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Can House Plants Solve IAQ Problems?

The idea of common plants solving IAQ problems is attractive. Most people like having plants in their homes and offices and in the hotels, stores, and public buildings they visit. However, important questions exist as to whether plants can actually affect indoor air sufficiently to warrant their use as air cleaners.

Nearly everyone has read or heard a press story about how common house plants can affect IAQ. Many stories say spider plants or Boston ferns remove formaldehdye. The Associated Landscape Contractors of America (ALCA) and their promotional organization "Plants for Clean Air Council" aggressively promote the idea through press releases, media briefings, and other efforts.

Some scientists and interiorscapers (people who design and provide plant environments in buildings) say that National Aeronautics and Space Administration (NASA) research demonstrates the efficacy of plants as indoor air cleaners. Critics and skeptics include high-ranking officials of the EPA's Indoor Air Division. They say the research, if valid, indicates the need for huge numbers of plants to remove indoor air contaminants as effectively as normal air exchange in an energy-efficient house or in a typical office building. In this article we discuss the research promoting the use of plants, the limitations of the studies, and our own thoughts on the subject.

Advocates' Views

Scientists funded by NASA say their research shows that plants clean indoor air. These scientists and other vigorous advocates say that plants have been cleaning the earth's atmosphere for millions of years. They say that eventually their critics at EPA and elsewhere will realize that using plants is the most reasonable method for indoor air pollution control.

NASA research tested plants' ability to clean indoor air for possible use in space stations. Even before awareness of indoor air pollution increased in the early 1980s, NASA had funded research on using plants to biologically treat waste water. Biological waste water treatment technology proved effective and is used at small- to medium-scale municipal sewage treatment plants and to reclaim water for irrigation.

NASA is concerned about poor indoor air depositing gaseous contaminants on critical electronic components inside spacecraft. NASA contractors test for excessive emissions from both building materials and items taken aboard spacecraft. They even test astronauts' space suits for emissions. Chemicals depositing on spacecraft electronics can cause short-circuiting, arcing, or bridging. The sensitivity of the electronic components and the value of the space program missions have justified carefully cataloguing thousands of materials and products from ball-point pens, cameras and space suits to paints and gaskets. The testing has been so extensive that NASA's emission data may prove applicable to evaluating mundane indoor air pollution sources.

Plant Studies

Dr. Bill C. Wolverton, since retired from NASA's Stennis Space Center in Mississippi, carried out much of NASA's research. He had previously studied the use of plants for waste water treatment. He researched the effectiveness of plants in removing the common indoor air pollutants benzene, trichloroethylene, and formaldehyde.

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Since leaving NASA, Wolverton has continued to conduct research with funding from ALCA.

While at NASA, Wolverton and his colleagues placed over a dozen popular indoor plants in sealed plexiglass chambers of 0.44 to 0.88 m^3 (18.54 - 34.08 ft^3). In the early work he tested all three chemicals by injecting them into the chamber to reach concentrations from 15 to 20 ppm. After 24 hours, chemical measurements were only fractions of the chemicals measured in the chamber air immediately after injection. Reported removal rates were from 10 to 70% of the initial concentrations. In control tests without plants Wolverton reported that chamber leakage could account for from 2.8 to 10% of the reduction in chemical concentration.

Then the researchers ran tests on the removal of benzene and trichloroethylene at 0.1 - 0.4 ppm. These lower concentrations are slightly closer to those measured in indoor air although still 100 to 1000 times higher than typical indoor air concentrations. The reported removal rates ranged from 9.2 to 89.8% and averaged 45.1% for the 15 plants tested. The researchers reported that at low concentrations (<0.15 ppm), pots containing potting soil alone without a plant present removed 20.1% and 9.2% of the measured initial benzene and TCE concentrations respectively. Removal by leakage was reported at 5.3 and <1.0% for benzene and TCE respectively.

Foliage Not the Key

Because the researchers initially assumed that the plants removed the chemicals by uptake through the leaves and photosynthetic processes, they carefully measured leaf surface area. However, when researchers removed the lower leaves or all leaves of some test plants, they found that the percentage of the tested chemicals removed actually increased. Although initially puzzled by this result, they later observed that this "...occurred only when large amounts of foliage covered the potting soil surface reducing contact between the soil and the air inside the chamber."

Researchers then removed only the lower leaves and the results showed that soil surface exposure to the air was important. Further studies investigated the role of soil microorganisms in the chemical removal process. Soil bacteria measurements did not always correlate with increased chemical removal, leading to the hypothesis that "other yet unidentified biological factors may also be important." They did not say what those factors might be.

Soil Bacteria

The scientists identified several common soil bacteria isolates in the root-soil zone. The researchers said they were "common soil microorganisms" most of which are "known to be capable of biodegrading toxic chemicals when activated by plant root growth." [During a recent phone conversation, Wolverton told ***IAB*** that he has reviewed the extensive Australian and Canadian literature on soil microorganisms. He believes the selection of the right bacteria is the key to improving system efficiency.]

The belief that soil bacteria were important led to efforts to increase air-soil contact. Researchers used fans to move air rapidly through the soil, and they used activated carbon in conjunction with the plants in some tests. According to the final report, these studies were not part of the NASA-ALCA two-year study. Air concentrations of 0.15 and 0.25 ppm of TCE and benzene respectively were reduced to close to zero in two hours using an eight-inch activated carbon filter system with a golden pothos plant. Concentrations of 36 ppm of both chemicals also dropped to nearly zero in two hours by the same system.

Researchers' Conclusions

The NASA report concluded that the charcoal-fan-plant combination was "an essential part of an indoor air pollution control system with plants to remove high concentrations of pollutants such as cigarette smoke and organic solvents." The researchers concluded that the activated carbon adsorbed the chemicals and held them until the "plant roots and microorganisms can utilize them as a food source, therefore, bioregenerating the carbon."

Philip Morey of Clayton Environmental Consultants confirmed the potential efficacy of the bacteria. Morey is a plant physiologist by training and is well known for his studies of microorganism-related problems in buildings. He told us that there are typically 10^{10} to 10^{12} mg of bacteria in a spoonful of soil. The bacteria eat sloughed-off plant cells, thus creating a species-specific symbiosis. Additionally, Morey said that because house plants are generally wide-leafed they intercept much light. This makes them suitable for low-light conditions.

Limitations of the NASA Plant Tests

We have to ask how well the tests run on plants help us understand their actual performance in buildings. A number of conditions in the NASA tests were not "real world," and this raises questions about the applicability of the results. Because of this limitation, we can't yet evaluate plants' efficacy as indoor air cleaners.

Dynamic chamber studies with air exchange rates and mixing resembling real-world conditions would help significantly. The results could easily be modeled to predict performance in real-world settings. The best test, of course, would be to place the plants in typical rooms in homes and office buildings. Then scientists could evaluate the actual impact of plants on indoor air concentrations of organic chemicals.

Failed Field Study

To date, advocates have not reported the results from actual field tests. One field study was begun and failed, according to a strong advocate of the interiorscape approach to IAQ control. Stuart Snyder is the president of Aqua/Trends of Boca Raton, Florida, a firm that sells irrigation systems for interiorscapes. He offered his explanation as part of a 13-page letter to Robert Axelrad, Director of EPA's Indoor Air Division.

Responding to what he calls EPA's criticism of the NASA work, Snyder wrote, "In many ways small systems are better able to isolate factors, and more clearly define mechanisms at work.... Larger environments are too subject to conflicting variables. Real life, field studies with their complex dynamics are also valuable, and should be implemented at later stages of research — they are however, more difficult to accurately stage and evaluate."

Snyder continued, "Scaled up studies must be made at some point. Associated Landscape Contractors of America have already attempted a controlled study in an office building. It failed as a study because of these difficulties." The office-building study was done for over a year under realistic conditions and with as much control as can be achieved in a field study, There was no indication that the presence of plants had any measurable effect. HBI Inc., which conducted the study, reported virtually no effect of plants on the VOC concentrations.

John Girman's Critique

John R. Girman (Chief of the Analysis Branch at EPA's Indoor Air Division) has prepared a memo that details some shortcomings of the NASA study's claims for the efficacy of plants. The memo was included in correspondence between Axelrad and Snyder. Girman's memo responds to some of the technical issues presented by Snyder and other advocates of IAQ control with house plants. The memo's title is "Comment on the Use of Plants as a Means to Control Indoor Air Pollution," (undated.) Girman analyzes the notion that NASA research shows plants are effective at removing indoor air pollutants at realistic concentrations and time frames. He calculates that at the most favorable conditions, it would take 680 plants in a typical house to achieve the same pollutant removal rate Wolverton and his colleagues reported they achieved in the test chamber.

Girman, a chemist by training, is a thoughtful, experienced, and knowledgeable indoor air researcher who brings important technical insights to EPA's Indoor Air Division. Because the interest in NASA's research is so large, we present Girman's memo in its entirety.

"Comment on the Use of Plants as a Means to Control Indoor Air Pollution" by John Girman

"Several issues must be addressed before the use of plants can be considered to be an effective means to control indoor air pollution. It is certainly true that plants remove carbon dioxide from the air. It is also well known that plants can remove other pollutants from water and this forms the basis for many pollution control methods. However, the ability of plants to control air pollution, particularly indoors, is less well established. Even ignoring the debate about what specific processes are important in the removal of airborne pollutants by plants, e.g., photosynthesis in leaves, deposition on foliage, microorganisms in roots or soil, etc., and accepting the validity of the laboratory experiments that Wolverton has conducted, there are still basic concerns about the effectiveness of controlling indoor air pollution with plants."

"For example, if a particular plant can remove 90% of a specific pollutant in 24 h in a closed chamber (which appears to be one of the better test results), then the pollutant concentration at the conclusion of the test is only 10% of the initial concentration. [The highest removal rate reported by Wolverton in the NASA study was 89.9% of the initial concentration after 24 hours.] The equation

$$C = C_0 e^{-kt}$$

determines the concentration in the chamber, where
C = concentration of the pollutant at time t,
C_0 = the initial concentration of the pollutant,
k = the first order pollutant removal rate constant, and
t = the time in hours since the beginning of the test.

Rearranging the equation, we obtain

$$-(1/t)\ln(C/C_0) = k.$$

Since for our example, $t = 24$ h and $C/C_0 = 0.10$, k or the pollutant removal rate is $0.096\ h^{-1}$. Determining the pollutant removal rate constant in this manner is useful for two reasons: (1) it allows comparison of a pollutant removal process with the most common pollutant removal rate of the plant to environments other than just a test chamber."

"The pollutant removal rate of a plant in the test chamber (with appropriate considerations of scale) can be compared with ventilation rates (the most common pollutant removal process) of typical environments. Office buildings have ventilation rates ranging from about $0.5\ h^{-1}$ (or half an air change per hour) to about $2\ h^{-1}$. A typical residence may have a ventilation rate of about $0.75\ h^{-1}$ and a tight house may have a ventilation rate of $0.25\ h^{-1}$. Thus, even ignoring scale up considerations for the moment, the pollutant removal rate of plants in chambers, $0.096\ h^{-1}$, is much lower than typical low ventilation rates found in residences and offices."

"However, scale-up considerations are also important. It appears that the average chamber volume used in Wolverton's tests was 0.5 m^3. This means the results must be appropriately scaled-up for use in a larger environment to allow for differences in volumetric loading (the number of plants per volume of space). This does not appear to have been done. The volume of a typical house in the U.S. is 340 m^3 with a floor area of 139 m^2 (1500 ft^2). Thus, the recommendation that one plant be used per 100 ft^2 implies the use of 15 plants in a typical house. [ALCA recommends 1 plant per 100 ft^2. Wolverton recently told us he now recommends 2 or 3 plants/100 ft^2, but he says he is "just throwing a dart."] This would provide for 340 m^3/15 plants or 23 m^3 per plant, not 0.5 m^3 per plant as in the chamber. This means that each plant would have to clean 46 times more volume than it did in the test chamber or, as would actually happen, it will clean the larger volume less effectively. To be more precise, each plant will have a pollutant removal rate which is only 1/46 of the rate it would have in the chamber, i.e., only 0.002 h^{-1}. Thus, plants at the volumetric loading recommended would be expected to contribute relatively little to pollutant removal in any indoor environment with typical ventilation."

"To achieve the same pollutant removal rate as realized in the test chamber, one would need to have the same volumetric loading, i.e., 680 plants in a typical house (340 m^3 divided by 0.5 m^3 per plant). This does not seem practical and this forms the basis for concern that adequate and realistic scale-up considerations are necessary before the use of plants can be recommended as a means to control IAQ. Similar concerns apply to the use of plants to control IAQ in office environments. It is hardly surprising that the attempt to validate the test chamber results by Associated Landscape Contractors of America did not provide measurable success."

"In addition, many of the reported tests relied upon a fan to circulate air containing pollutants near the plant. This would serve to inflate pollutant removal rate of a plant in a test chamber unless fans were also used to circulate air containing pollutants in a house or office. (The use of fans in this manner would increase operating costs and requires a separate analysis to determine if bringing in additional outside air for ventilation would be more cost effective.) It also appears that a large part of the test space was occluded by the plant itself, which also tends to inflate the pollutant removal rate. This would not be practical in most indoor environments."

"The above is not intended as a criticism of small chamber testing. Small chamber testing, *when used in conjunction with modeling*, is an important tool for improving IAQ. EPA has encouraged its use for source emission characterization, for product comparisons and to evaluate various mitigation actions."

"However, there are aspects of Wolverton's chamber test conditions which must be addressed in translating his results to typical indoor environments. The test method employed by Wolverton is a static test method, in which a one-time injection of a pollutant occurs. This is appropriate only for certain types of indoor air pollution, i.e., when the pollutant source does not emit pollutants continuously. Many important pollutant sources, such as building materials and furnishings, are continuous emitters. In the case of continuous sources, plants would be even less effective in real environments than the test results would indicate. This occurs because, while the plant is removing a particular pollutant, more of that same pollutant is being emitted at the same time by an indoor source of that pollutant. These types of sources can be dealt with by chamber studies which incorporate dynamic conditions, i.e., continuous injection of a pollutant. In addition, because indoor environments, with few exceptions, always have some ventilation, realistic chamber tests usually incorporate some ventilation. The effect of this ventilation is easily accounted for by modeling."

"Using the same conditions as the example above (0.5 m^3 chamber, one plant per chamber; pollutant removal of 90% in 24 h under static conditions), one can model that under dynamic conditions which include some ventilation (a low rate of 0.5 h^{-1} and a continuous pollutant source, the pollutant removal at steady state would be only 16% rather than 90%. This result, when considered in concert with the need for very large amounts of plants in indoor environments to achieve results comparable to those of small test chambers, suggests that a great deal of validation remains before the use of plants can be recommended for *effective* control of indoor air pollution."

"Finally, few technologies produce only benefits; there is often some drawback. Humidity and microbial contaminants are potential concerns in some indoor environments and applications. The use of large numbers of plants in an indoor environment could increase the humidity to problem levels. The use of fans to draw air over the soil of large numbers of plants may have the potential to cause microbial problems. In addition, while our understanding of the degradation products produced by plants metabolizing pollutants is limited, we must be certain that these products are not problems themselves. For example, there are literature reports that the degradation products of trichloroethylene metabolism by plants are dichloroethylenes and vinyl chloride, which are also harmful pollutants. Should the performance of plants in controlling air pollutants improve greatly, this aspect would require a thorough examination."

IAB Comments

We think Girman has raised some excellent points while being rather generous with the NASA research. The 90% removal rate was one of the highest reported. The average NASA study measurement was 45.1%, about half the value used by Girman. We believe Wolverton's claim that research will allow selecting the most effective plants, but he told us that a variety of plants were likely to be needed to deal with the wide range of indoor air contaminants. Thus, the removal rate for all chemicals per plant may be near the average.

How much of the reported removal occurred by adsorption of the chemicals on the chamber walls? We asked some of the best indoor air scientists we know to speculate on this question. Given the results reported by NASA, some theoretical considerations, and each one's experience, the estimates we feel comfortable reporting are between 10 and 20% of the total mass introduced into the chamber.

The question arises as to whether Wolverton made "initial" measurements before or after the occurrence of any possible sink effect. As we read his reports, in some cases his measurements were made very quickly, while in others they waited for 30 or even 60 minutes. The removal rates were calculated by subtracting the final concentration from the initial concentration to determine the percent removed. Theoretically, the control test with the pot full of soil without a plant should be a good indicator of the total removed by adsorption on the chamber walls, pot, and soil and by leakage from the chamber. However, it does not allow us to separate these various potential loss mechanisms. Thus, the removal by plants may be even less.

Future Issues

We do not think the research reported to date suggests a significant role for plants in cleaning indoor air. Phil Morey told ***IAB***: "I've been in buildings where there are hundreds of plants, and I've never considered them a significant factor [in terms of controlling VOC concentrations]. Morey said it is perfectly reasonable that a bacterium at the root-hair interface could consume VOCs.

Indeed, Morey cautioned that there is a large literature on plants themselves being a source of VOCs. Leaves have chemicals for insect defense, and some of these chemicals are semi-volatile compounds that sit on the leaf surface. Some are volatiles like terpenes. We need more work to check the possible negative consequences of introducing large numbers of plants into building environments.

Both Snyder and Wolverton were critical of Girman's memo and of EPA's attitude as they see it. However, Wolverton told ***IAB*** he has seen progress and is optimistic from his conversations with EPA officials. ***IAB*** contacted NASA officials connected with the research; they think the idea is interesting but that more research is needed. They also said NASA has not advocated using plants to clean indoor air.

We think EPA should guide Wolverton, ALCA, NASA, and others interested in testing or promoting the use of plants to clean indoor air. Both chamber and full-scale testing should be encouraged, but careful experimental design is required. The research done to date does not demonstrate familiarity with many of the techniques now widely used by indoor air researchers. We feel that the reporting and the limited methodologies reported in the NASA study and a more recent study conducted by Dr. Wolverton are inadequate. We hope that their future work will address some of these concerns.

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Understanding IAQ Measurements — Making Investigation Results Meaningful

I recently reviewed two studies that were very difficult to interpret. There were large numbers of expensive contaminant measurements, but the investigators failed to describe some essential variables and inadequately described their measurement methods and procedures.

In one case, the researchers didn't report ventilation rates. Since ventilation rates strongly affect contaminant concentrations, I couldn't assess the significance of the reported concentrations. They also didn't characterize source strengths in a meaningful way, thus preventing me from interpolating or extrapolating the results to other situations.

The omissions were disappointing. The results were interesting, and I wanted to understand their implications. I could generously assume that the researchers made measurements using valid methods, but the report still lacked necessary information about critical factors that could have affected the contaminant concentrations and the reported measurement results.

They had done a large amount of work; yet their results would have been far more meaningful if they had characterized certain critical environmental factors and more fully described their measurement methods and procedures.

In the other study, researchers measured several indoor-air contaminants with methods intended for industrial hygiene applications. The methods they used just weren't sensitive enough. The concentrations of concern were ten- to one-hundred times higher in industrial settings than in indoor-air settings. Standards exist for the industrial applications of some of the methods; however, they are not accurate or sensitive enough at the indoor-air concentrations measured in the investigation. It is simply impossible to accurately interpret their results.

Unfortunately, these experiences are far too common. Enormous amounts of effort go into implementing an investigation or study, and then some uncharacterized variables leave the reader at a loss as to how to interpret the results. Important decisions are then made on the basis of too little information.

Related factors that affect results must be characterized — either by qualitative description or by measurement. Investigators must identify relevant environmental variables and include qualifications and cautions when important information is either unavailable or must be obtained through indirect or unreliable means.

Characterizing Related Factors

Related factors are all the variables that affect contaminant concentrations or their significance. There are four main factors that can affect indoor air pollutant concentrations: building, ventilation, environmental, and source. Each of these factors can significantly impact the meaning of any measured concentrations.

Describing all these factors for every building can be cumbersome. But you must describe those that are relevant to a set of measurements if they are to be meaningful. The relevant factors in any given case depend on what you are measuring and its interdependence with other related factors. Any one of them could have a significant impact on IAQ.

Importance of Ventilation Rates

Ventilation rates directly affect the concentration of a chemical if the source strength is constant. Figure 1 shows the dramatic impact of ventilation on VOC concentrations especially in the region from 0.5 to 1.0 air changes per hour (ach).

Figure 2 shows the relationships between ventilation and various source strengths. Note that for source strengths from 0.1 to 20 milligrams per square meter per hour ($mg{\cdot}m^{-2}{\cdot}h^{-1}$), ventilation rates lower than 1.2 ach

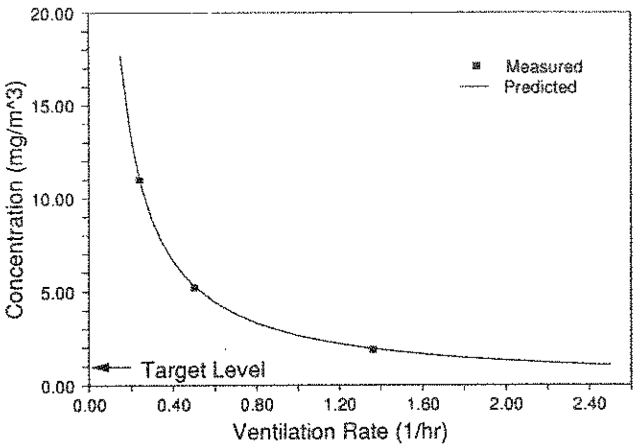

Figure 1 - Impact of Ventilation on VOC Concentrations.

Building	Environmental
Building design: size, configuration	Indoor and outdoor temperature
Plan relationships of important spaces	Indoor and outdoor relative humidity
Layout of test spaces and dimensions (L x W x H)	Indoor air velocities
Building materials (major surface materials)	Outdoor wind direction and velocity
Furnishings	Other outdoor weather conditions
Equipment	**Source**
Occupancy patterns and schedules	Occupant characteristics and density
Maintenance materials and schedules	Patterns/schedules of building use
Housekeeping procedures and schedules	Occupant activities, especially those that generate contaminants
Ventilation	Appliances, machines
System type - major equipment and control	Adjacent and neighborhood source activities
Operating schedule and modes	Recent and current construction in the building, especially in the occupied zone, adjacent spaces, and other spaces served by the same air handler.
Air exchange rate (air changes per hour)	Sinks: examples include fleecy materials such as carpets, drapes, fabric wall and furniture coverings; thermal, acoustic and fire insulation exposed to circulating air; open shelving; exposed, unpainted surfaces of gypsum wall board; and other materials with large virtual surface areas.
Outside air supply rate per occupant	The presence of any noticeable odors, and their source, when known.
Type and layout of heating, ventilating, and air-conditioning system	
Type and condition of air filtration and cleaning equipment	
Air supply volumes and distribution in the occupied zone	
Return and exhaust ventilation type, flow, and location	

Table 1 - Related Factors Significant for Interpreting IAQ Measurements.

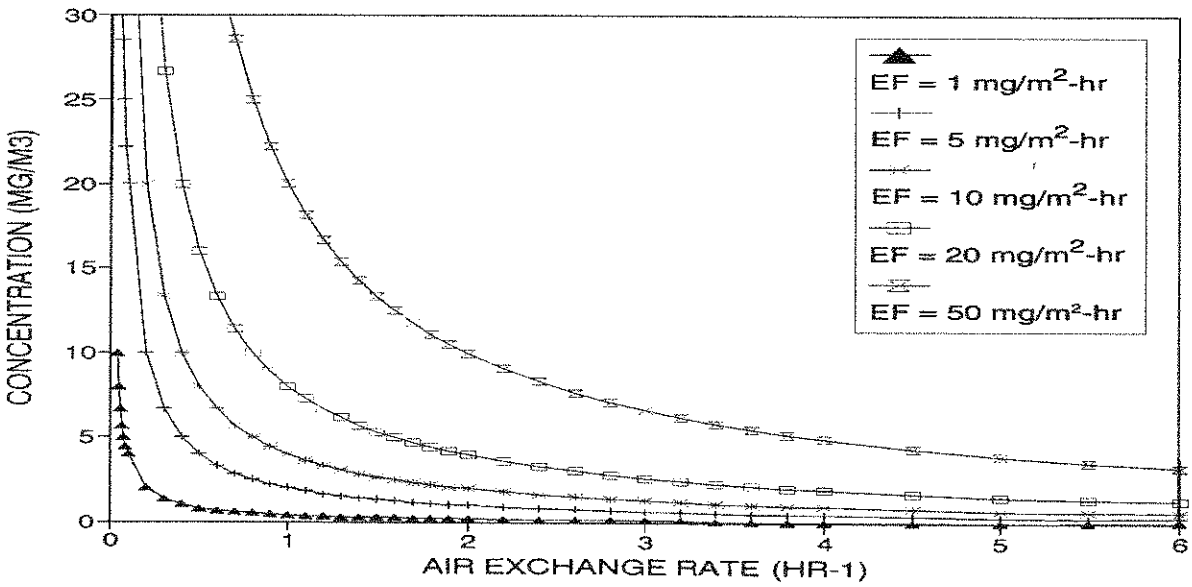

Figure 2 - Relationships Between Ventilation and Various Source Strengths.

strongly influence the airborne concentration of chemicals.

Most buildings operate at ventilation rates less than 1.2 ach a significant portion of the time. Almost all buildings operate at less than 1.2 ach when it is warm outdoors and indoor air temperatures are near the upper limit of the operating range, about 75 to 78°F (23.8 to 25.6°C). VOC concentrations emitted from building materials, furnishings, and consumer products are likely to be highest exactly when it is warm indoors and ventilation rates are minimal. This is because vapor pressure governs VOC emissions and vapor pressure increases as temperature increases.

For source strengths greater than 20 $mg{\cdot}m^{-2}{\cdot}h^{-1}$, changes in ventilation rates up to more than 3.0 ach significantly affect concentrations. While such high source strengths are rare, they can result from freshly applied paints, waxes, stains, polishes, and other "wet" products that have high emission rates during the first one to ten hours after application. Therefore, it is important to characterize ventilation rates as well as source strengths.

Because formaldehyde is very soluble in water, its airborne concentrations depend greatly on temperature and humidity. Increases in either temperature or humidity within the normal comfort range can easily double, triple, or even quadruple an air concentration. Therefore, when measuring formaldehyde and other water-soluble substances, it is essential to measure and report both the temperature and the humidity. Figures 3 and 4 show how formaldehyde emissions from particleboard depend on temperature and humidity.

Ventilation is critical because it affects VOC source strength and, independent of source strength, it affects concentrations of all contaminants. Humidity does not greatly affect most substance concentrations, but its impact is significant for those it does affect.

Incorporating Related Factors into Results

Considering critical related factors is an essential part of designing an air-monitoring project or study and of establishing a testing protocol. Therefore, include this information in your reports; others will need it to critically evaluate your results. You won't always be able to precisely characterize all the important variables, but include at least a qualitative characterization of the essential ones.

For ventilation, this might mean describing the system operating schedule, the design values for air exchange, the programmed flow conditions during the sample collection, and any measured values that might help in determining the air exchange rate. (See our comments on the letter from Joe Ventresca elsewhere in this issue for some ideas about quantifying ventilation rate without making expensive measurements.)

Measurement Methods

Sometimes, circumstances are straightforward – useful, reliable measurement methods exist, and you can apply them in your situation. In other cases, there may be some problem in using instrumentation prescribed by standard methods. Or, no standard methods may exist for the contaminant in question at the concentrations of concern. In these cases, you may need to adapt other methods and instruments. However, you must validate your measurement methods for the results to be meaningful.

Indoor air measurement methods may or may not be standardized. Using standard measurement methods is the rule in industrial hygiene practice and ambient air quality measurement for regulated contaminants. In fact, most regulations are tied to a specific measurement method.

However, indoor air contaminant measurement methods are not standardized for many contaminants. Even where standard ambient or workplace methods are available, close conformance to the requirements of the standard method is not always the case. Many investigators simply use the equipment specified in a standard method without following the specified procedures.

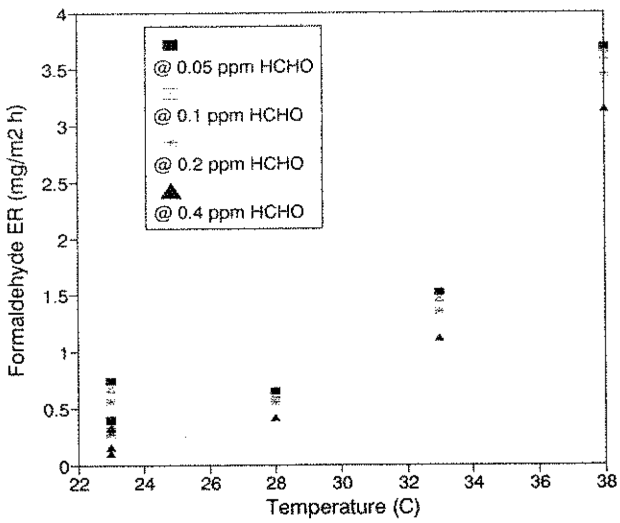

Figure 3 - Formaldehyde Emission Rates at Different Temperatures and Concentrations.

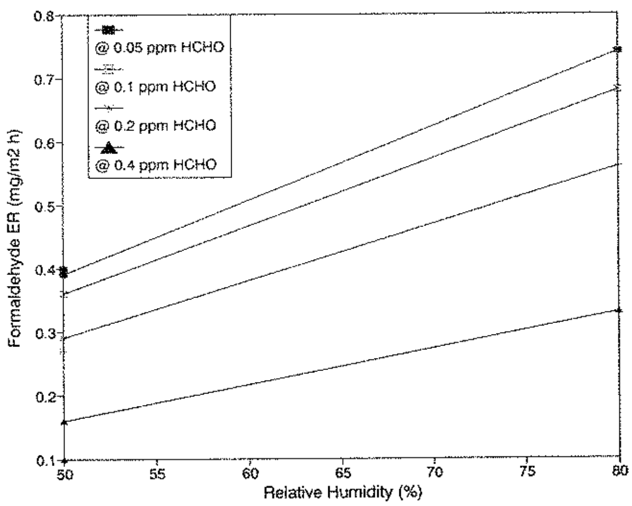

Figure 4 - Formaldehyde Emission Rates at 23°C, Different Humidities, and Different Concentrations.

Ad Hoc Validation

If investigators make measurements with non-standard methods, the method's performance should be evaluated specifically for the reported application. This usually requires some measurement under controlled conditions that allows for evaluating the method's sample collection efficiency; analytical sensitivity and accuracy; and, overall reliability, interferences, biases, and measurement system precision. Such evaluation, often called validation, is not easy. However, without validation, measurements may not be meaningfully compared to values obtained with other measurement methods. Nor can the reliability of the measurements be determined.

Following Standard Procedures

We recently discussed CO_2 measurements (see *IAB*, Vol. 1, No. 7, December 1991). There are now economical devices for direct reading measurement of CO_2. These devices appear reliable when operated properly, but authorities stress the importance of calibrating equipment for measuring CO_2. While this is not easy, it appears to be essential to making reliable measurements that can be compared to any sort of standard or guideline value.

Another example is reporting measurements of total volatile organic compounds (TVOC). While we think the use of TVOC measurements can be misleading, there are times when it is useful. However, when gas chromatography/flame ionization detection (GC/FID) quantification is used, calibrating the detector to a relevant standard and reporting that standard are critical for accurately interpreting the results.

Improving Measurement Methods

Measuring IAQ is difficult, but we see two ways to improve the situation. One, develop new methods that are more appropriate and useful, and two, develop standards for existing and new methods. Doing either of these requires investments either from private companies that have a stake in them or by government. One thing is certain: reasonable regulation of IAQ cannot occur until such developments occur.

Developing Methods

Measurement methods must be improved for important indoor air contaminants such as VOCs, semi-volatile organic compounds, microorganisms, and carbon dioxide. Improved methods will be more economical, sensitive, portable, faster, and easy to use.

Funding to develop these improved methods can come from measurement-device manufacturers, user groups such as ventilation system control manufacturers, industry, and government. Scientific and manufacturing entities can do the development work. In any case, large investment for developing improved methodologies is necessary.

Standardizing Methods

In 1986, the American Society for Testing and Materials (ASTM) established Subcommittee D22.05 on Indoor Air under Committee D22 on Sampling and Analysis of Atmospheres. During its six years of work, the committee has developed many standards to assist those wishing to measure indoor air. However, it has only covered a small fraction of the many useful methods for measuring indoor air contaminants. It has held two symposia that produced very useful publications, and it will hold its third in late April. See the references at the end of this article.

Participation in ASTM activities is open to all who are interested. Those willing to participate in drafting new standards or reviewing drafts as they progress are particularly encouraged to attend. Membership is not required to attend meetings or to participate in drafting standards, but it is required to vote on standards submitted for adoption. Members must vote on balloted standards and chronic non-voting results in membership cancellation. Non-voting status is available to members on request. The small annual fee is well worth the investment: members receive a volume of the *Annual Book of Standards* each year.

Conclusion

IAQ depends on a number of different, often inter-related factors. Analyzing and reporting any one factor or set of measurements out of context is usually not useful; we need to understand all relevant related factors to make sense out of quantitative measurement results. Above all, we need to understand source characteristics and ventilation factors to assess and interpret measurement results.

Additionally, measurement methods need to be flexible, appropriate, valid, and reproducible. In the absence of standards, or when unique methods are used, some way to objectively compare results must be provided. The easiest way is to use standard methods when they are applicable. In their absence, validation of methods is important to ensure the integrity of the data and its comparability to other reported measurements.

For more information:

Contact ASTM, 1916 Race Street, Philadelphia, PA 19103. You can speak to Staff Manager George Luciw, (215) 299-5571, or Administrative Assistant Terry Kaminski, (215) 299-5513.

References:

Alfred Hodgson, Joan Daisey, and Richard Grot, "Source Strengths and Sources of Volatile Organic Compounds in a New Office Building." Paper 89-80.7, presented at Air and Waste Management Association, 82nd Annual Meeting, June 25-30, 1989.

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N.L. Nagda, H. Rector, and R. Fortmann, *Guidelines for Monitoring Indoor Air Quality*. Washington: Hemisphere Publishing Co. 1986. 290 pp. ($42.50 from Hemisphere, New York, (212) 725-1999).

N.L. Nagda, and J.P. Harper, (Eds.) *Design and Protocol for Monitoring Indoor Air Quality. ASTM STP 1002*. Philadelphia: American Society for Testing and Materials, 1988. 309 pp.

P. R. Morey, , J. Feeley, and J. Otten, (Eds.) *Biological Contaminants in Indoor Air*, STP 1071, Philadelphia: American Society for Testing and Materials. 1990. 244 pp.

J. E. Yocum and S. M. McCarthy, *Measuring Indoor Air Quality: A Practical Guide*. New York: John Wiley & Sons. 1992. 228 pp. ($89.95). (See *Publications* in this issue.)

Clarification

Envirosense Not Sponsored by Philip Morris

Larry Abblitt of Interface Research Corporation called to correct an error in the January ***IAB***. On page 10, we quoted the February 25th *Los Angeles Times* article on Gray Robertson that identified Philip Morris as a member of Envirosense. According to Abblitt, Philip Morris co-sponsored the Envirosense seminar tour, but Philip Morris is not a member of Envirosense.

Abblitt informed us that Envirosense is a coalition of a diverse group of companies with interests in IAQ. Abblitt's company, the Interface Research Corporation, is a major player in the Envirosense coalition.

We called *L. A. Times* reporter Myron Levin and relayed Abblitt's message. He said he stood by his story based on the information provided at the seminar. He also said that neither he nor his editors at the *Times* had been contacted to make the correction.

Letters

Gray Robertson of Healthy Buildings International Responds

Gray Robertson of Healthy Buildings International wrote us concerning our comment on a recent Los Angeles Times newspaper article. The following is his letter reprinted in its entirety.

Dear Mr. Levin:

I was more than a little dismayed by your recent article "IAQ 'Experts' and the Tobacco Industry" (Indoor Air Bulletin, Jan.1992, page 9). The article contains much that is inaccurate. The report's implications, however, are much more distressing.

If you had paid me the courtesy of a telephone call before running your story on me and my company, Healthy Buildings International Inc. (HBI), I could have corrected a number of misimpressions and helped you avoid defamatory statements, including the following:

1. Over the last ten years, we have investigated air quality in approximately 820 major buildings for more than 200 separate clients. Our clients include federal and state government agencies, major hospitals, commercial office property owners and developers, banks, schools and hotels. We also have completed projects, including building inspections, for tobacco companies as well as The Tobacco Institute.

2. We have acknowledged, publicly and repeatedly, the work that we have done for the tobacco industry. We have never "denied" undertaking such work, nor have we acknowledged it "reluctantly", as your article suggests. Had you checked, for example, you would have discovered that the testimony that I gave in Congress on IAQ legislation expressly acknowledged that I had served as a consultant to the tobacco industry on IAQ matters. Similarly, the printed materials given to those who attended the California seminar referred to in your article acknowledged the support that had been provided by the Philip Morris Company, among others. The same acknowledgment was provided to those who attended the press briefing that followed the seminar. Furthermore, in response to one reporter's question during this briefing I stated that HBI had inspected several buildings for tobacco companies, we had appeared before Congress, the

National Academy of Sciences and several state legislative panels as a consultant for the tobacco industry and we had done several research projects funded by the industry including projects for the Center for Indoor Air Research (CIAR), which also receives funds from tobacco companies. However, the current seminar and press briefing included only a small section about tobacco - namely the Philip Morris design of a smoking lounge using displacement ventilation techniques. The major focus of these seminars was the concept of Envirosense, a group incidentally of which Philip Morris is not a member. In these respects, the L.A. Times article by Myron Levin to which you referred was in error, as the printed materials from the seminar and briefing will demonstrate.

3. We were particularly dismayed by your allegation that we use low cost IAQ studies in order to obtain engagements to undertake expensive duct cleaning. The fact is that we have not been in the duct cleaning business for more than six years, except for special projects for select clients who had particularly difficult problems that others could not, or would not, complete. However, these projects in total over this six year period accounted for less than four percent of our turnover. Moreover, on the relatively few occasions that we see a need for duct cleaning in client buildings we advise our clients to seek services from others. In this regard our role is that of an independent, and particularly well trained, third party consultant dedicated to looking after our client's interests. I would have thought that a responsible reporter would have made such inquiries before accusing us, in essence, of using bait - and - switch practices.

With regard to our costs being low with respect to "some of the best known IAQ investigation firms", we can only plead guilty. The fact is that our proactive monitoring programs, developed and priced carefully for property manager's maintenance budgets, have become the cornerstone of good IAQ practices in hundreds of major buildings.

4. So far as the recirculation of air in buildings in which smoking is permitted is concerned, we limit ourselves to reporting the actual measurements of pollutants. Almost invariably, in buildings with reasonable to good ventilation rates we typically find only very low levels of tobacco related materials in non-smoking areas. A number of other investigators have reported comparable findings. I have difficulty understanding why you view such findings, or our disclosure of them, to be a cause of concern or consternation. Similarly, why make the statement "smoking-permissive buildings do not make business sense"? We encounter numerous property owners who wish to accommodate both smoking and non-smoking tenants.

Obviously, more is at work in your article than a mere recitation of the article's inaccuracies can convey. In a rather crude way, your article defames any firm or individual who either (I) has done work for or consulted with any tobacco company or (2) has reported findings that are inconsistent with the notion that environmental tobacco smoke is a major cause of Sick Building Syndrome. I suppose that you could include Prof. Alan Hedge of Cornell University, whose work you recite occasionally, in the latter category since his study of 3155 office workers in 18 air-conditioned office buildings concluded that smoking policies had no effect on SBS symptoms.

Frankly, you cheapen any reasonable discussion of indoor air quality when you resort to tactics such as placing quotation marks on words such as "Experts" when referring to firms that have done work for tobacco companies; using the word "glossy" when describing our company magazine, apparently attempting to suggest thereby that our publication is somehow tainted; and referring to "many in the indoor air community" as unnamed sources for your assertions. I know that neither you nor I have a monopoly of knowledge on indoor air quality issues. For my part, I read your articles and reports with an open mind. Sometimes I learn from them, at other times I disagree with your comments. However, at all times I respect your right to a different point of view. I wish you would do the same for me.

Yours sincerely,

Gray Robertson, President

Healthy Buildings International

Joe Ventresca on Operation and Maintenance

Dear Hal:

I would like to compliment you for your fine discussion of "IAQ, Productivity, and Occupant Control" in the December issue, and the follow-up comments in the January issue. Our experience in managing facilities is that good temperature control is critical.

We find that complaints of stale air, inadequate ventilation, and dryness, peak in the spring and fall. But this is when our buildings (located in temperate climate) are operating on economizer, with maximum amounts of outside air.

We noticed that the complaints peaked on sunny winter afternoons, when there was overheating. Integrated temperature measurements showed that complaints correlated with a temperature pattern starting the day at about 68 degrees [20°C] and then rising to 77 degrees [25°C] or higher by 3-4 p.m. Our experience verifies Dr. [Larry] Berglund's laboratory results, that indicate that we perceive cooler air to be fresher. When we repaired the economizer and temperature controls to reduce overheating on winter afternoons, there was a dramatic increase in IAQ complaints.

I was particularly perplexed that people did not complain that they were too hot. I suspect that they have found that complaining about temperature does not generally improve the situation. Their attitude was that the temperature control had always been poor, and would always be that way.

We expected complaints of inadequate ventilation, stale air, to peak in July and August because this is when our buildings' operate continuously at minimum outside air. (That's because it takes more energy to cool the hot, humid summer outdoor air, than the buildings' return air.) As long as the temperatures are cool in the summer, even though there is minimum outside air, there are rarely complaints of inadequate ventilation. However, during the fall, winter, and spring when our buildings have maximum amounts of outside "fresh" air. If the building temperature is too warm, then there is perceived staleness, stuffiness, inadequate ventilation, and dryness.

Results of our energy simulations research, yields a general rule of thumb that many buildings with air economizer "should" bring in more than 20 cfm of outside air whenever the outside air temperature is between about 20°F [-6.7°C] and 70°F [21.1°C] due to the normal economizer operation. If there are complaints of inadequate ventilation during these outdoor temperatures, it is likely that the central economizer is operating improperly and/or the terminal air distribution supply box and thermostats are operating improperly. This strongly indicates the need for proper operations and maintenance of the economizer and temperature control system.

I developed a detailed technical discussion of the relationship of economizer operation and IAQ complaints, which appeared in the January *ASHRAE* Journal. I hope that in the future you will have the opportunity to take an in-depth look at practical economizer and temperature controls maintenance issues.

Sincerely,

Joseph Ventresca, Energy Coordinator

City of Columbus

IAB's Reply

We will take a further look at economizer and temperature control maintenance issues in a future issue of the ***IAB***. Meanwhile, the following are the five major operations and maintenance conditions that Ventresca identified as causes of improper economizer operation. These comments generally assume a return air (RA) temperature of somewhere around 78°F (25.6°C) on most afternoons. The outside air (OA) is used for "free" cooling — thence the name "economizer" — when it is at least somewhat cooler than the return air.

When cooling is required, supply air is set to 55°F. Thus, OA at 32°F could be mixed with 78°F RA in a 50/50 ratio to yield 55°F supply air. As the OA temperature rises, more of it can be used for "free cooling" until the 55 °F temperature is reached. Once that temperature is reached, cooling is required to achieve the 55°F designed supply air temperature. The percent outside air is shown as a function of outside air temperature in Figure 5.

Ventresca says his ten years' experience in Columbus shows that one or more of the following five conditions exist in many buildings. Our own experience is consistent with Ventresca's findings. Correcting these problems "should be a first step toward improved indoor air quality."

- *Outside damper closing from freeze stat signal.* The freeze stat closes the dampers to

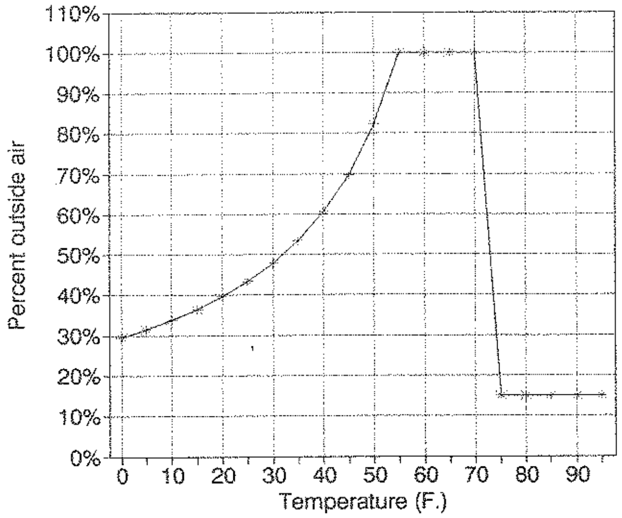

Figure 5 - Percent Outside Air as a Function of Outside Air Temperature.

protect the coils from freezing air resulting from poor design and stratified air flow. The result is overheating, inadequate ventilation, and improper building operation with negative pressure and deteriorating IAQ. The solution Ventresca proposes is to modify ductwork and dampers to provide proper air mixing that eliminates the potential for freezing coils.

- *Chiller water towers that are inoperable in the winter.* In cooler climates, it is common to drain cooling towers during the winter. Yet, on warmer winter afternoons, some cooling will be required, even with 100% outside air. Without chilling, indoor air temperatures will rise above the comfort zone. Ventresca does not provide a remedy for this situation.

- *Improper tracking of supply and return air fans.* The proportion of outside air is a function of both the damper position and the supply and return fan volumes. Ventresca points out that even when dampers are wide open, the fan volumes must be properly balanced to pull outside air into the system. He says fan tracking and economizer problems are especially common in VAV systems due to the fairly constant change of volumes throughout the day. The solution, he says, depends on the type of air flow volume equipment used in a particular building.

- *Return air damper malfunction.* When outside air intake is set to 100%, the return air damper must fully close and seal to avoid leakage and return recirculation resulting in overheating. The solution is maintenance, calibration, and adjustment of the three dampers (outside air, return air, and mixed air) and the economizer controls.

- *HVAC control problems.* Overheating due to improper economizer functioning. This, Ventresca says, is a system maintenance problem. Start with the central economizer itself, then adjust, calibrate, and balance the terminal air supply boxes and room thermostats.

Letters

Earon Davis on MCS-Related Reports

Earon Davis, J.D., M.P.H., is an environmental health law consultant in Evanston, Illinois. He was an invited participant at both the 1987 and 1991 workshops on multiple chemical sensitivities (MCS) held by the National Academy of Sciences and served as an invited reviewer for the New Jersey and Maryland reports on MCS. Among his clients is the American Academy of Environmental Medicine, an association of physicians that treat patients with MCS.

Dear Editor:

Your readers might be interested in two new reports just released by the National Academy of Sciences. [These reports] support standards for indoor air quality as well as the position that Multiple Chemical Sensitivity (also known as Environmental Illness) is a public health problem that requires a substantial research effort. The assertion that chemical sensitivity is largely a psychological problem was rejected.

In *Biologic Markers in Immunotoxicology* released in April, the Biologic Markers Committee of the National Research Council gave explicit recognition to sick building syndrome, which many scientists believe is a subset or precursor of multiple chemical sensitivities. The committee stated that "sick building syndrome appears to be a real phenomenon caused by contamination of indoor air that cause discomfort to a substantial number of workers."

The committee recommended the establishment of : indoor air pollution standards for homes, schools, workplaces: to "restrict offending agents including volatile organic compounds to levels below those at which significant numbers of occupants develop symptoms."

On a broader level, the report is an impressive review of the potential hazards of our chemical environment to the human immune system. It is "must reading" for anyone involved with this fledgling field.

Regarding multiple chemical sensitivity, the committee described a "paucity of solid scientific data" and made recommendations for research. They concluded that "There is a need to establish a multidisciplinary team of experts ... to study patients with these purported syndromes."

Of special interest is the report's Chapter 9, "Use of Biologic Markers in Controversial Areas of Environmental Health." This chapter provides a solid review of the environmental illness issue and presents the recommendations of the March 1991 Workshop on MCS, which included research on people with MCS, especially in environmental control units where adaptation and de-adaptation phenomena can be studied.

In reviewing the work of Abba Terr, M.D., who concludes that there is no reason to believe that MCS is real, the Committee found, at page 134, that "Terr's conclusions are poorly supported opinion expressed by one who has evaluated patients on behalf of a workers' compensation appeals board."

The second report, *Multiple Chemical Sensitivities*, was released as an addendum to the "biologic markers" report. This report is a compilation of the proceedings of the 1991 workshop held by the National Academy of Sciences and the U.S. Environmental Protection Agency. *Multiple Chemical Sensitivity* is an outstanding collection of information on this problem, aided by in-depth articles by physicians and scientists including Claudia S. Miller, M.D., Prof. Nicholas A. Ashford, Iris R. Bell, M.D., William Meggs, M.D., Gunnar Heuser, M.D., and William J. Rea, M.D., and his associates.

The inclusion of the "Environmental Medicine" experts in the workshop and in this volume indicates a watershed in efforts to de-politicize the multiple chemical sensitivity issue. The National Academy of Sciences is to be congratulated for its recognition of the pseudoscientific nature of the "studies" which purport to show MCS and "Clinical Ecology" to be without merit.

Of course, the report does include a summation of the political position against MCS. In a brief chapter, Roy L. DeHart, M.D., presents the opinions of some allergy academies and unenlightened groups within the industry. This material was not fully presented at the original symposium as it was irrelevant to the scientific inquiry at hand. However, it may have been inserted to remind us all that science does not operate in a vacuum.

By the publication of these two, objective reports, the National Academy of Sciences has placed indoor air quality and MCS on our nation's research agenda. ...However, there are still those who oppose research on MCS.

Biologic Markers in Immunotoxicology at 206 pages, including index, is available for $37.95. *Multiple Chemical Sensitivities* is available for $24.00. copies of these reports may be ordered by credit card by calling (800) 624-6242 or by writing to National Academy Press, P. O. Box 285. Washington, D.C. 20055. Prompt shipment can be arranged for a small additional fee. [The first printing of "Biologic Markers" sold out and is on back order as of press time. Estimated availability is June 1.]

Sincerely,

Earon Davis

Publications

Database of Indoor Air Pollution Sources (DIAPS)

DIAPS is EPA's Indoor Air Branch's long-awaited IAQ source data base. It is a menu driven, user friendly data base for IBM PCs and compatibles. It will be available on both 5 1/4" and 3 1/2" floppy disks.

DIAPS contains a primary citation and an abstract, a pollutants list, a sources list, an activity list, data on sampling and analytical procedures, emissions rates, and emissions factors. This data is retrievable through a set of reporting formats as well as a browsing feature.

DIAPS is designed to be an archive of IAQ data taken from the literature and other referenced sources. Potential entries are reviewed to determine their relevance to DIAPS, but it is important to note that DIAPS is intended to be an archive. Consequently, EPA does not assume responsibility for providing quality assurance/quality control for the original researcher's effort. However, they will make every effort to assure that the data contained in DIAPS is consistent with the reported data. Sufficient information will be presented in each reference to enable a user to judge whether he or she wants to acquire the article. EPA will not supply the article itself.

DIAPS will be available in June, 1992; the initial distribution will be handled out of the Indoor Air Branch. Future updates will also be handled by the Indoor Air Branch and will be done as growth in the field demands. Hopefully, a system will develop where users will provide data to augment DIAPS. Depending on the response, this may lead to an IAQ bulletin-board type of system.

Watch the ***IAB*** for information on how to obtain a copy.

Publications

Recent Indoor Air Books

Indoor air publications are coming out faster than we can keep up with them. The following are some recently received books. We will try to review as many of them as possible in future issues.

• Bradford O. Brooks and William F. Davis, *Understanding Indoor Air Quality*. Boca Raton: CRC Press, Inc. Lewis Publishers, 1992. 189 pages. ($55. in the U.S., $66. outside the U.S.)

Aptly named "understanding" IAQ, this is an interesting publication written from a health effects perspective. Brooks has an unique way of presenting information, at times delightful, at times almost tedious or flat. But the perspective of a health scientist who works on practical indoor air quality problems for IBM Corporation is worth the effort to read.

• J. Kay, G. Keller, and J. Miller, (eds) *Indoor Air Pollution: Radon, Bioaerosols, and VOC's*. Chelsea, Michigan: Lewis Publishers, 1991. 259 pages. ($69.95)

This book is a collection of papers presented at an American Chemical Society symposium held in September 1989. Most of the authors are highly regarded authorities, and the papers are of high quality. The content is uneven as is bound to be the case with almost any collection of separate papers by scientists. The editors do little to correct this shortcoming. Nonetheless, many of the papers are valuable, and this book would be an important addition at least to the library of a chemist interested in IAQ.

• J. E. Yocum and S. M. McCarthy, *Measuring Indoor Air Quality: A Practical Guide*. New York: John Wiley & Sons. 1992. 228 pp. ($89.95)

Yocum made some of the earliest measurements of indoor air and his work called attention to the high indoor/outdoor ratios of many contaminant concentrations. The book is broad in its scope and is an ambitious undertaking. While it is an extremely valuable tool for those working in indoor air, we found it rather uneven in the depth and comprehensiveness of its coverage in certain areas. The authors' task was enormous, and they have made an excellent start. We think this will be a valuable book to those who are directly involved in measuring indoor air.

Calendar

April 30 - May 2, 1992. **The First Annual IAQ Conference and Exposition**, "Indoor Air Quality: Service & Technology," Tampa Convention Center, Tampa, Florida. Sponsored by the National Coalition on Indoor Air Quality. Contact: National Coalition on Indoor Air Quality, 1518 K Street, NW, Washington, DC 20005.

May 3-8, 1992. **"Measurement of Toxic and Related Air Pollutants"** (International symposium and course.), Omni Durham Hotel and Convention Center, Durham, North Carolina. Sponsored by Air & Waste Management Association and U.S. EPA. Contact A&WMA, P. O. Box 2861, Pittsburgh, PA 15230. (412) 232-3444, fax (412) 232-3450.

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 $750 for five days.

May 7-8, 1992. **"Diagnosing and Mitigating Indoor Air Quality Problems,"** Omni, Georgetown, Washington, DC. Sponsored by American Association of Energy Engineers (AEE). Contact: AEE, P.O. Box 1026, Lilburn, GA 30326. 404-925-9633. Fax 404-381-9865. *Instructor is IAQ expert Francis J. "Bud" Offermann, PE, CIH. Fee is $685 for AEE Members, $785 for non-members.*

May 14-15, 1992. **"Indoor Air Quality" Professional Development Seminar**, Oklahoma City, OK. Sponsored by ASHRAE. Contact: Education Coordinator, ASHRAE, 1791 Tullie Circle N.E., Atlanta, GA 30329. (404) 636-8400, Fax (404) 321-5478. *Registration fee is $530 for ASHRAE members, $605 for non-members. Discount for early registration.*

June 1-5, 1992. **Annual Conference**, American Industrial Hygiene Conference. John B. Hines Veterans Memorial Convention Center, Boston, Massacusetts. Contact: AIHA, P.O Box 8390, Akron, Ohio 44320. (216) 873-2442.

June 17-19, 1992. **Indoor Air Quality Continuing Education Course**, American Industrial Hygiene Association, Washington, D.C. Contact: Continuing Education, AIHA, P.O. Box 8390, White Pond Drive, (216) 873-2442, Fax (216) 873-1642.

June 18-22, 1992. **American Institute of Architects Committee on the Environment** (AIA COTE), Meeting in conjunction with the AIA Convention, Boston, Massachusetts. Contact: Kristine Dombrowski or Patrick Lally, AIA, 1735 New York Avenue NW, Washington, DC 20006, Tel. (202) 626-7400, Fax (202) 626-7518.

June 21-26, 1992. **85th Annual Air & Waste Management Association Meeting and Exhibition,** Kansas City, MO. Contact A&WMA at address above for May 3-8. In Canada, A&WMA Annual Meeting, P. O. Box 11149, Postal Station A, Toronto, Ontario M5W 2G5.

June 27-July 1. **ASHRAE Annual Meeting,** Baltimore, Maryland. Contact: ASHRAE Meetings Dept., 1791 Tullie Circle N.E., Atlanta, GA 30329, (404) 636-8400.

July 12-17, 1992. **"Asbestos Measurement, Risk Assessment, Laboratory Accreditation."** Johnson State College, Johnson, Vermont. Sponsored by ASTM Committee D-22 on Sampling and Analysis of Atmospheres. Contact: George Luciw, ASTM, 1916 Race Street, Philadelphia, PA 19103, (215) 299-5471.

July 14-15, 1992. **"Indoor Air Quality for Facility Managers."** Sponsored by International Facility Managers Association (IFMA), Boston, Massachusetts. Contact: Susan Biggs, IFMA, 1 East Greenway Plaza, 11th Floor, Houston, TX 77046-0194, (800) 359-4362, Fax (713) 623-6124. *Instructor is **IAB** Editor Hal Levin.*

August 5-7, 1992. **"Environmentally Sound Architecture: New Technologies for Healthful, Efficient Buildings."** Harvard Graduate School of Design. Contact: Professional Development, Harvard GSD, 48 Quincy Street, Cambridge, MA 02138. 617-495-1680, Fax 617-495-5967. *Three day course: Day 1 - Indoor Air Quality by Design; Day 2 - Energy Efficient Lighting; Day 3 - Housing Energy Efficiency. Tuition/materials: $675, or $250/day.*

August 30 - September 5, 1992. **"Achieving Technical Potential: Programs and Technologies that Work!"** ACEEE 1992 Summer Study on Energy Efficiency in Buildings, Asilomar Conference Center, Pacific Grove, California. Sponsored by The American Council for an Energy-Efficient Economy. Contact: ACEEE 1992 Summer Study Office, 2140 Shattuck Avenue, Suite 202, Berkeley, CA 94704. *The ten topics include "human dimensions" of which indoor air quality, health and comfort are a part.*

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.

September 30 - October 2, 1992. **"Lead-Tech '92: Solutions for a Nation at Risk,"** Hyatt Regency Hotel, Bethesda, Maryland. Sponsored by IAQ Publications, Inc. Contact: Mary Lou Downing, Conference Manager, Lead-Tech '92, 4520 East-West Highway, Suite 610, Bethesda, MD 20814. (301) 913-0115; Fax (301) 913-0119. *The sponsors say this is the first industry-wide lead detection and abatement conference and exposition. The conference will cover technical and regulatory issues.*

October 18-20, 1992. **IAQ 92 - Environments for People,** Golden Gate Holiday Inn, San Francisco, California. Sponsored by ASHRAE, ACGIH, and AIHA. Contact; Jim Norman, Manager of Technical Services, American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., 1791 Tullie Circle NE, Atlanta, GA 30329, (404) 636-8400.

October 19-21, 1992. **Indoor Air Quality Continuing Education Course**, American Industrial Hygiene Association, Salt Lake City, Utah. Contact: Continuing Education, AIHA, P.O. Box 8390, White Pond Drive, (216) 873-2442. Fax (216) 873-1642.

International

June 9-11, 1992. **Aerobiology 1992:** Symposium of the Pan-American Aerobiology Association, Scarborough College, University of Toronto, Toronto, Canada. Contact: Christine Rogers, Conference Organizer, Life Science, Scarborough College, University of Toronto, 1265 Military Trail, Scarborough, Ontario, Canada M1C 1A4. (416) 287-7421; Fax (416) 287-7642. *The main focus is the distribution, production, dispersal, and deposition of airborne biological particles, and the implication of these processes to ecology, allergy, and plant pathology among other areas. All relevant interests will be accommodated.*

July 22-24, 1992. **1992 International Symposium on Ventilation Effectiveness,** Tokyo, Japan, sponsored by the Institute of Industrial Science, The University of Tokyo. (co-sponsored by ASHRAE). Contact ASHRAE in the US.

September 2-4, 1992. **Roomvent '92, The Third International 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.

October 12-16, 1992. **Second International Course on Sick Building Syndrome**, sponsored by the Nordic Institute of Occupational Health (NIVA). Hotel Oranje Boulevard, Noordwijk aan Zee, The Netherlands. Contact: Gunilla Ahlberg, NIVA, Topeliuksenkatu 41 a A, SF-00250 Helsinki, Finland. Tel +358 0 474 498. Fax +358 0 414 634. *A five day course intended for occupational safety and health experts and industrial hygienists working in the field of indoor air quality. Enrollment limited to 50.*

February 17-19, 1993. **"Building Design, Technology & Occupant Well Being in Cold and Temperate Climates,"** Palais des Congrés, Brussels, Belgium. Contact: ATIC-CDH, chausee d'Alsemberg 196, B-1180 Brussels, Belgium. Tel. 32-2-348-05-50; Fax 32-2-343-98-42. *Abstracts of no more than 300 words are due by August 15, 1992. The official languages will be English, French, and Flemish.*

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.