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Proposing a Contaminant of Concern List for Implementation of ASHRAE Standard 62.1 Indoor Air Quality Procedure

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SUMMARY

The Indoor Air Quality (IAQ) Procedure of ASHRAE Standard 62.1-2007 allows designers to reduce energy consumption by incorporating contaminant reduction measures, such as air cleaning, which in turn should reduce the required outdoor ventilation rates of a building. One key requirement of the IAQ Procedure is to define appropriate contaminants of concern (CoC). IAQ Professionals have proposed methods of choosing these CoC for the IAQ Procedure ranging from research of building material emissions to performing chemical air sampling in a building. However, a list of typical CoC to consider is still unclear.

This paper presents a summary of contaminants from published IAQ Procedure applications and research ranking common indoor air volatile organic compounds (VOCs) based on odor, sensory irritation, and noncancer chronic toxicity. Three publications referenced successful application of the IAQ Procedure with information pertaining to CoC. Comparing these applications to the reviewed VOC ranking research provided insight into developing a base CoC set for IAQ Procedure applications in office buildings.

INTRODUCTION

Energy usage and associated environmental impacts of electric energy production are receiving much attention today. Engineers scour their designs for opportunities to reduce short-term and long-term carbon footprints while providing an acceptable indoor environment. ASHRAE Standard 62.1-2007 provides two ventilation strategies to meet these goals: the Ventilation Rate Procedure and the Indoor Air Quality (IAQ) Procedure. The Ventilation Rate Procedure provides prescriptive amounts of outdoor air depending on the space types within a building. The IAQ Procedure is a contaminant based design method, which allows designers to reduce energy consumption by incorporating contaminant reduction measures, such as air cleaning. Using the IAQ Procedure should allow a reduction in the required outdoor ventilation rates and associated energy requirements. Figure 1 displays the potential energy savings from applying gas-phase filtration and reducing outdoor ventilation rates.

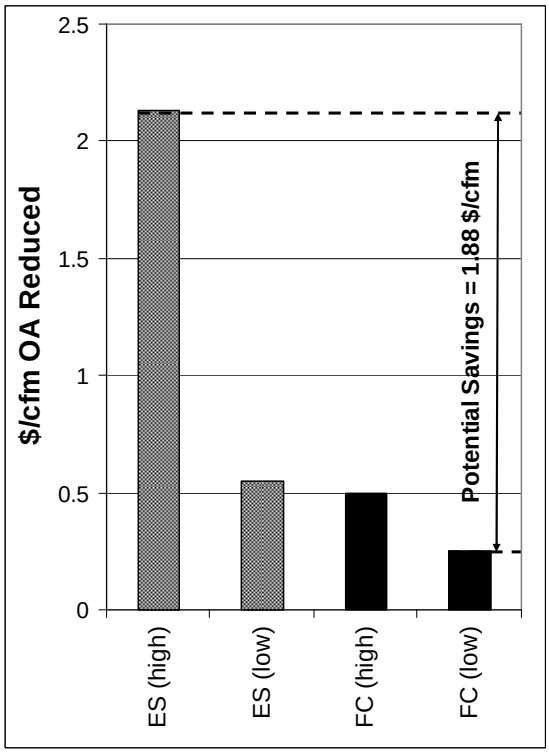

Figure 1 – Potential Energy Savings with the IAQ Procedure, where ES = energy savings and FC = filtration cost. The total potential savings (ES – FC) is 1.88 $/cfm of reduced outdoor air (Fisk, 2007).

One key requirement of the IAQ Procedure is to define appropriate contaminants of concern (CoC). Engineers and architects must define the CoC for specific applications since ASHRAE 62.1-2007 does not define potential CoC. Due to their importance and the possibility of improper contaminant choice, design professionals have posed the question "How do designers choose the CoC?" (Stanke, 2007).

IAQ professionals have proposed methods of choosing these CoC for the IAQ Procedure ranging from research of building material emissions to performing chemical air sampling in a building (ASHRAE, 2007). Authors and

presenters have also referenced successful applications of the IAQ Procedure using specific contaminants (Johnson, 2006; Lamping, 2008). However, the minimum numbers of CoC an engineer should consider is unclear. This paper approaches this topic by comparing contaminants referenced in published IAQ Procedure applications to research ranking common indoor air volatile organic compounds (VOCs) found in building studies and proposes a typical list of CoC for office buildings.

CONTAMINANTS FROM PUBLISHED APPLICATIONS AND BUILDING STUDIES

Three publications reference successful application of the IAQ Procedure using air cleaning and citing contaminants considered in the design. Table I summarizes these applications. The first application (Publication 1) was applied to an office building (Stanley, 2002). Building specifics including floor area and number of occupants were omitted and the application success was based on contaminant simulation results showing concentrations less than target concentration limits. The second application (Publication 2) was applied to a school auditorium (Johnson, 2006). The auditorium had a maximum design occupancy of 1,000 people and a total supply airflow of 30,600 m^3/hr (18,000 ft^3/min). The facility manager performed air sampling and kept a log of complaints as an indicator of occupant satisfaction to measure the success of the IAQ Procedure. The third application (Publication 3) was applied to a high school (Lamping, 2008). The high school had a design occupancy of 448 people, a total supply airflow of 41,600 m^3/hr (24,500 ft^3/min), and a floor area of 1,440 m^2 (15,500 ft^2). The facility manager performed air sampling and kept an IAQ complaint log as an indicator of occupant satisfaction to measure the success of the IAQ Procedure.

Table I – Summary of the Published IAQ Procedure Applications

Pub. #	Building Type	Success Basis
1	Office Building	Contaminant Simulation
2	School Auditorium	Air Sampling & Complaint Log
3	High School Wing	Air Sampling & Complaint Log

Pub. = Publication

Hodgson and Levin (2003) presented a methodology to classify the relative importance of individual indoor VOCs with respect to odor, sensory irritation, and noncancer chronic toxicity. They evaluated VOC studies from residences and office buildings (including the U.S. Environmental Protection Agency's Building Assessment and Survey Evaluation [BASE]) taken between 1990 and 2003 by applying a hazard quotient methodology to the identified VOCs. Table II summarizes this study. The authors found "only a small number of the more than 100 reported VOCs were shown to exceed levels that might be of concern with respect to the comfort and health endpoints considered."

Table II – Summary of the Building Data Review Ranking VOCs from Residences and Office Buildings (Hodgson, 2003)

Bldg. Type	Studies	Ranking
• Offices • Res.	• 1990-2003 • Multiple VOC studies • EPA BASE	• Hazard Quotient Methodology • Odor • Sensory Irritation • Noncancer Chronic Toxicity

Bldg. = Building
Res. = Residences

DISCUSSION

Table III displays contaminant lists from the referenced IAQ Procedure publications and the Building Data Review. The IAQ Procedure Applications referenced a total of four VOCs plus TVOC. The Building Data Review identified more than 100 individual VOCs in offices and residences, of which the researchers ranked those in Table III as most likely to impact occupants through the hazard quotient method. The only VOC common to all four was formaldehyde. Additionally, the TVOC of Publications 1 and 3 includes many of the VOCs from the Building Data Review. While there are significant differences in building usages and consequential selection criteria in determining the CoC it may be prudent to consider indoor chemicals that have been identified as typical and ranked with a ranking methodology similar to Hodgson and Levin's work as a beginning list of CoC representing VOCs in indoor air. Probable choices are the 14 compounds shown under the Building Data Review column of Table III. Additionally, TVOC values are a well accepted overall indicator of VOC levels and a useful unofficial CoC to consider.

Table III – Identified Contaminants from Applications of the IAQ Procedure and from a Review of Building Study Data

	Contaminant	Pub. 1[a]	Pub. 2[b]	Pub. 3[c]	BDR[d]
VOCs	1,4 dichloro-benzene				☑
	3-methylbutanal				☑
	acetaldehyde				☑
	acetic acid				☑
	acetone	☑		☑	
	benzene				☑
	formaldehyde	☑		☑	☑
	heptanal				☑
	hexanal				☑
	hexanoic acid				☑
	methyl alcohol	☑		☑	
	naphthalene				☑
	nonanal				☑
	octanal				☑
	phenol			☑	
	propionaldehyde				☑
	tetrachloroethene				☑
	TVOC	☑		☑	
OTHER	carbon dioxide		☑		
	carbon monoxide			☑	
INORG.	ammonia		☑	☑	
	hydrogen sulfide			☑	
	nitrogen dioxide	☑		☑	
	ozone	☑		☑	
	sulfur dioxide	☑		☑	

BDR = Building Data Review
Inorg. = Inorganics

[a] Publication 1 was an office building. It grouped the contaminants into three types, those from outdoor air (nitrogen dioxide, ozone, sulfur dioxide), occupants (acetone, methyl alcohol), and building materials (formaldehyde, TVOC).

[b] Publication 2 was a school auditorium. It considered other contaminants, but only specifically stated and measured the two listed contaminants.

[c] Publication 3 was a high school. It grouped the contaminants into three types, those from outdoor air (carbon monoxide, nitrogen dioxide, ozone, sulfur dioxide), occupants (acetone, ammonia, hydrogen sulfide, methyl alcohol, phenol), and building materials (formaldehyde, TVOC).

[d] The BDR list represents an office building. The list includes those VOCs whose hazard quotients (95 percentile maximum value divided by the respective threshold value) were greater than 0.1. It also includes contaminants whose hazard quotients were greater than 0.1 in residences, but were not considered or not monitored in the office building and therefore cannot be ruled out. These compounds were (3-methylbutanal, acetaldehyde, acetic acid, formaldehyde, heptanal, hexanoic acid, octanal, propionaldehyde).

The Building Data Review (4th column above) only considered VOCs. The sources of the listed inorganic and other compounds for the IAQ Procedure Applications were mainly outdoor air, with the exception of ammonia and hydrogen sulfide. For outdoor air, the EPA has already delineated a criteria pollutant list in the National Ambient Air Quality Standards, which includes all of the outdoor sourced inorganics of Table III and serves as the most likely starting point for outdoor sourced CoC – lead, $PM_{2.5}$, PM_{10}, carbon monoxide, nitrogen dioxide, ozone, and sulfur dioxide (EPA, 2009).

A proposed CoC list is a combination of the VOCs ranked as significant by the Building Data Review work, the internally generated inorganics found in multiple IAQ Procedure Applications (ammonia), and the EPA criteria pollutants. Table IV displays this proposed list. It represents a typical office building without any special or problematic sources of contaminants.

Table IV – Proposed CoC List for a Typical Office Building

Inorganics	VOCs
ammonia	1,4 dichlorobenzene
carbon monoxide	3-methylbutanal
nitrogen dioxide	acetaldehyde
ozone	acetic acid
sulfur dioxide	benzene
Particulates	formaldehyde
	heptanal
lead	hexanal
$PM_{2.5}$	hexanoic acid
PM_{10}	naphthalene
	nonanal
	octanal
	propionaldehyde
	tetrachloroethene

CONCLUSIONS

The IAQ Procedure of ASHRAE 62.1 has the potential to significantly impact the energy consumption of HVAC equipment through reductions in outdoor ventilation rates by controlling indoor contaminants using control methods such as air cleaning. In order for the IAQ Procedure of ASHRAE 62.1 to be widely used, there needs to be a base CoC set. This paper has provided a starting point for a typical office building. Further research, collaboration, and publication is needed from IAQ professionals to establish a base CoC list for engineers using the IAQ Procedure of ASHRAE 62.1.

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