#6482

IAB Comments

According to Wyon, determining how to mitigate IAQ problems presents substantial ethical and economic challenges. Wyon has shown that an experimental approach can be practical and meet ethical criteria related to experiments involving human subjects. He believes the Malmö approach addressed these ethical questions in ways many other studies fail to consider.

Wyon concluded that field experiments studying the effects of various technical measures on SBS can provide a "cost-effective basis for investment decisions, whether or not the underlying cause of the problem is understood." This, of course, is anathema to many researchers who believe that it's not enough to know that a method works: one has to know why it works. Scientific tradition limits the acceptability of such practical approaches for many in the indoor air community. However, for building owners, managers, tenants, or designers, what works is what counts.

Reference:

David P. Wyon, 1992. "Sick Buildings and the Experimental Approach." *Environmental Technology*, vol. 13, pp. 313-322.

For more information:

David P. Wyon, National Swedish Institute for Building Research, Box 785, 801 29 Gavle, Sweden.

Ventilation

Europeans Publish New Ventilation Guideline

The Commission of the European Communities (CEC) has published a ventilation guideline that establishes a new approach to determining ventilation rates. The approach is two-fold; first, that there should be no more than a negligible health risk for occupants breathing indoor air. Second, that occupants should perceive the air as "fresh and pleasant rather than stale, stuffy, and irritating." It says that "the quality of the indoor air may be expressed as the extent to which human requirements are met. The air quality is [considered] high if few people are dissatisfied and there is a negligible health risk."

The report presents more explicit guidance on indoor air VOC concentrations than has previously been adopted by any authoritative body. The VOC guidelines, if followed, will severely limit pollutant source strengths. The guidelines also allow the designer to specify air quality based on three distinct categories of acceptability: 10%, 20%, and 30% or less of occupants being dissatisfied. Determining acceptability is based on the predicted percent of occupants that will be dissatisfied with the perceived air quality using subjective assessment of the odor, comfort, and irritation aspects of the air.

The document, *Guidelines for Ventilation Requirements in Buildings*, reflects a voluntary consensus among representatives from the CEC member nations. It is a set of recommendations rather than a regulatory document. Its provisions are extremely important; however, they are not free from controversy. Ultimately, each member nation independently determines whether to adopt the *Guidelines'* provisions. However, the publication of the *Guidelines* report is likely to lead to the adoption of at least some of its significant recommendations.

Purpose

The Purpose statement says: "This document recommends the ventilation required to obtain a desired indoor air quality in a space. Selection of low-polluting materials and products in buildings is recommended." The scope statement excludes thermal comfort parameters but references ISO Standard 7730, which is essentially the same set of thermal comfort requirements as ASHRAE Standard 55-1981.

Individuals involved in the *Guidelines'* development and adoption told ***IAB*** that implementing the detailed requirements requires data that are not yet generally available. However, they believe the document will stimulate developing the necessary data. These data include chemical emissions rates from building materials and subjective evaluations of emissions and indoor air.

Pollutant Guidelines

An oft-repeated criticism of ASHRAE Standard 62, *Ventilation for Acceptable Indoor Air Quality*, is that it provides little practical guidance on indoor air pollutant concentrations even though it mandates maintaining IAQ within "acceptable" limits. It provides threshold limit values (TLVs) for occupational exposures and guidance information on scores of contaminants in an appendix. Yet the appendix advises that the TLVs are too high for non-industrial indoor air. It suggests that 1/10 of the TLVs be used as guideline values, but that these values might not protect sensitive individuals. In sum, the ASHRAE standard backs away from establishing exposure guideline values.

ntaminant Exposure

'he European guideline does provide direction on taminant exposures, although it hedges. It references World Health Organization (WHO) *Air Quality idelines for Europe* and provides rather detailed advice VOCs. Guidance is also given for several indoor air lutants including radon, gases from landfills and waste es, combustion products, environmental tobacco oke, formaldehyde, metabolic gases, humidity, and cro-organisms. Specific discussions of each of these ntaminants or categories address sources and public alth significance. In most cases, the reader is referred other publications for more detail. Most of the *idelines*' health goals are addressed by referencing isting CEC guidelines (contained in various publicaons) and the World Health Organization limits ontained in *Air Quality Guidelines for Europe*) for ecific substances.

The report does not address complex mixtures or comnations of pollutants. It says that efforts to address ombinations are hampered by the diverse nature of the ffects of mixtures compared to individual compounds. n different cases effects may be additive, synergistic, ntagonistic, or independent. Instead, it says that the preferred method for indoor air quality management is ontrol of the pollution sources. The choice methods for ontrolling the dominant sources are source removal/relacement, isolation, and local ventilation."

'OC Control

Guideline recommendations for controlling VOCs efer to two methods. The first is attributed to Lars Aølhave of Denmark. It classifies exposures to total VOC TVOC) as measured by flame ionization detection alibrated to toluene. The levels are listed as a "comfort ange" of <200 μg/m^3, a "multifactorial exposure range" f 200 to 3000 μg/m^3, a "discomfort range" of 3000 to 5000 μg/m^3, and a "toxic range" of >25000 μg/m^3. The eport does not state what the "multifactorial range is, but e know from other work by Mølhave that it refers to a ange where individual factors cannot adequately explain ne discomfort and health complaints of occupants.

The second method derives from the work of Bernd eifert of Germany. Starting with Mølhave's work, eifert establishes a TVOC target guideline value based n looking at the predominant ten compounds in each of ix compound classes. The classes (and guidelines for nem individually) are alkanes (100 μg/m^3), aromatics 50 μg/m^3), terpenes (30 μg/m^3), halocarbons (30 μg/m^3), sters (20 μg/m^3), carbonyls excluding formaldehyde (20 g/m^3), and "other" (50 μg/m^3). The totals from each lass are added to derive the TVOC value. A target of 300 g/m^3 for TVOC is given, but a disclaimer is immediately dded that the values are not based on toxicological considerations. Rather, they are based on existing values and professional judgment about achievable levels.

Then the report says that while the two approaches are different, their practical implications are in agreement. The first suggests a comfort range of <200 μg/m^3 and the second a target value of 300 μg/m^3 for TVOC. The report says that since TVOC are "emitted by certain building materials, furnishings, consumer products and equipment, it is recommended to select materials and designs that minimize the emission of VOC."

Perceived Air Quality

The most unique aspect of the guideline is that it establishes three categories of perceived air quality — A, B, and C. The ventilation rates required to achieve each category vary according to the strength of the sources to be controlled and the percent of dissatisfied occupants that is deemed acceptable. Category A limits dissatisfied occupants to less than 10%, category B to less than 20%, and category C to less than 30%.

The notion that design is targeted to achieve a certain level of acceptability derives from the ASHRAE thermal comfort standard. The design temperature range is intended to result in no more than 20% of the occupants expressing dissatisfaction with the thermal environment if the design conditions are met. Since no set of thermal conditions can produce 100% satisfaction, there will always be some occupants who, when asked about their thermal comfort, will express dissatisfaction.

The ventilation standard (ASHRAE Standard 62-1989) borrowed this approach of limiting dissatisfaction as a design basis. As with thermal conditions, there are always likely to be some building occupants who will perceive the air quality as unacceptable under any conditions. The ASHRAE standard is based on limiting dissatisfaction with bioeffluents (emissions from occupants) and uses CO_2 as a surrogate for bioeffluent concentrations. This derives from the historic situation where people bathed far less frequently and human body odor was a significant source of complaints and odor discomfort in buildings. Ventilation rates were established to control body odor concentrations and the ASHRAE ventilation standard still reflects this heritage.

Predicting Dissatisfaction with "Perceived Air Quality"

Dissatisfaction rates are predicted on the basis of the research by Ole Fanger and his colleagues at the Technical University of Denmark. The method involves subjective air quality assessment by trained panels of visitors to a building who render judgments as to the acceptability of the air quality. The judgments are made from a combination of odor intensity, pleasantness, and the degree of irritation. We see this as one of the weaknesses of the method (and, therefore, the *Guidelines*) — the weighting or precise combination of odor intensity and pleasantness and the degree of irritation are not well defined.

This subjective approach, often referred to as the "olf and decipol" method, or the "Fanger method," involves quantifying the strength of pollution sources by equating one olf to the pollution emitted by one standard person — defined as one who bathes every 1.6 days. One decipol "is the perceived air quality in a space with a pollution source strength of one olf, ventilated by 10 l/s [20 cfm] of clean air." Thus, 1 decipol = 0.1 olf/(l/s). Figure 3 shows the relationship between ventilation rate in l/s per standard person and percent dissatisfied as predicted by Fanger's model. This approach is directly traceable to the CO_2-based ASHRAE standard.

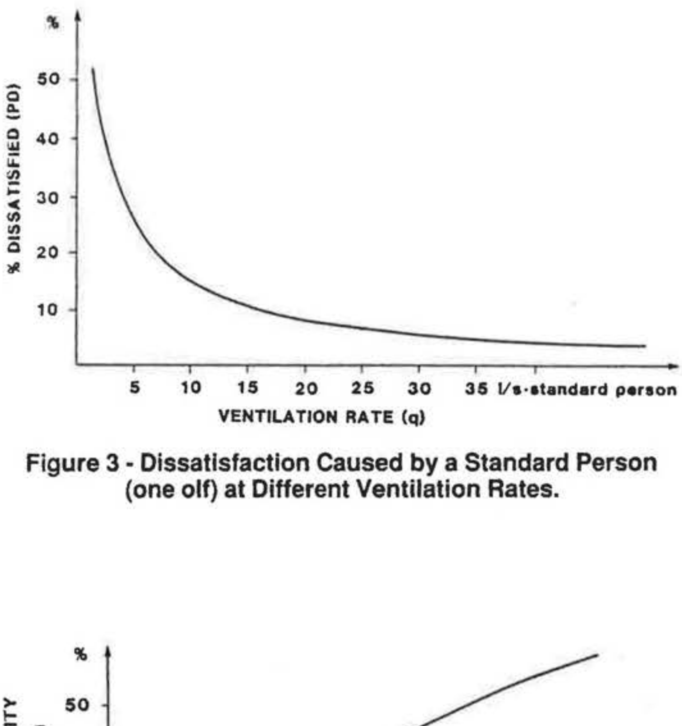

Figure 3 - Dissatisfaction Caused by a Standard Person (one olf) at Different Ventilation Rates.

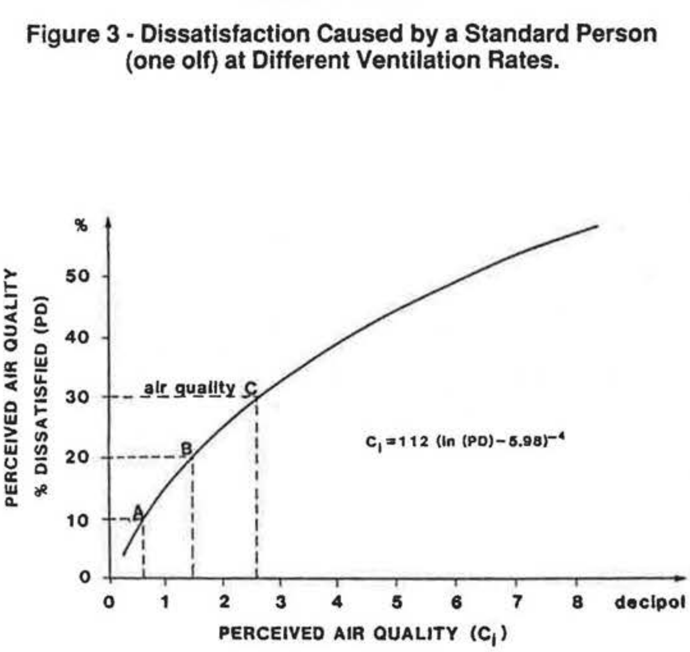

Figure 4 - Relation Between Perceived Air Quality Expressed by the Percentage of Dissatisfied and Expressed in Decipols.

Figure 4 shows the relationship between "perceived air quality" (in decipols) and the *Guidelines'* percent dissatisfied with the three levels, A, B, and C, plotted based on 10%, 20%, and 30% dissatisfied respectively. We recently pointed out to Fanger that we think the x-axis is mislabeled; if the units are decipols, then the label should not be labeled "perceived air quality" but "perceived air pollution" instead.

Limitations of Subjective Evaluations

A widely acknowledged weakness of relying on subjective evaluations is that there may be no relationship between perceived air quality and human health effects from harmful pollutants. For example, harmful odorless gases may contain radon, asbestos, and other carcinogens; carbon monoxide is odorless and lethal. Some members of the CEC committees that developed and adopted the guidelines were concerned about exclusive or excessive reliance on subjective evaluations of air quality. However, the *Guideline* argues, the risks of potential health effects are normally lessened when poor perceived air quality is addressed by removing pollutant sources and improving ventilation. This is also the argument of those who support the ASHRAE standard's related approach. The problem is that there is no guarantee.

Another major weakness is that indoor air acceptability cannot be determined until a building is completed and occupied. Then it is too late to revise the design to achieve better air quality. Advocates argue that, as more data become available on the strengths of emissions from building materials and other sources, it will be possible to add the subjectively perceived strengths of separate sources and predict the concentrations in the completed building under various ventilation rates. The proposed procedure is similar to one already used to estimate airborne concentrations of VOC from material sources based on environmental chamber measurements of chemical emissions. Critics argue that sufficient data won't become available in the foreseeable future to make the method practical. Odor/irritation research by William S. Cain and his colleagues at Yale suggests that odors are not necessarily additive while irritation responses are additive for separate chemicals. Defenders of the *Guidelines'* approach note that it is only a qualitative guideline; its real intent is to push things in a positive direction.

Determining Sensory Pollution Loads

Fanger and his collaborators report that sensory pollution loads can be obtained by adding separate loads. He includes occupants, buildings, furnishings, and ventilation systems on his list of usual sources. Therefore, to design ventilation, we have to know all of the pollution

	Sensory pollution load olf/(m² floor) Mean	Range
Existing buildings		
Offices[1]	0.3	0.02-0.95
Schools[2] (classrooms)	0.3	0.12-0.54
Kindergartens[3]	0.4	0.20-0.74
Assembly halls[4]	0.5	0.13-1.32
Low-polluting buildings (target values)		0.05-0.1

[1] Data for 24 mechanically ventilated office buildings.
[2] Data for 6 mechanically ventilated schools.
[3] Data for 9 mechanically ventilated kindergartens.
[4] Data for 5 mechanically ventilated assembly halls.

Table 5 - Pollution Load Caused by the Building, Including Furnishing, Carpets, and Ventilation System.

sources and their olf values. Then we calculate the total sensory pollution load (olf/m^2) in order to determine the required ventilation to achieve the target air quality level: A, B, or C.

However, the report indicates that presently data are available "...for only a few materials." Therefore, it says, a more feasible approach is to estimate the pollution loads in different types of existing buildings. The report provides some information developed by Fanger on typical sensory pollution loads based on field research. The sensory load is defined as the pollution load from those sources that impact perceived air quality. Fanger and his collaborators at the Technical University of Denmark in Copenhagen have evaluated the sensory pollution loads (given in olf/m^2 of floor area) in a variety of building types and published their results elsewhere. These results are tabulated in the report and are shown in Table 5.

Reviewing Table 5, we see a very large range of olf values for the building types listed. Offices varied by a factor of 47 for the 24 mechanically ventilated offices studied. The researchers evaluated far fewer buildings for the other building types and found smaller ranges of sensory pollution loads. We expect that if more buildings in each building type were evaluated, the range of olf/m^2 values observed might increase. This tells us that we cannot simply assume what a pollution load will be; we must identify sources in each building we design to accurately predict the sensory pollution loads.

The report acknowledges the wide range of values occurring in various buildings. To address this it says that "...it is essential that new buildings be designed as low-polluting buildings." It then provides target values for "low-polluting" buildings of the types listed in Table 5 as 0.05-0.1 olf/m^2 floor area. To achieve these target values, the report says, requires "a systematic selection of low-polluting materials for the building including furnishing, carpets, and ventilation system." [In Europe, the term "carpet" often refers to all rolled, sheet or tile floor coverings including textile and resilient materials.]

While we think it's a good idea to specify low-polluting materials, we do not see how it resolves the complex issues in estimating pollution loads during design in order to specify the appropriate ventilation rate and achieve a target air quality level. Most designers do not have access to any information on pollution source strengths of various

	Sensory Pollution load olf/occupant	Carbon dioxide l/(h · occupant)	Carbon monoxide[2] l/(h · occupant)	Water vapor[3] l/(g · occupant)
Sedentary. 1-1/2 met[1]				
0% smokers	1	10		50
20% smokers[4]	2	19	$11 \cdot 10^{-3}$	50
40% smokers[4]	3	19	$21 \cdot 10^{-3}$	50
100% smokers[4]	6	19	$53 \cdot 10^{-3}$	50
Physical exercise				
Low level, 3 met	4	50		200
Medium level, 6 met	10	100		430
High level, (athletes), 10 met	20	170		750
Children				
Kindergarten, 3-6 years, 2.7 met	1.2	18		90
School, 14-16 years, 1-1.2 met	1.3	19		50

[1] 1 met is the metabolic rate of a resting sedentary person (1 met = 58W/m^2 skin area, i.e. approx. 100W for an average person).
[2] From tobacco smoking.
[3] Applies for persons close to thermal neutrality.
[4] Average smoking rate 1.2 cigarettes/hour per smoker, emission rate 44ml CO/cigarette.

Table 6- Pollution Load Caused by Occupants.

materials, and even the research community has extremely limited information. (See IAB Vol. 1, No. 6, pp. 1-11.) The report conveys a sense of a very quantitative approach to design for sensory pollution load and acceptability. However, in the end, the report leaves practical implementation to a future time when far more data will be available.

The report provides some data on sensory pollution loads from certain types of occupants (see Table 6), but it does not provide any values for the pollution contributions of the other sources identified as important, i.e., "the building including furnishings, carpeting, and ventilation system." Table 6 shows some examples based on a standard person emitting 1 olf. A smoker emits 6 olfs while smoking, a physically active person emits 10 to 20 olfs, and school children emit 1.2 to 1.3 olfs, depending on age.

The report concludes this section by recommending the calculation of total sensory pollution loads "by simple addition of the loads from the individual pollution sources in the space." This, the report says, provides a reasonable first approximation of the combined loads. Then it qualifies this statement by saying that future research might show that simple addition of individual loads will fail to adequately predict total pollution loads.

We find that qualification an important one in light of William Cain's odor and irritation research. His work shows that while most irritant responses add together in a simple way, many odors do not. Since Fanger's approach evaluates some combination of odor and irritation, it may be that for more irritating substances, additive approaches will be inadequate. Since irritation may be a more reasonable predictor of discomfort or significant potential health effects, we think the sensory pollution load as defined by Fanger's "perceived air quality" may be an unreliable predictor of occupant dissatisfaction, SBS symptoms, and building related illness.

Other Factors

The report says that the quantity of outdoor air required depends on the quality of that air. It lists perceived values for outdoor air quality, but these listings are rather vague with respect to the decipol values. Air "at sea" is rated as 0 decipol, air in towns with "good air quality" is rated as <0.1 decipol, and air in towns with "poor" air quality is rated as 0.5 decipols. These values are of little use to the designer and, again, leave us only with qualitative information for design.

The report's final consideration for determining required ventilation rates is the efficiency of ventilation. It uses pollution removal efficiency (rather than outside air delivery efficiency like ASHRAE Standard 62). The lower the pollution removal efficiency, the greater the required ventilation rate. This is a logical and important consideration.

The required ventilation for health and comfort "...should be calculated separately and the highest value used for design." Thus, the report does not rely solely on either evaluation, but suggests full consideration of both. It then gives examples of how to calculate the required ventilation for comfort (sensory pollution load) and then for health based on some examples.

IAB Comments

In the end, the data do not exist to adequately predict quantitative pollution loads during design. The report intends to stimulate research that will increase our ability to do so and to make us more aware of qualitative and semi-quantitative bases for design. These are important and reasonable goals. Unfortunately, we think the report undermines its potential impact by creating expectations regarding quantitative methods of building design that are beyond current capabilities and feasibility.

References:

CEC, 1992. *Guidelines for Ventilation Requirements in Buildings.* Report No. 11, European Concerted Action: Indoor Air Quality and Its Impact on Man. (EUR 14449 EN), Commission of the European Communities, Directorate General for Science, Research and Development, Joint Research Centre - Environment Institute, Ispra, Varese, Italy.

Available from Commission of the European Communities, Joint Research Centre - Environment Institute, Ispra, 21020 (Varese) Italy. Fax +39 332 78 50 22 or +39 332 78 92 22.

WHO, 1987. *Air Quality Guidelines for Europe.* Copenhagen: WHO Regional Office for Europe. WHO Regional Publications, European Series: No. 23.