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Important New IAQ Guideline Values Published

"Everybody knows" that chemicals found in indoor air usually are measured at concentrations far below those likely to cause health effects. Twenty years ago, people began to use a rule of thumb for IAQ guidelines: to take 1/10 or 1/100 of the threshold limit value (TLV) used for occupational exposure. ASHRAE Standard 62-1981 included a 1/10 ratio as an IAQ guideline. Authorities generally believed this would provide an adequate margin of safety. Still, it wasn't clear why many occupants reported adverse reactions in buildings where all the *measured* contaminants were at concentrations well below occupational limit values and even well below the guideline values thus obtained. Many IAQ investigators questioned the adequacy of the safety margin. Others raised questions about the additive, synergistic, and cumulative effects of exposures to a mixture of scores of chemicals (Wolkoff, 1997).

Back in 1982, Lars Mølhave of Denmark reviewed the health effects literature on dozens of chemicals frequently found in indoor air. Mølhave concluded that more than 80% were known or suspected mucous membrane irritants (Mølhave, 1982). Some people thought this might explain the increasingly common reports of skin, eye, nose, and upper-respiratory tract irritation in certain buildings. However, this was hardly definitive. Very little work had been done to study mixtures of chemicals. And, far too little additional work has been done since that time to understand the effects of exposure to chemical mixtures and the cumulative effects of exposure to individual chemicals and chemical mixtures.

Later, Mølhave began studying people's reactions to a particular mixture of 22 volatile organic chemicals (VOCs) he obtained by a rational (although not universally endorsed) process to select the study chemicals and their concentrations. He studied odor, irritation, memory, task performance, and other effects of his 22-VOC mixture in a series of carefully controlled experiments in his environmental chamber at Århus University. He reported his results in terms of responses to total VOC (TVOC) concentrations. The details of the exposure were available to those who read his publications (Mølhave and Nielsen, 1992), but the details were ignored by many who were looking for a simple answer to the "sick building mystery." There was widespread interest within the indoor air field in finding a simple answer. The TVOC approach seemed an excellent candidate, so the results were widely misinterpreted and reported by others as a TVOC guideline or even standard. Mølhave himself contributed to this misinterpretation with his plenary paper and presentation at the Fifth International Conference on Indoor Air Quality and Climate, Indoor Air '90 in Toronto, Canada (Mølhave, 1991).

More recently, the IAQ community has learned that the causes of occupant symptoms are diverse and manifold. Not only chemical compounds but also particulate matter including both organic and inorganic materials can be involved. Bioaerosols have become a particularly important focus during the past five years as investigations discover more and more microbe-contaminated problem buildings. It is known that the poor control of temperature or humidity can contribute to higher occupant symptom rates. It is also known that increasing the outdoor air ventilation rate or providing occupant access to operable windows are both likely but not certain to decrease symptom prevalence rates. Generally speaking, clean, dry, well-ventilated buildings are far less likely to

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have problems than dirty or moist ones. Conversely, dirty or wet buildings appear increasingly to be at risk for IAQ-related problems.

What are the right levels of ventilation? There is still a great desire to know what chemical concentrations are "acceptable." Frequently, we hear that there simply is insufficient research to inform this question. However, buildings must be designed to some ventilation rate, and the right ventilation rates are still believed linked to the acceptable concentrations of indoor air contaminants. This, in turn, requires knowing the concentrations likely to cause odor, irritation, and health problems.

In a vain effort to find a simple answer to this complex question, many have suggested that the TVOC concentration could be an adequate indicator of IAQ. More recently, there has been a strong move away from this belief by most responsible researchers. The European Commission indoor air committee has just published a guideline that revises the concept of TVOC to include identification and quantification of 64 specific chemicals chosen on the basis of their common occurrence in indoor air and their potential odor, irritation, or health effects. Mølhave led this guideline project which is reported on page 12 of this issue of the *BULLETIN*.

Recent research by Gunnar Damgård Nielsen and his colleagues at the Danish National Institute of Occupational Health in Copenhagen sheds new light on these issues. Nielsen and his colleagues reported their work in a series of articles in *Indoor Air Supplement 5* (Nielsen *et al.*, 1998) and elsewhere (Nielsen *et al.*, 1997a;b;c) and summarized the work in a report from the Nordic Committee on Building Regulations (NKB) (Nielsen *et al.*, 1997). The NKB report recommends guidelines for 26 chemicals and summarizes the methodology for preparing guidelines for more substances.

The Nordic Committee on Building Regulations Report

The report by Nielsen and his colleagues is a landmark document. "Toxicological based air quality guidelines for substances in indoor air," describes the methodology and provides the results of the detailed analyses they performed. The appendices summarize the analyses presented in far greater detail in the *Indoor Air Supplement No. 5* (Nielsen *et al.*, 1998).

For many years, Nielsen's work at the Danish National Institute of Occupational Health has focused on toxicology using mice and other assays. Now, in the first set of toxicology-based guidelines for IAQ, he and his colleagues present a general approach that may be valid across a wide spectrum of indoor air contaminants. If so, the longed-for IAQ guideline values that are so necessary to assess building air quality are far closer than before, at least for individual VOCs.

The purpose of preparing the guidelines, according to the authors, was to make it easier for "engineers, architects, builders, and authorities to evaluate indoor air effects." Surely, if it can be generalized, their approach will do that and more. It could revolutionize assessments of IAQ, the development of ventilation guidelines and standards, and the evaluation of the acceptability of chemicals emitted from building materials and other indoor sources.

The values recommended in the report as acceptable guidelines for 26 different indoor air contaminants range from 1/40 to 1/4 of the OELs. OELs are similar to the American Conference of Governmental Industrial Hygienist's (ACGIH) TLVs, the German MAKs, the European Union limits, and the Nordic limits. The report summarizes the process for making the assessments and presents the conclusions for the assessments of each of the 26 chemicals. Three articles published in the *Supplement* to *Indoor Air* and in the previously published *Indoor Air* articles contain the scientific work supporting this guideline.

The Evaluation Process

The authors evaluated indoor air exposures on the basis of four separate types of effects. The first two effects were odor and sensory irritation (eyes and upper respiratory tract). The third evaluation was of non-carcinogenic effects on the lower respiratory tract and the alveoli (lung) and systemic effects. The fourth was carcinogenic effects of "genotoxic" substances. The authors stress the importance of keeping each effect type separate in the overall evaluation. Nielsen commented that the odor effects were "...only touched superficially, *i.e.*, from a threshold. Annoyance is not included" (personal communication, 1998).

The evaluation process assumed that the *total dose* is important rather than the *duration of exposure* (Haber's Law). While the authors acknowledge this is a simplifying assumption, they chose it because it allows conversion of the occupational exposure into a continuous exposure. For example, assuming that an OEL protects against harmful effects during a 40-hour work week, then the corresponding dose for a week-long exposure is the fraction 8/24 multiplied by the fraction 5/7. It relates to the 8-hour occupational exposure day versus the 24-hour non-occupational exposure day and the 7-day week rather than the 5-day work week. (8/24) (5/7) OEL ≅1/4OEL does not normally include sensitive individuals, a safety factor of 10 is chosen arbitrarily to protect such individuals.

The authors reason that while it is difficult to define "sensitive" individuals, it is clear that children's nervous systems are more sensitive to lead and that asthmatics are more sensitive to substances to which they are sensitized. Yet, they continue, there is no indication that there are large differences in sensitivity to VOCs (Nielsen *et al.*, 1995). Thus, they argue, a safety factor of 10 should be sufficient, and a health-based IAQ guideline value corresponding to 1/40 the OEL should be adequate. A different safety factor from within the range 1/40-1/4 can be selected if there is adequate documentation of the rationale, they added.

According to the authors, a number of effects do not follow Haber's Law. For example, if a person metabolizes the same dose of ethanol as that in one alcoholic drink (for example, beer) in one hour, then he should be able to have a drink every hour of the day (a total of 24 drinks) without accumulating ethanol in the body. However, if 24 drinks are consumed in 8 hours, only 8 drinks worth of alcohol are metabolized and the accumulated alcohol dose corresponds to 16 drinks. If Haber's Law were applied to a dose with no effect in 8 hours, then the dose converted to a continuous 24-hour exposure is a maximum intake of 8 drinks in 24 hours. Thus, the example shows that an additional safety factor is built in when Haber's Law is used to convert 8-hour, 5-day per week exposures to 24-hour, 7-day-a-week exposures.

Sensory irritation usually occurs quickly after initial exposure and disappears soon after exposure ends. Thus, the effect is determined by the instantaneous concentration and not by exposure (concentration times time). Low-molecular weight substances tend to have increased effects corresponding to only moderately increased concentrations. Thus, a safety factor of 4 might be sufficient for these substances. Since the same factor of 4 is derived in applying Haber's Law, the authors chose to use this safety factor to convert the OEL's to an acceptable indoor air concentration for the majority of the population. Where no detailed evaluation of the irritation effect is available, a safety factor of 10 is used instead in order to protect sensitive individuals. Thereby, irritation and "health-based effects" can be treated in the same way, at least as a first approximation. If the OEL is based on evaluation of sensory irritation only, the "health-based effects" are automatically overestimated and vice versa, according to the authors.

Where the authors could not find OEL or indoor air guidelines with adequate documentation, they advocate collecting adequate toxicological documentation before proposing a guideline value. Where reliable authoritative literature surveys (such as the WHO's "Environmental Health Criteria" documents) are available, the collection and review of literature can be limited. The guideline value should "...be based on the latest authoritative surveys whenever possible."

As a final step in the NKB report, the authors compared the values they obtained to those established by James and Gardner (1996) for "Spacecraft Maximum Allowable Concentrations." The same principles and procedures were applied to derive those values. Since astronauts tend to be more sensitive during space flights, they might be considered surrogates for sensitive members of the general population. Thus, it is interesting to compare the values derived for the astronauts with those derived by the Nordic working group for the two common substances reported by both groups, ammonia and 2-ethoxyhexanol (see Table 4). Both groups derived similar values.

Health-Based Guideline Values

The health-based guideline values addressing toxic effects are shown in Table 1. The guideline values range from 0.3 to 10 mg/m^3 (0.2 to 10 ppm). There are a few obvious patterns in the values. Half the guideline values are 1 mg/m^3 or less and three fourths are 4 mg/m^3 or less.

Only four of the guideline values are less than 0.5 mg/m^3. They are formic acid (0.3 mg/m^3), octanal (0.35 mg/m^3), 2-ethoxyethanol (0.4 mg/m^3) and hexanal (0.4 mg/m^3). These values are all in same range as typical TVOC values for most reasonably ventilated, non-industrial buildings. Rarely are single compounds ever in that range. In fact, most of the guideline substances are rarely found at indoor air concentrations approaching a tenth of their guideline values, more often far less than that.

Odor vs. Irritation Thresholds

One of the valuable byproducts of the Nielsen work is updated and carefully researched odor and irritation thresholds. Since these are two of the most significant effects of concern in indoor air, a review of the results is worthwhile. The results and our calculation of the odor-to-irritation ratios are presented in Table 2.

Nineteen of the twenty-six substances have both odor and irritation thresholds listed. For most of the substances, the irritation threshold values are higher, usually three to ten times (or more) higher than their odor threshold. These odor-to-irritation threshold ratios are consistent with the findings of Cometto-Muñiz and Cain for many of the substances they have studied (1992). Excluding the single, very large ratio of odor-to-irritation threshold, that of formic acid, (26.5 to 1), the mean ratio is 0.44 and the median ratio is 0.15.

Table 1 - Health-based IAQ guideline values addressing the toxic effects (derived from Nielsen *et al.*, 1997).

Substance	*Guideline value (mg/m³)*
Formic acid	0.3
Octanal	0.35
2-Ethoxyethanol	0.4
Phenol	0.4
Hexanal	0.8
Acetic acid	1
Benzaldehyde	1
Benzyl alcohol	1
Butanal	1
Butyric acid	1
Propanal	1
2-Ethylhexanol	2
α-Pinene	4
β-Pinene	4
Ammonia	4
Camphene	4
2-(2-Ethoxy-ethoxy) ethanol	6
Propionic acid	7
2-(2-Butoxy-ethoxy) ethanol	9
1-Methoxy-2-propanol	10
Isobutyl alcohol	10

Only four out of the 19 substances had odor-to-irritation thresholds equal to or greater than 1. Twelve of the 19 are 0.2 or less, meaning that the irritation threshold is five times (or more) higher than the odor threshold. Thus, in general, using an odor threshold is adequate to protect against irritation. However, there are exceptions. Specifically, more than one-fifth of the substances actually did have odor thresholds higher than the irritation threshold, demonstrating yet again that generalizations about indoor air can be dangerous.

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Table 2 shows that none of the irritation thresholds were less than 1 mg/m³ while indoor air concentrations of individual compounds rarely exceed a few hundred µg/m³ range and are more commonly in the single or double-digit µg/m³ range.

In Table 3 we compare some of the health guideline values to values reported by Brown *et al.* from an extensive survey of indoor air VOC concentrations obtained from researchers and published literature (1992). The guideline values are generally far above the concentrations reported in indoor air. Looking at the indoor air concentrations reported by Brown *et al.* (1992; 1994), for example, we find concentrations

Table 2 - Factors significant for work-related symptoms at the time of the audit (derived from Nielsen *et al.*, 1997).

Substance	*Odor threshold (mg/m³)*	*Irritation threshold (mg/m³)*	*Ratio odor/irritation thresholds*
Octanal	0.007	4	0.002
Butyric acid	0.014	4	0.004
Butanal	0.03	3	0.01
Propanal	0.06	4	0.015
Hexanal	0.06	3	0.02
Propionic acid	0.1	3	0.033
1-Methoxy-2-propanol	0.7	10	0.07
Phenol	0.4	4	0.1
Acetic acid	0.36	2.5	0.144
Isobutyl alcohol	3	20	0.15
α-Pinene	4	20	0.2
Benzaldehyde	0.2	1	0.2
2-Ethoxyethanol	5	10	0.5
2-Ethylhexanol	1	2	0.5
Ammonia	4	4	1.0
Camphene	30	20	1.5
2-(2-Ethoxy-ethoxy) ethanol	4	2.5	1.6
β-Pinene	40	20	2
Formic acid	53	2	26.5

two to three orders of magnitude below the guideline values recommended by Nielsen *et al.* Note that the units in Table 3 are in µg/m³.

This comparison indicates that the indoor air concentrations are generally well below the guideline values and, presumably, they are not likely to cause occupant complaints or health effects. This should be encouraging to all of us, whether we design, construct, operate, or occupy buildings. There appears to be good reason to believe that IAQ is generally "safe" based on current knowledge.

However, these results do not mean that buildings are free of chemicals that can cause odor, irritation, or toxicity. What it means is that, in general, building concentrations of the chemicals studied by both Nielsen *et al.* and by Brown *et al.* are not generally at concentrations that are known to be problematic. We cannot explain the prevalence of reported occupant discomfort, irritation, odor, or toxic effects by measuring these substances.

Combinations of chemicals in complex mixtures, indoor air chemistry, and chemicals combined with other environmental, social, or personal factors could contribute to adverse occupant responses to the indoor environment (Wolkoff *et al.*, 1997; Weschler, 1998; Levin, 1995;1996).

Certainly, many of the assumptions underpinning the methodology used by Nielsen *et al.* deserve and surely will receive scrutiny and abundant discussion. However, until some reasonable alternative is proposed, the method and the values derived should serve as useful guidelines for individual chemicals in indoor air. Far more research is necessary to define the role of these chemicals in combination with other chemicals or environmental factors. Meanwhile, Nielsen and his colleagues have given us a handy rule-of-thumb guideline, specific VOC guidelines for a number of important indoor air contaminants, and a substantially validated approach to establishing guideline values. This work responds to one of the basic needs for progress in the indoor air field.

Editor's Note: An earlier version of this article appeared as a Guest Editorial to Indoor Air Supplement 5/1998, discussed and referenced in this article.

References:

Brown, S., Sim, M., Abrahamson, M. J., Gray, C. N., 1992. Progress towards national indoor air quality goals for volatile organic compounds, report to the Air Quality Panel of the National Health and Medical Research Council (Australia).

Brown, Steve, 1994. *Indoor Air*, 4:123-134.

Cometto-Muñiz, J. E. and Cain, W. S. 1992. Sensory irritation: Relation to indoor air pollution. *Annals of the New York Academy of Sciences*, 641, 137-151.

James, J. T. and Gardner, D. E. 1996. "Exposure limits for airborne contaminants in spacecraft atmospheres," *Applied Occupational and Environmental Hygiene*, Vol. 11, 1424-1432.

Levin, H., 1995. "Physical Factors in the Indoor Environment," in Seltzer, J. (ed.), *Effects of the Indoor Environment on Health*, Occupational Medicine: State of the Art Reviews, Vol. 10, No. 1, January-March, 1995.

Levin, H., 1996. "Design for multiple indoor environmental factors," in *Indoor Air '96, Proceedings of the Seventh International Conference on Indoor Air Quality and Climate, Volume 2*, pp. 741-746, July 21-26, Nagoya, Japan.

Levin, H., 1998. "Introduction," Guest editorial to Gunuar Damgård Nielsen, Lea Frimann Hansen, Bjørn Andersen Nexø, and Otto Melchior Poulsen, 1998. "Indoor Air Guideline Values for Organic Acids, Phenols, and Glycol Ethers," *Indoor Air, Supplement No. 5*, 1998.

Mølhave, L., 1982. "Indoor air pollution due to organic gases and vapours of solvents in building materials," *Env. Intl.*, Vol. 8, pp. 117-127.

Mølhave, Lars, 1991. "Volatile Organic Compounds, Indoor Air Quality, and Health," *Indoor Air*, 1, 357-376.

Table 3 — Odor, sensory irritation, and health guideline values from Nielsen *et al.*, 1997, compared to concentrations found in buildings as reported by Brown *et al.*, 1992.

	Brown et al., 1992						*Nielsen et al., 1997; 1998*			
							Guideline Values			*Target Organ(s)*
Compound	*Boiling Point*	*AMC (μg/m³)*	*WAGM (μg/m³)*	*WAAM (μg/m³)*	*90PC (μg/m³)*	*Comments*	*Odor threshold (μg/m³)*	*Sensory irritation (μg/m³)*	*Health-based IAQ guideline (μg/m³)*	
Butanal	104	34	1.5	2.7	6		30	3,000	1000	Lungs and reprotoxic effects
Acetic acid	118	-	12	22	50	bioeffluent	360	2,500	1000	Lungs
Hexanal	128	24	1	2	5	poor sample	60	3,000	80	Lungs ?
Phenol	182	-	9	16	36		400	4,000	400	Reproductive toxicity
β-Pinene	165	34	1	2	3		40,000	20,000	4,000	Set by analogy from α-pinene
2-Ethyl-1-hexanol	185	10	1	2	3	poor sample	1,000	2,000	2,000	Irritation of mucous membranes, and effect on liver and kidney

AMC = arithmetic mean concentration
WAGM = Weighted average geometric mean
WAAM = Weighted average arithmetic mean
90PC = 90th percentile concentration

Table 4 — Summary of proposed health guideline values for evaluation of indoor air effects of non-carcinogenic substances (Adapted from Nielsen *et al.*, 1997).

Substance name	*Guideline values (mg/m³)(ppm)*			*Target organ(s)*
	Odor threshold	*Sensory irritation*	*Health-based IAQ guideline*	
Carboxylic acids				
Formic acid	53 (28)	2 (1)	0.3 (0.2)	CNS, lungs, liver, kidneys
Acetic acid	0.36 (0.14)	2.5 (1)	1 (0.5)	Lungs
Propionic acid	0.1 (0.035)	3 (1)	7 (2)	Effects on mucous membranes
Butyric acid	0.014 (0.004)	4 (1)	1 (0.3)	Effect on cell line
Phenols				
Phenol	0.4 (0.1)	4 (1)	0.4 (0.1)	Reproductive toxicity
BHT (Butylated hydroxytoluene)	Neglected	Disregarded	0.5 (0.06)	Liver and promoter effects
Glycol Ethers				
2-Ethoxyethanol	5 (1)	10 (3)	0.4 (0.1)	Liver and kidneys
2-Ethoxyethanol [a]			0.26 (0.07)	Anemia
2-(2-Ethoxy-ethoxy) ethanol	4 (0.7)	2.5 (0.5)	6 (1)	Kidneys and liver
2-(2-Butoxy-ethoxy) ethanol	0.009 (0.001)	Disregarded	9 (1.5)	Reduced weight gain
1-Methoxy-2-propanol	0.7 (0.2)	10 (3)	10 (3)	Liver, kidneys, and lungs
Aldehydes				
Propanal	0.06 (0.03)	4 (*2)	1 (0.4)	Lungs
Butanal	0.03 (0.009)	3 (1)	1 (0.3)	Lungs and reprotoxic effects
Hexanal	0.06 (0.014)	3 (0.8)	0.8 (0.2)	Lungs ?
Octanal	0.007 ((0.001)	4 (0.8)	0.35 (0.07	Lungs ?
Benzaldehyde	0.2 (0.04)	1 (0.3)	1 (0.2)	Damage to mucous membranes and nongenotoxic cancer
Terpenes				
α-Pinene	4 (0.7)	20 (~3.5)	4 (0.7)	Effects on liver, kidney, and reproduction
β-Pinene	40 (6)	20 (~3.5)	4 (0.7)	Set by analogy from α-pinene
Camphene	30 (5)	20 (~3.5)	4 (0.7)	Set by analogy from α-pinene
Alcohols				
Isobutyl alcohol	~3 (0.8)	40 (14)	10 (~3)	Reduced weight gain and carcinogenic effect
2-Ethylhexanol	1 (~0.2)	2 (0.3)	2 (0.3)	Irritation of mucous membranes, and effect on liver and kidney
Benzyl alcohol	? (~0.1 - <670)	Disregarded	1 (0.2)	Acidosis, CNS and multiple organ effects
Texanol (2,2,4-trimethyl-1,3-pentanediol monoisobutyrate)[b]	? (<150)	Disregarded	1 (0.1)	Enzyme induction in the liver
Miscellaneous				
Ammonia[b]	4	4	4 (~7)	Irritation of mucous membranes
Ammonia[a]	-	7	7 (10)	Irritation of mucous membranes
(2-Butanone oxim)[b]	? (<4-18)	4-18	0.1 (0.03)	Hematological effect
Propylene glycol[b]	Neglected	Disregarded	4 (~1)	Acidosis
TXIB (2,2,4-trimethyl-1,3-pentanediol diisobutyrate)[c]	?	Disregarded	1 (0.1)	Enzyme induction in the liver

a Exposure limits for airborne contaminants in spacecraft atmosphere for 180 days (James and Gardner, 1996).
b Nielsen *et al.*, 1997.
c Included in the documentation of Texanol (Nielsen *et al.*, 1997).

Mølhave, L., G. D. Nielsen, 1992. Interpretation of the concept "total volatile organic compounds" (TVOC) as an indicator or human responses to exposures of volatile organic compounds in indoor air. *Indoor Air*, Vol. 2, 65-77.

Nielsen, Gunnar Damgård, Lea Frimann Hansen, Bjørn Andersen Nexø, and Otto Melchior Poulsen, 1997. Nordic committee on Building Regulations, NKB, Indoor Climate Committee, NKB Committee and Work Reports 1996:11E.

Nielsen, G. D., Hansen, L. F., Mammer, M., Vejrup, K. V., Wolkoff, P., 1997a. "Chemical and Biologieal Evaluation of Building Material Emissions, I. A Screening Procedure based on a Closed Emission System," *Indoor Air*, 7: 8-16.

Nielsen, G.D., Hansen, L. F., and Wolkoff, P., 1997b. "Chemical and biological evaluation of building material emissions. II. Approaches for setting indoor air standards and guidelines for chemicals," *Indoor Air*, Vol 7, 17-32.

Nielsen, G.D., Hammer, M., Hansen, L. F., 1997c. "Chemical and Biological Evaluation of Building Material Emissions, III. Screening of a Low-Emitting Fibrous Acoustic Insulation Material," *Indoor Air* 7: 33-40.

Nielsen, Gunnar Damgård, Lea Frimann Hansen, Bjørn Andersen Nexø, and Otto Melchior Poulsen, 1998. "Indoor Air Guideline Values for Organic Acids, Phenols, and Glycol Ethers," *Indoor Air, Supplement No. 5, 1998.*

Weschler, C. J., Shields, H. C., 1997. "Potential Reactions Among Indoor Pollutants," *Atmos Environ.*, 31, 3487-3495.

Wolkoff, Peder, Clausen, P. A., Jensen, B., Nielsen, G. D., and Wilkins, C. K., 1997. "Are we measuring the relevant indoor pollutants?" *Indoor Air*, 7: 78-91.

Standards

Standard 62-1989 Update — Ventilation for Acceptable IAQ

[BULLETIN editor Hal Levin has been a member of ASHRAE's SSPC 62, the committee that has worked on the revision to Standard 62-1989, for the past seven years.]

Most veterans of the IAQ field, at least in the US and Canada, consider ASHRAE Standard 62-1989, "Ventilation for Acceptable Indoor Air Quality" the most important single IAQ document. It comes from the US, whose sheer size and economy make it important. It has regulatory status by having been adopted (in whole or in part) into many local building codes in the US. It has a history going back to the 19th Century. And, ASHRAE itself is a pioneer in the indoor air field.

Like all technology standards, Standard 62-1989 requires frequent updating. Adoption of the latest proposed revision, known as 62-89R, was heavily contested and beset by conflicting interests. This article discusses the importance of Standard 62-1989, the public review draft 62-89R, the different interests that guided its fate, and our view of Standard 62-1989's current status and future prospects.

The Importance of Standard 62-1989

While there are many IAQ guideline documents, both in the US and abroad, few have attempted to set standards that would have the impact Standard 62 has had, partly because it is likely to be adopted into code. In Europe, where IAQ research and public awareness are often far ahead of the US, most established IAQ guidelines and standards are voluntary rather than regulatory in nature. Canadian government guidelines which reference Standard 62-1989 are also largely voluntary with authority left to the provinces to adopt regulations. Only in Japan do IAQ standards (established more than two decades ago) have force similar to the force of law that building codes have in the US.

Standard 62-1989 has evolved over the years and has served as the main reference for building codes and for professional practice. This, we believe, has had the effect of reducing pressure on government at all levels to initiate regulatory action. Only a few states have IAQ programs. The absence of other standards itself elevates Standard 62-1989.

62-89R — The Revision

IAQ issues and their regulation affect anyone who designs, constructs, or owns or operates buildings. Manufacturers of building materials, furniture, and many other types of consumer products also feel the economic ramifications. It is, therefore, no surprise that the development of Standard 62-1989 was so contentious. It took eight years to develop Standard 62-1989, the last of which were spent on appeals and challenges.

ASHRAE established the Standing Special Project Committee 62 (SSPC 62) to revise Standard 62-1989 in late 1991 and the committee began work in January 1992. The ASHRAE Standards Committee instructed the SSPC 62 to write the document in code language to facilitate its adoption by the model code bodies. After five and a half years of committee work, involving as many as seven three-day meetings per year, a Public Review Draft was finished. The committee released the draft, known as 62-89R, in August, 1996 with comments due by December.

62-89R drew over 8,000 comments (although almost half of them, orchestrated by the National Association of Home Builders, were similar or identical). SSPC 62 worked intensively during the first six months of 1997 to review the comments and respond to them with a revised, improved draft that was to be put out for a second public review. That revised draft was almost complete at the time of the ASHRAE Annual Meeting in Boston in June of that year.

The vast majority of the 8000 comments were directed at the residential section of 62R. The Standards Committee of ASHRAE responded by splitting future versions of Standard 62-1989 into a commercial-institutional standard (62.1) and a residential standard (62.2). The existing committee was redesignated as at SSPC 62.1 and a new project committee, SPC 62.2P, was formed to focus on the residential standard. The main focus of the controversy is on the commercial-institutional standard.

A Comparison of Standard 62-1989 and 62-89R

The following are some of the key differences between the existing Standard 62-1989 and 62-89R and the reasons why 62-89R had been under such scrutiny.

- *Code language* — 62-89R was to be written in code language. Thus, where Standard 62-1989 says certain things "should" be "considered" or done, 62-89R said they "shall" be done for compliance with the standard. Instead of just having to consider certain things, 62-89R would have required them, often providing a substantial amount of detail in the requirements.
- *Tobacco smoking* — Under Standard 62-1989, compliance is achieved if ventilation rates in Table 2 are met with "...an adequate margin of safety and to account for health variations among people, varied activity levels, and a moderate amount of smoking." 62-89R did not provide for compliance when tobacco smoking occurred. This resulted in strong and continuous opposition to the standard's development throughout the process. This opposition came from several tobacco industry representatives and consultants as well as their friends on the committee and outside. One IAQ newsletter, published by a consultant to the tobacco industry, urged its readers to submit comments on 62-89R and presented many articles critical of the draft.
- *Unusual sources* — Standard 62-1989 requires that "unusual sources" of contaminants be considered and addressed, but it is general and vague. 62-89R proposed a specific method for addressing contaminants from all sorts of sources, the "Analytical Method," using a basic mass-balance approach. Although the analytical method was no more complicated than the ordinary design process used by structural engineers for structural components of a building, many within ASHRAE, including some committee members, believed the proposed method was too complex and difficult for ASHRAE engineers.
- *Calculation and Documentation* — 62-89R required considerably more calculation and documentation by ventilation engineers. There are many engineers whose ventilation designs only involve plugging in a number from the ventilation rate table (Table 2) in Standard 62-1989. They design primarily for thermal control and energy considerations. HVAC system first costs govern most decisions. Having to tell their clients that more ventilation is required and asking for more money for design and presumably for more expensive systems was not something many of them welcomed and supported. While Standard 62-1989 requires design documentation, it is not very specific or detailed, and it is rarely followed.
- *Emission Rates and the Analytical Method* — The absence of good emission rate data for many indoor sources meant the applicability of the "Analytical Method" was limited, but the committee believed more data would become available with the method included in the standard. Manufacturers of products that were strong sources were nervous about potentially having to reveal their products' VOC emissions to designers and the world. Some representatives of these industries openly opposed issuance of the public review draft.
- *System Requirements* — 62-89R included a number of detailed requirements for ventilation systems and equipment that were consistent with the general language in Section 5 of Standard 62-1989. Many of the proposed requirements would have required modifications of many common ventilation system components, particularly so-called "package" systems — small, roof-top mounted units that are widely used on small buildings or for low-end larger structures. Such changes are not welcomed by industry, especially when imposed by outsiders. The proposed changes made clear that some of the equipment on the market has deficiencies, and this was not something the manufacturers wanted to endorse.
- *Operation and Maintenance* — 62-89R contained requirements for the operation and maintenance of buildings. This is not part of Standard 62-1989, and there were many new opponents of the proposed revision because these requirements were included in 62-89R.

The Fate of 62-89R

The controversy over 62-89R was substantial. Within ASHRAE there were many members who believed it was not the right thing to do. There was much heated discussion and debate about the direction the SSPC 62 was headed with the revision. Much criticism was instigated or stimulated by the tobacco industry representatives and their consultants, some by other economic interests, and some by ASHRAE members who claimed that the standard was just too complex. While committee leaders claim that they were not proposing anything so very different from what is in Standard 62-1989, there were some key differences.

In part due to the controversy, 1996-7 ASHRAE president Jim Hill of NIST appointed an *ad hoc* committee to review the multi-disciplinary, high-profile Standard 62-1989 and Standard 90.1 (energy conservation in non-residential buildings). Both of these standards received extensive comments during their public review periods and were subjected to much heated debate within ASHRAE. The fate of Standard 90.1 still remains unresolved. The committee reported to the ASHRAE Board of Directors in June, 1997, and one of its recommendations was to immediately place Standard 62-1989 on continuous maintenance (CM). The ASHRAE board quickly voted unanimously — in a move some say was procedurally inappropriate or even illegitimate — to do that. Another recommendation was to develop two documents – a minimum code language document and a more comprehensive guideline document.

CM is a technical term of the American National Standards Institute (ANSI) — an independent body that reviews and approves the procedures used to develop consensus standards before it accepts them as ANSI standards. (Building code officials are reluctant to adopt standards in whole or in part that ANSI has not accepted.)

What this means is that ASHRAE has withdrawn 62-89R and has instructed the committee to revise Standard 62-1989 incrementally rather than develop an entirely new document. The committee must also convert the existing standard into a code language document through the incremental addendum process. The revision process is to produce a "minimum standard," not a "best current practice" standard. The ASHRAE board charged the committee with developing a Guideline in addition to and separate from Standard 62-1989 that will reflect good IAQ practice, going beyond the minimum requirements of the code-language document.

The ASHRAE Board's View of 62-89R

Rumors abound as to why ASHRAE's board decided to put Standard 62-1989 on CM and on the implications of this action on the future of the standard. Did the tobacco industry win their battle to stop the revision and retain the existing standard? Has the committee working on the revision been disbanded?

We discussed this with other members of SSPC 62 and with several key ASHRAE officials. The ASHRAE board was reportedly frustrated by all the internal strife within the organization. Many directors believed that SSPC 62 was responding too slowly to the public review comments and the abundant expressions of unhappiness with the draft. Another view is that the board simply acted to keep the existing Standard 62-1989 from losing ANSI approval status due to ASHRAE's failure to review it in a timely fashion as required by ANSI. Others said that the board, especially its leadership, was reacting to the cacophony within ASHRAE, to the many members critical of the draft, and to the need to develop more harmonious internal relationships.

One director said that ASHRAE writes standards "...to protect the interests of the manufacturers who dominate ASHRAE. If it [the standard] is going to work, it has to meet the needs of the Society — the ASHRAE membership is mostly manufacturers of HVAC and refrigeration equipment." Indeed, only 20% of ASHRAE members are ventilation system engineers. The Society is dominated by industry manufacturers and contractors.

An ASHRAE Standards Committee veteran opined that the engineering profession is not acting as a profession but instead as agents for their clients. He said that professionals are supposed to stand up for their professional code of ethics first and the client second. According to him, Standard 62-1989 is a "battle of interests." He went on to say that ASHRAE is not procedurally equipped to deal with a battle of interests. It is equipped to deal with situations where there are people acting in good faith for a shared objective, such as a consensus test method. For standard test methods, members may disagree on details but they agree on the goal. They are not equipped to deal with people who believe they will be adversely affected by getting a new standard. He also said that ASHRAE is in theory and practice the best place to do ventilation for IAQ. But, he said, there is no way a Standard 90 or a Standard 62-1989 can be apolitical. By its constitution, ASHRAE is a professional society, but its membership is deviating from that.

However, one ASHRAE director said that ASHRAE is not, in fact, a professional society but rather a technical one. When the current form of ASHRAE was established, its constitution included the following statement of purpose:

> "To establish, approve, adopt and promulgate codes, standards, and procedures in the fields of heating, refrigeration, and air conditioning and ventilation, and the allied arts and sciences, subject to the proviso that all such activities shall be conducted solely for the advancement of engineering science."

No one we interviewed inside ASHRAE pinned the blame for the demise of 62-89R solely on the tobacco industry and its consultants, although most identified them as a major obstacle to revision of the standard. The tobacco industry representatives and consultants had unabashedly opposed the revised draft ever since the early versions appeared that eliminated compliance where smoking occurs. The various versions of the draft revision had, since the earliest versions, stated that "acceptable indoor air quality" could not be achieved where smoking was permitted indoors. This, the document had said, was because of EPA's carcinogen status designation of environmental tobacco smoke.

An appendix to 62-89R discussed the requirements for achieving acceptable "perceived indoor air quality" when tobacco smoke occurs indoors. Standard 62-1989 permits a "moderate amount of [tobacco] smoking" as a footnote to the table that provides outdoor air ventilation rate requirements. Recently, SSPC 62 has initiated an addendum that would remove this footnote.

Nevertheless, tobacco industry representatives and their consultants aggressively attacked 62-89R for several years. Two of the more notorious consultants made strong statements at the very first meeting of the SSPC 62 seven years ago. Tobacco industry consultants actively drummed up opposition to the revised standard as it was being developed. They were cheerleaders for the opposition, encouraging ASHRAE members and others to submit critical comments.

Many believe the tobacco industry was behind an attack on ASHRAE and the EPA with the intention of discrediting the revision process. A 1995 letter by Texas Congressman Barton accused EPA of improprieties in assisting ASHRAE by providing some funding for committee activity and an EPA scientist to serve as chair of SSPC 62 for its first four years. Barton's subcommittee reports to Congressman Bliley of Virginia, a tobacco industry advocate.

The People Behind the Controversy

IAQ standards, regulations, and guidelines affect many diverse interests. No matter what is proposed, there will be strong opposition. For example, a classic argument continues to take place between building owners, who want source control (including, in many cases, smoking prohibitions) and the industries associated with the sources such as tobacco, chemical, and building product manufacturers. ASHRAE's efforts to provide opportunities for affected parties to participate in review processes often results in committee meetings that appear more like battles of special interests than the work of a group of well-informed professionals.

Among those involved in the development of 62-89R were not only professional designers, especially ventilation system designers, and IAQ consultants, but also the manufacturers, building developers and owners, contractors, manufacturers of products that are strong sources of indoor pollutants, employers, and, not least of all, building occupants. An engineer on the committee even represented tobacco interests while an attorney (and law professor) represented anti-smoking activist organizations.

Many professionals and consultants working in the ventilation system design and operation fields were asked to serve on the SSPC 62 in order to bring state-of-the-art knowledge to the process. They naturally pushed for a standard that reflects the latest scientific and professional knowledge and experience. Their proposals generally reflect their knowledge on avoiding IAQ problems in the buildings that many of them have spent decades studying and investigating.

Some representatives of ventilation equipment manufacturers and "traditional" practitioners found the changes proposed by the IAQ experts to be too aggressive and, in some cases, believed them unnecessary. Certainly many "traditional" designers are threatened by the possibility of having to admit that their past practices were inadequate. Understandably, they don't want to acknowledge the need to perform more rigorous analysis of IAQ to design HVAC systems.

Tobacco industry consultants consistently opposed changes in the standard through the past seven years of work on the revision. Several consultants attended all meetings of the committee and participated extensively in the discussions. They submitted enormous amounts of material before and during the public review. They frequently registered procedural objections and asked for their statements to be noted in the minutes. The longest single comment submitted on 62-89R was from Mayada Logue, a consultant for R. J. Reynolds and a constant observer of committee activities. Many observers expect them to appeal any action ASHRAE might take to change the status of smoking within the ventilation standard.

The Future of Standard 62-1989

The eventual code language document is likely to be short and establish minimum performance levels based on health criteria but using engineering judgment on the available science. There will also be a guideline document to establish good ventilation and IAQ practice. The guideline document will not be written in mandatory language. It is likely to be substantially longer and more detailed than the standard, and it may go beyond just health as a basis for its content.

However, for the past year, the SSPC 62 has been working to adopt addenda under the CM process. So far there has been strong opposition to all but the smallest changes proposed. The opposition continues to come from the same quarters that vocally criticized 62-89R. To date, very little progress has been made.

CM is a standards-writing strategy that allows parts of a standard to be changed without changing other parts. It has both advantages and disadvantages compared to the more normal batch-mode process called Periodic Maintenance (PM).

CM is used successfully on standards such as the boiler code that are very large and change only evolutionarily. ASHRAE uses CM successfully on standards such as its refrigerant standard (34) to allow new refrigerants to be added without modifying or re-balloting the entire document. CM can also be useful when a standard is inherently multidisciplinary because specific, especially controversial, issues can be isolated and debated on their own merits.

ASHRAE is requiring its High Profile Standards (HPS) to be on CM mostly for this latter reason. The intensity of the response to public review drafts of 90.1R and 62-89R have convinced ASHRAE that only by making multiple individual changes can consensus be reached. Some have interpreted this to mean that only small changes can be made to CM standards, but in fact it is the responsibility of the project committees to determine the number and extent of the needed changes.

When the consensus-forming body and the public are both satisfied with the extant standard, CM can save time and effort by not requiring a lot of processing. When interested parties feel that significant changes are warranted to a CM standard, however, the load on the Standards Writing Organization (SWO) can be extreme. Standard 62-1989 is currently in this situation. The real question is whether ASHRAE has what it takes to really carry out CM for these HPS.

Standard 62-1989 is the first HPS to go on CM. Although it has not yet issued any addenda, several are in various stages of the process and their processing is quite illuminating as far as the strengths and weaknesses of the procedure as well as the demands on the system. It is clear that CM puts extra burdens of several types on many layers of the system.

The staff burden for CM is significant. Not only are there more public reviews with CM, but the system is less tolerant of delays than with PM. For example, missing a particular balloting deadline can cost six months in the processing of a public review draft. For a standard on PM, an extra six months is usually less than a 10% delay in publication, but for a CM standard that is expected to be updated annually, it is a 50% delay. More importantly perhaps, changes to CM standards are often tiered so that one change cannot be put forward until another one is accepted. Thus, a six-month delay can turn into a three-year delay on a multi-step process. No amount of reorganization can make this burden disappear; simply put, CM requires more staff and more staff puts a financial burden on ASHRAE and hence its membership.

There are two different kinds of burdens for the administrative bodies of ASHRAE. Firstly, the multiple addenda mean that there is more paperwork to handle approvals for things like public review, changes to scopes, or publication. Secondly, administrative bodies have to keep to their charter. The administrative bodies are responsible for assuring that policies and procedures have been followed — forming the technical consensus is the responsibility of the project committee. As we have already seen with the HPS, administrators often substitute their technical judgment for that of the project committee. Although it is an understandable tendency, it is quite unethical for these bodies to base their votes on technical considerations. The challenge for the administrative bodies is to keep to administrative concerns and not get involved on a technical level.

The small steps of CM can be an advantage because they can isolate and address narrow but controversial issues. The small steps of CM can be a disadvantage because they can make it harder to make a complex or large change. It can easily happen that a project committee can see where it wants to go. With PM that is not a problem. Under CM, however, it may be necessary to get to that spot through a series of steps (addenda) where each intermediate is a poorer situation than the final result. Such sub-optimization grates on any respectable engineer. Such a process, nevertheless, is part and parcel of CM and must be accepted. It is necessary not only to determine an optimal spot, but to also find a CM path to get there.

The *BULLETIN* Comments

The example of the revision of Standard 62-1989 suggests that ASHRAE does not have what it takes to process HPS. Since all three parts of the process have failed to meet their burdens, there is plenty of blame to go around: there have been insufficient staff resources; the administrative bodies have been meddling in technical issues, and the project committee refuses to embrace the CM process.

This is not to say that it cannot be done or that the policy should be changed. If ASHRAE wishes, however, to succeed it is going to have to exhibit a lot more commitment, professionalism, and discipline than it has so far. ASHRAE has a lot to offer its membership, its profession and society as a whole with its HPS. No other body has the technical ability to produce quality consensus standards in these areas. Unless the system is given a good swift kick, however, it is unlikely that ASHRAE will be able to deliver.

The world has changed much since Standard 62-1989 was written in the late 80s. There has been an enormous increase in our understanding of IAQ since then. The challenge is to find a way to reflect this increased understanding in the standard while also meeting all the directives and procedural constraints confronting the committee. While it is clear that significant changes to Standard 62-1989 are warranted, it is equally clear that they will be strongly opposed. ASHRAE has got to come to grips with this situation and find a way to move forward. The next few months will reveal much about its ability to do so.

VOCs

New European Guideline Changes TVOC Concept

Leading European indoor air researchers have proposed a radical new definition of total VOC (TVOC). This new definition virtually eliminates the concept of TVOC and requires identifying and quantifying "...a substantial proportion of the compounds in an air sample...using their respective response factors."

The new definition also does away with the common, simple approach most often used for indoor air investigations. No longer can researchers simply use direct injection of an air sample into a GC with a flame ionization detector calibrated to toluene to give toluene-equivalent TVOC. Nor can the sum of the most prevalent separate compounds be accepted as a TVOC value under a new guideline document.

The reasons given for this change relate to the purpose of VOC measurements for assessing potential health implications. The main reason given for the change is that TVOC values reported in the literature are mostly not comparable. Comparability can be increased by clearly defining TVOC and standardizing methods.

The European Commission project European Collaborative Action; Indoor Air Quality & Its Impact on Man published this important document late last year. While we have seen few changes in the use of the term TVOC, the underlying principles articulated by Report 19 should result in significant changes in the interpretation of traditional TVOC measurements. The report specifies the application of the VOC concept in IAQ investigations.

The New TVOC Procedure

Under the new definition, Tenax TA (or sorbents giving equal or better performance) is used to collect the TVOC sample. Thermal elution is used to transfer the collected VOCs from the sorbent to a deactivated, non-polar GC column. The system detection limit must be capable of detecting toluene and 2-butoxyethanol at 0.5 $\mu g/m^3$ and 2.5 $\mu g/m^3$ respectively (three times their noise level). All compounds found in the chromatogram from n-hexane to n-hexadecane are considered. This is a slight modification of the WHO definition of VOC which based the range of interest on boiling points rather than the analytical window.

The analyst must quantify as many VOCs as possible but at least those on the list of "known VOCs of special interest" and those representing the 10 highest peaks. There are 64 compounds on the list. The sum of the concentrations is then calculated. The response factor for toluene is used to sum the concentrations of the unidentified VOCs.

If the sum of the identified and unidentified VOCs is less than 1 mg/m^3, then the sum is considered an acceptable TVOC value if the sum of identified VOC ≥ the sum of unidentified VOC. If the concentration is greater than 1 mg/m^3, the sum of identified VOC must be ≥ 2/3 of the total of identified and unidentified VOCs.

If many and/or abundant compounds are observed outside the VOC range, then this should be noted in reporting the results. It is also important to note that the above procedure will not include all organic compounds in indoor air. This is especially true of lower molecular weight aldehydes that the report recommends always be analyzed in addition to TVOC during IAQ investigations, preferably using the DNPH method.

How the TVOC Indicator Should Not be Used

The working group does not recommend the use of TVOC based on summation of only a selected group of target compounds. The TVOC indicator has no basis for use as an indicator in relation to health and discomfort other than sensory irritation. Even when the procedures described in the report are followed, "*...TVOC cannot be used as a surrogate for the intensity or acceptability of any effects.*" Investigators must recognize that specific VOCs may turn out in the future to be much more potent causes of human effects than the average VOCs. Thus, individual compounds will continue to need to be evaluated individually and a list of important compounds should be established. In any case, the TVOC value should be used with caution in the non-industrial environment where other factors such as temperature, humidity, noise, etc. are outside normal ranges.

The Future

According to the committee chairman, Lars Mølhave of Denmark, future revisions of the guideline are expected to include additional chemicals. The report recommends that the correlation of TVOC measurements be obtained using different measuring techniques to look at a variety of mixtures. Alfred Hodgson reported such a study in *Indoor Air*, Volume 5, No. 4, 247-257, (reported in the ***BULLETIN***, Vol. 3, No. 8, pp. 13-14).

The *BULLETIN* Comments

The acronym TVOC is preserved by the report, but the concept is vastly different. It requires specific measurements by GC/MS of the 64 chemicals and a general measurement by GC/FID of the remaining chemicals. And, if the concentration of the remaining chemicals is large, the measurement is not considered valid. There are not likely to be many changes in future practice as a result of the report, but there certainly should be a heightened awareness of the limitations of the historical TVOC data.

Availability

The full title of the report is "ECA-IAQ, Total Volatile Organic Compounds (TVOC) in Indoor Air Quality Investigations." Report 19 (EUR 17675 EN). European Collaborative Action: Indoor Air Quality and Its Impact on Man. Copies are available from the Commission of the European Communities, Directorate for Science, Research, and Development, Joint Research Centre, Environment Institute, Ispra, Varese, Italy 20120, and from its Washington D.C. office at (202) 862-9500.

IAQ Organizations

ISIAQ Alive and Well

The International Society of Indoor Air Quality and Climate (ISIAQ) is back. After over half a year of virtual silence, ISIAQ has finally re-established communication with those members whose subscription information it has been able to obtain from the former Secretariat, Doug Walkinshaw, who contested the 1997 ISIAQ election. Walkinshaw did not turn over the records to the new Secretariat until mid-1998. Since that time, the new ISIAQ Secretariat in Milan, Italy, has been busy reconstructing the records and has attempted to contact all known members and former members of the Society.

ISIAQ was founded in 1992 by 109 international scientists and practitioners following the 5th International Conference on Indoor Air Quality and Climate, Indoor Air '90 (Toronto, 1990). It is an international, independent, multidisciplinary, scientific, non-profit organization whose purpose is to support the creation of healthy, comfortable and productivity-encouraging indoor environments. Some of ISIAQ's most important activities include:

- Publishing a high profile, quarterly professional journal *Indoor Air* which reports original research results in the broad area defined by the indoor environment of non-industrial buildings.
- Publishing a newsletter which carries news and information.
- Developing guideline documents and reports by a number of Task Forces focused on specific issues.
- Organizing the Healthy Building conference series as primary Society conferences and co-organizing the Indoor Air conference series.

Membership in ISIAQ includes a subscription to the quarterly journal, *Indoor Air*, and a subscription to the Society newsletter. Members will receive substantial discounts to major ISIAQ organized or co-sponsored events including Indoor Air '99 and Healthy Buildings 2000. National chapters have been formed, including a very active one in Finland.

If you were an ISIAQ member in the past and have not heard from ISIAQ or have not been receiving your copy of the very high quality, official Society journal, *Indoor Air*, then you should contact the secretariat at isiaq@nemo.it. Some confusion in the transition to the new Secretariat has resulted in some "lost" members.

If you would like information on ISIAQ membership, publications, or events, see the web site at www.isiaq.org. If you do not have Internet access, you can contact ISIAQ, Via Magenta, 25, 20020 Busto Garolfo (Milan), Italy, Phone +39-331-568587, Fax +39-331-568023.

Potential Causes of IAQ-Related Health Symptoms

A new study by the National Institute for Occupational Safety and Health (NIOSH) indicates that HVAC maintenance appears to be strongly associated with complaints in problem buildings. The study, conducted among 2435 workers in 80 office buildings, was conducted by researchers at NIOSH in Cincinnati. Requests for investigations came from 500 buildings. 160 buildings were studied, and 80 were selected for the analysis reported in the study.

Increased Risk of Multiple Lower-Respiratory Symptoms

The NIOSH investigators found a strong association between observations of debris inside air intakes, poor or no drainage from drain pans, and dirty ductwork with an increased risk of multiple lower-respiratory symptoms. Increased risk was defined as at least three of four symptoms: shortness of breath, cough, chest tightness, and wheezing.

The Relative Risk and 95% Confidence Intervals for these HVAC maintenance problems were as follows:

Debris inside air intakes (RR = 3.1, 95% CI = 1.8, 5.2);
Poor or no drainage from drain pans (RR = 3.0, 95% CI = 1.7, 5.2);
Dirty ductwork (RR = 2.1, 95% CI = 1.2, 3.7)

HVAC design problems were also associated with an elevated risk for multiple lower-respiratory symptoms. These included outdoor air intakes within 25 ft. (8 m) of standing water, exhaust vents, sanitary vents, vehicle traffic, or trash dumpsters.

Elevated Risk of "Multiple Atopic Symptoms"

The presence of suspended ceiling panels was associated with a 2.3 Relative Risk ratio for multiple atopic symptoms. The multiple atopic symptom group required all three of the following: sneezing, eye irritation, and stuffy/runny nose/nasal congestion. Data for this risk along with the other strong associations with multiple atopic symptoms were the following:

Suspended ceiling panels (RR = 2.3, 95% CI = 1.0, 5.5)
Air ductwork never cleaned (RR=1.8, 95% CI = 1.0, 3.0);
No testing and balancing report available (RR = 1.8, 95% CI = 1.3, 2.5);
No scheduled air handler inspection (RR = 1.3, 95% CI = 1.0, 1.8);
Interior pesticides had been applied (RR = 1.5, 95% CI = 1.0, 2.3).

Elevated Asthma Risks

Relative Risks of asthma diagnosed after beginning work in the building were strongest when dirty HVAC system air filters were observed (RR = 2.0, 95% confidence interval – CI = 1.2 - 3.5). Other elevated risks factors were renovation, including installation of new drywall within the past three weeks (RR = 2.5, 95% CI = 1.4, 4.5), and debris inside air intakes (RR = 2.1, 95% CI = 1.2, 3.5).

Conclusions

The NIOSH study authors wrote that the findings could best be interpreted "...as identifying indicators of inappropriate building or work space design or maintenance which may represent exposures causing increased health symptoms within office buildings." They caution that the buildings studied may not represent office buildings as a whole since the investigations were all conducted in buildings where complaints led to requests for investigations.

In order to more fully present the results, we have included the full table of Relative Risks by Health Condition (see Table 5). The study authors warn that their findings are neither definitive proof of causal relationships for those factors with high relative risks nor do they exonerate factors with low relative risks. They are only findings of associations in the buildings studied.

The authors conclude that existing HVAC and building design and maintenance procedure guidelines are appropriate. They refer to the EPA-NIOSH publication, "Building Air Quality: A Guide for Building Owners and Facility Managers," published in 1991, as well as other publications.

The EPA-NIOSH document is available on the Web at http://www.epa.gov/iaq/base/baqtoc.html. However, this Acrobat format document on the Web does not contain the pictures that are in the full print version. To obtain the looseleaf-format version of the Building Air Quality guide, complete with appendices, an index, and a full set of useful forms, GPO Stock # 055-000-00602-4, for $28, contact the: Superintendent of Documents, U.S. Government Printing Office (GPO), P.O. Box 371954, Pittsburgh, PA 15250-7954, (202) 512-1800, Fax (202) 512-2250.

Also available from EPA is the Building Air Quality Action Plan (EPA Publication No. 402-K-98-001, DHHS (NIOSH) Publication No. 98-123. It is available on the Web at http://www.epa.gov/iaq/base/actionpl.html and from the EPA Indoor Air Clearinghouse (800) 438-4318.

Reference

W. Karl Sieber *et al.*, "The National Institute for Occupational Safety and Health Indoor Environmental Evaluation Experience. Part Three: Associations Between Environmental Factors and Self-Reported Health Conditions. *Applied Occupational and Environmental Hygiene*, Vol. 11, No. 12, December 1996, 1387-1392.

Table 5 - Relative Risks by Health Condition (Sieber *et al.*, 1996). All models corrected for age and gender.

	Health Conditions					
	Multiple Lower-Respiratory Symptoms		*Multiple Atopic Symptoms*		*Asthma Diagnosed After Beginning Work in Building*	
Variable Category and Analysis Variable	*RR*	*CI*[A]	*RR*	*CI*[A]	*RR*	*CI*[A]
1. Environmental HVAC design						
Outdoor air intakes within 25 ft. of:						
- Standing water	2.3[B]	(1.2, 4.3)	1.0	(0.7, 1.6)	0.6	(0.2, 1.7)
- Exhaust vents	2.4[B]	(1.3, 4.3)	1.1	(0.8, 1.7)	1.1	(0.5, 2.3)
- Sanitary vents	2.2[B]	(1.2, 4.1)	1.0	(0.6, 1.5)	0.7	(0.3, 1.8)
- Cooling tower	0.6	(0.1, 2.8)	0.3[B]	(0.1, 0.8)	1.4	(0.5, 3.8)
- Vehicle traffic	1.8[B]	(1.0, 3.5)	1.1	(0.7, 1.7)	1.2	(0.6, 2.6)
- Trash dumpster	2.1[B]	(1.0, 4.6)	0.9	(0.5, 1.8)	1.6	(0.6, 3.8)
HVAC maintenance						
No scheduled air handler inspection	2.0[B]	(1.2, 3.6)	1.3	(1.0, 1.8)	1.5	(0.8, 2.6)
No testing and balancing report available	1.6	(0.9, 3.0)	1.8[B]	(1.3, 2.5)	0.8	(0.4, 1.5)
Particulate filtration system:						
- Filters not secure in place	2.2[B]	(1.0, 4.6)	0.8	(0.4, 1.5)	0.5	(0.1, 2.2)
- Dirty filters	1.9[B]	(1.1, 3.2)	0.8	(0.5, 1.1)	2.0[B]	(1.2, 3.4)
HVAC cleanliness[C]	1.8[B]	(0.9, 3.0)	1.3[B]	(0.9, 1.7)	1.5	(0.8, 2.3)
HVAC condition						
- Debris inside air intake	3.1[B]	(1.8, 5.2)	1.1	(0.8, 1.5)	2.0[B]	(1.2, 3.5)
- Residue/dirt in drain pans	1.6[B]	(1.0, 2.8)	1.1	(0.8, 1.5)	1.5	(0.9, 2.6)
- Poor or no drainage from pans	3.0[B]	(1.7, 5.2)	1.2	(0.8, 1.7)	1.2	(0.6, 2.3)
- Dirty ductwork	2.1[B]	(1.2, 3.7)	1.2	(0.9, 1.7)	0.6	(0.3, 1.4)
Presence of moisture in HVAC system	2.2[B]	(1.3, 3.9)	1.2	(0.8, 1.6)	1.1	(0.6, 2.0)
Air ductwork never cleaned	2.8[B]	(0.9, 9.1)	1.8[B]	(1.0, 3.0)	0.6[B]	(0.3, 1.1)
Building design						
Presence of fabric wall covering	0.4[B]	(0.1, 1.0)	0.8	(0.5, 1.2)	1.0	(0.5, 2.0)
Presence of cloth partitions	1.2	(0.7, 2.1)	0.9	(0.7, 1.2)	1.7[B]	(0.9, 3.1)
Presence of suspended ceiling tiles	3.4	(0.4, 27.2)	2.3[B]	(1.0, 5.5)	3.2	(0.5, 23.5)
Building maintenance						
Daily surface cleaning with solution	0.7	(0.4, 1.3)	1.0	(0.7, 1.4)	0.5[B]	(0.2, 1.0)
Daily vacuuming	0.5[B]	(0.3, 0.9)	1.1	(0.8, 1.5)	0.7	(0.4, 1.2)
Daily surface dusting	0.6[B]	(0.4, 1.1)	1.3[B]	(1.0, 1.8)	0.5[B]	(0.3, 0.9)
Interior pesticides have been applied	0.5[B]	(0.3, 0.9)	1.5[B]	(1.0, 2.3)	1.2	(0.6, 2.4)
Monthly floor stripping and waxing	0.4[B]	(0.2, 1.2)	1.1	(0.8, 1.6)	0.5	(0.2, 1.4)
Renovation including installation of new drywall within last three weeks	1.1	(0.5, 2.3)	0.8	(0.5, 1.3)	2.5	(1.4, 4.5)
2. Personal and questionnaire data						
Demographic						
Female gender	2.8[B]	(1.3, 5.8)	2.2[B]	(1.5, 3.2)	2.9[B]	(1.4, 5.9)
Age: over 40 years old	2.4[B]	(1.3, 4.5)	1.2[B]	(0.9, 1.6)	2.0[B]	(1.2, 3.6)
Work organizational factors						
Conflict at job	1.2[B]	(1.1, 1.3)	1.1[B]	(1.0, 1.2)	1.1[B]	(1.2, 1.2)
Sufficient time to do things on job	1.1[B]	(1.0, 1.2)	1.1[B]	(1.0, 1.1)	1.0	(1.0, 1.1)
Job category (comparted to managerial)						
- Professional	0.8	(0.4, 1.6)	1.0	(0.7, 1.4)	1.6[B]	(0.7, 3.4)
- Technical	0.8	(0.3, 2.0)	1.2	(0.7, 2.0)	2.2[B]	(0.9, 5.3)
- Secretarial/clerical	0.7	(0.4, 1.5)	1.1	(0.7, 1.6)	1.4[B]	(0.7, 3.2)

A – 95 percent confidence interval
B - Variable statistically significant at $p \leq 0.10$ for this health condition
C – Any one of ten conditions in the HVAC system: dusty air handler, dirty sound liner, presence of debris inside air intake, moist sound liner, dirty coils, residue/dirt in drain pans, poor/no drainage from drain pans, dirty or moist ductwork, or dirty duct liner.

Corrections

In the *BULLETIN* Vol. 3, No. 10 article "Cleaning: A Solution to the Sick Building Mystery?" on page 8, the airborne dust burden reported in Table 4 for Routine Housekeeping should have been 11.9 $\mu g/m^3$, not 119 $\mu g/m^3$ as printed in the article. In Lance Wallace's letter on page 12, the reference at the end of paragraph three should read: Wallace, Pellizzari, and Wendell, 1991. Indoor Air 4:465-477. Wallace's address is Lance Wallace, US EPA, 555 National Center, 12201 Sunrise Valley Drive, Reston, VA, 20192.

IAQ Events

Calendar

January 23-27, 1999. **ASHRAE Winter Meeting**, Chicago. Contact: ASHRAE Meetings Department, 1791 Tullie Circle, NE, Atlanta, GA 30329, 404 636 8400, fax 404 321-5478.
Look for meeting information on the ASHRAE web site, www.ashrae.org.

February 8-9, 1999. **Bioaerosols: Assessment and Control Course**, sponsored by ACGIH, co-sponsored by The University of Tulsa, Indoor Air Quality Program/EPA Region 4. Delta Orlando Resort, Orlando, Florida. Contact: POC: ACGIH, 1330 Kemper Meadow Drive, Cincinnati, OH, 45240, 513 742 2020, Fax 513 742 3355, e-mail: mem@acgih.org, http://www.acgih.org/events/bio_summ.htm.
Attendees submit up to 5 questions about real-world problems to be addressed by instructors. The course text is the new ACGIH publication, "Bioaerosols: Assessment and Control."

April 19-20, 1999. **ASTM Subcommittee D22.05 on Indoor Air**, Spring Meeting, Seattle, WA. Workshop on emissions testing to be held Monday afternoon and Tuesday morning. Contact: George Luciw, ASTM, 100 Barr Harbor Drive, West Conshohocken, PA, 19428-2959, 610 832 9710, Fax 610 832 9666.
There is no cost for attending or participating in the meeting. ASTM membership is open to all.

International Events

November 30 - December 4, 1998. **Second International Conference on Human-Environment System**, Yokohama National University, Yokohama, Japan. Contact: Dr. Masahiro Hori, c/o Department of Material Science and Technology, Faculty of Engineering, Yokohama National University, Tokiwadai 156, Hodogaya-ku, Yokohama 240, Japan +81 45 335 1451, Ext 2890, Fax +81 45 331 6593, email kawa@post.me.ynu.ac.jp.
A call for abstacts has been issued. Abstracts are due February 28, 1998; papers are due June 30, 1998.

August 8-13, 1999. **Indoor Air '99, The 8th International Conference on Indoor Air Quality and Climate**, Edinburgh, Scotland. Contact: Conference President, Professor Gary Raw, BRE, Garston, Watford WD2 7JR, United Kingdom, Tel: +44 1923 664123, Fax: +44 1923 664443, web site www.ia99.org, e-mail: ia99@bre.co.uk or Claire Aizelwood, IA99, Building Research Establishment, Watford, England.
Topics: all types of indoor air pollutants plus thermal and moisture problems; health, comfort and human performance in relation to the indoor environment; ventilation, infiltration and building services; building design and materials; measurement, modelling and research methods; policy and regulations.

August 6-10, 2000. **Healthy Buildings 2000 Conference**, Espoo, Finland. Contact: Conference President, Professor Olli Seppänen, Conference Secretariat, HB 2000, PO Box 25, FIN-02131 Espoo, Finland, Fax +358 9 4355 5655, www.hb2000.org.
Topics: criteria for the design and operation of healthy buildings; economical gains of healthier buildings; ventilation and air quality; control of moisture and old in structures and buildings; moist-proof materials and constructions; radon-safe structures; low-emission building and interior materials; quality control of the building process; design methods for better IAQ; cost effects of indoor climate; prediction and calculation of IAQ; how to build and maintain clean ventilation systems; cleaning of air from particles and gases; cleaning for healthier indoor climate; measuring of air quality and indoor climate; codes and guidelines for healthy buildings; governmental and voluntary programs for healthy buildings.

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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.
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