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Schleibinger, H.; Yang, W.

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## Indoor air quality and mould

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### **IRC-ORAL-835**

Schleibinger, H.; Yang, W.

March 2007

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Canada



**NRC-CNRC**

*Institute for  
Research in  
Construction*

## **Indoor Air Quality and Mould**

Newfoundland and Labrador  
Environmental Industry Association

Annual General Meeting,  
Conference and Trade Show March 2007

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**Hans Schleibinger and Wenping Yang**

Indoor Environment Research Program  
Institute for Research in Construction



National Research  
Council Canada

Conseil national  
de recherches Canada

Canada

# Standards & Guidelines for CO<sub>2</sub> in Indoor Air

[ppm = parts per million]

Canada (2006)	WHO (2006)	U.S. EPA (2006)	Hong Kong (2003)	Finland (2001)	Germany (2007)	Singapore (1996)	U.S. (OSHA)	U.S. (NIOSH) (2005)	U.S. (ACGIH) (2004)	Germany (2005)
<b>R</b>	-	-	R + O	R + O	O	O	W	W	W	W
<b>3,500</b>			800 / 1,000 [8 hr]	1200	1,500 (mech. Vent.)	1,000 [8 hr]	5,000 [8 hr]	5,000 [10 hr] 30,000 [15 min]	5,000 [8 hr] 30,000 [15 min]	5,000 [8 hr]

**A: Ambient Air; O: Offices; R: Residential Homes; W: Workplace**

**(Canada)** – Health Canada; **(WHO)** – World Health Organization

**(EPA)** - U.S. Environmental Protection Agency

**(OSHA)** - U.S. Department of Labor, Occupational Safety and Health Administration

**(MAK)** - Maximum Concentrations Values (Germany)

**(NIOSH)** – National Institute for Occupational Safety and Health

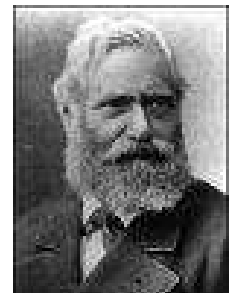
**(ACGIH)** – American Conference of Governmental Industrial Hygienists

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**(German)** – German Federal Environmental Agency

**(Singapore)** – Ministry of the Environment, Singapore



**Max von Pettenkofer**

German chemist  
and hygienist  
1818–1901:

**1000 ppm CO<sub>2</sub>**

# Ventilation System

## Supply of:

- 'fresh' [outside] air
- oxygen

## Removal of:

- CO<sub>2</sub>
- formaldehyde
- odours
- microbiological agents
- volatile organic compounds
- .....

Return [recycled] air: up to 90 %

# Recommended Air Supply

[outdoor air rates

in Liter per person and second]

Type of Space	Canadian standard Associations	Canadian Occupational Health & Safety	ASHRAE 62.1 (2004)		CFR (2002) 10.435.107
		refers readers to ASHRAE 62.	Default Occupant Density (#/100 m <sup>2</sup> )	Default Outdoor Air Rate (L/s.p)	refers readers to ASHRAE 62.
Office Space	10		5	8.5	
Reception Areas	8		30	3.5	
Telephone / Data Entry	10		60	3.0	
Main Entry Lobbies			10	5.5	
Conference Rooms	10				

**ASHRAE:** American Society of Heating, Refrigerating and Air-Conditioning Engineers

**CSA Z412:** Canadian Standards Association, *Guideline on office ergonomics* (2000)

**COHS:** Canadian Occupational Health and Safety (2007)

**CFR:** U.S. Code of Federal Regulations



# HVAC system: periodic change of filters



# HVAC system: dust and debris





# Standards & Guidelines for Formaldehyde in Indoor Air [ppm]

Canada (2006)	WHO (2006)	EPA (2006)	Hong Kong (2003)	Finland (2001)	Germany (2007)	Singapore (1996)	U.S. (ACGIH) (2004)	U.S. (NIOSH) (2005)	U.S. (OSHA)	Germany (2005)
R	School + R + A	A	R + O	R + O	R	O	W	W	W	W
0.04 [8 hr] 0.1 [1 hr]	0.081 [30 min]	-	0.024 / 0.081 [8 hr]	0.08	0.1	0.1 [8 hr]	0.3 [C]	0.016 [10 hr] 0.1 [C, 15 min]	0.75 [8 hr] 2 [15 min]	0.3 [8 hr]

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**(Singapore)** – Ministry of the Environment, Singapore

# Standards & Guidelines for CO in Indoor Air

[ppm]

Canada (2006)	WHO (2006)	EPA (2006)	Finland (2001)	Hong Kong (2003)	Germany (2007)	U.S. (ACGIH) (2004)	U.S. (NIOSH) (2005)	U.S. (OSHA)	Germany (2005)	Singapore (1996)
R	School + R + A	A	R + O	R + O	R	W	W	W	W	O
11 [8 hr]  25 [1 hr]	90 [15 min] 50 [30 min] 25 [1 hr] 10 [8 hr]	9 [8 hr] 35 [1 hr]	7	1.7 / 8.7 [8 hr]	52 / 5.2 [0.5 h] 13 / 1.3 [8 h]	25 [8 hr]	35 [10 hr] 200 [C]	50 [8 hr]	30 [8 hr]	9 [8 hr]

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**(German)** – German Federal Environmental Agency

**(Singapore)** – Ministry of the Environment, Singapore

# Standards & Guidelines for Ozone in Indoor Air

[ppm]

Canada (2006)	WHO (2006)	EPA (2006)	Hong Kong (2003)	Finland (2001)	Singapore (1996)	U.S. (ACGIH) (2004)	U.S. (NIOSH) (2005)	U.S. (OSHA)	Germany (2005)
R	School + R + A	A	B	B	O	W	W	W	W
<b>0.12</b> [1 hr]	<b>0.05</b> [8 hr]	<b>0.12</b> [1 hr] 0.08 [8 hr]	0.025 / 0.061 [8 hr]	0.04	0.05 [8 hr]	0.05 [8 hr] (Heavy work) 0.08 [8 hr] (Moderate) 0.10 [8 hr] (Light work) 0.20 [≤2hr] (Any work)	0.1 [C]	0.1 [8 hr]	Carcinogen no threshold

**A:** Ambient Air; **O:** Offices; **R:** Residential Homes; **W:** Workplace

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**(German)** – German Federal Environmental Agency

**(Singapore)** – Ministry of the Environment, Singapore

# Standards & Guidelines for NO<sub>2</sub> in Indoor Air

[ppm]

Canada (2006)	WHO (2006)	EPA (2006)	Hong Kong (2003)	Finland (2001)	Germany (2007)	Singapore (1996)	U.S. (OSHA)	U.S. (NIOSH) (2005)	U.S. (ACGIH) (2004)	Germany (2005)
R	School + R + A	A	R + O	R + O	R	O	W	W	W	W
<b>0.25</b> [1 hr] 0.05 [L]	<b>0.1</b> [1 hr] <b>0.02</b> [1 yr]	<b>0.053</b> [1 yr]	0.021 / 0.080 [8 hr]		0.19 [0.5 h] 0.03 [1 wk]		5 [C]	1.0 [15 min]	3 [8 hr] 5 [15 min]	Carcinogen no threshold

**A:** Ambient Air; **O:** Offices; **R:** Residential Homes; **W:** Workplace;

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**(German)** – German Federal Environmental Agency;

**(Singapore)** – Ministry of the Environment, Singapore;



# Standards & Guidelines for Particles in Indoor Air

[ $\mu\text{g}/\text{m}^3$ ]

	Canada (2006)	WHO (2006)	EPA (2006)	Hong Kong (2003)	Finland (2001)	Germany (2007)	Singapore (1996)	Germany (2005)	U.S. (OSHA)	U.S. NIOSH (2005)	U.S. (ACGIH) (2004)
	R	School + R + A	A	R + O	R + O	R	O	W	W	W	W
<b>Particle Matter (PM<sub>2.5</sub>)</b>	<b>100</b> [1 hr] <b>40</b> [L]	<b>10</b> [1 yr] <b>25</b> [24hr]	15 [1 yr] 35 [24 hr]					1,500 for <4 $\mu\text{m}$ [8 hr]	5,000 [8 hr]		3,000 [8 hr]
<b>Particle Matter (PM<sub>10</sub>)</b>		<b>20</b> [1 yr] <b>50</b> [24hr]	150 [24 hr]	20 / 180 [8 hr]	50 [24hr]		150	4,000 [8 hr]			10,000 [8 hr]

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(OSHA) - U.S. Department of Labor, Occupational Safety and Health Administration

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# Future: Energy-Efficient and Healthy Indoor Environments

## **Demand-controlled ventilation**

- CO<sub>2</sub>
- relative humidity / moisture
- formaldehyde
- volatile organic compounds (VOC)

## **Demand-controlled filtration (supply air / return air)**

- CO, SO<sub>2</sub>, NO<sub>2</sub>
- particles
- formaldehyde
- volatile organic compounds

## **Development of sensors and control systems**

- (single) volatile organic compounds
- odours
- a<sub>w</sub> (water activity / water availability) sensors against mould growth

# Mould Damages





# Mould in HVAC systems





# Wood Rot Fungi



# Damages by Wood Rot Fungi





# Damages by Wood Rot Fungi



# Hidden Damage: Mould & Wood Rot Fungi





# HVAC system: bio-contamination



# Causes of Mould Damages

## **I. Water Damages**

**flooding  
storms  
broken pipes  
leaking roofs  
....**

## **II. Condensation Damages**

**poor building envelope  
(exfiltration / infiltration)  
poor wall insulation  
insufficient ventilation  
(ventilation / exhaust fan off)  
too many people  
excessive moisture release  
(cooking, showering)**

# Detection of Mould Damages

- Building inspection
- Inspection of cavities
- Inspection of HVAC system / air ducts
- Air samples
- House dust samples

# Guidelines for Airborne Mould Spores in Indoor Air

Canada Health Canada (1995)	Canada Public Works (2005)	WHO (1988)	OSHA (1999)	ACGIH (1989)	Hong Kong (2003)	Commission of European Committees (1993)	Singapore (1996)
<p><math>\leq 150</math> CFU/m<sup>3</sup> OK if a mixture of the outdoor air spores.</p> <p><math>\leq 500</math> CFU/m<sup>3</sup> OK in summer if the species present are primarily <i>Cladosporium</i> or other tree and leaf fungi.</p> <p>Contamination if <math>&gt;50</math> CFU/m<sup>3</sup> of a single species.</p>	<p>Indoor fungal quantities should be lower compared to outside.</p> <p>Contamination if quantity of normal outdoor [phyloplane] species <math>\geq 500</math> CFU/m<sup>3</sup> indoors.</p>	<p><math>&lt; 500</math> CFU/m<sup>3</sup></p>	<p>Contamination indicators :</p> <p><math>\geq 1000</math> CFU/m<sup>3</sup>;</p> <p><math>\geq 10^6</math> fungi/g dust;</p> <p><math>\geq 10^5</math> fungi/mL stagnant water or slime.</p>	<p><math>&lt; 100</math> CFU/m<sup>3</sup> considered of no concern,</p> <p>200 CFU/m<sup>3</sup> recommended as a guideline for fungal bioaerosols.</p>	<p>500 / 1000 CFU/m<sup>3</sup></p>	<p><b>Houses</b> (CFU/m<sup>3</sup>):</p> <p><math>&gt; 10,000</math> -very high</p> <p><math>&lt; 10,000</math> - high</p> <p><math>&lt; 1000</math>- intermediate</p> <p><math>&lt; 200</math> - low</p> <p><math>&lt; 50</math>- very low</p> <p><b>Non-industrial indoor env.</b> (CFU/m<sup>3</sup>):</p> <p><math>&gt; 2000</math> - very high</p> <p><math>&lt; 2000</math> - high</p> <p><math>&lt; 500</math>- intermediate</p> <p><math>&lt; 100</math> - low</p> <p><math>&lt; 25</math> - very low</p>	<p><math>&lt; 500</math> CFU/m<sup>3</sup></p>

(WHO) – World Health Organization

(OSHA) - U.S. Department of Labor, Occupational Safety and Health Administration

(ACGIH) – American Conference of Governmental Industrial Hygienists

(Hong Kong) – The Government of the Hong Kong Special Administrative Region

(Commission of European Committees) – Luxembourg: Office for Official Publications of the European Communities

(Singapore) – Ministry of the Environment, Singapore



# Mould Refurbishment

- Clean contaminated building materials
- Remove contaminated building materials
- Protect rest of the building (negative pressurization)
- No need for disinfection

## **Critical questions:**

- When do we have to remove building material?
- How far do we go in refurbishing?
- What is 'clean'?



**Thank you for your attention!**

# Source Documents for Outdoor Air Supply Rates

- (**ASHRAE**) – American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). (2004). *ANSI/ASHRAE Standard 62.1-2004: Ventilation for Acceptable Indoor Air Quality*. Atlanta, GA: ASHRAE.
- (**CSA**) – Canadian Standards Association (2000). *Guideline on office ergonomics* (CSA Z412-00 – updated June 2003). Toronto, Canada: CSA.
- (**COHS**) – Canadian Occupational Health and Safety (2007). Part II: Permanent structures, Division III: HVAC systems. In *Regulations respecting occupational health and safety made under part II of the Canada Labour Code*. Ottawa, Canada: COHS. [Online at: <http://laws.justice.gc.ca/en/L-2/SOR-86-304/31290.html>]
- (**CFR**) – U.S. Code of Federal Regulations (2002). *Heating, ventilation, and air-conditioning (HVAC) systems* (U.S. Department of Energy) (10.435.107). Washington, DC: National Archives and Records Administration, Office of the Federal Register.

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- (**EPA**) – U.S. Environmental Protection Agency. (2006). *Code of Federal Regulations*, Title 40, Part 50. National Ambient Air Quality Standards. [Online at: <http://www.epa.gov/air/criteria.html>]
- (**OSHA**) – U.S. Department of Labor, Occupational Safety and Health Administration. *Code of Federal Regulations*, Title 29, Part 1910.1000-1910.1450. [Online at: [http://www.osha.gov/pls/oshaweb/owadisp.show\\_document?p\\_table=STANDARDS&p\\_id=9992](http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9992)]
- (**MAK**) – *List of MAK and BAT Values 2005*. Commission for the Investigation of Health Hazard of Chemical Compounds in the Work Area, Report No. 41, Federal Republic of Germany.
- (**NIOSH**) – NIOSH (2005). *NIOSH Publication No. 2005-149: The NIOSH Pocket Guide to Chemical Hazards (NPG)*, National Institute for Occupational Safety and Health, September 2005. [Online at: <http://www.cdc.gov/niosh/npg/default.html>]
- (**ACGIH**) – ACGIH (2004), *Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices*. American Conference of Governmental Industrial Hygienists, 1330 Kemper Meadow Drive, 6500 Glenway, Building D-7, Cincinnati, OH, 45240-1630.
- (**Hong Kong**) – The Government of the Hong Kong Special Administrative Region, *A Guide on Indoor Air Quality Certification Scheme*, 12 Feb. 2007 [Online at: <http://www.iaq.gov.hk/cert/doc/CertGuide-eng.pdf>]
- (**Finland**) – Finnish Society of Indoor Air Quality and Climate (FiSIAQ), 2001. *Classification of Indoor Climate 2000; Target Values, Design Guidance and Product Requirements*, [online at: <http://www.tervetalo.net/lataa/siy5-eng-part-1.pdf#search=%22classification%20of%20indoor%20climate%202000%22>]
- (**German**) – Umwelt Bundes Amt (German Federal Environmental Agency). *Guideline Value for Indoor Air*, 12 Feb. 2007 [Online at: <http://www.umweltbundesamt.de/uba-info-daten/daten/gesundheit/irk.htm>]
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# Source Documents of Recommendations for Moulds in Indoor Space

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(**WHO**) – World Health Organization (1988), *Indoor air quality: biological contaminants*. World Health Organization, European Series, n. 31, Copenhagen, Denmark.

(**ACGIH**) – American Conference of Governmental Industrial Hygienists (1989), *Guidelines for the assessment about aerosols in the indoor environment*. Cincinnati, Ohio (1989)

(**Hong Kong**) – The Government of the Hong Kong Special Administrative Region, *A Guide on Indoor Air Quality Certification Scheme*, 12 Feb. 2007 [Online at: <http://www.iaq.gov.hk/cert/doc/CertGuide-eng.pdf>]

(**OSHA**) – U.S. Department of Labor, Occupational Safety and Health Administration, OSHA Technical Manual 1999, [online at : [http://www.osha.gov/dts/osta/otm/otm\\_iii/otm\\_iii\\_2.html#text9](http://www.osha.gov/dts/osta/otm/otm_iii/otm_iii_2.html#text9)]

(**Commission of European Committees**) – Luxembourg: Office for Official Publications of the European Communities, 1993, *Environment and Quality of Life. Report No. 12. Biological. in Indoor Environment*, [online at: [http://www.inive.org/medias/ECA/ECA\\_Report12.pdf](http://www.inive.org/medias/ECA/ECA_Report12.pdf)]

(**Singapore**) – Ministry of the Environment, Singapore, 1996. *Guidelines for good indoor air quality in office premises*. [online at: [http://www.nea.gov.sg/cms/qed/indoor\\_air.pdf](http://www.nea.gov.sg/cms/qed/indoor_air.pdf)]



# Standards & Guidelines for Pb [ $\mu\text{g}/\text{m}^3$ ] in Indoor Air

Canada (2006)	WHO (2006)	EPA (2006)	Hong Kong (2003)	Finland (2001 )	Germany (2007)	Singapore (1996)	OSHA	MAK (2005)	NIOSH (2005)	ACGIH (2004)
R	School + R + A	A	R + O	R + O	R	O	W	W	W	W
minimize exposure	0.5 [1 yr]	1.5 [3 months]					50 [8 hr]	BLW: 400 mg/m <sup>3</sup> 100 mg/m <sup>3</sup> (women <45 yrs)	50 [10 hr]	50 [8 hr]

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**(German)** – German Federal Environmental Agency;

**(Singapore)** – Ministry of the Environment, Singapore;

BLW (“Biologischer Leit-Wert”) is the amount of a chemical substance or its metabolites or the deviation from the norm of biological parameters induced by the substance in exposed humans which serves as an indicator for necessary protective measures.