Indoor Air BULLETIN™ Hal Levin, Editor

Technology, Research, and News for Indoor Environmental Quality

Volume 3 Number 10

Cleaning: A Solution to the Sick Building Mystery?

The connection between health and cleanliness is, for most people, a matter of common sense. Office workers report higher rates of discomfort when they perceive a dirty, dusty environment. Research, not surprisingly, shows that certain cleaning methods are effective in reducing dust on surfaces and in reducing the levels of indoor air contaminants. Yet some cleaning practices, like the use of improperly diluted cleaning solutions, are themselves significant threats to good IAQ. As with everything else, there are right and wrong ways to clean. In this article and in the following issue, the ***BULLETIN*** discusses building cleaning and the relationships between cleaning and IAQ.

Office Worker Symptoms and Building Cleanliness

Occurrences of office worker symptoms (also known as sick-building syndrome or SBS symptoms) have often been associated with poorly cleaned buildings. And, many times when we go in to investigate a problem building, we find that the building was poorly cleaned. Offices are often dusty simply because of a low level of cleaning, but at times the clutter around work stations precludes thorough and effective cleaning.

Strong relationships exist between the quality of indoor air and the concentrations of dust and chemicals found on building interior surfaces. The relationships are well-documented in the literature for some pesticides. Several studies reported at Indoor Air '96 in Nagoya showed the cleanliness of filters in ventilation systems directly affected the quality of air downstream from the filters. On the basis of physical principles, none of this is very surprising.

Studies done at the EPA headquarters in Washington "...indicated that the workplace variable affecting the largest number of health symptoms and comfort/odor concerns was dust." Occupant perceptions of dusty environments were strongly associated with SBS symptom prevalence rates, more strongly than any physical factor measured in the study. Researchers identified dust as "...the characteristic contributing most powerfully to a wide variety of health, comfort, and odor concerns" (Wallace *et al.*, 1991).

The Danish Town Hall Study found that dust was the most highly correlated variable with self-reported health symptoms (Skov *et al.*, 1989). A Swedish study found that intensive cleaning of carpets and wet dusting reduced health symptoms in an office building for at least the following two months (Norbäck and Torgen, 1989). A British study by Roys *et al.* (1993) reported that intensive office cleaning was followed by more than a 35% reduction in the average number of office worker symptoms.

IAQ and Surface Contamination

Gases and vapors can adsorb and particles can deposit on surfaces. These gases and vapors are in constant flux, moving from the surfaces to the air and back again. Some of the larger particles (>1 micron dia) can also be dislodged from surfaces and redeposit else-

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where, while smaller particles (<1 micron dia) tend to remain on surfaces until dislodged by deliberate cleaning. Particles (that are heavy enough) can fall to horizontal surfaces due to gravity, or stick to both vertical and horizontal surfaces due to impaction or (in the case of lighter particles) diffusion, electrostatic forces, and thermophoresis.

Dust on floors or wall surfaces can be re-suspended in the air when the surface is disturbed by people walking on or near it, by the vibration caused by many ordinary human activities, or even by cleaning activities themselves. Nearly everyone is familiar with the smell of dust in the air after vacuuming with ordinary household vacuum cleaners. Many studies have shown that airborne dust levels are actually higher after vacuuming with typical equipment. Similarly, the vibration of an earthquake raises dust levels measurably.

The rate of removal of dust from the air by gravity and by deposition on surfaces depends on the size of the particles involved. Thomas Schneider of the Danish National Institute of Occupational Health has reported these removal rates on floor, walls, and ceilings in terms of equivalent air exchange rates for particles of different sizes. The results are shown in Figure 1.

Modern Office Environments

There is an enormous amount of surface area in a typical office building that rarely or never gets cleaned. The largest single surface area in a typical open office environment is on the free-standing partitions separating work stations, which often have a surface area (both sides) of more than 3.5 times the floor area. The second largest surface area exposed to circulating air is the ceiling tile where the concealed space above a suspended ceiling is used as a return air plenum. In this common configuration, the ceiling tile surface area approaches twice that of the floor area (Levin, 1987). Neither the partitions nor the ceiling tile are cleaned routinely, if ever. If there is a relationship between the cleanliness of surfaces and the quality of indoor air, is it any wonder that maintaining good IAQ is such a challenge?

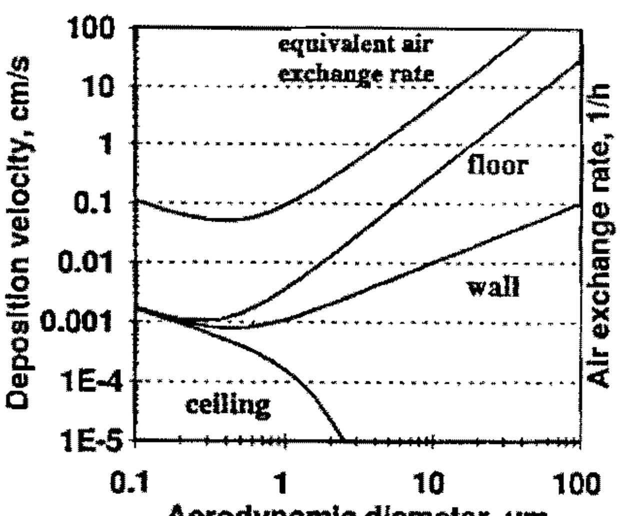

Figure 1 - Deposition velocity onto room surfaces of airborne particles and resulting equivalent air exchange rate . (Schneider, 1995).

Dust and Computers

Schneider *et al.* measured particle deposition velocities on a mannequin in front of a computer and modeled factors determining deposition velocities (1993). They found that both the electromagnetic fields and the air currents associated with computer monitors and computer cooling fans affect the deposition of particles on users' facial skin and eyes — increasing deposition velocities by up to ten-fold.

The weaker the air currents, the greater the influence of the electrostatic fields. The electrical field influences are greatest, according to the model, for particles near 1 µm; air currents are most important for particles near 10 µm. According to Schneider, the results are important for assessing the contribution of particles to "office eye syndrome" attributed to particles and particle-bound surfactants in office environments.

Thus, workers in front of a computer may have much greater exposure to dust and other particulate matter than other workers in nearby areas. Furthermore, dust levels may be more important where skin or eye irritation or even respiratory tract irritation occurs.

Biological Contaminants

Increasing evidence from all over the world indicates that moisture in homes is associated with higher rates of asthma and allergy. It is logically assumed that the presence of moisture signals higher concentrations of microbial contaminants and bioaerosols. Thus, from a health perspective, moisture control is important for reducing biological pollutant exposure in homes, and, presumably, in other environments as well. A number of recent, well-publicized lawsuits in Florida make it clear that moisture control is essential to maintaining low concentrations of microbial contaminants. Very serious health hazards can accompany some microbial pollutants.

Dust is also a reservoir for microbial contaminants. Danish Town Hall researchers (among others) have suggested that the cause of health problems in offices and schools could be physical irritation, allergens, or endotoxins related to dust exposures (Gravesen *et al.*, 1990). Since microbial growth strongly depends on the presence of moisture, the combination of moisture and dust is an obvious one to consider as an indicator of potential IAQ problems. Clearly, then, moisture intrusion should be considered as a major risk factor for IAQ problems. Controlling humidity and moisture in materials and on surfaces is obviously important to reducing risks of microbial contamination.

Indoor Air Pollutants from Cleaning Products and Solvents

The California Healthy Buildings Study (CHBS) and the Bell Communications Research (Bellcore) telephone company administration buildings studies found distinct sets of chemicals that were predominantly either from indoor or from outdoor sources (Ten Brinke, 1995; Shields, Fleischer and Weschler, 1996). Among those found in the CHBS predominantly from indoor sources were compounds used for cleaning and degreasing — dichloromethane, trichloroethene, and 1,1,1-trichloroethane. Their geometric means and ranges of concentrations (ppb) in the CHBS were as follows: dichloromethane, 0.49 ± 6.7 (<0.1 - 41); trichloroethene, 2.0 ± 2.2 (0.31 - 6.9); and, 1,1,1-trichloroethane 4.1 ± 3.8 (0.10 - 41).

These chlorinated hydrocarbons are usually found in indoor air, although, perhaps, more frequently in the US than in Europe. Individually, these chemicals can cause health and comfort problems at higher concentrations than those usually found indoors. Too little is known about their combined effects at the lower concentrations typically found indoors. The 1,1,1- trichloroethane geometric mean concentration for all the buildings in the CHBS study was second-highest of all the 40 compounds quantified; it was second only to ethanol with a geometric mean of 22 ± 1.8 ppb and a range of 8.7 - 130 ppb.

Current Cleaning Trends

Accumulating evidence shows the importance of cleaning for IAQ and for the significance of IAQ for occupant health, comfort, and productivity. However, the amount of cleaning routinely done in many North American buildings appears to be declining, according to a survey of their members by the Building Owners and Managers Association (BOMA).

Comparisons of 1990 and 1996 study results show that most property managers have maintained their level of service while some property managers reduced the frequency of some activities (see Table 1). Two notable examples are the vacuuming of low-traffic carpet areas and the dusting of desks and shelves. Half of the survey respondents still provide both activities on a daily basis; however, it appears that the trend is to shift low-traffic carpet vacuuming to two to three times a week and dusting of desks and shelves to once a week. On the other hand, the frequencies of other essential activities such as high-traffic carpet vacuuming and trash removal remain virtually the same.

BOMA reports the average cleaning cost for US private-sector office buildings was $1.09/ft^2 in 1995 (CAN $1.06/ft^2 for Canadian private-sector buildings, about US $.79). Cleaning expenses consist of payroll/contract expenses for both daytime and evening routine cleaning, specialized contract cleaning, supplies and equipment replacements, and trash removal and recycling (in the form of either expenses or revenues that offset trash removal). (Source: 1996 Experience Exchange Report, a publication that "reports the

Table 1 - High-frequency cleaning activities 1990 data (in parentheses) vs. 1996 data (BOMA).

Service	*No. of Responses*	*Daily*	*2-3x week*	*1x week*	*1-2x month*	*1-2x yr.*	*3-4x yr.*	*as needed*	*not done*	*other*
Dust/damp mop high traffic hard floors	845	91% (91%)	4% (4%)	2% (3%)	1% (1%)	0%	0%	2%	0% (1%)	0%
Dust/damp mop low traffic hard floors	833	54% (58%)	22% (20%)	18% (19%)	3% (3%)	0%	0%	3%	1%	0%
Vacuum high traffic carpets	847	94% (97%)	4% (3%)	2%	0%	0%	0%	0.3%	0.2%	0%
Vacuum low traffic carpets	842	52% (61%)	25% (20%)	19.3% (18%)	1.2% (1%)	0%	0%	2.2%	0.2%	0.1%
Dust desks/shelves	833	47% (60%)	17% (19%)	26%	4%	0%	0%	5%	0.4%	0.6%
Trash removal from interior space	845	98% (98%)	1% (1%)	1% (1%)	0%	0%	0%	0%	0%	0%

actual rental income and operating expenses for office buildings in North America.")

Cleaning expenses (adjusted for inflation) have steadily dropped for the past 10 years, BOMA says. What accounts for the decrease in costs, more efficient cleaning or less frequency? The answer, according to BOMA, appears to be that some decrease in frequency contributes to the cost savings. According to the report, cleaning expenses accounted for 13% in the US and 10% in Canada of the total operational plus fixed expenses (see Figure 2). Overall, property managers do well in controlling cleaning costs, according to BOMA.

Commercial Carpet Cleaning

A major issue in indoor air has been the impact of carpets on IAQ and carpet's role in reports of occupant health symptoms and discomfort. While emissions of VOCs from new carpets has been a major focus in the past, cleaning and maintenance throughout a carpet's useful life is probably a far more relevant issue for determining total occupant exposure. Cleaning carpets is a challenge, as it is with any permanently installed textile material.

Various factors determine the accumulation, binding, and re-suspension of dust. These factors include activity, quality of cleaning, type of carpet, humidity, and size of particles among others. Dybendal *et al.* (1991) found that the daily vacuuming of carpets in schools was ineffective in preventing the build-up of allergen deposits. Only prolonged, vigorous vacuuming was effective in removing lead from carpets, and only 20 - 40% of the dust was removed from one m^2 of carpet after one minute. Five minutes of repeated cleaning resulted in removal of 60 - 90% of the dust (Ewers *et al.*, 1989). Roberts *et al.* found that normal residential vacuum cleaners were extremely ineffective in removing dust from carpets or the lead contained in the dust (1991).

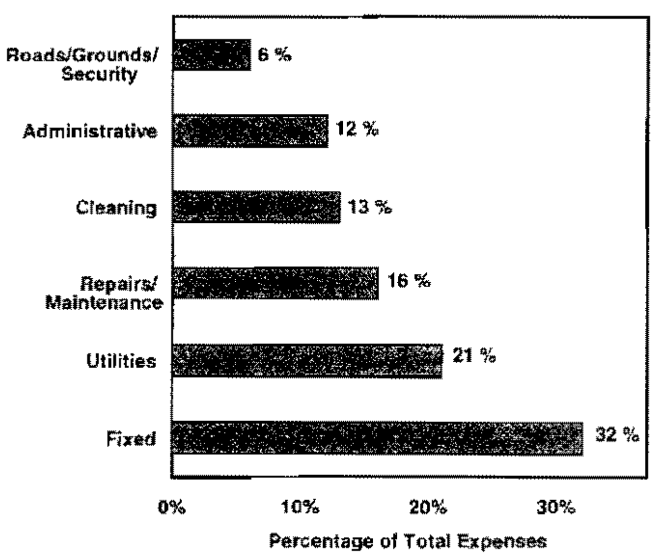

Figure 2 - Ratio of major expenses to total expenses: US private sector (BOMA).

We discuss a significant cleaning study performed by the Research Triangle Institute (RTI) in North Carolina in the following section. One of the improved cleaning methods the RTI used involved a more effective, commercially-available carpet cleaning system, "The Big Green Clean Machine." The recommended cleaning procedure is to first dry-vacuum with the unit, then wet-extract the carpet. This procedure was tested in a portion of the day-care area comprising about 58 m^2 (~620 ft^2). Researchers recorded the initial and final water plus carpet cleaner volumes and the total volume of water extracted from the carpet. Before the initial carpet cleaning, the dust loading was 0.68g/m^2. After cleaning, it was 0.38 g/m^2. The dry vacuuming with the "Clean Machine" extracted 0.19 g/m^2.

The initial volume in the unit was 8270 ml (8000 ml of water and 270 ml of cleaner). The final volume of clean water remaining in the unit was 2440 ml and the volume of extracted water was 2400 ml. By calculation, the unit applied 5830 ml of water. It extracted only 41% of the water that was put on the carpet and 60 ml of water per square meter remained on the carpet after cleaning. This appears to be a significant amount of moisture to leave in the carpets.

Thomas Schneider on Cleaning and the Indoor Environment

Schneider has focused a considerable amount of attention on the control of dust in indoor air. He is an expert in aerosol science and, together with his colleagues, has elevated the study of dust and particles in indoor air to a fine art.

Schneider reports that airborne dust concentrations of 0.1 mg/m^2 are typical for Danish offices. This concentration results in deposition of dust on the floor at a rate of about 0.02 g/m^2 per day. This rate compares to the rate at which track-in dust is deposited far away from the entrance to a building.

According to Schneider, surface contamination by dust must exceed 0.2% in order to be seen by a person, and contamination levels must differ by more than 0.45% to be perceived as different. Thus, he asserts, it is not possible to assess the amount of dust by visual inspection alone and objective methods are needed. Among his contributions are a small device, about the size and shape of a home microscope, that can characterize the amount of dust on surfaces. A sticky, transparent tape applied by a roller to standardize pressure collects dust from a surface. It is then inserted in the measuring device where the amount of light passing through the tape results in a reading of the percent of blocked light and, thus, the fraction of the surface covered by dust.

This measuring device is useful in studies but also useful in establishing standards for cleaning-contractor performance. Schneider and his colleagues have established standards based on their work in Denmark and other parts of Scandinavia. Objective measures for assessing cleanliness are essential for evaluating cleaning worker performance. Cleaning is a multibillion ECU per year business in Scandinavian countries. In the US, using BOMA cleaning cost data cited above — cleaning costs in excess of $1.00 per square foot per year or more — the figure is more than $13 billion in commercial office space alone in the US.

Schneider asks the following questions about building cleaning:

1. Do customers get what they are paying for and how would they know?
2. Would IAQ improve from spending more?
3. Is it necessary to spend so much?
4. Which of the many cleaning methods are most effective?

Recommended Surface Contamination Levels

Schneider suggests three levels of quality to use as standards: a baseline level, an improved level, and an indoor environmental level. He shows proposed norms in Table 2.

Baseline quality: The potential dust sources can readily be controlled to this level by using appropriate cleaning methods.

Improved quality and indoor environmental quality: The degree of surface cleanliness is maintained by using the best currently available cleaning methods and programs. Control of secondary dust sources to this level does not imply that SBS will not occur. "The suggested quality guidelines are a first attempt to quantify the quality of cleaning in relation to the indoor environment. As more measurements are taken and more experience is gained, the recommended values may have to be adjusted."

Schneider says these limits do not specify how clean surfaces should become after cleaning, but, rather, the levels that should not be exceeded during the time between cleanings. He suggests that it is the task of the cleaning company to select appropriate cleaning methods and frequencies. We believe that only a very sophisticated company might be able to do this, but that a sophisticated facility manager along with the cleaning company might, over time, be able to observe the dust levels and jointly determine the appropriate cleaning frequency to maintain dust coverage below the recommended maximum levels.

A different set of values is necessary for carpets, since the sample collection will not provide the same sort of index for carpets as for hard surfaces. A separate set of recommendations by Schneider for carpets is based on the dust sampling instrument.

Recommendations for Cleaning

An overview of recommendations for cleaning from Michael Berry's book, "Protecting the Built Environment: Cleaning for Health," is presented below.

I. Cleaning should be organized, scheduled, and focused on achieving specific objectives, especially those related to health protection and maintenance or restoration of valuable property.

II. The cleaning process should be coordinated with other basic environmental management strategies: source control, activity management, dilution, and design intervention.

III. Cleaning should always follow fundamental environmental protection guidelines:
   - safety
   - cleaning for health first and appearance second
   - maximum extraction for pollutants (particles, gas, and biopollutants) from the occupied space

Table 2 - Proposed norms for non-textile surfaces.

		Percent area covered by dust		
Cleaning object	*Location*	*Indoor Environmental Quality*	*Improved Quality*	*Baseline Quality*
Hard surface furniture	Close to person	1	2	4
	Easily accessible	1.5	3	6
	Other	5	10	15
Hard floors	Walk area	3	7	12
	Other	5	10	18

- minimize chemical, particle, and moisture residue
- minimize human exposure to pollutants
- clean in relation to improving the total environment, and
- proper disposal of cleaning wastes.

BOMA Survey Respondents on Cleaning and IAQ

The BOMA cleaning study revealed that 49% of the respondents consider IAQ programs to be part of their day-to-day cleaning operations. Their IAQ programs tend to incorporate both mandatory and optional requirements of applicable federal, state, and local regulations as well as guidance materials. An operations and maintenance (O&M) program usually consists of the following:

- The operation and maintenance of HVAC equipment.
- The oversight of activities that impact IAQ (for example, painting, construction/renovation, cleaning personnel, and pest-control practices).
- Tenant relations.

"Of particular importance in the above O&M list is the cleaning function. Cleaning practices can directly affect the air quality within your building. Property managers can help to ensure that their cleaning practices do not have a negative IAQ effect on their buildings by taking into account some of the following suggestions:

- Poor housekeeping that fails to remove dust and other dirt can contribute to IAQ complaints.
- Cleaning materials can contribute to poor IAQ as a result of the odors they may produce or emit." [Note that the problem is identified only as an odor emission problem and not as the emission of irritating or even toxic chemicals.]

Since janitorial staff or contractors may be the first to recognize and respond to potential IAQ problems, they should be educated on the following topics:

Cleaning schedules. Janitorial staff or contractors need to be aware of when cleaning activities are scheduled. If possible, cleaning should be performed during off-peak hours with the air-handling units still on the "occupied" cycle.

Purchasing cleaning products. Janitorial staff or contractors need to learn about the chemicals in cleaning and maintenance products and their potential toxicity. They should review material safety data sheets and obtain information from the supplier about chemical emissions of materials being considered for purchase. Currently, there are no general systems for verifying or labeling low-emission products. Nor are there any standard procedures that building managers can use in gathering emissions data on products they are considering buying. Limited information on some materials, such as pressed-wood products, is available, and more may be expected in the future. Public- and private-sector organizations are working to develop product testing procedures for acceptance by such organizations as the American Society for Testing and Materials (ASTM).

Materials handling and storage. Janitorial staff or contractors should review the use of cleaning materials to ensure proper use and storage.

Trash disposal. Proper trash disposal procedures should be followed. For example, containers should be covered, pest control should be effective, and the trash collection area should be cleaned every day.

Ducts

If cleaning carpets, desks, and shelves is so effective, then shouldn't duct cleaning be effective as well? We asked some leading IAQ experts, and their responses were mixed. Yet, a series of studies reported at Indoor Air '96 in Nagoya showed definitively that the HVAC system in many buildings is an important source of indoor air pollution. Several studies using Ole Fanger's trained panels had found that ventilation systems are often the source of sensory pollution in buildings. This seemed surprising at first because we tend to look to ventilation systems as the source of clean air.

The final report of a recent study by the EPA on duct cleaning in residences will be released soon. But research in the US to date has not demonstrated that air coming out of cleaned ducts is any cleaner than air coming out of just-plain-old-dirty ducts. There is no question, however, that good hygiene practices related to HVAC system cleanliness is warranted. This includes filters, coils, drain pans, dampers, baffles, insulation, and duct surfaces themselves. Even dust from metal ducts can be cultured — that is, it is viable microbial material with the potential to create IAQ problems.

RTI Office/Day Care Center Cleaning Study

Never satisfied with even the most obvious and logical conclusions without empirical evidence, scientists have once again conducted research to prove what was previously assumed. There is now well-documented evidence that proper and adequate cleaning of building interiors has a significant (measurable) impact on IAQ.

Researchers at Research Triangle Institute studied the efficacy of improved cleaning practices for one year in an office/day care center. During the study's first five-months, the previous "normal" cleaning practices were followed. Then, improved practices were instituted for the last seven months of the study. Many typical IAQ parameters were measured, and most showed convincingly that improved cleaning results in better IAQ. The improved cleaning measures applied in the study are listed in Table 3.

Table 4 shows a comparison of the results from IAQ measurements during the first and second phases of the study. It is apparent from the data that considerable improvement was made in virtually every parameter that was monitored.

Conclusions

We have discussed many of the issues and technical details related to the cleanliness of the indoor environment and IAQ. In the next ***BULLETIN***, we will present a comprehensive set of building cleaning recommendations from various authorities including those whose work is described in this article.

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Table 3 - Fundamental envirorimental protection guidelines applied to the study.

Guideline	*Examples found in study*
Provide for safety	Cleaning was conducted in unoccupied environments.
	All toxic materials were kept away from adult occupants and children.
	All observed physical hazards were removed.
	Blood-borne pathogens were treated separately from other managed wastes in the building.
Clean for health first and appearance second	Effective disinfectants were used regardless of their bleaching effect on fabrics.
	When fungi were observed on an interior wall surface, the entire wall was removed to effectively control biopollutants.
	The primary objective of all cleaning conducted in the building was to guard the health of the occupants.
Maximize the extraction of pollutants from the building envelope	Maintenance staff were re-equipped with state-of-the-art vacuums for removal of particles.
	Vacuum bags with high collection efficiencies were used.
	High-temperature hot-water extraction cleaning was used to clean all carpets in the building.
	Routine dust collection was done with damp dust cloth.
	Teachers were equipped with special wet-process cleaning machines to immediately clean after accidents.
Minimize chemical, particle, and moisture residue	Rapid drying was achieved through improved ventilation and, in some cases, fans.
	Many VOC-based cleaning agents were replaced with water-based solutions.
	Extraction was improved with more efficient equipment and cleaning systems.
	Moisture-damaged ceiling tiles were removed and replaced.
Minimize human exposure to pollutants	Non-toxic cleaning agents were used.
	Walk-off mats were placed at all entrances to trap pollutants.
	High-efficiency filters in vacuums reduced human exposure during cleaning operations.
	Accidents in child-care areas were cleaned immediately.
Clean in relation to improving the total environment	The ventilation system was balanced to improve air circulation through the building.
	Pests were controlled through the removal and proper storage of food in the building.
	Water-damaged areas of the building were identified and repaired.
	Cleaning was done in proportion to the level of human activity in the building.
Properly dispose of cleaning wastes	All cleaning wastes were properly disposed of in the sewage treatment or solid-waste management system.
	Human wastes were managed separately from other wastes.

Table 4 - The effects of the cleaning on IAQ (Cole *et al.*, 1994).

Air Pollutant Category	*Routine Housekeeping (5 months)*	*Improved Housekeeping (7 months)*	*% Change*	*Most probable contribution to improved air quality*
Airborne Dust Burdens (Building means)	119 μg/m^3 (4.4-24.2)	5.7 μg/m^3 (1.4-11.9)	-52%	• Efficient vacuum cleaners and bags • Walk off mats • Damp dust cloths • Frequent vacuuming and dusting • Deep cleaning entire building Dust control on hard surfaces
Total VOC (Building means)	324 μg/m^3 (88-530) (3 months)	166 μg/m^3 (29-309)	-49%	• Cleaning chemicals with less VOC • Extraction from carpets • Balanced ventilation system
Biopollutants* (Building means)				• Rapid use of disinfectants after accidents • Control of food and perishables • New extraction equipment • Hot water extraction of carpets • Moisture control • Removal of contaminated sources (wall, rotten tree stump) • Walk-off mats
Total Bacteria	395 CFU/m^3 (71-855)	237 CFU/m^3 (34-868)	-40%	
Gram-negative bacteria	17 CFU/m^3 (1-171)	2 CFU/m^3 (0-9)	-88%	
Endotoxin (surface)	352 (3-1800)	100 (4-260)	-72%	
Bacillus	22 CFU/m^3 (1-85)	18 CFU/m^3 (2-71)	-18%	
Actinomycetes	36 CFU/m^3 (0-312)	2 CFU/m^3 (0-4)	-94%	
Total Fungi	127 CFU/m^3 (22-406)	50 CFU/m^3 (2-219)	-61%	
Penicillum	38 CFU/m^3 (4-284)	5 CFU/m^3 (1-39)	-87%	
Aspergillus	4 CFU/m^3 (0-17)	1 CFU/m^3 (0-11)	-75%	
Cladosporium	35 CFU/m^3 (8-102)	27 CFU/m^3 (0-175)	-23%	

* Anderson sampler data only

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Lars Mølhave Responds to "TVOC: Is It Dead?"

*In Vol. 3, No. 8 of the **BULLETIN**, p. 10-14, we discussed the TVOC construct and its lengthy historical discussions within the IAQ community. We recently received an "answer/comment" from Lars Mølhave whose work on the TVOC concept is probably the most extensive and best known in the world. Many of his publications on the subject were cited in the article on VOC health effects published in the last **BULLETIN**, Vol. 3, No. 9. Dr. Mølhave offered his comments for publication in the **BULLETIN**, and encouraged editorial corrections, a few of which have been made. We have attempted to preserve the intent of his submitted comment, and he has reviewed and approved the text that appears below. Readers may want to read articles by Mølhave on the approach being used by WG13 (referred to below) in the Proceedings from Indoor Air '96, from Healthy Buildings '95, or from "Indoor Air Quality, Ventilation, and Energy Conservation in Buildings" (held in Montreal, Canada, May 9-12, 1995).*

We asked Alfred Hodgson, Lance Wallace, and Michael Hodgson to comment on Mølhave's remarks. Their comments follow Mølhave's. Note that Alfred Hodgson and Michael Hodgson are not related.

In Vol. 3, No. 8 (pages 10-14) of the ***BULLETIN***, several pages were used to address the TVOC construct and its use in the IAQ context. The heading was "TVOC: Is It Dead?" The author summarizes the ongoing discussion on TVOC and makes several references to statements made by me. The article as a whole carries the answer: "Yes" to the question, "TVOC: Is It Dead?" as most of the citations seem to object to the only logical alternative which is "Yes - It is Alive."

Several years ago, a working group (EU-ECA WG13) consisting of 15 European scientists was established with the "European Concerted Action on Indoor Climate and Its Impact on Man." The group discussed the use of the TVOC measure for evaluation of the importance of volatile organic compounds (VOC) for the indoor climate of non-industrial buildings and will publish its report in the Spring of 1997. In its report, the working group will deal with the questions raised in the ***BULLETIN*** and I recommend that the readers abstain from jumping to any final conclusions regarding TVOC until the report has been published *and read.* [emphasis in original]

The following are my personal comments to the notes in the ***BULLETIN***, and they should be looked upon in that light. To me, it is an unacceptable oversimplification only to discuss whether TVOC is "dead" or "alive." The question instead should be "under what circumstances can useful information be extracted from TVOC measurements?" The following summarizes my interpretation of the TVOC, an interpretation which has not fundamentally changed during the last 10 years.

Dose response data (DR) are well known for many individual VOCs. They describe the relation between the air concentration of a substance and the prevalence or risk of a specified health effect, for example. For each individual VOC, a set of such DR relations exists, one for each type of health or comfort effect.

It is generally expected that for any VOC mixture with a constant composition, such DR-functions also exist for each of the health effects of this specific mixture. However, at present, this relation cannot be established from knowledge of the components, their individual concentrations, and DR relations, etc.

Most researchers agree that in principle, sometime in the future, it may be possible to construct a set of such mathematical functions (one for each type of health effect) which, for a known composition of air polluted with any mixture of VOC, may be used to calculate the expected effects. This development, however, may take decades, but VOCs already have been demonstrated to be important for IAQ. Therefore, we cannot wait for the researchers to establish these dose-response relations. So, what do we do until then?

TVOC is the simplest first approximation to the unknown general DR-relationship. The TVOC measure assumes an equal relative weight of each type of VOC in relation to health. This, in practice, corresponds to saying that less VOC is better than more. (In many ways this is the same as the procedure used in interpretation of such indices as TSP (total suspended particles) or total PAN. As such, the accuracy cannot be expected to be high. Further, this approximation should not be used for general health, but only for sensory irritation, etc. and can only cover the effects on IAQ of a limited range of indoor air pollutants.

This approximation to the DR-relation needs to be standardized and documented before it can be generally used. It should be modified and refined as soon as more knowledge accumulates. Until then, the TVOC, at best, should be considered to be a screening tool.

In contrast to the view of TVOC described above, some practitioners have developed a practice of using a few measurements of TVOC (often without specifying the measuring procedure) to classify buildings as acceptable/unacceptable. This is often done with great personal or financial consequences for the building occupants and owners. These practitioners are using TVOC as an exposure measure in a hypothetical, generalized DR relation covering all VOCs and all VOC mixtures and for all types of health effects. Clearly, the scientific literature does not support this. Therefore, this practice is a misuse of TVOC, and I agree with the Nordic Committee and EU-ECA WG13 that this use of TVOC must stop.

However, we still have the problem of VOC indoors. The reporting of long lists of compounds and concentrations is impressive and may be scientifically useful, but it does not help the practitioner. The practitioners have for years and will probably continue to report VOC, and we still have to tell them how much (or how little) health information they can extract from their lists. If they decide to use TVOC, then at best TVOC can be used to indicate that the probability of effects is high at high TVOC and low at very low TVOC levels. This is the approach used by the ECA working group WG13. I support this interpretation.

Therefore, the essence of my message to the practitioner has been that in doing IAQ evaluations they should do the following:

a) Not only focus on VOC. There are other physical, chemical, and biological factors to consider in relation to IAQ. TVOC does not cover these factors and TVOC is not a measure of general IAQ, but rather of the possible contribution of VOC to IAQ problems.

b) Not only focus on sensory irritation. There are other health and comfort effects to consider in relation to IAQ. TVOC does not cover these effects.

c) If more accurate evaluation procedures are developed in the future, then use them instead of TVOC if you expect VOC to be a major exposure factor.

d) If such methods do not exist, then as a fallback solution, measure TVOC in a standardized way (*e.g.*, according to EU-ECA WG-13).

e) The practitioner may then use TVOC to extract a minimum of health information from the lists of measured compounds. This can only be made in relation to discomfort, for screening purposes, and never for a sharp Yes/No decision. This means that only very small TVOC values are of no concern and only very large values can be classified as unacceptable. In between, the practitioner has to do something else to demonstrate that VOC is part of the problem.

f) My approximately 10-year-old summary and conclusions about TVOC levels (Mølhave, 1986) found in field investigations was already then, when published, described as being based on an incomplete review of publications using measurements which were not standardized. As concluded both by EU-ECA WG13 and by the Nordic group, little additional information has been made available since then, and there is still no scientific basis for setting official limit values. The use of the values 0.2 and 3-5 mg/m^3 in this context as recommended definitive guideline values is not advisable.

However, the data mentioned above are those which are available, and nobody can object if the practitioner, in the absence of official guidelines, uses these estimates of the low and high values as discussed under point e). This, of course, has to be done with many precautions. These precautions have, among other things, been the target for discussions of the EU-ECA WG13.

In conclusion, for years I have wanted to stop the ongoing, fruitless discussion and speculation pro or con TVOC as illustrated in the article in the ***BULLETIN***. A more constructive approach would be to develop guidance for practitioners on how to measure and report VOC and how to avoid misusing the TVOC. This is the aim of both the EU-ECA WG13 and the Nordic IAQ Working Group.

If we, in relation to an IAQ guideline, need a simple measure such as TVOC for VOC exposure, then we must establish an acceptable scientific basis for accepting or rejecting the scientific hypothesis that TVOC is an acceptable guideline. If not, then we must develop a better approximation than TVOC as an exposure measure in the general DR-relation for VOC mixtures. (Members of the scientific community already are discussing such models.)

Lars Mølhave, MD, Åarhus University, Åarhus, Denmark.

References

Bornehag *et al.*, 1996. Report from a Nordic Scientific Consensus Meeting at Långholmen in Stockholm.

Mølhave, L., Bach, B., and Pedersen, O.F., 1986. Human reactions to low concentrations of volatile organic compounds. *Environment International*, Vol. 12, Nos. 1-4, pp. 167-176.

Alfred Hodgson Responds to Mølhave's Comments

We invited Alfred Hodgson to offer his views on Mølhave's comments. Al is with the Indoor Environment Program, Lawrence Berkeley National Laboratory, in Berkeley, California.

I am in basic agreement with Dr. Mølhave's comments. It appears that much of the scientific community may be moving in a similar direction with respect to the analysis and interpretation of exposures to volatile organic compounds (VOCs) in indoor environments.

The measurement of total VOCs (TVOC) in indoor air is limited in its usefulness for a variety of reasons. The measurements themselves are highly uncertain (although general consistency can be achieved among several of the predominant methods). Important compounds with respect to health effects may not be measured while the biological potency of individual compounds typically included in the measurements often varies by orders of magnitude. Finally, associations between TVOC concentrations and health effects have not been convincingly demonstrated.

Nevertheless, I agree that TVOC is still useful as a screening tool. In particular, it is useful for general building investigations in which no attempt is being made to diagnose specific complaints, such as odor or sensory irritation. If concentrations of TVOC are found to be elevated with respect to typical TVOC concentrations, then a strong source(s) and/or inadequate ventilation is suggested. This is useful information warranting further investigation. A prudent response might dictate reducing occupant exposures through increased ventilation or another form of source management.

When specific complaints are being investigated which could conceivably be due to exposures to VOCs, it is my experience that it is necessary to identify and quantify individual VOCs. It is not currently possible to combine this speciation data into a useful predictor of health effects, such as sensory irritation. However, the speciation data may show the presence of compounds, which are either know to be strong irritants or which are representative of irritant classes of compounds. The data may also suggest the possible source(s) these compounds which can be confirmed by further investigation. Once identified, the source can be managed to reduce exposures. Obviously, this approach can not guaranty success in solving the complaint problem, but it is reasonable, best practice based on our current state of knowledge.

More useful metrics for assessing the health impacts of exposures to complex mixtures of VOCs in indoor air are clearly needed. Our research program has been working on such an approach that is based on the hypothesis that sensory irritation effects are additive for individual compounds at relatively low concentrations. The available human and animal bioassay data on irritancy are used to calculate the irritancies of the individually quantified compounds relative to a standard compound, such as toluene. The usefulness of this approach is limited by the lack of consistent health effects data for a number of compounds of potential interest. However, principal components analysis using source categories for which we have some indicator compounds may be one way to account for compounds without health effects data or which may not be included in our standard analyses of VOCs. This later approach has shown a relationship between exposures to VOCs and certain health effects for a group workers in 12 California office buildings. The next step is to attempt to confirm the relationship using another appropriate data set.

There is another need, which is to define a standard set of target compounds to be measured in systematic investigations of VOCs in buildings to help us understand the potential relationships between VOC exposures and health effects. This set should include: 1) compounds which are strong irritants or odorants at relatively low concentrations; 2) compounds which are indicative of particular sources which have the potential to cause health effects; and 3) compounds produced by reaction of ozone with indoor surfaces. Many of these compounds will be oxidized species, for which we have very little systematic data. For practical reasons the set should probably contain no more than about 50 compounds. Perhaps the ***BULLETIN*** can serve as a discussion forum for developing such a list.

Alfred T. Hodgson, Indoor Environment Program Lawrence Berkeley National Laboratory, Berkeley, CA, 510 486-5301, athodgson@lbl.gov.

Lance Wallace Responds to Mølhave's Comments

We also invited Lance Wallace of the US EPA to offer his views on Mølhave's comments. Dr. Wallace's comments are made in his capacity as a private citizen and scientist and do not necessarily represent the position of the EPA.

As usual, I find myself in agreement with nearly everything Lars Mølhave has to say. Like Lars, I am shocked by the idea that major decisions would be made on the basis of TVOC alone. (I have no personal knowledge of such actions, however, and I hope and presume that they are few and far between.) Possibly unlike Lars, however, I would view this misuse of the TVOC concept as one of several reasons to avoid using the concept as much as possible.

I have always felt that individual VOCs should be measured and reported, both because dose-response functions are sometimes known, unlike for TVOCs, and also because the individual VOCs carry information about the possible source. For example, a cluster of C10-11 hydrocarbons might implicate a wet-process copying machine, or a very high level of *p*-dichlorobenzene might indicate overuse of toilet deodorizers.

All of the work that the Research Triangle Institute (RTI) carried out for EPA on VOCs, both in residences and buildings, reported individual compounds and made no use of the TVOC concept. It was only as an attempt to add useful measured data to the TVOC discussion that I supported going back to the 2700 samples we had collected over 8 years and calculating the total VOC loadings (Wallace, Pellizzari, and Wendell, Indoor Air 4:465-477, 1971).

This exercise was useful in showing that the 25-32 targeted VOCs in our studies accounted for only 3-20% of the total VOCs collected by the Tenax samplers. It also extended the TVOC concept to personal exposures — 1500 personal samples had a geometric mean of 1.1 mg/m^3, compared to 0.7 mg/m^3 for 198 residential indoor air samples and 0.3 mg/m^3 for 371 outdoor air samples at homes.

However, these numbers may not be directly comparable to other TVOC values determined by methods different from the one we employed — namely, calculation of individual total ion current (TIC) relative response factors (RRF) for 17 chemicals followed by application of the mean RRF to every computerized GC/MS scan between chloroform and dodecane. So once again interpretation of the absolute TVOC numbers is difficult, although the observed personal:indoor:outdoor ratio of approximately 3:2:1 for several hundred residences is probably highly trustworthy.

(This raises an interesting point that I am not sure has been fully discussed. Mølhave's studies of the 22-compound mixture measured indoor concentrations in a small chamber, which would be expected to be equal to the personal exposures of the subjects. However, in a real-world situation, personal exposures to VOCs at the office may be rather different from the concentrations measured by a fixed sampler. People move about and may be close to a major source such as a copier for a period of time, resulting in higher personal exposures than the concentration measured at the fixed sampler. Since the dose-response function was based on personal exposure, then possibly the corresponding guideline for indoor concentrations should be ratcheted downward to take into account the likely increment in personal exposures due to source proximity. A proper test of this possibility would require simultaneous personal and indoor air monitoring in the office environment, a study that I am not aware has ever been carried out.)

Had we measured only TVOC in these studies, the loss of information would have been devastating. We would not have discovered the high levels of chloroform in homes due to use of chlorinated water; the high levels of *p*-dichlorobenzene in some homes due to use of moth cakes and room air fresheners; the infiltration of benzene and other gasoline vapors from attached garages; the extensive personal exposure and elevated indoor concentrations from wearing and storing dry-cleaned clothes, etc.

In our building studies, TVOC measurements alone would certainly have shown the 50-fold difference between new buildings and old, but would not have told us that most of the difference in two buildings was due to xylenes, decane, and undecane, whereas in a third building a chlorinated chemical — 1,1,1-trichloroethane — was a major actor.

Lance A Wallace, Ph.D. US EPA National Exposure Research Lab - Reston Building: ENC, Room: 115, Reston, VA, 20192.

Michael Hodgson Responds to Mølhave's Comments

We also solicited an opinion from Michael Hodgson. Michael, an MD, is an associate professor at the University of Connecticut School of Medicine, Occupational Medicine Program, in Farmington, Connecticut.

Your newsletter is starting to serve an interesting purpose in providing such a formalized discussion. This is actually fun, stimulating, and probably quite useful. You asked for comments on the viability of TVOC.

Ideas live in a cave, far removed from life as we know it. That cave is also inhabited by other ideas, some conflicting, some contradictory, some consistent but not derivable. Gödel demonstrated the weakness inherent in our attempts to maintain consistency in every aspect of what we do.

The concept of dose-response relationships is fundamental to environmental health, implying that more exposure causes more effect. Nevertheless, such exposure-effects relationships can be defined in more than one way. In fact, in the world of toxicology, we distinguish between theoretical models (quantitative structure activity relationships, such as those developed by Abraham, Alarie, Cain, and Nielsen); isolated, organ-based, cell-based studies (none available for indoor air); animal studies (Alarie, Nielsen); and human studies. The latter include chamber and field studies (epidemiology).

Both exposures and effects must be measured, and both are then no longer pure ideas but defined in our world. Measurement error, problems of definition (construct and face validity, external validity, precision and accuracy), and temporal patterns serve to influence the relationships.

There has long been controversy on how to "add" exposures. The ACGIH and the OSHA Standard provide a simplistic approach on how to sum up the effects on one organ. Bill Cain (1995, Milan) has provided some data that "addition" may be an oversimplification. Few formal data sets have been collected in an attempt to sum up effects. Where they have, interactions were common. One need only remember the combined effects of trauma and radiation exposure or of asbestos and cigarette smoking to recognize how complicated the topic is.

Research is generally performed in one of two settings. In the lab, under controlled conditions, specific, well-defined hypotheses are tested on a well-defined population. Spatially homogenous and species-defined controlled exposures allow testing of well defined problems. These allow documentation of mechanisms and D-R relationships. The results may be extrapolated to a distinct set of conditions similar to those found in the experimental setting. Field studies, with all of their messiness, may identify susceptible populations and provide estimates of the magnitude of effects.

Work using the "Mølhave mixture" has suggested dose-response relationships for symptoms (eye, nose) and perfomance (cognitive impairment). As only one (or including the EPA, with a minor modification two) specific mixture(s) have been used, the data have limited extrapolatability in a strict scientific sense. In field studies (Franck and Skov, Kjaergard) these relationships have been difficult to replicate suggesting larger inter-subject variability. On the other hand, there is evidence on other levels of the importance of VOCs, in general (Menzies and Nunes in humans; Alarie, Nielsen and Wolkoff in animals).

I've been trying to do field work with screening techniques, recognizing the cost of triple sorbent tubes for each individual would break my unfunded budget. We have found weak though somewhat consistent relationships in two separate field studies of non-problem buildings. In the first (1991), VOCs measured with a photoionization detector (that responds more strongly to "reactive" than to "non-reactive" compounds) suggested a direct relationship. This pushed me away from my interest in particles and bioaerosols, at least in "non-problem" buildings. In a follow-up study, using a very poor instrument (Bruel and Kjaer PAD), we found relationships only after controlling for work stress, lighting and noise. So I'm meanwhile convinced that it is now appropriate to study VOCs more formally in the field with personal sampling, with triple-sorbent tubes, given the problems of exposure heterogeneity. The correct sampling interval remains to be determined.

I agree with Lars that an argument like TVOC is dead misses the point. The Olf may be dead too, but Ole Fanger's important documentation, that HVAC systems may be primary sources of contaminants, is meanwhile pretty much unchallenged. Science, and its revolutions, go on without philosophizing — although I really like to do so too.

Michael J. Hodgson, MD, Associate Professor, University of Connecticut School of Medicine, Occupational Medicine Program, U. Conn. Health Center, Farmington, CT, 06030.

Air Change Effectiveness

*In Vol. 3, No. 7 of the **BULLETIN** we featured comments by several international IAQ experts on their perceptions of important findings at Indoor Air '96. David Wyon's comments included one we omitted that suggested his colleague at JCI, Cliff Federspiel, had an important paper. Wyon's omitted comment follows:*

"...I would recommend to your attention the two papers by my JCI colleague Cliff Federspiel. His "reverse engineered" method of rapidly and effectively detecting step-changes in occupancy from a knowledge of system parameters and the initial rate of change of CO^2 in exhaust air (3:395) involves some heavy mathematics: the (1994) conference paper in which it was presented was judged the most significant paper of the session by the control engineers who understand it. The rest of us can appreciate that the practical applications in building management are not limited to demand-controlled ventilation, but may extend to lighting control (detecting occupants), security (detecting intruders) and fire prevention (detecting smouldering concealed fires), once CO^2 detectors become cheap enough to be located in every zone, or even in every room, and connected to a central building management computer. His demonstration that recirculation is an almost universal source of large and systematic error in calculating air change effectiveness from age-of-air measurements (3:971) may seem esoteric but addresses a source of major and previously unsuspected error in published IAQ research and HVAC practice."

Our omission led to this letter from Cliff Federspiel followed by a comment by Bill Fisk.

Engineers measure air-change effectiveness (also called ventilation effectiveness, ventilation efficiency, and air diffusion efficiency) to determine one of the following: (1) the "flow pattern" in the space (*e.g.*, the amount of "short-circuiting" or "displacement" flow), (2) how much higher or lower the ventilation rate (*e.g.*, in air changes per hour) in the occupied zone would be if the space were perfectly mixed. The most popular measurement methods involve the use of tracer gases and the calculation of age of air. Information about air-change effectiveness and age of air can be found in [1,2,3]. Here are two facts regarding the measurement methods:

1) In general, measurement methods designed to determine (2) cannot be used to quantitatively determine (1) because the determination of (1) requires that the age of the supply air be measured, while the determination of (2) does not [4,5]. The exception is when the age of the supply air is zero.

2) If a method designed to evaluate (2) is used to evaluate (1), the relative error may be as large as 100%. "Errors of this magnitude have been identified and are described in [4,5]."

References

[1] Sandberg, M., (1992), "Ventilation Effectiveness and Purging Flow Rate - A Review," *Proceedings of the 1992 International Symposium on Room Air Convection and Ventilation Effectiveness*, Eds. S. Murakami, M Kaizuka, H. Yoshino, and S. Kato, pp. 17-28.

[2] Persily, A. K., (1992), "Ventilation Effectiveness and Purging Flow Rate - A Review," *Proceedings of the 1992 International Symposium on Room Air Convection and Ventilation Effectiveness*, Eds. S. Murakami, M Kaizuka, H. Yoshino, and S. Kato, pp. 201-212.

[3] Fisk, W. J. and D. Faulkner, (1992), "Ventilation Effectiveness and Purging Flow Rate - A Review," *Proceedings of the 1992 International Symposium on Room Air Convection and Ventilation Effectiveness*, Eds. S. Murakami, M Kaizuka, H. Yoshino, and S. Kato, pp. 213-223.

[4] Federspiel, C. C., (1996), "The Effect of Recirculation on Air-Change Effectiveness Calculations," *Proceedings of Indoor Air '96*, Vol. 3, pp. 971-976.

[5] Federspiel, C. C., (1996), "The Effect of Recirculation on Air-Change Effectiveness," *Proceedings of the 17th AIVC Conference*, Gothenburg, Sweden, Vol. 1, pp. 15-23.

Cliff Federspiel, Johnson Controls, Inc., 507 East Michigan Street, Milwaukee, WI 53202, 414 274-5071, Fax: 414 274-5810, email: clifford.c.federspiel@jci.com.

Fisk on Federspiel's Letter

I believe that most of the major researchers of ventilation efficiency (*e.g.*, of air change effectiveness, etc.) have recognized for a very long time that both the indoor air flow pattern (inside the room) and mechanical recirculation are important and that both phenomena influence measurement results. In the case of pollutant removal efficiencies, we also recognize that the nature of the pollutant source, such as location, velocity, is important. The research community (at least the majority) has not had major flaws in their thinking about this subject. For example, my work, both field and laboratory studies, has often included measurements with 100% outside air and measurements with mechanical recirculation. We have, in many cases, been guilty of sloppy language, often stating without qualification that the ACE is a indicator of the indoor air flow pattern. The concepts are complex and difficult to describe concisely in writing. For example, one can think of the indoor air flow pattern as just the pattern of flow in the occupied space or as the pattern of flow in the building with an HVAC system, which includes mechanical recirculation. Also, one can think about the short circuiting flow patterns of air within a room or one can think about the effective short circuiting, just of outside air, between the outside air intake and the building exhaust. None of these conceptual models meets all of our needs. The application of age of air theory to this field has brought substantial mathematical rigor, but we still try to use simple conceptual models (*e.g.*, amount of short circuiting) to explain what is happening. Different people use different internal conceptual models, which makes communication difficult.

I believe that Clifford has developed a model (mathematical, not conceptual) that relates ACE with recirculation to that without recirculation. This model is an important addition to the research literature and may be shown in the future to have considerable practical value, but it does not invalidate prior research.

[This] discussion should help us to clarify our language in future papers.

William J. Fisk, Ph.D., Lawrence Berkeley National Laboratory, University of California, Berkeley, CA, 94720.

SBS

Discovery of Causes Trails Discovery of Preventive Measures

The history of medicine is full of cases where preventive measures for important diseases were found long before causative mechanisms or therapeutic activities were understood. The same principle applies for SBS.

E. L. Wynder discussed some of the classic examples of the long lag time between the discovery of preventive measures and the discovery of the "true causative or preventive agent" in the *American Journal of Epidemiology*. Wynder clearly shows some representative examples from the history of medicine in Table 5. It shows the gap between when preventive measures based on clinical or epidemiological observations were known and the time causative or curative agent became known. In the case of scurvy, the gap was 175 years. For pellagra, scrotal cancer, and smallpox, the gap was more than 150 years.

For diseases, as important as mechanistic studies are to understanding disease pathogenesis, the preventive measures can reduce disease incidence decades or even centuries before our understanding of the intricate pathogenesis is complete.

Wynder says that if Americans didn't smoke, "...lung cancer would be about as uncommon as it was in 1912 when I. Adler apologized for writing a monograph on a disease as rare as lung cancer." According to Wynder, the "...major causes of death, notably cardiovascular diseases, cancers, and acquired immunodeficiency syndrome, are related to lifestyle and environmental variables. Much of this disease burden could be significantly reduced on the basis of existing evidence without much more knowledge than we have now about the specific mechanisms by which these factors induce disease."

The same can be said for SBS and building-related illness. We know how dramatically to reduce the incidence of these and other building problems. These also involve simple "lifestyle" changes.

Reference

E. L. Wynder, 1994. "Invited Commentary - Studies in Mechanism and Prevention: Striking a Proper Balance." *American Journal of Epidemiology*, Vol. 139 (6): 547-549.

Table 5 - Comparison of the date of discovery of a measure to prevent a disease with the date of identification of its true causative or preventive agent. * References in the table are available in Wynder, 1994 or upon request from the ***BULLETIN***.

Disease	*Discoverer of preventive measure* *	*Discovery of preventive measure*	*Discovery of agent*	*Causative or preventive agent*	*Discoverer of agent* *
Scurvy	J. Lind	1753	1928	(Ascorbic acid)	A. Szent-Gyorgi
Pellagra	G. Casal	1755	1924	(Niacin)	J. Goldberger *et al.*
Scrotal cancer	P. Pott	1775	1933	Benzo[a]pyrene	J. W. Cook *et al.*
Smallpox	E. Jenner	1798	1958	Orthopoxvirus	F. Fenner
Puerperal fever	I. Semmelweiss	1847	1879	Streptococcus	L. Pasteur
Cholera	J. Snow	1849	1893	Vibrio cholerae	R. Koch
Bladder cancer	L. Rehn	1895	1938	2-Napththylamine	W.C. Hueper *et al.*
Yellow fever	W. Reed *et al.*	1901	1928	Flavivirus	A. Stokes *et al.*
Oral Cancer	R. Abbe	1915	1974	N-nitrosonormicotine	D. Hoffmann *et al.*

Corrections

Bud Offerman, PE, CIH, of Indoor Environmental Engineering in San Francisco, wrote to say: "I just wanted to be the first (am I ?) to call your attention to a mathematical error on page 2, column 2, paragraph 2, 2nd to the last line: It should read: 'Source strengths are calculated by multiplying the concentrations by the ventilation rate.' Not dividing." He also wrote: "Vol. 3, No. 9, page 13. The reference for Nunes *et al.* contained an incorrect listing for the page numbers. The correct reference is *Proceedings of Indoor Air '93*, Vol. 1, pp. 38-43."

Peder Wolkoff of the Danish National Institute of Occupational Health wrote: "Re: IAB article on VOCBASE, on page 16 in Volume 3, No. 9, there is a misprint in our fax area code. It should be: +45 39 270 107."

Calendar of IAQ Events

March 22-26, 1996. **Environmental Issues in Buildings and Real Estate Issues,** Marriott Hotel on Canal Street, New Orleans. Sponsored by the Environmental Information Association. Contact: EIA toll free 888 343 4342 for an attendee brochure. *Sessions include indoor air quality as well as asbestos, lead, environmental site assessments, and regulatory updates from EPA, OSHA, and HUD.*

March 24-25, 1997. **Lead and the Law '97: A Strategic Conference on New Regulation, Litigation, and Liability,** sponsored by IAQ Publications Inc. Contact: IAQ Publications Inc., 2 Wisconsin Circle, Sutie 430, Chevy Chase, MD 20815. 800 394 0115, Fax 301 931 0119. *Cost: $525 per person, group rate: $475 per person with groups of 3 or more.*

April 7-8, 1997. **ASTM Subcommittee D22.05 on Indoor Air,** spring meeting, St. Louis, MO. Contact: George Luciw, Staff Manager, ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959. 610 832 9710, Fax 610 832 9666, email: gluciw@astm.org. *The subcommittee is working on guides and practices for measuring emissions from indoor sources among other ASTM standards. There is no charge for attending ASTM committee meetings, and ASTM membership is not required.*

April 7-9, 1997. **Indoor Environment: Setting the Standard for Healthy Building Management,** Hyatt Regency Hotel on the Inner Harbor, Baltimore, MD, sponsored by IAQ Publications Inc. Contact: IAQ Publications Inc., 2 Wisconsin Circle, Sutie 430, Chevy Chase, MD 20815, 800 394 0115, Fax 301 931 0119. *Cost is $525 per person. Group discount price is $400 per person for groups of three or more from the same organization.*

April 16-18, 1997. **Biological Contamination of Indoor Environments,** Holiday Inn O'Hare International, Chicago, Illinois. MidAtlantic Environmental Hygiene Resource Center. Contact: MidAtlantic Environmental Hygiene Resource Center, University City Science Center, Philadelphia, PA. *Topics to be covered are Biology of biocontaminants in indoor environments; Health effects and risk assessment; Occupational exposures in industrial and agricultural food processing facilities. Investigating biocontamination problems; and, Control, prevention, and remediation. Cost is $695, $345 for government or non-profit organization employees.*

July 21-23, 1997. **Engineering Solutions to Indoor Air Quality Problems,** Research Triangle Park, North Carolina; sponsored by the U. S. Environmental Protection Agency and the Air and Waste Mangaement Assocation (A&WMA). Contact: Kelly W. Leovic, U. S. EPA, MD-54, Research Triangle Park, NC 27711. 919 541 7717, Fax 919 541 2157, email: kleovic@engineer.aeerl.epa.gov.

September 27 - October 2, 1997. **Healthy Buildings/IAQ '97: Global Issues and Regional Solutions,** Washington, DC. Organized by ISIAQ, ASHRAE, and Virginia Tech. Contact: Professor James E. Woods, Virginia Tech, PO Box 7430, Falls Church, VA 22040, USA, + 1 703 698 4725, Fax: + 1 703 698 4729, email: hbiaq.97@vt.edu. *Second Announcement and Final Call for Papers has been issued. For updates: http://www.vt.edu:10021/contEd/conted.html.*

International Events

June 9-12, 1997. **Buildings and the Environment,** Organized by CSTB and CIB T18, Paris, France. Contact: Ms. Angela Ghivasky, International Affairs, CSTB, 4, Avenue du Recteur Poincaré, 75782 - Paris Cedex 16, FRANCE, +33 1 40 50 29 13, Fax +33 1 40 50 28 76, email ghivasky@cstb.fr.

August 30 - September 2, 1997. **Clima 2000,** Brussels. Organized by Belgian Royal Technical Society of Heating, Ventilation, and Related Technology Industry (ATIC), on behalf of Federation of European Heating and Air-conditioning Associations (REHVA). Contact: Clima 2000 '97, c/o SRBII, Ravenstein 3, B-1000 Brussels, Belgium, +32 (0)2 511 7469, Fax +32 (0)2 511 7597. *The conference language will be English.*

Indoor Air BULLETIN

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Editorial Office: 2548 Empire Grade, Santa Cruz, CA, 95060, 408 425 3946, Fax 408 426 6522.
Subscription Office: P.O. Box 8446, Santa Cruz, CA, 95061-8446, 408 426 6624, Fax 408 426 6522.

Subscriptions: $195 per year (12 issues) in the US and Canada, $235 per year (12 issues) elsewhere.
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Printed in Santa Cruz, California, January 1997.