not the case."

- "Formaldehyde is clearly becoming a problem of the past."
- "From an IAQ, energy conservation, and public health point of view, we know exactly what we should do about ETS, regardless of what cancer risk estimates we choose to believe."
- "We have today much larger and more systematic radon survey results and they have been used in development of geological radon risk modeling... Mitigation alternatives are becoming reasonably well understood... Our understanding about population dose distribution in relation to building radon level distribution has improved significantly, and I dare say that we are close to an agreeable risk assessment."
- "Significant developments have occurred in personal exposure measurement by passive and active monitors and micro-environmental monitoring, and exposure modeling based on activity diaries and micro-environmental pollution data, or population exposure modeling based on Monte Carlo simulation of exposure histories through activity and micro-environmental databases... What is now needed is agreement on how to present exposure distributions in understandable and meaningful ways that would help in comprehension and comparison of the complicated data from different studies."
- "Much work has been done in material emissions testing. Before this work can have a general impact on IAQ, the work must converge into standardized material testing protocols and product information sheets. This work is under way – but in pursuit of perfection, the goal remains too far."
- "The relation of SBS to thermal and moisture/mold problems, and insufficient ventilation of especially new and newly renovated buildings is now well established, although many cases require additional explanations."
- "One of the elements of the interface between environmental research and environmental policy that deteriorates the consistency of risk management is the selection between the two questions: Have the scientists developed full consensus that X is really causing cancer in non-smoking individuals in a non-industrial setting? Or, has it really been proven beyond doubt that Y is not causing cancer under any circumstances? Taken separately, both questions sound equally scientific, concerned, and relevant. The society's approach to a given environmental pollutant can depend strongly on which of these two questions happens to be asked first by an acceptable or unacceptable authority. The difference in the risk level can be several orders of magnitude."

Next Month in the *BULLETIN*

We will discuss some of the conference highlights and opinions of IAQ experts in the next issue of the *BULLETIN*. If you went to the conference and want to nominate a "most important paper" or "most important lesson" from the conference, please send us your ideas by mail or fax us at 408 426-6522.

Copies of the Proceedings

If you didn't make it to Helsinki and want to purchase the Proceedings, copies are available for 900 Finnish Marks (about US $160) plus postage. Inquiries and orders should be sent to Indoor Air '93, P. O. Box 87, SF02151, Espoo, Finland. 358 0 451 3595, fax 358 0 451 3611.

Academy Selects Japan For Indoor Air '96

The next (seventh) International Conference on Indoor Air Quality and Climate (Indoor Air '96) will take place from July 21 to 26, 1996, in Nagoya, Japan. Members of the International Academy for Indoor Air Sciences met during Indoor Air '93 in Helsinki and elected Professor Susumi Yoshizawa to be president of the 1996 meeting. Professor Yoshizawa is associated with the Science University of Tokyo. His proposal was selected over those made by scientists from the United States and Italy.

Conference and Call for Papers

ASTM To Hold Emissions Testing Symposium

The ASTM Subcommittee D22.05 on Indoor Air has issued a call for papers on emissions testing. The papers will be presented at the Symposium on Characterizing Indoor Sources and Sinks, September 25-28, 1994, in Washington, DC. At the committee's symposium last year on Modeling Indoor Air, a large fraction of the papers included data, assumptions, or calculations of emissions. Emissions from sources form roughly one half of the indoor air pollution picture, and the indoor air research and consulting communities are recognizing the importance of understanding emissions to control IAQ.

Bruce Tichenor, Ph.D., of the Indoor Air Branch at the EPA's Air, Energy, and Environmental Research Laboratory will chair the symposium. Tichenor has been a leader in developing methods for characterizing emissions from indoor sources, and he was the lead author on ASTM D5116-90, Standard Guide for Small-Scale Environmental Chamber Determinations of Organic Emissions from Indoor Materials/Products. The method articulates the fundamental concepts for standardized VOC emissions measurements in environmental chambers, whether small or large. It is the basis for the European standard guide.

Abstracts are invited on chamber design, characterization, and performance; operation; data interpretation and application; and, other topics related to emissions testing. Prospective authors should submit a title, abstract (250-300 words) and the ASTM Paper Submittal Form by October 28, 1993. Symposium chair Tichenor will notify authors by December 28, 1993. Authors must submit final manuscripts by July 28, 1994. ASTM will publish the papers in a Special Technical Publication (STP) if they are approved through the ASTM peer review process.

Send abstracts to Dorothy Savini, Symposia Operations, ASTM, 1916 Race Street, Philadelphia, PA, 19103-1187, 215 299-5413. Paper submittal forms are available from Ms. Savini or Dr. Tichenor at the EPA. Those wishing to become more familiar with emissions testing can learn more by reading the references below.

For more information:

Symposium Chairman Dr. Bruce Tichenor, EPA/AEERL, Indoor Air Branch, MD-54, Research Triangle Park, NC 27711, 919 541-2991, fax 919 541-2157.

References and Bibliography:

ASTM, "ASTM D5116-90, Standard Guide for Small-Scale Environmental Chamber Determinations of Organic Emissions from Indoor Materials/Products," *1992 Annual Book of Standards, Vol. 11.03, Atmospheric Analysis; Occupational Health and Safety*. Philadelphia: ASTM. 1916 Race Street, Philadelphia, PA 19103, 215 299-5400.

Commission of the European Communities, "Guideline for the characterization of volatile organic compounds emitted from indoor materials and products using small test chambers," Report EUR13593 EN, 1991. Available at no cost from Commission of the European Communities, Directorate for Science, Research, and Development, Joint Research Centre, Environment Institute, Ispra, Varese, Italy 20120., or, in the U.S., Commission of the European Communities, Washington, D.C., Monday - Thursday, 10am - 4pm, 202 862-9500.

Commission of the European Communities, "Determination of VOCs Emitted from Indoor Materials and Products: Interlaboratory Comparison of Small Chamber Measurements." Report EUR15054 EN, 1993. Available at no cost from Commission of the European Communities in Ispra, Italy or Washington, D.C., at the addresses/phone numbers above.

Tucker, W. G., B.P. Leaderer, L. Mølhave, and W.S. Cain, (Eds), *Sources of Indoor Air Contaminants: Characterizing Emissions and Health Impacts*, Annals of the New York Academy of Sciences, Volume 641. April, 1992. Available from The NY Academy of Sciences, 2 East 63 Street, New York, New York, 10021. Copies are $65.00.

CFC Substitutes

Manufacturers are rapidly introducing refrigeration equipment that can use non-ozone-depleting CFC substitutes and the EPA is helping those who want more information. A list of acceptable and unacceptable CFC substitutes is available from the EPA by contacting Betsy Agle, EPA, Stratospheric Protection Division, 401 M Street, SW, Washington, DC 20460, 202 223-9046.

Ozone and IAQ

Many people believe that ozone is not an important contaminant. They think that ozone brought indoors by ventilation or infiltration does not persist because it is highly reactive. There are two flaws in this reasoning. First, while ozone is highly reactive and does not last long, it does last long enough to create high indoor concentrations, especially when outdoor air ventilation rates are above one or two air changes per hour (ach). Secondly, because it is reactive, new compounds are formed in its presence; some of these compounds may be more irritating or toxic than their original, constituent elements.

In school classrooms with 1000 ft^2, a 10-ft. ceiling, 30 children, and a teacher, the minimum outdoor air ventilation rate required by ASHRAE Standard 62-1989 is 2.8 ach (31 people times 15 cfm times 60 minutes divided by 10000 ft^3). At this ventilation rate, ozone indoors can reach or exceed 50% of outdoor concentrations.

Where schools are naturally ventilated and the outdoor temperatures are high, teachers tend to open up doors and windows to maximize airflow through the classroom. In these cases, air exchange rates can easily reach 3 to 5 ach, and this can result in indoor-outdoor ozone concentration ratios approaching 0.60 and higher.

When outdoor concentrations exceed two-thirds of the 120 ppb NAAQS limit, exposures will reach levels that definitely impact respiratory function, according to recent research. Considering that school children play outdoors during at least part of the day, often during the peak ozone periods, it is unreasonable to assume that they are adequately protected from adverse health effects.

Carbon filters will protect against ozone in mechanically-ventilated spaces. Recent research from Bell Research Corporation also indicates that these filters may have rather long effective lives, at least at the high air flow rates in the study buildings. Given the potential health significance of ozone exposure, we recommend using filters in areas where ozone levels often exceed standards.

References:

Morton Lippman, "Health Effects of Tropospheric Ozone: Review of Recent Research Findings and Their Implications to Ambient Air Quality Standards," *Journal of Exposure Analysis and Environmental Epidemiology*, Vol. 3, No. 1, 1993, pp. 103-129.

Weschler, C. J., H. C. Shields, and D. V. Naik, "Indoor Ozone Exposures," *Journal of the Air Pollution Control Association*, Vol. 39, 1989, pp. 924-934.

EPA Budgets for Radon, Indoor Air, Asbestos

The EPA will award financial aid to 156 school districts for 305 asbestos abatement projects in 239 schools this year. There were applications from 410 local education agencies for the $5.7 million in funds and $70.5 million in interest-free loans. Since 1985, the EPA has awarded a total of $422 million to 1,409 local educational agencies for 3,238 project in 2,377 schools.

How do these asbestos-related expenditures compare with those for radon and indoor air? Various sources inside the EPA provided us with various estimates. In general, they all paint a similar picture. Radon program office budgets for this year and next are more than $12 million, about double the indoor air program budget. The EPA's research budget for indoor air is also approximately $6 or $7 million, again varying with the source providing the information. This pales in comparison to the expenditures for outdoor air pollution research; yet we know that indoor exposures constitute a far greater threat to human health.

Given the lack of evidence regarding the health effects of radon exposure on non-smokers, many question the appropriateness of the budget priorities. When one considers the enormity of the public and private sector expenditures on construction, renovation, and ventilation in US buildings, it seems to us that considerably more should be spent on indoor air research and programs. Admittedly, we are biased because our work has not been directly concerned with radon research, policy, and control strategies.

For more information on asbestos abatement in schools, call the EPA's TSCA Hotline at 202 554-1404.

Calendar

Domestic Events

August 11-12, 1993. Indoor Air Quality by Design, Harvard University, Cambridge, Massachusetts, Sponsored by Harvard Graduate School of Design. Contact: Professional Development, GSD, 48 Quincy Street, Cambridge, MA 02138, 617-495-1680, fax 617-495-5967. *BULLETIN Editor Hal Levin is the course instructor for this class focusing on IAQ issues for building design professionals and facility managers. Tuition fee is $510.*

August 17-20, 1993. Advanced Hands-on Indoor Air Quality/HVAC Diagnostics, Harrison, Maine, The H.L. Turner Group Inc. (also offered September 28-October 1). Contact the H. L. Turner Group, Inc., RR#1, Box 535A, Harrison, Maine 04040, 603 228-1122. *An intensive course with a high-powered faculty.*

October 10-13, 1993. Understanding the Workplace of Tomorrow, 14th Annual Conference and Exposition on Facility Management, International Facility Managers Association (IFMA). Denver Convention Center, Denver, Colorado. Contact IFMA Headquarters, 1 East Greenway Plaza, 11th Floor, Houston, TX 77046-0194, 800-359-4362.

October 26-27, 1993. ASTM Subcommittee D22.05 on Indoor Air, Albuquerque, New Mexico. Contact George Luciw, Staff Manager, ASTM, 1916 Race Street, Philadelphia, PA, 19103, 215-299-5571.

November 7-10, 1993. IAQ '93: Operating and Maintaining Buildings for Health, Comfort and Productivity, Philadelphia, Pennsylvania. Sponsored by ASHRAE. Contact ASHRAE Meetings Department, 1791 Tullie Circle NE, Atlanta, GA 30329, 404-636-8400.

January 22-26, 1994. ASHRAE Winter Meeting and Exposition, New Orleans, LA. See listing for November 7-10, 1993.

September 25-28, 1994. Symposium: Emissions from Indoor Sources, Washington, DC. Sponsored by ASTM Subcommittee D22.05 on Indoor Air. Contact: Symposium Chairman Bruce Tichenor, EPA/AEERL, Research Triangle Park, NC 27711, 919-541-2991, fax 919-541-2157. *More details are available in this issue of the **BULLETIN**.*

International Events

September 21-23, 1993. Energy Impact of Ventilation and Air Infiltration, 14th AIVC Conference, Copenhagen, Denmark. Contact AIVC, Univ. of Warwick Science Park, Sir Williams Lyons Road, Coventry, CV4 7EZ, UK, 44 203 692 050, fax 44 203 416 306.

October 27-28, 1993. Volatile Organic Compounds, Royal College of Physicians, London, England. Sponsored by Indoor Air International (IAI). Contact: Conference Secretariat, International VOC Conference, Unit 179, 2 Old Brompton Road, London SW7 3DQ, UK, +44 767 318 474, fax +44 767 313 929.

November 1-3, 1993. Clima 2000, Queen Elizabeth Conference Centre, London, England. Contact: Anne Gibbins, CIBSE Headquarters, 222 Baltham High Road, London, SW 12 9BS, fax 44-1-6755449.

March 15 - 18, 1994. Cold Climate HVAC '94 - International Conference on HVAC in Cold Climates, City of Rovaniemi, Finland. Sponsored by FINVAC, Federation of Societies of Heating, Air Conditioning and Sanitary Engineers in Finland. Contact: FINVAC/Cold Climate HVAC '94, Mr. Ilpo Nousiainen, Sitratori 5, SF-00420 Helsinki, Finland, +358 0 563 3600, fax +358 0 566 5093. *The official conference language is English.*

April 17-19, 1994. International Symposium on Volatile Organic Compounds in the Environment, Montreal, Quebec, Canada. Sponsored by ASTM Committee E-47 on Biological Effects and Environmental Fate. Contact: symposium chair Dr. Wuncheng Wang, U.S. Geological Survey, WRD, P. O Box 1230, Iowa City, IA 52244, 319-337-4191, fax 319-354-0510.

August 22-25, 1994. Healthy Buildings '94, Sponsored by CIB, ISIAQ, and HAS, and co-sponsored by the World Health Organization, ASHRAE, and other international organizations. Budapest, Hungary. President, Professor László Bánhidi, Healthy Buildings '94, Technical University of Budapest, H. 1521 Budapest, Pf. 91, Hungary, 361 1812 960, fax 361 1666 808. *The second announcement and call for papers is out, and potential participants may submit abstracts of not more than 300 words until October 15, 1993. Fax abstracts are not acceptable. Conference organizers plan a meeting very similar to the very successful Healthy Buildings '88 held in Stockholm, September, 1988. The official language will be English. Discounted advance registration fee is $450, $150 for students.*

September 5-9, 1994, Ventilation '94, The Fourth International Symposium on Ventilation for Contaminant Control, Stockholm, Sweden, Sponsored by Swedish National Institute of Occupational Health. Contact Ventilation '94, National Institute of Occupational Health, S-171 84 Solna, Sweden, +46 8 730 9448, fax +46 8 275 307.

Indoor Air BULLETIN

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Indoor Air BULLETIN sincerely invites letters or any comments you may have on either the topics presented within or on other indoor environmental issues of interest.