DRAFT

Finish Carpentry and Related Wood Product Selection for Schools

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1. INTRODUCTION

This paper was undertaken to provide the Department of Education with requested input from a healthy building perspective on the finish carpentry draft specifications for the new DC350 DRM. of January, 2007 (*See Appendix A*).
This paper is not intended to be a comprehensive report, but to give an overview of the issues from a Healthy Schools perspective.

Materials choices for finish cabinetry and built-in furniture can influence the short term and long term indoor environment in schools and the consequent health, comfort and learning/performance of occupants (*See Appendix B*). Chemical molecules that enter the body are either removed by the body's detoxification processes, are used, or are stored in the body tissues. "Environmental chemicals can cause a broad spectrum of effects, which depend not only on the route of exposure and dose but on the susceptibility of the exposed individual. For example, age, gender, and genotype can determine whether an exposure causes a problem." said Linda S. Birnbaum, director of EPA's Experimental Toxicology Division (*See Appendix C*).

Much progress has been made in recent years on the use of low emission building materials in Nova Scotia schools. However, some concerns have remained regarding materials choices for the finish carpentry and built in furniture. Encapsulation has been partially successful only, given the odours that needed flushing out of the new cabinetry at Halifax West High School and subsequent schools. Teachers commented well over a year after Halifax West was built, that they got a whiff of chemicals each time they opened cupboards. What could be the cause of the emissions from these sealed surface cabinets? Possibly they were from incomplete sealing of MDF, VOC emissions other than formaldehyde, terpenes from the wood particles, or plastic materials from the edging and coating.

2. EMISSIONS

Emissions from finish cabinetry can include formaldehyde, other VOCs from the wood panels, VOCs from glues, paints and sealants, from plastics/PVC/phthalates, and natural wood terpenes (*See Appendix D*).

2.1 Formaldehyde as an Indoor Chemical Contaminant:

Formaldehyde is a simple and common aldehyde known as HCHO. It is a colourless gas at room temperature, but can have a pungent odour. Formaldehyde is a upper respiratory irritant and may produce irritation in sensitive populations. The American Conference of Industrial Governmental Hygienists (ACGIH) (*1*) lists it as a suspected human carcinogen.

Low levels of formaldehyde are common in indoor environments; primary sources may include pressed (composite) wood products such as particleboard, plywood, medium density fibreboard (MDF), and Melamine Composite Panels (MCP). Also laminate finishes and their adhesives, shelving and casework when made with composites.

Typical concentrations range from 0.01-0.03 ppm in office buildings and an average level of 0.03 ppm has been found in schools; new or recently renovated environments may have higher levels. The maximum current maximum permissable level is 0.1ppm, recently reduced from 0.3 ppm (ACGIH). In 2006, Health Canada's IAQ Section revised the guideline for Formaldehyde exposure in conformance with ACGIH (*See Appendix E*). This guideline notes that a one hour exposure at a concentration of 0.10 ppm may cause eye irritation and an eight hour exposure at 0.04 ppm may cause respiratory symptoms in children.

Careful selection and use of low emitting materials may keep formaldehyde at acceptable levels. Although Formaldehyde is only one of many Volatile Organic Compounds (VOC's) of concern in indoor environments, due to its prevalence in today's building materials and significant related health concerns, it is singled out for action to minimize ambient concentrations.
LEED for Schools Public Review Draft, August 2006, address this specific concern re Credit Options, pages 67 and 80 (*See Appendix F*).

Public Works and Government Services Canada (PW&GSC) offer guidelines to minimize Formaldehyde concentrations in their Real Property Branch publication "The Environmentally Responsible Construction Handbook", 25/08/05 (*See Appendix G*). PW&GSC recommend specifying materials with no/low formaldehyde content. Chapter 5 of The Healthy Housing Reference Manual offers guidance, in concert with the Consumer Products Safety Commission, in the selection and specification of building products to minimize introduction of formaldehyde to indoor environments (*See Appendix H*).

2.2 VOC Emissions from Composite Wood Products:
In indoor environments, Volatile Organic Compounds are normally measured as Total VOC's expressed as TVOC's. There are many sources of VOC's, however, for the purposes of this report, refer only those related to emissions from composite wood products, finishes and adhesives used for finish carpentry including shelving, cabinets and paneling. When TVOC's are measured, all sources are included. The current ACGIH permissable exposure level is 0.2 mg/cubic meter of air, with no individual VOC> 10% of the TVOC. The term organic means that the chemical contains carbon and hydrogen, and volatile means possessing a low boiling point, permitting rapid transformation from liquid to gaseous state at relatively low (room) or somewhat elevated temperatures.

Adverse health effects at low exposure levels may include fatigue, headache, drowsiness, dizziness, weakness, blurred vision, skin and eye irritation, respiratory irritation (including asthma) and inability to concentrate. These effects vary with the individual, some being sensitive to varying degrees, and some experiencing no sensitivity. Chemical "smells" or malodours, although sometimes misleading, may be indicative of VOC presence.

The composite wood products producers have been working on the issue of chemical emissions from their products since the 1980s (*See Appendix I*). Initially, formaldehyde emissions were addressed, with substantial improvements achieved such as the use of Phenol-Formaldehyde vs. Urea-Formaldehyde. Although there are no government regulations for other VOC's, other than total VOC's, there is an increasing concern and interest in ensuring that building products are not having negative affects on indoor air quality. Current R&D has been directed at assessing the extent to which VOC emissions are affecting IAQ and developing ways to mitigate these affects.

Assuming that new construction involves the use of some wood and composite wood products containing compounds that off-gas VOC's, a successful strategy that has been employed, is the use of emission barriers. These barriers involve the application of laminates or coatings to seal the product. (*2*) The effectiveness of an emission barrier is measured by the permeability, completeness of application and integrity of the surfaces so encapsulated, i.e., no holes, open joints, etc. Different coatings and laminates have been employed, with varying degrees of success. Some coatings will emit VOC's while curing, usually dissipating to low levels in several days. Others escape over longer periods of time. Some coatings may be water based, having a lower VOC content. Other coating techniques may employ two different products as primary and secondary coats or two or more coats of the same product (*See Appendix J*). The key to the encapsulation approach is the completeness of the barrier on all exposed surfaces.

VOC Decay rates vary enormously (thus impact on chronic exposure) (*see slide 14 IAQUEST, Appendix K*). Small surface area materials can release strong long-term emissions. Odour and Irritation are important aspects of IAQ and thus for assessment of product emissions, but odour and irritancy thresholds are often above health effect levels, thus detailed chemical analysis coupled with toxicological assessment is needed. (*See Appendix K*).

2.3 PVC and plastic coatings

Phthalates are plasticizers added to numerous products, including building materials, to increase flexibility. These chemicals do gas off from PVC and plastics and enter the breathing space under normal conditions. There are other means of exposure, including ingestion and through skin application of some personal products. Phthalates are endocrine disruptors that have been linked to reproductive abnormalities in animals and male humans. (*3*)

In its largest study ever conducted, the US Centers for Disease Control found widespread low-level chemical contamination in a random sample of Americans in 1999-2000. Levels of phthalates were among chemicals present at levels associated with health effects. "Levels of phthalates are highest in children and women of reproductive age, creating the potential for developmental effects on the fetus and children." (*4*)

In addition, when PVC and other plastics burn they give off Dioxin, an organic product that is a deadly poison. A simple fire isolated to a cabinet made with plastic coatings could have deadly effects not associated with wooden cabinetry.

Several sources, including CMHC, recommend reduction of the use of plastics/PVCs and phthalates when alternatives exist (*See Appendix L*).

2.4 Terpenes

Although natural terpenes from wood products are considered to be less problematic than most manufactured chemicals, they can contribute to airborne chemical load and carry specific health impacts for individuals. They can trigger asthma or other symptoms in susceptible individuals and some terpenes react with ozone or other oxides to produce aldehydes including formaldehyde. (*5*)

CMHC's *Building Materials for the Environmentally Hypersensitive (6)* advises sealing all surfaces or limiting use of some woods such as pine and spruce, which give off stronger terpenes than some others. Terpene off gassing has been found to be significantly higher from processed wood products than from the same wood in solid form because the process of reducing wood into small particles releases more of their terpenes. (*7*)

Local hardwood such as poplar and aspen are useful in solid-core or strip-core wood panel production because they are readily available, low in terpenes and less expensive than hardwoods such as oak. (*8*)

2.5 National Research Council Canada - Institute for Research in Construction: "90 Target VOC's Strategy" (*See Appendix M*)

This initiative was taken because of the scarcity of health-relevant emissions information to enable comparison of products. NRC - IRC presented their strategy at the Indoor Air 2005 conference on 06 Sept 05. This strategy was further developed by a presentation at a Healthy Indoor Partnership (HIP) workshop on 06 Feb 07. This research involved the selection of 69 solid and engineered wood materials commonly used in Canada and applying ASTM emissions testing for 90 Target VOC's and "abundant" VOC's. The target VOC's selection was based on 11 published lists from national and international organizations. The emission characteristics for each material were arranged into a material emission database linked to a program to simulate indoor air levels. This database and simulation can provide a screening method to compare materials for health related VOC's of the greatest concern. A careful study of Tables 1 and 3 (as numbered in their report) reveal interesting differences in different building products; depending upon the chemical emission of greatest health concern, enabling some comparisons to be made.

Table 1. "Target" VOC List and Reference Levels

VOC #	Group	CAS #	Chemical Compound	Existing List (see References) 1	2	3	4	5	6	7	8	9	10	11	Sum	Reference Levels (µg/m³) WHO Guidelines[1] (µg/m³)	WHO Guidelines[1] (avg. time)	CREL[2]	OSHA PEL[3]	Odor Detect. Threshold[4]
1	Aldehydes	75-07-0	Acetaldehyde			1		1		1	1	1			5	50	(1 yr)	9	3.6E+05	3.4E+02
2		107-02-8	Acrolein			1			1	1	1	1			5	50	(30 min)	0.06	2.3E+02	4.1E+02
3		100-52-7	Benzaldehyde	1										1	2					1.9E+02
4		123-72-8	Butanal	1											1					2.8E+01
5		112-31-2	Decanal		1										1					5.9E+00
6		50-00-0	Formaldehyde			1		1	1	1	1	1			6	100	(30 min)	3	9.2E+02	1.1E+03
7		98-01-1	Furfural												0				2.0E+04	2.5E+02
8		111-71-7	Heptanal												0					2.3E+01
9		66-25-1	Hexanal	1										1	2					5.8E+01
10		124-19-6	Nonanal	1	1									1	3					1.4E+01
11		124-13-0	Octanal												0					7.2E+00
12		110-62-3	Pentanal	1											1					2.2E+01
13	Ketones	78-93-3	Methyl ethyl ketone	1	1		1		1	1			1	1	7				5.9E+05	8.7E+02
14		67-64-1	Acetone		1		1		1		1		1	1	6	n.p.			2.4E+06	1.4E+04
15		98-86-2	Acetophenone	1						1					2					1.8E+03
16		108-94-1	Cyclohexanone	1										1	2				2.0E+05	8.3E+01
17		108-10-1	Methyl isobutyl ketone	1	1		1		1	1				1	6				4.1E+05	5.4E+02
18	Alcohols, Glycols, GlycoEthers	107-21-1	1,2-Ethanediol			1				1		1			3			400		6.3E+04
19		57-55-6	1,2-Propanediol												0					
20		71-36-3	1-Butanol	1	1		1							1	4				3.0E+05	9.0E+01
21		107-98-2	1-Methoxy-2-propanol	1								1			2			7000		1.2E+01
22		71-23-8	1-Propanol		1						1				2	n.p.			5.0E+05	6.0E+03
23		111-76-2	2-Butoxyethanol	1		1				1	1			1	5	13100	(1 wk)		2.4E+05	5.1E+00
24		112-34-5	2-Butoxyethoxyethanol	1											1					9.2E+00
25		110-80-5	2-Ethoxyethanol	1		1		1			1	1			5	n.p.		70	7.4E+05	4.6E+03
26		104-76-7	2-Ethyl-1-hexanol												0					5.0E+02
27		109-86-4	2-Methoxyethanol	1		1		1			1	1			5	n.p.		60	8.0E+04	3.6E+03
28		75-65-0	2-Methyl-2-propanol												0				3.0E+05	7.1E+04
29		67-63-0	2-Propanol	1	1		1				1	1		1	6	n.p.		7000	9.8E+05	1.2E+03
30		64-17-5	Ethanol	1	1									1	3				1.9E+06	2.8E+02
31		108-95-2	Phenol			1			1	1		1		1	5			200	1.9E+04	4.3E+02
32	Esters	108-21-4	1-Methylethyl acetate	1											1				1.0E+06	1.0E+04
33		111-15-9	2-Ethoxyethyl acetate	1				1				1			3	n.p.		300	5.4E+05	1.0E+03
34		123-86-4	Butyl acetate	1	1									1	3				7.1E+05	4.7E+01
35		141-78-6	Ethyl acetate	1	1									1	3				1.4E+06	2.4E+03
36		6846-50-0	TM-PD-DIB**	1											1					
37	Halo-Carbons	95-50-1	1,2-Dichlorobenzene			1			1				1	1	4				3.0E+05	4.5E+02
38		106-46-7	1,4-Dichlorobenzene	1	1	1		1	1	1	1	1	1	1	10	1000	(1 yr)	800	4.5E+05	3.0E+02
39		75-09-2	Dichloromethane			1		1	1	1		1		1	6			400	8.7E+04	3.4E+03
40		79-01-6	Trichloroethylene	1	1	1			1	1	1	1	1		8	n.v.		600	5.4E+05	8.0E+03
41	Aliphatic Hydrocarbons	107-83-5	2-Methylpentane	1											1					2.9E+02
42		96-14-0	3-Methylpentane	1											1					
43		124-18-5	Decane	1	1		1						1	1	5					4.4E+03
44		112-40-3	Dodecane	1	1								1		3					1.5E+04
45		142-82-5	Heptane	1	1									1	3				2.1E+06	4.1E+04
46		544-76-3	Hexadecane	1	1										2					
47		110-54-3	Hexane	1	1					1		1		1	5			7000	1.8E+06	7.9E+04
48		111-84-2	Nonane	1	1										2					6.8E+03
49		111-65-9	Octane	1	1									1	3				2.3E+06	2.8E+04
50		629-62-9	Pentadecane	1	1										2					
51		629-59-4	Tetradecane	1	1										2					
52		629-50-5	Tridecane	1	1										2					1.7E+04
53		1120-21-4	Undecane	1	1								1		3					7.8E+03
54	Aromatic Hydrocarbons	95-93-2	1,2,4,5-Tetramethylbenz		1										1					1.5E+02
55		611-14-3	2-Ethyltoluene	1	1										2					
56		620-14-4	3-Ethyltoluene		1										1					
57		622-96-8	4-Ethyltoluene		1										1					
58		4994-16-5	4-Phenylcyclohexene	1											1					
59		71-43-2	Benzene	1	1	1		1	1	1	1	1	1	1	10	n.v.		60	3.2E+04	3.3E+04
60		526-73-8	1,2,3-Trimethylbenzene		1										1					
61		95-63-6	1,2,4-Trimethylbenzene	1	1		1						1		4					7.8E+02
62		95-47-6	1,2-Dimethylbenzene	1	1	1			1	1	1	1	1	1	9	870 *	(1 yr)	700 *	4.3E+05 *	3.8E+03
63		108-67-8	1,3,5-Trimethylbenzene	1	1										2					1.2E+03
64		108-38-3	1,3-Dimethylbenzene	1	1	1			1	1	1	1	1	1	9	870 *	(1 yr)	700 *	4.3E+05 *	1.4E+03
65		106-42-3	1,4-Dimethylbenzene	1	1	1			1	1	1	1	1	1	9	870 *	(1 yr)	700 *	4.3E+05 *	2.1E+03
66		98-82-8	Isopropylbenzene							1			1		2				2.5E+05	1.2E+02
67		103-65-1	Propylbenzene	1											1					4.8E+01
68		100-41-4	Ethylbenzene	1	1		1		1	1	1	1	1		8	22000	(1 yr)	2000	4.3E+05	1.0E+04
69		91-20-3	Naphthalene	1			1	1	1	1		1	1		7			9	5.5E+04	7.9E+01
70		99-87-6	Isopropyltoluene												0					1.2E+01
71		100-42-5	Styrene	1	1	1			1	1	1	1	1		8	260	(1 wk)	900	4.3E+05	1.6E+02
72		108-88-3	Toluene	1	1	1		1	1	1	1	1	1	1	10	260	(1 wk)	300	7.5E+05	6.4E+02
73	Cyclo-Alkanes	110-82-7	Cyclohexane	1			1								2				1.0E+06	3.2E+05
74		1678-93-9	Butylcyclohexane												0					
75		1678-91-7	Ethylcyclohexane												0					
76		1678-92-8	Propylcyclohexane												0					
77		91-17-8	Decahydronaphthalene												0					5.7E+05
78	Terpenes	80-56-8	alpha-Pinene	1	1								1	1	4					3.9E+03
79		99-86-5	alpha-Terpinene												0					2.3E+03
80		127-91-3	beta-Pinene	1	1									1	3					
81		99-85-4	gamma-Terpinene												0					1.5E+03
82		13466-78-9	3-Carene	1											1					
83		79-92-5	Camphene				1								1					
84		138-86-3	Limonene	1	1									1	3					2.5E+03
85	Other	3777-69-3	2-Pentylfuran	1											1					
86		872-50-4	1-Methyl-2-pyrrolidinone					1							1					
87		64-19-7	Acetic acid												0				2.5E+04	4.3E+01
88		142-62-1	Hexanoic acid	1											1					6.0E+01
89		142-96-1	n-Butyl ether												0					3.0E+01
90		109-52-4	Pentanoic acid												0					2.0E+01

[1] #8 in References, n.p (not provided), n.v. (no value is available for chemicals with cancer health endpoints); [2] # 9 in References; [3] PEL: permissible exposure level by OSHA (OSHA, 2005); [4] VOCBASE: database with properties of 808 VOCs, B.Jensen, P.Wolkoff, Nat. Inst. Occup. Health, Denmark, 1996; * Dimethylbenzenes (mixture of 1,2-, 1,3- & 1,4-dimethylbenzene); **2,2,4-Trimethyl-1,3-pentanediol diisobutyrate

Table 3. Range of Emission Factors of Selected Materials ($\mu g/m^2/h$) at 24 h

Group	VOC #	Solid & Engineered Wood Materials: OSB Min	OSB Max	Plywood Min	Plywood Max	Solid wood Min	Solid wood Max	MDF	Flooring: Carpet/ Assembly Min	Carpet/ Assembly Max	Underpad Min	Underpad Max	Laminate/ Assembly Min	Laminate/ Assembly Max	Linoleum/ Vinyl Flooring Min	Linoleum/ Vinyl Flooring Max	Installation Materials: Adhesive Min	Adhesive Max	Caulking Min	Caulking Max	% (Detection)
Aldehydes	1	41.8	265.5					69.9	1.67	20.85			3.68	11.49	2.0	28.5					46
	2																				0
	3	0.1	2.6			0.2	0.2	0.2	0.08	1.41	0.21	1.42	0.01	0.09	0.90	1.55			6057	6057	60
	4	2.7	59.8	2.1	6.0	0.3	1.7	6.0	0.19	0.48	0.21	0.93	2.33	2.33	0.15	0.15			361	361	52
	5	0.6	44.6	3.3	25.4	1.9	10.4	0.9	13.45	13.45	1.08	7.42	0.53	0.53	0.53	0.71			225	757	63
	6	11.1	53.7					441.6	6.17	40.46	6.70	76.57	1.32	37.66	1.2	19.0					54
	7	4.3	4.3			0.3	0.3														3
	8	0.3	6.5	0.9	3.6	0.7	0.7	1.4			0.15	0.15	0.03	1.62	0.9	1.3					46
	9	29.4	1256.7	12.3	33.0	0.4	5.7	135.7			0.25	0.25	12.67	12.67	21.7	26.2					56
	10	1.1	47.3	3.3	24.7	1.6	12.4	2.5	0.60	0.90	3.03	6.37	0.50	0.50	0.3	1.9	89	89	170	742	67
	11	0.6	6.7	1.0	12.8	0.4	3.6	2.6	0.46	2.43	0.60	0.60	0.30	0.30	1.3	1.6					52
	12	12.9	354.1	3.4	12.2	0.4	4.4	29.0					7.70	7.70	15.5	15.5			762	762	49
Ketones	13	0.7	1.9	2.6	2.6	0.4	0.4		0.04	0.77	3.04	4.58							1564	1564	27
	14	6.0	338.4	4.5	24.3	3.4	4.2	7.8	0.39	93.23	0.99	3.41	21.4	290.2	0.3	271.5	25	25	109	4986	79
	15	0.1	0.6			0.1	0.1		0.21	1.26					0.32	0.32			1106	1106	33
	16																				2
	17								0.24	0.24											6
Alcohols, Glycols, GlycoEthers	18												0.44	0.44							2
	19								3.72	3.98	3.11	3.11									8
	20	2.1	2.1			0.5	0.5				1.75	4.46			0.6	2.0					13
	21																				0
	22																				2
	23																				0
	24																				2
	25																				2
	26	0.5	5.3			0.5	0.5	1.5	0.28	0.28	3.73	3.73	0.01	2.00	0.4	2.3					37
	27																				0
	28																				0
	29								230.7	230.7											3
	30			2.5	2.5	0.4	0.4										2694	2694			5
	31					7.5	7.5								64.1	64.1					5
Esters	32					1.3	1.3								4.2	4.2					5
	33	1.8	1.8			3.1	3.1														6
	34										0.87	0.87									3
	35					1.8	1.8										2235	2235	13415	15146	8
	36										44.90	44.90			418.7	418.7					11
Halo-Carbons	37								0.10	1.4	0.32	0.32									11
	38	0.25	28.6	0.43	0.89	0.12	0.12	0.04	0.08	0.5	0.36	0.89	0.003	0.08	0.05	2.77	6	48	145	191	71
	39	0.05	0.3	2.68	2.68	0.02	0.02		0.16	0.8	0.46	0.46			0.16	0.34	604	604			24
	40	1.35	1.4	0.28	0.28	0.42	0.42		0.17	0.2											16
Aliphatic Hydrocarbons	41	0.48	6.1	0.17	0.17	0.05	26.45		0.04	1.3					0.09	0.09	13	67750	649	649	40
	42	0.25	1.8	0.26	0.26	0.03	0.03		0.03	0.3							60	40481	385	385	30
	43	1.13	11.4	0.28	1.07	0.31	7.99	0.31	0.26	78433	1.58	2.71	0.01	0.38	0.09	8.5	9	334	1213	456853	84
	44	0.14	4.1	0.14	0.49	0.09	4.86	0.09	0.12	398	6.95	9.58	0.19	0.19	0.04	181.5	42	42	40	39682	86
	45	0.51	8.2	0.34	1.45	0.02	1.03	1.04	0.13	207			0.45	11.80	0.02	61.5			322	322	51
	46	0.07	0.3	0.15	0.29	0.05	0.05		0.07	1066	3.22	3.22	0.22	0.22	0.11	4.0	2070	2070			49
	47	0.18	2.3	0.43	0.45	0.07	5.34		0.05	0.6	0.16	0.16	2.46	2.46	0.02	0.0	170	634	805	805	60
	48	1.08	7.8	0.26	0.39	0.08	0.08	0.52	0.19	26322			3.50	3.50	0.03	1.3	9	9	3843	115166	65
	49	1.06	7.1	0.57	2.89	0.03	1.00	0.79	0.05	156.1			29.78	29.78	0.44	0.7	56	56	167	355	63
	50	0.14	1.4	0.28	0.39	0.07	0.08		0.05	10.2	19.85	19.85	0.08	0.08	0.07	35.2	22676	22676			57
	51	0.18	3.5	0.60	0.79	0.15	1.79	0.26	0.14	32.5	5.54	87.97			1.17	443.5	37809	37809			70
	52	0.07	1.2	0.19	0.22	0.05	0.28		0.41	40.1	14.56	64.77			0.17	498.0	3363	3363	49	49	63
	53	0.31	3.6	0.33	0.79	0.29	2.03	0.23	0.85	19536	2.99	8.11	0.10	0.10	0.05	8.42	20	134	79	271978	90
Aromatic Hydrocarbons	54	0.00	0.0			0.01	0.01		0.31	493	1.22	3.23			0.08	0.08			149	149	33
	55	0.02	0.4			0.01	0.01	0.02	0.04	4787	0.14	1.95	0.06	0.06	0.01	0.73	2	2	527	5375	65
	56	0.02	0.9			0.02	0.02	0.03	0.25	1215	0.49	0.65	0.05	0.05	0.06	1.88	8	8	1462	72255	68
	57	0.09	0.1			0.01	0.01	0.14	0.15	9571	0.28	0.29			0.03	0.93	3	3	752	27175	52
	58								0.06	74.6	1.03	19.08			0.19	0.19					21
	59	0.53	3.5	0.26	0.73	0.09	1.29	1.11	0.11	0.7	0.12	0.34	0.05	1.68	0.08	3.95	11	252	146	905	89
	60	0.01	0.5						0.12	6561	0.69	2.38	0.01	0.01	0.05	2.72			892	1049	57
	61	0.05	1.7			0.05	0.05	0.08	0.07	14202	1.14	2.55	0.04	0.04	0.03	4.44			2571	24232	68
	62	0.15	2.7	0.12	0.17	0.02	0.26	0.08	0.09	1942	0.28	0.44	0.002	0.12	0.05	0.12	3	3	601	2151850	83
	63	0.01	0.2			0.01	0.01	0.03	0.04	5023	0.23	0.33	0.02	0.02	0.02	1.18	2	2	956	21762	70
	64	0.26	3.9	0.50	0.54	0.09	2.38	0.10	0.19	1548	0.96	1.46	0.01	0.28	0.10	0.28	14	79	833	3521988	89
	65	0.06	2.3	0.34	0.37	0.06	1.64	0.10	0.13	514	0.66	1.00	0.002	0.10	0.05	0.13	10	48	572	2421387	84
	66	0.03	0.1	0.09	0.09	0.01	0.01		0.06	6218	0.09	0.09			0.04	0.19			31103	31103	41
	67	0.06	0.5			0.01	0.01		0.20	4790	0.13	0.17	0.06	0.06	0.02	0.39	3	3	543	12697	62
	68	0.13	1.3	0.05	0.09	0.03	0.28	0.94	0.03	291	0.21	0.23	0.01	0.20	0.04	0.11	5	5	151	4457281	88
	69	0.02	0.2	0.07	0.07	0.19	0.19		0.04	164.8	2.12	9.87	0.001	0.001	0.09	0.57	1	1	310	310	59
	70	0.03	0.7	2.82	34.10	0.38	211.6	0.05	0.06	1091.1	0.21	0.21	0.003	0.01					365	365	49
	71	0.08	1.1			0.02	0.02		0.16	16.7	0.44	0.66	0.06	0.06			43	43			40
	72	0.40	6.8	0.80	2.92	0.15	3.45	2.10	0.22	7.3	1.43	1.73	0.08	1.06	0.2	2.4	16	127	32	45800	97
Cyclo-Alkanes	73	0.19	0.2			2.82	2.82		0.30	1.3			1.70	2.54	322.2	322.2	1	372	2739	5446	27
	74								0.11	8334					0.7	0.7			305	45975	21
	75								509.0	509							11	11	1636	1851	19
	76	0.17	0.4						0.09	9564									859	54261	29
	77								2947.3	2947									774	19813	19
Terpenes	78	0.56	14.2	30.9	172.4	2322.5	2322.5	0.10	0.11	0.43			1.68	7.94					712	712	51
	79			8.2	14.8	222.0	222.0														6
	80	0.16	9.1	32.5	75.0	1152.9	1152.9	0.18					0.27	1.92							37
	81			0.1	3.9	113.2	113.2						0.0012	0.0012							11
	82	0.85	2.5	8.4	114.4	14.5	14.5	0.09					0.09	1.09							24
	83	0.03	1.2	3.5	29.7	512.3	512.3						0.17	0.32					1533	1533	35
	84	0.25	1.8	7.1	63.8	0.1	659.7	0.29	0.28	2.69	1.75	1.77	0.02	0.29					16649	16649	56
Other	85	6.39	112.5	1.6	5.0	0.1	0.1	0.67					4.35	4.35	0.1	0.1					37
	86														2.0	3.7					3
	87	18.9	460.3	11.9	23.3	37.4	141.1	178.6	1.74	9.65	2.66	3.01	0.81	3.88	0.8	39.7	65	65	445693	445693	59
	88	13.9	155.7												10.6	10.6					16
	89																				3
	90	3.2	3.2																		2

Note: Refer to Table 1 for chemical compounds.
The same value for "Min"and "Max" indicates there is only one data point.
No data are given for TVOC and additional abundant VOCs.
The numbers of the column of "% detection" are based on all data.

The practical application of using this model as a tool for material selection was further developed at the Feb 07 HIP Workshop. A number of national and international organizations are interested and are involved in further development of this project. The project will be known as the IAQ Emission Simulation Tool for material selection.

3. MITIGATING EMISSIONS

Air contaminants can be in the form of particles or gasses and can be removed through filtration from the air, ventilation, encapsulation, or source reduction.

3.1 Source Control

"Source control is always the first and most important step in mitigating contaminant levels and effects on office occupants. Ventilation strategies are then used to introduce fresh air into the space and carry out contaminants produced by both occupant activities and emissions from the materials within the building."*(9)*

"Characterization of emissions from building materials is an important step towards source control. In this research, 69 building material specimens commonly used in Canada were tested in accordance with an ASTM standard for their emissions for 90 "Target" VOCs and "Abundant" VOCs." *(See AppendixM).*

3.2 Material Selections

3.2.1 Selection Processes

3.2.1.1 Low emission materials can be selected by requiring that materials submissions include copies of specified standard tests such as the ASTM tests used in the study *A Material Emission database for 90 Target VOCs* (*Appendix M*).

3.2.1.2 Low emission materials can be selected by requiring that materials submissions include samples of actual products of specific size, age for evaluation by the less exact, but still useful "sniff test" (*See Appendix B, item 2.3, pp6&7*)

3.2.1.3 For some products, evaluation programs such as Envirodesic , Green Spec or IA-Quest may be useful.

3.2.2 Comments on Specific Materials

3.2.2.1 Plywood

CMHC has positive things to say about using softwood plywood (sanded), otherwise known as exterior grade, as it has less glue than other plywoods. (*10*)
CMHC's Healthy Housing Interiors fact sheet says "Cabinets and furniture made from solid hardwood or softwood have few of the toxic characteristics of composite or synthetic materials."(*11*)

However, new low-emission veneer core plywoods are finding their way to the marketplace, some still using phenol formaldehyde and others using newly developed glues.

3.2.2.2 **Other products**
One Healthy School in Illinois chose 18-guage metal cabinetry with heavy duty hinges and hardware for classrooms.

3.3 **Encapsulation** can prevent release of VOCs.

3.3.1 PVC edging and melamine or plastic surface bonded products reduce VOC emissions, including terpenes and chemicals, from release from processed woods panels. However, drill holes and cut edges need to be sealed with two or three coats of water based sealant or combination coatings. (*As in Appendix J, for school desks and gymnasium floors.*) As mentioned, PVC edging and plastic surface coatings do gas off and can contribute to airborne VOCs.

3.3.2 Finishes
Painted-on melamine is not recommended as a VOC sealant for composite panels. However, two to three coats of a good quality water-based liquid sealant can serve well, provided all exposed areas are coated, including drilled holes and cut-away sections, such as where hinges are attached, and any other exposed surfaces. The goal is to eliminate surfaces that can allow VOCs to escape into the air. T-shaped edge banding does not provide a good barrier. Bona Kemi and Enviropro are two suggested sealants as examples. (*12*)

CMHC recommends acrylic sealants. Health issues associated with this material are minimal. The dispersants in acrylic sealer release slight odours and may be irritating during application, however, after curing there is a very low emission rate. Use of acrylic sealer reduces terpene emission from softwoods and formaldehyde emissions from wood products. (*13*)

4. COMMENTS ON DRAFT FINISH CABINETRY SPECIFICATION FOR DC350 DRM

To reflect the contents of this draft report, the following suggestions are offered for inclusion in the DC350 DRM finish carpentry section:

06200 Finish Carpentry

1.4 Plywood to read "1.4 Plywood, Composites & Laminate Finishes"

1.4.4 Poplar Plywood to read "Poplar (Aspen) Plywood"

06410 Custom Cabinets

1. Materials:

1.2 Strongly prefer only solid wood and hardwood faced plywood (made with Phenol Formaldehyde or new low-emission glues) over MDF and MCP. Both of the later products present long term off-gassing concerns re Formaldehyde and other VOC's. Encapsulation attempts are not always successful and sometimes not verifiable due to inadequate site inspections or visual difficulty to confirm. Also, future alterations/damage expose surfaces to off-gassing.

Other supporting reasons for the above preference include lack of product strength (bowing, bending, moisture susceptibility, lifting of laminates and swelling of product when exposed to water) and repair difficulties encountered when screwed fastenings fail or laminates have lifted. Repairs become both difficult and costly.

Given the design intent for a life expectancy of 50 yrs, past experience with composite products do not provide a confidence level for long term sustainability. Early replacement of finish carpentry components could overburden DOE budgets.

See Truro West Elementary School Spec. LLAL No. 06118, NSTPW No. B01-26-01-01, Part 2 Products - as a potential model (*See Appendix N*).

5. COST EFFECTIVENESS AND PERFORMANCE

A Study done by Dorgan Associates for the National Energy Management Institute, Alexandria, Virginia, estimates that actions taken to improve IAQ in buildings can result in a payback in terms of improved productivity and decreases in medical costs in less than two years. Included among the beneficial modifications is product selection (*See Appendix O*).

Metal cabinetry may be more expensive initially, but may be worth considering. Painting and scratch repair is done over the summer when metal handrails are also painted.

MDF and MCP generally have a lower initial cost, but there are durability issues. Such panels with melamine or plastic coatings and PVC edging can swell and peel from water damage. Idle students with jackknives can do damage that is hard to return to the original appearance without completely replacing the section. Screws that pull away may take chunks of particle board with them, leaving holes that are difficult to repair, or places where screws will no longer hold.

Emission encapsulation by sealing all screw holes and exposed areas is labour intensive and therefore costly up front.

Painted plywood with solid wood edges may be more expensive initially, but can be low-emission, require a minimum of sealing (low emission paint is adequate), has durability, can be repaired or touched up easily. It has the added bonus of optional complete colour scheme changes in the future.

6. EFFECTS ON THE NATURAL ENVIRONMENT

The LEED program and many others are working to reduce the impacts on Mother Earth. Locally grown and processes low terpene, low VOC wood panels have advantages over the composite woods with melamine and PVC edging. There is measurable impact from manufacture, use, and eventual disposal of composite wood products, including their glues, melamines, and PVCs, which are foreign to the natural environment. Their manufacture contributes to greenhouse gas emissions, exposes industrial workers to higher levels of toxic substances and ends by, in effect, spreading toxins across the land, air or water.

"The impact on the environment is substantial given that the USA alone manufactures 1.25 billion wood panels annually. http://www.nsc.org/library/chemical/Formalde.htm

INPUTS per 1000 sq ft (3/8" thickness) of OSB

Wood fuel	3871b
Natural gas	698 cu ft
Liquid propane gas	1.07 gal
Diesel	0.018 gal
Fuel oil	0.769
Electricity	183 kWh
Formaldehyde glue	42.4 lb
MDI resin	8.16 lb

The above table shows that considerable energy is used from non-wood sources.
Factoring in the phenol formaldehyde glue and MDI resin increases the amount of greenhouse gas produced, let alone toxic chemicals entering the environment. 1,200,000,000 kg of formaldehyde is consumed in these panels annually in Canada/USA." (*14*)

7. RECOMMENDATIONS

We can not expect to completely eliminate all plastics and chemicals in our school environments, but it is a wise choice to move in that direction, to minimize them wherever possible, especially now that medical research is indicating evidence of potential short-term and long-term health effects, and behavioural and performance effects from low level indoor air pollutants. Schools house some of our more vulnerable populations.

Use wood products from local fast-growing, low-terpene tree species, either solid or veneer core, and avoid using chip or sawdust-based MDF panels.

Choose water-based, low-emission glues and sealants with fast curing times and that are stable over the long term, and use acrylic, low-emission paints. Avoid PVCs and plastics where possible.

Thank you for the opportunity to provide input on this important topic that can contribute to the creation of Healthy Schools in Nova Scotia.

8. REFERENCES

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8. *Veridity Environmental Products Ltd product information*, D. Prior

9. *The Environmentally Responsible Construction and Renovation Handbook - Second Edition,* March, 2000.

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11. *www.cmhc-schl.gc.ca*

12. *Personal communication,* Vince Catalli, HOK Architects, and Ed Lowans, BydEsign Ltd.

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APPENDIX

DRAFT

Finish Carpentry and Related Wood Product Selection for Schools

APPENDIX A

DRM Draft
Jan. '07

06200 Finish Carpentry

1 Materials

1.1 Moisture content at time of installation

1.1.1 For interior locations: 7%

1.1.2 For exterior locations: 12%

1.2 Use only adhesives and fastenings that develop sufficient strength for intended use, are non-staining, are unaffected by the environment to which exposed and are manufactured to applicable CSA standards.

1.3 Wood:

1.3.1 Grade mark softwood and hardwood lumber by the appropriate association under authority of the National Lumber Grades Authority.

1.3.2 Where not exposed to view, use wood of grades suitable for fabrication, utility and structural needs.

1.3.3 Where exposed to view, use wood to meet requirements of AWMAC Quality Grade Standard.

1.4 Plywood:

1.4.1 Hardwood Plywood:

1.4.1.1 To CSA Ol 15-M of species and thickness indicated.

1.4.1.2 Rotary veneer.

1.4.1.3 Use veneer core with Type II bond.

1.4.1.4 Good grade, where exposed to view, sound grade otherwise.

1.4.2 Canadian Softwood Plywood (CSP)

1.4.2.1 To CSA 0151-M

1.4.2.2 Sanded exterior grade, good two sides where both sides are exposed to view and good one side where only one side is exposed to view.

1.4.3 Douglas Fir Plywood (DFP)

1.4.3.1 To CSA 0121-M.

1.4.3.2 Exterior grade, good two sides where both sides are exposed to view and good one side where only one side is exposed to view.

1.4.4 Poplar Plywood

1.4.4.1 To CSA 0153-M

1.4.5 Composite Materials

1.4.5.1 Particle Board: to ANSI A208.1, Grade M3:

1.4.5.1.1 For postformed counter tops: 11/16" thick,45 lb.cu.ft., built-up edge, front and back.

1.4.5.1.2 For Flat work and other work: medium density, 451b.cu.ft.

1.4.6 Plastic Laminate

1.4.6.1 Commercial grade to specified requirements of CSA CAN3-A172-M.

1.4.6.2 Approved manufacturer's:

1.4.6.2.1 Nevamar
1.4.6.2.2 Formica
1.4.6.2.3 Arborite
1.4.6.2.4 Pionite

1.4.6.3 Material:
1.4.6.3.1 For post-forming: 0.030" (0.75 mm) thick
1.4.6.3.2 For flat work : minimum 0.045 (L 15mm) thick, commercial grade.

1.4.6.4 Finish Suede; colours chosen by Consultant from manufacturer's full range. No more than 4 colors per job.

1.4.7 Melamine Composite Panels (MCP)
1.4.7.1 Material to be manufactured to American Laminators Association Performance Standards and ANSI A208.1, Grade M3 particleboard.
1.4.7.2 Construct laminated sandwich of melamine resin impregnated paper thermally fused to a particleboard core.
1.4.7.3 Finish Suede; colours chosen by Consultant from manufacturer's full range. No more than 4 colors per job.
1.4.7.4 Finish all sides to reduce emissions.
1.4.7.5 All MCPs to be edged on exposed or semi exposed edges with;
1.4.7.5.1 Solid high impact, purified colour-thru PVC, 3 mm thick, hot machine applied, and automatically trimmed face,back and corners for a uniform appearance.
1.4.7.5.2 Acceptable products: Wood-tape, Canplast and Polyplast.

1.4.8 Adhesives and Sealers: tested for acceptable VOC emissions in accordance with ASTM D2369 and ASTM D2832

2 Construction of Wood Material Cabinetry

2.1 Fasten work with nails generally, but use screws or special fasteners at critical joints, and where required by specified quality grade standards.
2.2 Glue built-up work, as well as nailing or screwing.
2.3 Blind nail where practical
2.4 Set finishing nails below finished surfaces receiving filler
2.5 Ensure each surface of Work, where exposed or semi-exposed, is finished appropriately.
2.6 3mm hardwood edge on exposed and semi-exposed edges of plywood construction cupboards. Hot machine applied and automatically trimmed face, back and corners for a uniform appearance.
2.7 Fine sand exposed surfaces level and smooth after fabrication.
2.8 Construct cabinetry sections that are square, plumb and true.

3 Construction of Melamine Composite Cabinetry

3.1 Drawer fronts to be the same color as doors; securely fastened to drawer box unit.
3.2 Exposed or semi-exposed edges to be covered with 3 mm PVC, as identified above for MCPs, radiused and rounded on all doors and drawer fronts, or sealed where not

exposed.
3.3 Toekicks to be 3/4" Douglas fir plywood.
3.4 Any required wood members to be hardwood.
3.5 Wooden dowels at all glued connections.
3.6 Plastic anchor inserts or bolt through construction for all hardware.
3.7 Bolt through connection for side to side connections.
3.8 Shop fabricated pre-finished cupboard sections that are self supporting, square, plumb and true.

06220 Millwork

1 Materials
1.1 To requirements of Part 1, Section 2, Division 06, item 06200.1 and as follows;
1.2 Where Standing and Running Trim is incorporated into design use Eastern White Pine or Clear Spruce.

2 Construction
2.1 To requirements of Part 1, Section 2, Division 06, item 06200 and as follows.
2.2 Do millwork to Quality Standards of the Architectural Woodwork Manufacturers' Association of Canada.

06410 Custom Cabinets

1 Materials
1.1 To requirements of Part 1, Section 2, Division 06, item 06200 and as follows.
1.2 Construct cabinets of either solid wood (plywood), Medium Density Fibreboard (MDF) or Melamine Composite Panels (MCP). Other materials will not be acceptable unless approved in writing by DTPW. Refer to PART 2, Section 2 for client specific requirements regarding acceptable materials.

2 Construction

2.1 To requirements of Part 1, Section 2, Division 06, item 06200 and as follows.
2.2 Do millwork to Custom Quality Standards of the Architectural Woodwork Manufacturers' Association of Canada.
2.3 For case bodies, shelving, doors, drawer fronts; plywood, MDF or MCP are accepted unless noted otherwise.
2.4 Case Construction:
2.4.1 bodies, ends, divisions and bottoms not less than 3/4" thick.
2.4.2 shelves up to 36" wide, 3/4" thick.
2.4.3 shelves greater than 36", up to 42" wide, 1" thick.
2.4.4 no shelves over 42" unsupported.
2.4.5 backs min. 1/4" thick and may be of plywood or tempered hardboard. 2.4.6 adjustable shelves supported by flush set metal standards.

2.5 Drawers:

2.5.1 Provide metal guides.

2.6 Doors:

2.6.1 Provide flush with eased edges.

2.7 Hardware:

2.7.1 concealed, self-closing hinges 110° opening.

2.7.2 drawer slides - captive guide rail, side mounted, heavy duty, steel, minimum capacity 150 lbs per pair.

2.7.3 pulls back mounted, 4" long rod type.

2.7.4 locks half mortised into back.

2.7.5 schedule hardware by cabinet groups.

2.7.6 specify bumpers on doors.

2.8 Countertops and backsplashes:

2.8.1 Provide postformed countertops with integral backsplashes of high pressure laminated plastic bonded to substrate, unless otherwise specified in project specific brief, or as approved in writing by DTPW.

2.8.2 edges and corners rounded.

2.8.3 Plastic laminate:

2.8.3.1 Layout laminate pieces in minimum 12' long pieces, and with joints at least 24" from sink cutouts. Ensure hairline cracks along joints.

2.8.3.2 Ensure laminate is fully supported by core material.

2.8.3.3 Adhere plastic laminate to core material in strict accordance with adhesive manufacturer's written instructions. Apply adhesive over entire surface.

2.8.3.4 Expose edges of flat work are to be moderately and uniformly beveled (20' off vertical)

2.8.3.5 All exposed edges of core material are to be faced with plastic laminate.

2.8.3.6 At joints, use draw bolts and splines, spaced at maximum 16", and so as to produce hairline crack along joints.

2.9 Finishing: (see also Division 09)

2.9.1 sand edges before finishing.

2.9.2 spray undercoat.

2.9.3 sand (fine paper)

2.9.4 two coats sprayed lacquer in colours, where no other finish is provided and material is exposed to view.

06420 Paneling

1 Where Architectural Woodwork Paneling is incorporated into design:

1.1 Flush Paneling:

1.1.1 decorative with a transparent finish.

1.1.2 AWMAC Custom grade.
1.1.3 specify matching (veneer pieces and between panels).

1.2 Stile and Rail Paneling:

1.2.1 decorative with a transparent finish.
1.2.2 AWMAC Premium grade.
1.2.3 provide scale elevations, panel mould details, specifications for material species and panel matching.

06450 Standing and Running Trim

1 Where Architectural Woodwork Standing and Running Trim is incorporated into design use Eastern White Pine or Clear Spruce.

2 Ensure warranty is provided which guarantees the millwork for a period of four (4) years beyond the date of performance assurance.

APPENDIX B

1.0 Why Children are More Vulnerable to Toxins Than Adults

- Larger Body Surface Area In Relation To Weight
- Higher Metabolic Rate and Oxygen Consumption and Intake of Air Per Unit of Body Weight.
- Different Body Composition
- Greater Energy and Fluid Requirements Per Unit of Body Weight
- Special Dietary Needs
- Rapid Growth, During Which Chemicals May Affect Growth or become Incorporated Into Tissues
- Functionally Immature Organs And Body Systems. (the brain does not slow its fast growth until at least 18 years of age)
  - The World Health Organization. Environmental Criteria 59, Principles for evaluating Health Risks from Chemicals during Infancy and Early Childhood: The need For a Special Approach. Geneva, 1986.

* * *

- At present, air quality and workplace hazard standards are based upon research predominantly done on healthy, 175 lb., adult males. There have not yet been safe levels determined for children, the ill, for women or fetuses.
- "There is an urgent need for more and better environmental health indicators and measures. Traditional health indicators, such as life expectancy at birth, do not take into account the changing physical environment of the last fifty years, or recognize its potential implications for human health and longevity.... In order to protect the health of Canada's children today, the Precautionary Principle needs to be applied, leading to action on developing environmental targets through enforceable legislation."
  - p.252, The Health of Canada's Children, third edition, Canadian Institute of Child Health. 2000.)
- "The Canadian building code references ASHRAE 62-1989 Ventilation For Acceptable Indoor Air Quality. Applying this standard to students in a school is questionable when this standard is based on 80% of at least 20 untrained subjects tested that perceived the air to be acceptable in 15 minutes, or 15 seconds for unadapted subjects. This test was conducted primarily on students at Yale University, Kansas State University and Denmark. It did not test babies, children, elderly, the infirm or sick, physically and mentally disabled, those with respiratory illness, and many other disenfranchised people. Thus the test may only be valid for a much smaller segment of the total population.
  Furthermore, this test is based primarily on elevated carbon dioxide in the test room and the perceived discomfort of the untrained subjects. None of the harmful contaminants such as

formaldehyde, carbon monoxide, moulds, radon, etc. were used. The ASHRAE standard for ventilation is clearly not applicable to all occupancies as it states, 'Considering the diversity of indoor air contaminants and the range of susceptibility in the population, compliance may not be acceptable for everyone.' We should be using housing standards in our schools."
- Professor Tang Lee, University of Calgary

- "The health risk from air pollution is as much as six times greater for children than for adults."
  - Medical Researchers at the University of California at Irvine

- "Exposures to building products, furnishings and materials that have toxic potential, as well as poor ventilation in schools, affect all children to some degree. It is becoming more and more evident that the central nervous system is particularly vulnerable to exposures to many toxicants and that these can affect both learning and behavioral abilities in subtle but serious ways."
  - B. McElgunn, Learning Disabilities Association of Canada

- "Health symptoms of chemical exposure such as headaches, breathing problems, itchy and watery nose and eyes, intestinal problems, fatigue, and coughing are often misdiagnosed as colds and flu. Behavioral symptoms of chemical exposure such as mood swings, aggressiveness, and hyperactivity are often seen as normal."
  - Dr. Gerald Ross, Past President the American Academy of Environmental Medicine.

- "Chemicals have replaced bacteria and viruses as the main threat to health. The diseases we are beginning to see as the major causes of death in the latter part of this century and into the 21st century are diseases of chemical origin."
  - Dr. Dick Irwin, Toxicologist, Texas A&M University

- In a study of 52 urban school buildings, the buildings were evaluated as being in "poor", "fair", or "excellent" condition. An assessment of student achievement in the schools was then made. Regression analysis was used to remove variables such as socioeconomic status. A strong correlation was found between building condition and student achievement. Students from schools in "poor" condition fell 5.5 percentage points behind those in the "fair" school buildings, and 10.9 percentage points behind those in the "excellent" school buildings.
  - Edwards, Maureen M., Building conditions, Parental Involvement, and Student Achievement in the D.C. Public School System. Georgetown University, 1991.

- We do not know how many children are affected by poor school ventilation and toxic exposure, but as Health Canada's ISSUES paper on environmental sensitivities states, "Prevention is the most important and simplest aspect of this problem."
  -Citizens for A Safe Learning Environment

2.0 Source Control

"Careful selection of building materials and furnishings alone will not eliminate VOC problems from buildings. But limiting materials' emissions is within the control of the designers and builders." (Cutter)

One example: Unless wooden chairs are chosen, there aren't many or any alternatives to the propylene ethylene copolymer chair "shells". Source control can be exercised by getting them early and offgassing in a well ventilated area, or requiring the supplier to guarantee they offgas them in a well-ventilated location several months before they are shipped.

In both the Stillwater school in Mineapolis and the Prairie Ridge school in Illinois, Source Control techniques were used for construction materials selection and use and for furniture and equipment choices. Also, the importance of working closely with the contractors during the construction phase was emphasised by those involved in healthy school aspects on both projects.

The five year old Prairie Ridge school has no carpeting, has low-emission paints, openable windows throughout, hardwood or metal furniture and cabinetry, a sophisticated computerized ventilation system with the best filters on the market at the time, and a good maintenance program. Particular attention was paid to large surface area items such as ceiling tiles, floor coverings, paints, and furniture. Bunsen burners were hooded. No plastic chairs. To keep them clean, ducts were capped daily during construction. Materials handling and storage were in the specs. Acoustic issues needed extra design attention because limiting "soft" surfaces caused sound to be more readily reflected. It was found that synthetic gym floors available at the time had less "give" than wood floors, and condensation caused them to become slick.. The school came in on time and on budget, proving it is not necessarily costly to build a healthier school. (Oberg)

The following source control information expands upon the brief points listed in Healthy School Design and Construction.

2.1 Materials:

Among the problem materials found in conventional schools, in order of priority are:

cabinetry with exposed particle board
high-emission carpeting
vinyl or chemically treated materials in sun-exposed areas
high-emission cleaning compounds
badly designed ductwork, with exposed fibreglass
use of strongly-emitting caulking compounds (e.g. some MONO types)

More subtle sources include:

wall paints
vinyl or other wall coverings
partitions with formaldehyde containing compounds
furnishings with long gas-out period

2.1.1 Formaldehyde:
In finished products formaldehyde will continue to offgas indefinitely and it has been linked to significant health problems. Neither Health Canada or the US EPA identify a "safe" level of exposure to formaldehyde. Although woods naturally contain some traces of natural formaldehyde, that can't be an excuse for adding more during manufacture. It is a carcinogen and so the goal is to be exposed to as little as possible, preferably none.

HUD (US Housing and Urban Development Institute) standard is .3 ppm ASHRAE 0.4 ppm for office environment
Health Canada 0.1 ppm target, but does not identify a "safe" level.
OSHA TWA for 8 hr. day is 0.75 ppm, an industry standard.
If a product emits 0.3 ppm (the ACGIH TLV) it is exceeding Health Canada's standard by 300%.
The 'convention' for scientists who work on this issue is to cut the OSHA standard by 1/10 for adults in offices, and cut this by another 1/10 for children.
Emission measurements are best done in an ASTM chamber. (DST Consulting)

2.2 How effective can source control be?

Dr. Greg Miller (Envirotest Brisbane 1997) captured air samples from a newly completed home which had been built entirely of inert or least toxic materials. The samples were analyzed to measure the levels of formaldehyde and VOCs. Australia's standard "safe" TVOC limit recommended is 500 micrograms per cubic metre of air (mg.m3). In new and renovated construction the TVOCs average 1,000 mg/m3. Miller's expectations for his "clean architecture" house was to find TVOC levels of 200-300mg/m3. The actual level found in this house was 25mg/m3. (The Human Ecologist, Fall, 1998)

2.3 How to Conduct a Sniff Test:

According to Envirodesic, earlier projects spent much money on emissions testing but their experience has shown another method works as well or better and is much less expensive. Here is the method:

1. Include certain requirements in the tender call and contract. (see below)
2. Screen the applicant's sample's MSDS to identify and eliminate obvious problem products.
3. Place samples in glass jars (as described in "How to Conduct a Sniff Test"), and have a committee of at least three people open each one and identify those that are not strongly offgassing.

Suggested specs/tender/contract requirements:
1. The preamble would state that it is the goal of the department to attain a healthy indoor environment and it is required that suppliers provide low emission products to assist in achieving this goal.

2. Samples shall be prepared by the manufacturer of fresh materials, for acceptance by (TPW or committee or whoever)
or
Samples of all substraits, coverage, adhesives, sealers, shall be prepared by the manufacturer for approval by (whoever). These shall be freshly made, no larger than...

Ask for more than one sample if they have more than one possible option available.
Use this same process for choosing foam and fabrics (especially vinyl ones) for furniture and other FF&E.

The Sniff Test:

Place the samples from each product in separate clean glass jars. Seal the jars with aluminum foil, dull side facing the sample. Leave the samples at least overnight. Moderate heating(not more than 100 degrees F) for a few hours might be helpful. Do not overheat the samples as that will distort the emissions compared to those which will occur in the building situation. The effort is to replicate the conditions in which the sample will be exposed. The jar test concentrates the emissions and the heating accelerates the process.

Next, open the jars in an odor-neutral environment with good ventilation and sniff the samples. Rate the samples for strength of odor, degree of pleasantness or unpleasantness, and any irritation or other physiological effects you might experience. Several people can participate. The process can be repeated two or three times. Also, try doing the test "blind", without the people knowing which sample they are sniffing.
If there are several jars and several samples, try doing comparisons. Remember, however, your reactions will change during the first few seconds you smell the odors. Do not linger over any one jar. Keep the jars closed except when you are actually sniffing.

All of this effort is useful only if the samples are representative of what will be in the building. Know what you are getting, where it is coming from, and how representative it is. For example do not take showroom samples. They have no doubt been sitting around for a long time. (Cutter)

2.6 Table 1 shows an outline of the procedure and criteria for determining which materials should be included in the solicitation for product information.

Table 1: Procedure and Criteria for Reviewing Materials During Design

a. *Identify generic building materials, products, and furnishings. All textiles, wet products, pressed-wood products, and other products believed to emit chemicals into the air.*

b. *Determine the quantity and type of use for each material.*
Exposed surface area as well as cross-sectional area and mass are important.

c. *Determine whether the material will be exposed to the indoor air or the ventilation air supply and return stream.*
Air movement at the surface will generally increase emission from the surface. Return air ducts and concealed spaces above ceilings serving as return air plenums are as important as supply air ductwork and air handlers, since re-circulated air will have passed through the return air system. Thus, the upper surfaces of ceiling tiles or lay-in panels and insulations on structural floors, beams, and columns will be exposed to the return air.

d. *Determine whether occupants are likely to come into direct or close contact with the material or product based on its contemplated use.*
The closer the occupant is to the product, the less dilution of the emissions can occur before exposure.

e. *Identify high surface area (fleecy) materials.*
Textiles and roughly textured insulation materials present large surface areas, which can emit at higher rates than smooth surfaces. Rough surfaces also act as adsorption sites for chemicals already in the air, then re-emit them later.

f. *Identify materials that will require "wet" maintenance products.*
Maintenance products such as waxes, polishes, cleaners, and solvents can result in indoor air quality problems if not properly applied or ventilated. Drying time available between application and occupancy and ventilation during and after application, are critical elements to reduce air contamination during occupancy.

(Cutter)

2.7 Flush Out and Source Control Reduce Contaminants in New Construction

There are often complaints about adverse health effects from new construction or renovations. Just as often, tests result in conclusions that the air quality is fine. Standard measured levels of this or that factor can provide misleading information and conclusions because they are based on research on isolated substances and often on minimum safety levels for protection of adult males over an eight hour work day. The failure may be (1) not taking into account a more sensitive population (children, or individuals with environmental sensitivities) or (2) not looking at the combined or synergistic effects of temperature, humidity, bioaerosols, VOCs, and other factors of indoor environment quality.

SOURCE CONTROL and GOOD DESIGN, CONSTRUCTION, OPERATION AND MAINTENANCE will more surely result in better Indoor Air Quality when the project is finished.
It is wise to include PERIODIC ASSESSMENT throughout the design & building phases so as not to have too many surprises at the end when making corrections would be costly. Humans being human, the temptation at that point would be to let things "slide" by.

What to do when reduction of emissions from new building materials is needed? In cases where least toxic options still have some emissions, a FLUSH OUT is the currently recommended procedure:

FLUSH OUT PROCEDURE:

(1) Remove all porous materials such as furniture, books, paper, fabrics, etc. Otherwise, the chemicals driven off may be absorbed by these materials to be gassed off later, defeating the purpose.

(2) Increase the ventilation throughout the area with the use of fans, open windows &/or turning the in-house ventilation system on high. Include increased exhaust ventilation to the outdoors so as to eliminate the pollution from the area. (Be sure the air intakes, other windows, do not draw the pollution back inside.

(3) Gradually increase the heat to a maximum of 35 degrees C. Ventilation is more important than heat, but heat will help if it can be achieved. Don't sacrifice the ventilation for heat. (Also, in a new construction, heating up or heating up too quickly can cause uneven drying and cracks or other damage to some new materials.)

(4) Maintain the flushout for as long as possible or necessary - usually a minimum of 24 hours, but sometimes as long as several months, depending on the materials being offgassed and the amount being offgassed. Some experts recommend that after completing the aggressive flushout, a high ventilation rate should be maintained for at least a year.

- Citizens for A Safe Learning Environment

APPENDIX C

HEALTH, LEARNING AND INDOOR AIR QUALITY

There is an ongoing effort to prevent or remove unnecessary indoor air pollution from new schools for the benefit of our province's young citizens - arguably our most valuable resource.
For example, glued wood products that use phenol formaldehyde have been an improvement over the use of urea formaldehyde glues, and finishes have been developed that do not contain isocyanates in a harmful form, if at all.

Pollutants are generally removed from the air by sorption, filtration, by being flushed away by air passing through the area, or by being breathed in by building occupants whose bodies must deal with these foreign substances one way or another. Health effects are quite clearly known for some pollutants, and not so clearly known for most, however, these molecules that enter the body, are either removed by the body's detoxification processes or are stored in the body tissues. Some do damage to the body as they pass through. All use up vitamins, minerals and body energy to process, and some, like lead or endocrine disruptors, mimic materials the body wants to keep, and can do serious damage. They are accepted as building blocks of the body. Some are stored temporarily and are thrown off later to do damage a second time as they are processed for elimination. Each molecule of foreign substance receives attention of some kind from the body it enters. More medical scientists are now recognizing that it is best to avoid taking these foreign molecules into the body at all, whether it be by inhalation, ingestion or by skin contact. Links to cancers and birth defects indicate the wisdom of taking precautions to limit chemical exposures.
Low levels of numerous chemicals in a space can combine to produce a sizeable exposure to a "soup" of chemicals which, when combined, can produce unknown health effects. Children, who have long lives ahead of them living in a world that invents more than 50 thousand new chemicals each year, need protection from potential long term as well as short term consequences.

"Some general principles should be considered when conducting or evaluating research on the effects of environmental exposures, said Linda S. Birnbaum, director of EPA's Experimental Toxicology Division. 'Environmental chemicals can cause a broad spectrum of effects, which depend not only on the route of exposure and dose but on the susceptibility of the exposed individual,' she said. For example, age, gender, and genotype can determine whether an exposure causes a problem.
'Even though the research is complicated and much is not known, some results are quite clear.' Birnbaum said. 'By using biomarkers to measure exposure and effect, as well as studies of some unfortunate poisoning episodes, we do know the effects of some environmental exposures,' she observed, 'just as in pharmaceutical research, animal studies give us much of our knowledge. When a particular environmental toxicant causes multiple effects in multiple species, people are highly likely to be susceptible."
University of California, San Francisco, and the Collaborative on Health & the Environment (CHE) cross-disciplinary conference, January, 2007.

"Health symptoms of chemical exposure such as headaches, breathing problems, itchy and watery nose and eyes, intestinal problems, fatigue, and coughing are often misdiagnosed as colds and flu. Behavioral symptoms of chemical exposure such as mood swings, aggressiveness, and hyperactivity are often seen as normal."
Dr. Gerald Ross, Past President the American Academy of Environmental Medicine.

"Chemicals have replaced bacteria and viruses as the main threat to health. The diseases we are beginning to see as the major causes of death in the latter part of this century and into the 21st century are diseases of chemical origin."
Dr. Dick Irwin, Toxicologist, Texas A&M University

We do not know how many children are affected by poor school ventilation and toxic exposure, but as Health Canada's ISSUES paper on environmental sensitivities states, "Prevention is the most important and simplest aspect of this problem."

Scientists such as those connected to the NRC, US EPA and Europe are beginning to make this topic a priority. Nova Scotia's school construction is applauded widely for being ahead of most regions in North America in our creation of healthier buildings for our school children. Standards are still hard to set, so in the meantime we attempt to use residential standards where possible and strive for source control combined with good ventilation to create the healthiest indoor air we can for our children.

APPENDIX D

TECHNOLOGY SUMMARIES

In an effort to increase benefits to all CELL division members, including those who are not able to attend the national meeting we will feature Technology Summaries in the division newsletters. These summaries are written by experts in their respective fields and are intended to be a brief overview of the state-of-the-art in a specific topical area. If you have specific technical areas that you would like to see reviewed or if you are willing to write a brief technology summary please contact Tor P. Schultz, Forest Products Lab, Mississippi State University, Mississippi State, MS 39762-9820, Phone (601) 325-3136. E-mail: schultz@fpl.msstate.edu.

Two reviewers are given; both are in the area of air emissions and possible environmental problems:

VOLATILE ORGANIC CHEMICAL EMISSIONS FROM COMPOSITE WOOD PRODUCTS: A REVIEW

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INTRODUCTION

Over the past several decades, air quality in homes and office buildings has become a matter of increasing concern. Most people spend 80 to 90 percent of their time indoors, where chemical concentrations are usually significantly higher than outdoors. This problem was exacerbated as a result of the energy crisis in the 1970s, when homeowners and builders worked to increase the energy efficiency of their buildings by decreasing air exchange rates. Decreased exchange rates permit volatile organic chemicals (VOCs) emitted by building materials, furnishings, and occupant activities to accumulate to detectable and possibly harmful concentrations. Adverse health effects associated with increased VOC concentrations include eye and respiratory irritation (including asthma), irritability, inability to concentrate, and sleepiness. Trätek, the Swedish Institute of Wood Technology Research, estimates that 7 to 10 percent of the Swedish population has suffered ill health as a direct result of poor indoor air quality, caused in part by VOCs emitted by building materials and furnishings.

A result of increased emphasis on indoor air quality is the need for accurate information regarding the amounts and types of VOCs that are emitted from building materials, furnishings, cleaning products, and other materials found or used in the indoor environment. This information is needed not only by building occupants, but also by product manufacturers, building designers and contractors, and regulatory and public health agencies. Product manufacturers are increasingly advertising "low VOC" materials or materials suitable for use by people with chemical sensitivities. Outperforming a competing product on indoor air tests may impart a significant competitive advantage. Building designers and contractors are now being asked to certify that new buildings will meet standard indoor air quality requirements. They need emissions information to make decisions on which materials will best meet those requirements while fulfilling structural and aesthetic needs.

The Washington State East Campus Plus project provides an example of how these requirements affect planning. During the design and construction of four state office buildings, indoor air quality specifications were established that limited VOC emissions from building materials and furnishings. To be sure of meeting the emissions specifications, many of the building and furnishing materials had to be tested for VOC emissions prior to installation. For example, office furniture systems were required to emit no more than 0.05 ppm formaldehyde and 0.50 ppm total VOCs to be considered for installation.

In the United States no federal regulations govern VOC concentration in indoor air. However, regulatory agencies such as the Environmental Protection Agency (EPA) and the Occupational Safety and Health Administration have shown interest in ensuring that people are not adversely affected by the indoor air in their homes and offices. Development of indoor air VOC standards by these agencies is complicated by several factors: correlations between product test methods and indoor concentrations are not straightforward; many VOCs are a result of occupant activities, including smoking, use of cleaning products or perfumes, and cooking; and the detection of specific VOCs at low concentrations does not indicate whether they will have long-term negative health effects.

Composite wood products such as particleboard, plywood, and medium density fiberboard (MDF) are widely used in indoor products such as subflooring, door cores, cabinets, paneling, and furniture. In 1994, combined shipments of particleboard and MDF were almost 5.4×10^{6} square meters (19 mm basis).[1] With the broad use of wood products in modern homes and offices, there are concerns that emissions from these products could have a significant impact on indoor air quality.

WOOD PRODUCTS AND FORMALDEHYDE

Most composite wood products are fairly simple combinations of wood and water-based adhesives, which are composed of either urea-formaldehyde (UF) or phenol-formaldehyde (PF) resin, inorganic components that act as catalysts, and other minor components such as wax. Plywood products may also contain fillers and extenders such as hydrolyzed corn cobs, wheat flour, or nut shell flour. A small number of products are bonded with polymeric methylene diisocyanate, but these products are for specialized purposes. Emissions of VOCs potentially can arise from each of the materials that compose the panels, but attention until recently has been on emissions of formaldehyde from UF resins used to bind the particleboard and MDF. During the 1970s and 1980s concern focused primarily on formaldehyde emissions from particleboard and hardwood plywood bonded with UF resins. These concerns led to regulations[3] and standards[4] in the United States that restricted the amount of formaldehyde that could be emitted from a product. The Department of Housing and Urban Development (HUD) regulations for materials used in mobile homes limit emissions to 0.3 ppm, and the American National Standards Institute (ANSI) standards for particleboard flooring products restrict formaldehyde gas emissions to 0.2 ppm as measured in the American Society for Testing and Materials (ASTM) large chamber test. All other materials must emit less than 0.3 ppm to meet the ANSI standard. Regulations in Europe are generally based on the amount of free formaldehyde in a product rather than the actual emmissions from the product, because it is presumed that the free formaldehyde would be emitted later. The German standard is currently the most stringent and sets the allowable level of formaldehyde at 6.5 mg/100g of dry board for particleboard and 7.0mg/100g of dry board for MDF, with the goal of achieving no more than 0.1 ppm formaldehyde in a steady state climate chamber test.

The principal method used to decrease formaldehyde emissions from particleboard is a change in resin formulation. The UF resin formulations in 1980 generally had formaldehyde-to-urea ratios (F/U) of 1.4 to 1.6. Today the ratios range from 1.05 to 1.2, which is generally achieved by separate additions of urea during the resin cook. A decrease in F/U ratio in the resin from 1.5 to 1.1 yields approximately a 10-fold decrease in free formaldehyde in the panel.[1] Between 1980 and 1985, U.S. industry saw an average 80-percent drop in initial formaldehyde emission rates from particleboard.[1] However, further decreases in F/U ratio will not likely be attained without unduly sacrificing mechanical performance of the bonded panel product. To further decrease emissions, other changes in resin formulation and application have been developed. In the United States, the principal methods of decreasing emissions include the use of a formaldehyde scavenger, such as urea solution, or the use of a high F/U resin mixed with a low F/U resin shortly before addition to the particleboard furnish. The use of melamine-urea-formaldehyde (MUF) resins to decrease formaldehyde emissions has largely been limited to European manufacturers. Although the addition of melamine increases the cost of producing panels, U.S. manufacturers are beginning to consider the use of MUF resins in order to meet the more stringent European formaldehyde regulations.

Use of other resin systems that do not emit as much or any formaldehyde, such as phenol-formaldehyde (PF) or polymeric methylene diisocyanate (pMDI), is limited for several reasons. Both PF and pMDI resins are considerably more expensive than UF resin; PF is dark colored; phenol supplies are not great enough to match the demand if UF resins were replaced by PF; pMDI has a tendency to adhere to press platens during manufacture; and there are concerns about worker health when using an isocyanate.

A pilot study was recently conducted by the EPA, with funding from the National Particleboard Association, to evaluate the contribution of UF-bonded building products to fomaldehyde concentrations in a newly constructed, single-family, two-story, unoccupied house that contained UF-bonded building materials with known emissions characteristics.[1] The reachers found levels within the house were between 0.02 and 0.06 ppm, well below the World Health Organization (WHO) recommendation of 0.1 ppm. These levels were much lower than the researchers expectations, which were based on commonly used EPA indoor air quality models. One possible reason for the lower than predicted indoor air concentrations in the house is the adsorption of formaldehyde by other materials in the room, most notably the painted gypsum wallboard. Whether EPA will conduct further research on the emissions of formaldehyde in a test home under this program is still unclear.

OTHER CHEMICAL EMISSIONS FROM WOOD PRODUCTS

Recently, interest has turned to other VOCs that may be emitted from wood products. For the wood industry, the "wake up call" came in 1992 when Radian Corporation, under an EPA contract, developed and circulated a draft Wood Products chapter to an *Indoor Air Pollutant Source Catalog*. This draft contained a significant amount of incorrect and misleading information about chemical emissions from wood products, including the assertion that "of the wood products, the natural wood products probably have the lowest emission potential." The authors of the chapter acknowledged that no studies were identified that measured emissions from natural wood, so this assertion was not based upon research data. Information that particularly concerned the wood industry included the listing of benzene, methylene chloride, toluene, and xylenes as either constituents of or emissions from particleboard. These chemicals are not components of either PF or UF adhesives and have not been shown to be constituents of wood itself. The studies from which these data were taken[1,8] were not specifically designed to evaluate chemical emissions from wood. They studied only one or two pieces of particleboard – not a wide range of products. Thus, it is impossible to say that these data are representative of the entire industry.

The *Indoor Air Pollutant Source Catalog* episode led the wood industry and other wood researchers to the realization that accurate, up-to-date information about wood product emissions was needed. Without such information, wood products could potentially lose market share to other building and furnishing materials whose chemical emissions have already been well documented or are presumed to be very low, as in the case of steel.

Whereas the concerns about formaldehyde focused almost exclusively on the contributions from the adhesive resins, non-formaldehyde VOC emission may arise from any component of the wood composite. A wide variety of VOCs have been found to be emitted from composite wood products, and many of these VOCs are natural components of the wood. Following are brief descriptions of some recent and ongoing studies on emissions from wood products. It should be noted that the types and quantities of VOCs may be significantly impacted by the test method; test conditions, such as ventilation rate, temperature, air velocity, and relative humidity; wood species; adhesive type; and sample handling prior to testing. The wide varability in the data shows how these factors may affect the resulting data and contributes to the still contentious nature of the debate concerning VOC emssions from wood products.

RECENT RESEARCH ON VOCS FROM WOOD PRODUCTS

The first published study [10] that included a variety of wood products, including lumber, was completed by researchers in Sweden. Hardboard, plywood, MDF, lumber, particleboard, sawdust, and coated particleboard were included in this study. The researchers quantified total VOCs, the higher aldehydes, terpenes, and formaldehyde. The sample with the highest total VOC emissions was freshly planed pine lumber, followed by 2-week-old particleboard, then sawdust. For lumber, total VOC emissions were 920 $\mu g/m^3$, with 81 percent of the VOC emissions attributed to terpenes, which are naturally occuring components of the wood; only 1 percent of the emissions were higher aldehydes, mainly hexanal. However, for the particleboard and sawdust, the total VOCs were 430_and 190_$\mu g/m^3$, respectively, terpenes contributed 22 and 20 percent, and aldehydes made up 32 and 27 percent of the emissions. With the exception of formaldehyde, individual aldehydes were not identified or quantified. The fact that this change in distribution occurred both in the particleboard, containing UF resin, and the sawdust indicates that the wood itself is responsible for the emission of the aldehydes. As these high concentrations of aldehydes have not been shown to be present in raw wood, it is proposed that their occurrence in particleboard and sawdust is the result of thermal degradation of the wood components during drying and pressing.

More recently, the North American particleboard trade associations, the National Particleboard Association (NPA) in the United States and the Canadian Particleboard Association (CPA) in Canada, have made significant commitments of money and time to ensure accurate and complete research on their members' products. To that end, the NPA provided funding to GEOMET Technologies, Georgia Tech Research Institute (GTRI), and the USDA-FS Forest Products Laboratory (FPL) for several studies on VOC emissions from unfinished and finished particleboard and MDF samples produced in the United States. The CPA has cooperated with and provided funding to scientists at Forintek to investigate emissions from particleboard, MDF, and coated wood products produced by Canadian manufacturers.

Most of the NPA- and CPA-funded studies used small environmental chambers as described in ASTM D5116-90[11] to enclose the samples during testing. Many other parameters such as chamber loading, air flow, and sample handling were similar to allow for comparison of results among studies. A synopsis of the types of emissions found in studies conducted at GEOMET[13] and Forintek[14] is presented in Table 1.

In the GEOMET study, concentrations of total VOCs ranged from 196 to 2599_$\mu g/m^3$ for uncoated samples and from 187 _ to 2520 _ $\mu g/m^3$ for coated samples. The major contributors to the VOC concentrations were acetone, hexanal, and fomaldehyde. On average, the concentrations of VOCs from the coated samples were about 40-percent lower than emissions from the uncoated samples, indicating that coating the samples with high-pressure laminates, melamine-saturated paper, or low-basis-weight paper may provide a means of decreasing VOC emission rates. Samples in this study containing a vinyl overlay were inconsistent, so the VOC mitigating effect of this type of coating cannot be assessed. A significant concern with the data from this study is that among the uncoated samples. α– and β –pinene were identified in the emissions from hardwood samples but not in either the Southern Pine or the western fir. None of the coated particleboard samples exhibited pinenes although all of these samples used Southern Pine as a substrate.

The Forintek study of CPA samples found that total VOC emissions from unfinished particleboard and MDF ranged from 0.23 to 23.45_$\mu g/m^3$, while emissions from coated samples ranged from 0_to 2.56_$\mu g/m^3$. Surface coatings in this study included low-pressure melamine and vinyl overlays. Emissions from the coated samples averaged less than 15 percent of the emissions from the uncoated samples. It is striking how much lower the concentrations of VOCs in this study were than in the GEOMET study, although both were done using very similar experimental methods. There are several possible explanations for these differences: (1) it is not clear in the studies how old the samples were before they were put into the test chambers, so the difference in emission concentrations could be due to sample age; (2) the species were not identified for the samples in the Forintek study, and it is likely that different species will have significantly different VOC emissions; (3) the Forintek study reports the total VOC expressed as α– pinene, but since mass special response for different compounds can vary greatly,this method may lead to erroneous results; and (4) the Forintek study did not report either formaldehyde or acetone, both of which were present in significant amounts in the GEOMET study. These differences point out the importance of experimental planning and sample handling to obtain results that are reproducible and comparable to the work of others.

Another study that was funded by NPA is worth noting. In 1993, NPA submitted samples of uncoated particleboard and particleboard with oak veneer to GTRI for VOC evaluation. This study did not target specific compounds as the GEOMET and Forintek studies did but rather attempted to identify all compounds that were emitted. In 23 different measurements, including some duplicates, almost 180 different compounds were found. Compounds that were present in high concentrations included acetone, akdehydes (benzaldehyde, hexanal, nonanal, octanal, pentanal), halogenated hydrocarbons, hydrocarbons, and terpenes (pinenes, 3-carene, camphene, thujone, and others). Contamination was a concern in this study because every sample contained chlorofluorocarbons (CFCs); the most notable was trichlorofluoromethane, which was emitted from every sample at an average of 218 µg/m³. Because blank samples of air from the chambers showed no traces of these hydrocarbons and samples were handled in the same manner as they had been in the GEOMET study, there is no explanation of the source of these chemicals in the wood samples. No studies in the published literature identify CFCs in natural wood, composite wood products, or the components used to manufacture wood products.

The EPA has funded research at Research Triangle Institute (RTI) to find methods of pollution prevention from composite wood products. In the first step, researchers evaluated emissions from several coated wood products. In this round, particleboard with oak veneer overlay and sealer and topcoat emitted the highest concentrations of VOCs. Further testing was conducted on individual components of the panel. The particleboard, before application of veneer, sealer, or topcoat, gave concentrations of nearly 1600 µg/m³, with about 70 percent of the emissions being either ketones or aldehydes. The veneer itself emitted very little, and only moderate emissions came from the particleboard with veneer applied before the addition of sealer or topcoat. However, the addition of sealer brought emissions up to the level of the unfinished particleboard. Putting the topcoat over the sealer increased the emissions even further. In the sealed and coated samples, the increase in emissions was principally due to an increase in the presence of alcohols, including 1-pentanol, 2-methoxy-1-butanol, 1-butanol, and 2-(2-butoxyethoxy)ethanol. Emissions of aldehydes and ketones from the sealed and topcoated samples were about 65 percent of those found in the unfinished particleboard. The next step in the RTI study is to investigate emissions from panels made with non-traditional substrates and adhesives. Alternative panels that are scheduled to be tested include straw with a pMDI binder, recycled newspaper with no binder, and lumber and plywood residuals with either a phenol-formaldehyde or a pMDI binder.

Research conducted at Trätek, the Swedish Institute for Wood Technology, was aimed at identifying chemical emissions from the wood itself, before any adhesive or binder was added.[11] The researchers obtained samples of pine, spruce, oak, birch, and beech at the time the trees were felled and ensured careful handling of the green wood samples prior to testing. Planks were cut from the tree samples and the VOCs were measured from the green wood. The wood was then dried in a climate chamber under conditions similar to those used in a commercial dry kiln. Measurements of VOCs were taken after the wood had been dried to 18-percent moisture content (MC) and after further drying to between 8- and 10-percent MC. The pine and spruce samples emitted terpenes almost exclusively, although at 18-percent MC the pine also showed significant emissions of hexanal. Emissions from the beech samples were dominated by aldehydes, including pentanal, hexanal, and heptanal, ethanol, and acetic acid, with almost no terpenes. Emissions of all compounds appeared to peak when the moisture content was near 18 percent, but were lower in both green wood and wood with MC less than 18 percent. The researchers noted that sorbent compounds used to collect emissions for analysis yield nonanal, decanal, and benzaldehyde upon decomposition. therefore, definitive data on the presence or absence of these compounds is not available. The data for oak and birch samples indicate that further research is needed to fully identify types and quantities of chemicals emitted.

ON-GOING STUDIES

Currently, the CPA and NPA have studies that are nearly complete at both Forintek and FPL. In the Forintek study 27 Samples of raw and coated particleboard were investigated. Samples were collected at mills at different times of the year to evaluate the effect of manufacturing conditions on ultimate VOC emmission rates. At FPL, small chamber tests were used to evaluate emissions from the unfinished products of 55 mills that produce particleboard and MDF in the United States. Emissions were sampled over a period of 4 days to estimate the rate of emission decay. The results From this research are being analyzed and will be published shortly.

Two studies of building and furnishing materials, including pressed wood products, are just being started in Canada and are worth noting for completeness and for future reference. In the first, the Canadian Task Force on Material Emissions and the Saskatchewan Research Council are conducting round-robin testing of a variety of building materials utilizing numerous testing laboratories in North America The principal objective of this study is to determine the consistency of data from dynamic chamber testing when the testing occurs in different laboratories. The second study, being conducted at the National Research Council of Canada, hopes to develop standard small and large chamber test methods for building materials and furnishings; develop a database of material emission characteristics and develop models to predict concentrations of VOCs in rooms based on room conditions and the emissions characteristics of materials within the rooms. This work is being supported by a consortium of interested parties including the EPA, the Canadian Wood Council, USG Corporation, the U.S. National institute for Standards and Technology, the Canada Mortgage and Housing Corporation, and others.

CONCLUSIONS

The composite wood industry has been wrestling with the issue of chemical emissions from its products since formaldehyde became a concern in the 1970s. While concerns about formaldehyde emissions have resulted in significant changes in products to reduce the emissions of this chemical, new concerns about other chemicals from wood products have recently surfaced. Although these are no government regulations for non-formaldehyde VOCs, the public, building owners and designers, and regulatory agencies are showing increasing interest in ensuring that building materials, including wood products, do not adversely affect indoor air quality. Current and ongoing research has been aimed at determining the extent to which wood products may affect indoor air, determining ways in which emissions from wood products may be mitigated, and developing databases to allow for prediction of indoor air concentrations of VOCs. The coming years will surely see considerably more research in this important area.

Table 1: Percentage of samples containing the chemical compound in the GEOMET and Forintek studies.[1]

Compound	GEOMET Uncoated	GEOMET Coated	Forintek Uncoated	Forintek Coated
Formaldehyde	100	100	*	*
Acetaldehyde	75	100	–**	–
Acetone	88	100	–	–
Benzaldehyde	100	10	–	–
Benzene	–	–	–	–
Borneol	75	–	–	–
Camphene	12	–	40	10
3-Carene	*	*	33	10
p-Cymene	38	–	33	10
Ethyl acetate	*	*	–	–
Ethylbenzene	–	20	13	–
Heptanal	88	50	–	–
Heptane	ND	30	–	–
1-Heptanol	75	–	–	–
2-Heptanone	50	–	–	–
3-Heptanone	*	*	13	–
Hexanal	100	90	60	–
Limonene	25	–	47	10
Nonanal	88	30	7	–
Octanal	88	30	–	–
t-2-Octanol	88	20	–	–
Pentanal	88	70	–	–
Pentane	–	–	–	–
1-Pentanol	75	30	–	–
a-Pinene	25	–	100	90
b-Pinene	12	–	47	30
Toluene	–	–	60	40
Phenol	–	50	*	*
Xylenes	–	60	60	40

[1] There were 8 uncoated and 10 coated samples in the GEOMET study, and 15 uncoated and 10 coated in the Forintek study.

* Not one of the target compounds for this study.

** Not detected in this study.

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APPENDIX E

Health Canada / Santé Canada

Healthy Environments and Consumer Safety / Santé environnementale et sécurité des consommateurs

Health Canada's Residential Indoor Air Quality Guideline for Formaldehyde

Canada

HECS - SESC

Outline

- Introduction
- Sources
- Concentrations
- Health effects
  - Acute effects
  - Chronic effects other than cancer
  - Cancer
- The new guideline

HECS - SESC

What is formaldehyde?

- A gas at room temperature
- Chemical formula: $CH_2=O$
- Reactive
- Irritant

HECS - SESC

Exposure Guidelines for Residential Indoor Air Quality

- Developed by the former Federal-Provincial Advisory Committee on Environmental and Occupational Health (CEOH)
- Issued in 1987
- For formaldehyde:
  - Action level: 0.10 ppm ~ 120 µg/m^3
  - Target level: 0.05 ppm ~ 60 µg/m^3

HECS - SESC

Why is Health Canada revising IAQ Guidelines?

- Several epidemiological and toxicological studies published since 1987
- Post-1980 epidemiologic studies generally stronger than pervious studies with respect to exposure assessment
- Formaldehyde declared "toxic" under the Canadian Environmental Protection Act (CEPA) in 2001

HECS - SESC

Sources of Formaldehyde in Indoor Environments

- Combustion
  - Fireplaces and woodstoves
  - Tobacco smoker
- Off-gassing
  - Wood-based products: plywood, particle board, medium-density fiberboard (MDF)
  - Paints and varnishes
  - Off-gassing decreases over time!

HECS - SESC

Formaldehyde Concentrations in Canadian Homes

- Few recent studies
- Small sample size
- Concentrations: 2.5 to 107 µg/m³ (0.002-0.087 ppm)
- Mean:
  - Smoking homes: 30-40 µg/m³ (0.024-0.033 ppm)
  - Smoke-free homes: 22-30 µg/m³ (0.018-0.024 ppm)

HECS - SESC

The Québec City Study

- Conducted jointly by Health Canada and the Institut national de santé publique du Québec (INSPQ)
- 96 houses sampled in the Winter 2005
- Concentrations ranged from 10 to 90 µg/m³ (0.008 to 0.073 ppm)
- Formaldehyde negatively correlated with air change rate
- Higher concentrations in homes with:
  - New wooden or melamine furniture
  - Recent painting or varnishing
  - Electrical main heating system

HECS - SESC

Health Effects: acute and subchronic toxicity

- Models: rodents
- Inhalation toxicity studies
  - Acute: generally 6 hours/day for <1 week
  - Subchronic: generally 6 hours/day for 1-6 week
- Effects: lesions in the nasal cavity
- Threshold generally independent form exposure duration
  - NOAEL: 1.2 mg/m³ (1 ppm)
  - LOAEL: 3.7 mg/m³ (3 ppm)

HECS - SESC

Health Effects: acute and subchronic toxicity (continued)

- Mice exposed to 0 or 2 mg/m³ 6 d/w for 10 days or 7 weeks and then sensitized to ovalbumin (Tarkowski and Gorski 1995)
  - ➢ Anti-ovalbumin IgE antibodies significantly increased in mice exposed for 10 weeks
- Guinea pigs exposed to 0, 160 or 310 µg/m³ for 5 days and then sensitized by inhalation to ovalbumin (Riedel et al. 1996)
  - ➢ Bronchial obstruction in 10/12 animals exposed to 310 µg/m³ vs 3/12 controls ($p<0.01$)

HECS - SESC

Health Effects: Chronic Toxicity

- Two major studies in rats and mice (Kerns et al. 1983; Monticello et al. 1996)
- Chronic exposure: 6 hours per day, 5 days per week for 2 years
- Large number of animals: 90 to 150 per exposure level
- No tumour of the nasal cavity at concentrations up to 2.4 mg/m³ (2 ppm)
- Increased incidence of carcinomas of the nasal cavity at levels of 6.7 mg/m³ (5.4 ppm) or over

HECS - SESC

Health Effects: Chronic Toxicity (continued)

- Mechanisms of carcinogenicity not entirely elucidated
- Regenerative proliferation following cytotoxicity appears to be an obligatory intermediate step
- Dose–response relationship modelled by CIIT on based on the Monticello et al. (1996) study and morphological and physiological differences between animal models and humans.
- Cancer risk associated with an 80-year exposure to levels between 1.23 and 123 µg/m³ (0.001 to 0.1 ppm): $< 2.7 \times 10^{-8}$ in non-smokers

Controlled exposure in humans

- Several studies
- In most study, one formaldehyde concentration (generally between 2 and 4 mg/m³, or 1-3 ppm) compared to a control exposure
- Only one study (Kulle 1993) included several exposure levels
  - NOAEL: 615 µg/m³ (0.5 ppm)
  - LOAEL: 1,230 µg/m³ (1 ppm)

Epidemiologic studies: non-cancer effects

- Several studies showed respiratory and allergic effects at levels generally lower than 123 µg/m³ (0.1 ppm)
  - Decreased lung function (Krzyzanowski et al. 1990)
  - Respiratory symptoms (Norback et al. 1995)
  - Asthma diagnosis (Smedje et al. 1997; Smedje and Norback 2001)
  - Asthma-related emergency visits (Rumchev et al. 2002)
  - Allergic sensitization (Wantke et al. 1996; Garrett et al. 1999)
  - Inflammation (Franklin et al. 2000; Norback et al. 2000)

Epidemiologic studies: non-cancer effects (continued)

- Only one study (Rumchev et al. 2002) analyzed in a way that enables to characterize exposure-response relationships
- Case-control study of asthma-related emergency visits in children aged 6 to 36 months

Formaldehyde	OR	IC 95%
<10 µg/m³	1.00	
10-29 µg/m³	0.98	0.82 – 1.10
30-49 µg/m³	0.99	0.78 – 1.21
50-59 µg/m³	1.22	0.89 – 1.62
>= 60 µg/m³	1.39	1.09 – 1.69

Epidemiologic Studies: Cancer

- Several cohort and case-control studies showed an association between occupational exposure to formaldehyde and sinonasal an nasopharyngeal cancer Very rare cancer types
- High exposure levels (non-exposed defined as <300 or <600 µg/m³)
- Simultaneous exposure to other carcinogens (e.g., wood dust) → synergism?

Summary of Effects

- Acute effects: irritation of eyes, nose and throat
  - Demonstrated in humans
  - Threshold: 615 – 1,230 µg/m³ (0.5 to 1.0 ppm)
- Chronic effects: allergic sensitization and respiratory symptoms
  - Association in humans (NOAEL: 40-60 µg/m³ or 0.03-0.05 ppm)
  - Biologically plausible

Summary of Effects (continued)

- Cancer
  - Associations in workers occupationally exposed
  - Demonstrated in animals – biologically plausible in humans
  - Non-linear dose-response relationship
  - Risk appears to be negligible at concentrations found in Canadian homes

HECS - SESC

Residential Indoor Air Quality Guideline for Formaldehyde

Exposure period	Concentration in µg/m³	Concentration in ppm	Critical effect
1 hour	123	0.10	Eye irritation
8 hours	50	0.04	Respiratory symptoms in children

HECS - SESC

For more information

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APPENDIX F

EQ Credit 4.4: Low-Emitting Materials: Composite Wood & Agrifiber Products
1 Point

Intent

Reduce the quantity of indoor air contaminants that are odorous, irritating and/or harmful to the comfort and well-being of installers and occupants.

Requirements

OPTION 1

Composite wood and agrifiber products used on the interior of the building (defined as inside of the weatherproofing system) shall contain no added urea-formaldehyde resins. Laminating adhesives used to fabricate on-site and shop-applied composite wood and agrifiber assemblies shall contain no added urea-formaldehyde resins.

OPTION 2

All composite wood and agrifiber products installed in the building interior shall meet the testing and product requirements of the California Department of Health Services *Standard Practice for The Testing Of Volatile Organic Emissions From Various Sources Using Small-Scale Environmental Chambers*, including 2004 Addenda, which can be found at:

www.dhs.ca.gov/iaq/VOCS/Section01350_7_15_2004_final_plus_addendum-2004-01.pdf

Composite wood and agrifiber products are defined as: particleboard, medium density fiberboard (MDF), plywood, wheatboard, strawboard, panel substrates and door cores. Materials considered furniture and fixtures, are not considered base building elements and are not included.

Potential Technologies & Strategies

Specify wood and agrifiber products that contain no added urea-formaldehyde resins. Specify laminating adhesives for field and shop applied assemblies that contain no added urea-formaldehyde resins.

ID Credit 1 Option: Low-Emitting Furniture & Furnishings

Intent

Reduce the quantity of indoor air contaminants that are odorous, potentially irritating and/or harmful to the comfort and well-being of installers and occupants.

Requirements

All systems furniture and seating* introduced into the project space that has been manufactured, refurbished or refinished within one year prior to occupancy must meet one of the requirements below.

Option A: Greenguard Indoor Air Quality Certified

OR

Option B: Calculated indoor air concentrations that are less than or equal to those established in Table 1 for furniture systems and seating determined by a procedure based on the U.S. Environmental Protection Agency's Environmental Technology Verification (ETV) Large Chamber Test Protocol for Measuring Emissions of VOCs and Aldehydes (September 1999) testing protocol conducted in an independent air quality testing laboratory.

Table 1. Indoor Air Concentrations

Chemical Contaminant	Emission Limits Systems Furniture	Emission Limits Seating
TVOC	0.5 mg/m^3	0.25 mg/m^3
Formaldehyde	50 parts per billion	25 parts per billion
Total Aldehydes	100 parts per billion	50 parts per billion
4 - Phenylcyclohexene (4-PCH)	0.0065 mg/m^3	0.00325 mg/m^3

Systems furniture *is defined as either a panel-based workstation comprised of modular interconnecting panels, hang-on components and drawer/filing components or a freestanding grouping of furniture items and their components that have been designed to work in concert. Furniture other than systems furniture and task and guest chairs used with systems furniture is defined as* ***occasional furniture*** *and is excluded from the credit requirements.*

Seating *is defined as task and guest chairs used with systems furniture.* ***Salvaged and used furniture*** *that is more than one year old at time of occupancy is excluded from the credit requirements.*

Potential Technologies & Strategies

Specify Low-VOC materials in construction documents. Ensure that VOC limits are clearly stated in each section where furniture assemblies are addressed.

APPENDIX G

The Environmentally Responsible Construction and Renovation Handbook

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Chapter 3 - Indoor Air Quality and Materials Selection

The IAQ component of the Green Office Building Plan embodies the definition of acceptable indoor air quality from ASHRAE's draft revision to Standard 62. The goal is to design the office interior and ventilation system such that the occupants will be satisfied with the indoor air quality and such that there are not likely to be contaminants at concentrations leading to exposures that pose a significant health risk.

The provision of IAQ falls into two main categories;

- minimizing sources of pollutants within the office and
- providing adequate ventilation to ensure remaining pollutants are removed effectively.

Source control is always the first and most important step in mitigating contaminant levels and effects on office occupants. Ventilation strategies are then used to introduce fresh air into the space and carry out contaminants produced by both occupant activities and emissions from the materials within the building. Requirements for strategies to be used in construction, renovation, and commissioning are provided under a third section below.

The following list of requirements is a foundation for providing healthy, comfortable indoor air. For Renovation, Recapitalization and Fit-up projects, the Project Manager needs to discuss the viability of incorporating each of these measures into the design at an early stage in the Project Delivery System (PDS) as discussed in Part A of the GOBP.

3.1 Source Control

- **Basement moisture control** is required to be provided by moisture- and vapour-proof construction details on basement floors and walls and slab-on-grade floors. To prevent soil gases and moisture from entering the office building, details such as polyethylene sheeting under floor slabs and dimpled polyethylene or glass fibre or grooved polystyrene drainage layer on the walls shall be provided, where viable. Petroleum derivative water-proofing should not be used.
- **Eliminate off-gassing from finishes** that come in contact with indoor air. Water-based (latex) finishes and adhesives should be the products of choice. Where such categories exist, products that are certified by a recognized third party for their low concentrations of hazardous chemicals or that meet the certification criteria (NAFTA) should be chosen. The

Environmental Choice Program (products bearing the EcoLogo label) is one such body. Ecologo products available include paints, caulking and adhesives.

- **Specify materials with no/low formaldehyde, no/low VOCs,** and/or other chemical emissions for 85% of the total interior surfaces in the building (i.e., all ceilings coatings, walls coverings and paints and floor coverings). Partitions and wall coverings made from vinyl or plastics contain a wide range of VOCs and should be replaced by products with less off-gassing potential. A wide variety of alternatives exist including textured wall coverings made from cellulose, natural fibre wall coverings such as sisal, decorative acoustical wall paneling made from fibreboard and cork, and so on.
- **Carpeting** has the potential to off-gas a variety of chemicals used in manufacturing. If carpeting is to be used it must be labeled by the Carpet and Rug Institute (CRI) certification program as a low VOC-emitting carpet. This program ensures that the emissions of the most common chemicals used in carpet manufacture meet the criteria for low emissions.
- **Limit carpeting on floors:** Ideally Carpeting shall cover no more than 50% of the floor area, but this will not always be practical.
- **Adhesive** for affixing carpeting is to be "low-tox" or water-based. Conventional glues are very high in VOCs and off-gas for long periods of time.
- **Condensation on interior surfaces** shall be prevented by ensuring all surfaces are at a minimum temperature of 10° C (50° F). Any individual heat-flow path through the structure should have an RSI value of not less than 0.5 (R-3) in locations with a winter design temperatures of -20° C (-4° F) or higher and not less that RSI 0.7 (R-4) for locations with lower design temperatures. Areas of thermal bridging that need to be considered include window frames, steel studs, flashings, fasteners or other highly conductive building components that penetrate from near the interior to near the exterior of the structure.
- **Ensure fresh air is drawn from a clean location.** Do not locate intake louvers near areas that could be contaminated by such pollutant sources as building exhausts, vehicular exhausts, cooling tower spray, combustion gases, sanitary vents, trash storage, and other hazardous air contaminants.
- **Ozone-generating devices** including those claiming to be air purification devices shall not be used.

3.2 Ventilation System Design

- **Ensure ventilation air system design meets the requirements of ASHRAE 62.** The standard provides details on calculating minimum fresh air requirements for offices and allowances for mixed air from adjoining spaces. Documentation provided with the drawings and specifications shall clearly show the design intent and calculations to verify compliance with the standard.
- **Ventilation supply and exhaust grille performance design** (i.e., direction and throw) and locations shall be such as to avoid short circuiting of supply air directly into the return grille.
- **All outside air louvers and ducts (including economisers)** shall be designed to limit intake air velocities to exclude rainwater entry. For most manufacturers the maximum allowable face velocity is approximately 2.54 m/s (500 ft/min).
- **Air velocities through cooling coils and humidifiers** shall be specified to prevent wetting of downstream surfaces. For most coils the maximum face velocity would be 2.54 m/s (500 ft/min) or less.
- **No fibrous duct-liner or glass-fibre ducting** shall be used. These materials hold moisture, are propagation sites for moulds, mildew, and bacteria and allow loose fibres to be blown into the space. Use non-porous (e.g., closed-cell polyethylene) duct-liners, exterior insulation, or acoustical baffles in strategic locations in lieu of linings. Use only metal or other hard surface ductwork.
- **Ventilation exhaust air from kitchens, washrooms, smoking lounges, custodial closets, cleaning chemical storage areas, and dedicated**

printing/copying areas shall be vented directly to the outdoors with no recirculation through the HVAC system.

3.3 Indoor Air Quality During Construction and Commissioning

There are a number of construction practices which can be harmful to construction materials and adversely affect indoor air quality as a result. To guard against these practices the following measures should be taken at all renovation, recapitalization and fit-up sites:

- **Protect construction materials** (especially soft materials) from rain and other moisture sources.
- **Ensure construction materials such as concrete are dry** before they are covered with flooring or enclosed in wall cavities.
- **Control fibre and particle release during installation of insulation** and require thorough cleanup by this trade immediately after completion of this work.
- **Verify all materials arriving on site comply** with the environmental specifications and requirements under which they were purchased.
- **Commission heating, ventilating, and air-conditioning systems** to ensure that the design intention and specifications have been met, and proper amounts of fresh air are delivered to each zone.

Post testing can be used to determine that the indoor air quality is acceptable. Table 3.1 lists major pollutants generally found in offices along with guidelines for acceptable levels of those pollutants. The guidelines or standards are currently in force either in Canada, or in other jurisdictions where a Canadian recommendation does not exist.

Table 3.1 Acceptable Levels of Air-Borne Contaminants

Substance	Maximum Permissable/Recommended Level
Carbon Dioxide	1,000 ppm
Carbon Monoxide	11 ppm
Formaldehyde	0.1 ppm
Particulate	.04 mg/m^3 (<2.5 microns mass mean aerodynamic diameter)
Radon	2.7 pCi/L
Total VOCs	0.2 mg/m^3 with no individual VOC > 10% of TVOC
Nitrogen Dioxide	0.05 ppm
Sulphur Dioxide	0.019 ppm
Ozone	0.05 ppm
Microbials/Micro-organisms	45 CFU/ m^3 for a single species

3.4 Additional IAQ Improvement Opportunities

This section includes suggestions on additional measures which can be taken to improve indoor air quality above and beyond those considered essential to provide good IAQ.

3.4.1 Source Control

- **Eliminate trim made from manufactured wood (MDF) containing**

formaldehyde and plastic trim containing VOCs. Finger jointed paintable trim should be used if it cannot be verified that other materials are free of emissions.
- **Cabinets, desks and bookshelves** are usually made from particleboard using urea-formaldehyde as a binder and employ adhesives containing VOC for adhering laminates. Alternative substrates such as Medite II which contain no formaldehyde can be used for cores. Paneling for cabinetry etc. can have all surfaces coated with a high quality sealer to keep formaldehyde from off-gassing. Reconditioned furniture can be specified and aging will have reduced the off-gassing potential to a significant extent.

3.4.2 Ventilation System Design

1. **Design for a minimum total air movement of 5.1 L/s/m²** where conventional ceiling mounted diffusers and mixed air are used. Use diffused manufacturer's velocity and throw information to avoid stagnant air in occupied spaces. Other distribution systems such as displacement ventilation and systems that provide 100% ventilation air can provide good air distribution at significantly lower air movement
2. **Install displacement ventilation.** Displacement ventilation has a floor to ceiling airflow pattern. Supply air enters floor level at low velocity carries pollutants up out of the breathing space and removes stale air from near the ceiling.
3. **Isolate potential pollution sources** through separate zoning of areas where contaminants are generated (e.g., independently-ventilated, enclosed printing/copying area),
4. **Use high-efficiency filters (minimum 60% dust-spot efficiency)** in all make-up and return air ducting. If outdoor air has high dust levels, use higher efficiency filters (80% dust spot efficiency) and include pre-filters (30% dust spot efficiency).
5. **Design air handler and control sequence to provide modulation** up to 100% of air handler capacity in outdoor air as outdoor conditions warrant. This strategy is called an Economizer Cycle (see Section 5.6).
6. **Specify a night purge cycle** to purge the building when there are minimal comfort concerns and minimal energy penalty.
7. **Evaluate natural ventilation** through the use of operable windows. This can offer energy and functional advantages over mechanical ventilation. The potential for using natural ventilation in a building should be evaluated at the conceptual design phase. Considerations would also include pressurization and stack effects in buildings of six stories or higher. If appropriate the concept should be incorporated into the building design.

3.5 Case Studies of Office Building with High IAQ Standards

3.5.1 Steelcase Corporate Development Center

Description: The Steelcase Corporate Development Center (CDC) in Michigan was designed to encourage communication and creativity for 800 product-development professionals, and to help them create innovative office products, programs, and services in shorter time frames. The building, which was opened in 1989, is a seven-level pyramid-shaped building encompassing 55,740 m² (600,000 ft²), of which 58 percent is devoted to offices and public space, and 42 percent is used for laboratories and building support services. The purpose of the building, in addition to supporting team activities and fostering interaction, is to provide a productive environment in which 800 employees can work.

Features: The Steelcase CDC was designed to improve indoor air quality by controlling source emissions, proper ventilation, environmental control (temperature and humidity), and through proper maintenance. Source emissions of toxins were controlled by selecting non-toxic building materials, such as flooring, paints and finishes, and also by selecting office equipment that minimize toxin outputs when possible.

Ventilation contamination is controlled through 35 percent dust-stop efficiency pre-filters and 60 percent efficiency final filters. Large flow rates dilute any remaining contaminants thereby eliminating the use of expensive HEPA filters. The total air distribution was designed to be a minimum of 6.6 L/s per gross square metre of office (1.3cfm per gross square foot). The ventilation rate is up to 35 L/s per person of outdoor air (ASHRAE standard is 7.1 L/s). The 35 L/s represents an average air distribution for the entire building with the majority of air being distributed through the lab space with 100% outdoor air.

Both temperature and humidity are controlled for optimum comfort. The temperature is held constant at 23° C (77° C). The humidity is adjusted depending on the season to prevent accumulation of moisture that can be destructive to building materials, and can cause the formation of bacteria and mold.

A comprehensive computerized scheduling program of preventive maintenance for all building systems is used. Monthly inspections are made of key equipment; filters are checked monthly and replaced when required; and heating and cooling coils are cleaned annually. Proper housekeeping is essential in maintaining a dust and microorganisms free environment. Carpets are shampooed on a continuous basis with a complete cleaning cycle taking approximately two months. Carpet in high traffic areas is shampooed every other day and on an as-needed basis.

Results: The concentration of key toxins is significantly lower than prescribed by ASHRAE standard 62-89. Measured toxin concentrations with ASHRAE standard in brackets; carbon monoxide 0ppm (9ppm), carbon dioxide 531ppm (1000ppm), respirable suspended particulates 19 ug/m^3 (50 ug/m^3), and formaldehyde 0.021ppm (0.1ppm).

3.5.2 Ridgehaven Office Building

Description: The 73,000 ft^2 building originally built in 1981, which houses the City of San Diego Environmental Services Department (ESD), showcases effective energy efficient renovations at a reasonable cost. Healthy indoor air quality was a primary goal. The ESD wanted to avoid sick building syndrome and create a healthy building environment for all of its employees.

Features: Improved indoor air quality was achieved through careful material selection, a new mechanical system design, environmental construction methods, and a healthful building maintenance plan.

Environmental criteria for materials included selecting materials with minimal chemical emissions, and minimizing volatile organic compounds (VOC's) during installation. Additional considerations included building products that inhibit the growth of biological contaminants. Careful specification of low-VOC materials based on the environmental criteria included the Low-VOC Paints, Sealers, and Stains: met South Coast Air Quality Management District (SCAQMD) requirements for low-VOC coatings, and contained no formaldehyde, petroleum-based solvents or other toxins. Carpet tiles met State of Washington Indoor Air Quality Specification criteria for low-VOC product, backing had anti-microbial properties, and were installed with minimal use of low-VOC adhesive.

Linoleum sheet flooring consisted of natural material components with minimal VOC's and natural anti-microbial characteristics. Ceramic tile included glass and clay content, are inherently inert, and have no VOC emissions. Gypsum wallboard caused no VOC emissions. Steel framing is inherently inert with no VOC emissions

An entirely new mechanical system, ducting, and cooling tower were installed. The metal ducting was insulated on the exterior with a foil-faced batt to prevent man-made mineral fibers from becoming air-borne within the HVAC system. The new ventilation system was designed to the ASHRAE 62-89 standard.

Cleaning for occupant health and worker safety was the main priority for building maintenance. This included the use of non-toxic cleaning products that were water-based and contained minimal chemical emissions. In addition, a least-toxic pest control plan using no pesticides was also important in maintaining healthy indoor air quality.

Results: Approximately two weeks after occupancy, the building had no noticeable "new building" smell or odor that would typically be caused by chemical emissions from new materials and furnishings. Anecdotal evidence from chemically sensitive employees indicates a healthier indoor ecology for this green office building. The city experienced lower absenteeism and higher employee productivity in this healthy "green" building demonstration project.

areas. VOCs that frequently pollute indoor air are toluene, styrene, xylenes, and trichloroethylene. Some of these chemicals may be emitted from aerosol products, dry-cleaned clothing, paints, varnishes, glues, supplies, cleaners, spot removers, floor waxes, polishes, and air fresheners. The health effects of these chemicals are varied. Trichlorethylene has been linked to childhood leukemia. Exposure to toluene can put pregnant women at risk for having babies with neurologic problems, retarded growth, and developmental problems. Xylenes have been linked to birth defects. Styrene is a suspected endocrine disruptor, a chemical that can block or mimic hormones in humans or animals. EPA data reveal that methylene chloride, a common component of some paint strippers, adhesive removers, and specialized aerosol spray paints, causes cancer in animals [38]. Methylene chloride is also converted to CO in the body and can cause symptoms associated with CO exposure. Benzene, a known human carcinogen, is contained in tobacco smoke, stored fuels, and paint supplies. Perchloroethylene, a product uncommonly found in homes, but common to dry cleaners, can be a pollution source by off-gassing from newly cleaned clothing. Environmental Media Services [39] also notes that xylene, ketones, and aldehydes are used in aerosol products and air fresheners.

To lower levels of VOCs in the home, follow these steps:

- use all household products according to directions;
- provide good ventilation when using these products;
- properly dispose of partially full containers of old or unneeded chemicals;
- purchase limited quantities of products; and
- minimize exposure to emissions from products containing methylene chloride, benzene, and perchlorethylene.

A prominent VOC found in household products and construction products is formaldehyde. According to CPSC [40], these products include the glue or adhesive used in pressed wood products; preservatives in paints, coating, and cosmetics; coatings used for permanent-press quality in fabrics and draperies; and the finish on paper products and certain insulation materials. Formaldehyde is contained in urea-formaldehyde (UF) foam insulation installed in the wall cavities of homes as an energy conservation measure. Levels of formaldehyde increase soon after installation of this product, but these levels decline with time. In 1982, CPSC voted to ban UF foam insulation. The courts overturned the ban; however, the publicity has decreased the use of this product.

More recently, the most significant source of formaldehyde in homes has been pressed wood products made using adhesives that contain UF resins [41]. The most significant of these is medium-density fiberboard, which contains a higher resin-to-wood ratio than any other UF pressed wood product. This product is generally recognized as being the highest formaldehyde-emitting pressed wood product. Additional pressed wood products are produced using phenol-formaldehyde resin. The latter type of resin generally emits formaldehyde at a considerably slower rate than those containing UF resin. The emission rate for both resins will change over time and will be influenced by high indoor temperatures and humidity. Since 1985, U.S. Department of Housing and Urban Development (HUD) regulations (24 CFR 3280.308, 3280.309, and 3280.406) have permitted only the use of plywood and particleboard that conform to specified formaldehyde emission limits in the construction of prefabricated and manufactured homes [42]. This limit was to ensure that indoor formaldehyde levels are below 0.4 ppm.

CPSC [40] notes that formaldehyde is a colorless, strong-smelling gas. At an air level above 0.1 ppm, it can cause watery eyes; burning sensations in the eyes, nose, and throat; nausea; coughing; chest tightness; wheezing; skin rashes; and allergic reactions. Laboratory animal studies have revealed that formaldehyde can cause cancer in animals and may cause cancer in humans. Formaldehyde is usually present at levels less than 0.03 ppm indoors and outdoors, with rural areas generally experiencing lower concentrations than urban areas. Indoor areas that contain products that release formaldehyde can have levels greater than 0.03 ppm. CPSC also recommends the following actions to avoid high levels of exposure to formaldehyde:

- Purchase pressed wood products that are labeled or stamped to be in conformance with American National Standards Institute criteria ANSI A208.1-1993. Use particleboard flooring marked with ANSI grades PBU, D2, or D3. Medium-density fiberboard should be in conformance with ANSI A208.2-1994 and hardwood plywood with ANSI/HPVA HP-1-1994 (Figure 5.4).
- Purchase furniture or cabinets that contain a high percentage of panel surface and edges that are laminated or coated. Unlaminated or uncoated

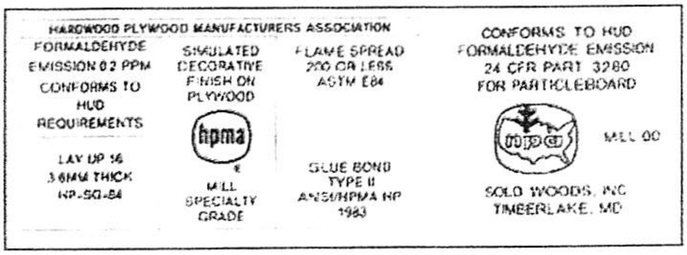

Figure 5.4. Wood Products Label [42]

(raw) panels of pressed wood panel products will generally emit more formaldehyde than those that are laminated or coated.

- Use alternative products, such as wood panel products not made with UF glues, lumber, or metal.
- Avoid the use of foamed-in-place insulation containing formaldehyde, especially UF foam insulation.
- Wash durable-press fabrics before use.

CPSC also recommends the following actions to reduce existing levels of indoor formaldehyde:

- Ventilate the home well by opening doors and windows and installing an exhaust fan(s).
- Seal the surfaces of formaldehyde-containing products that are not laminated or coated with paint, varnish, or a layer of vinyl or polyurethane-like materials.
- Remove products that release formaldehyde in the indoor air from the home.

Radon

According to the EPA [43], radon is a colorless, odorless gas that occurs naturally in soil and rock and is a decay product of uranium. The U.S. Geological Survey (USGS) [44] notes that the typical uranium content of rock and the surrounding soil is between 1 and 3 ppm. Higher levels of uranium are often contained in rock such as light-colored volcanic rock, granite, dark shale, and sedimentary rock containing phosphate. Uranium levels as high as 100 ppm may be present in various areas of the United States because of these rocks. The main source of high-level radon pollution in buildings is surrounding uranium-containing soil. Thus, the greater the level of uranium nearby, the greater the chances are that buildings in the area will have high levels of indoor radon. Figure 5.5 demonstrates the geographic variation in radon levels in the United States. Maps of the individual states and areas that have proven high for radon are available at http://www.epa.gov/iaq/radon/ zonemap.html. A free video is available from the U.S. EPA: call 1-800-438-4318 and ask for EPA 402-V-02-003 (TRT 13.10).

Radon, according to the California Geological Survey [45], is one of the intermediate radioactive elements formed during the radioactive decay of uranium-238, uranium-235, or thorium-232. Radon-222 is the radon isotope of most concern to public health because of its longer half-life (3.8 days). The mobility of radon gas is much greater than are uranium and radium, which are solids at room temperature. Thus, radon can leave rocks and soil, move through fractures and pore spaces, and ultimately enter a building to collect in high concentrations. When in water, radon moves less than 1 inch before it decays, compared to 6 feet or more in dry rocks or soil. USGS [44] notes that radon near the surface of soil typically escapes into the atmosphere. However, where a house is present, soil air often flows toward the house foundation because of

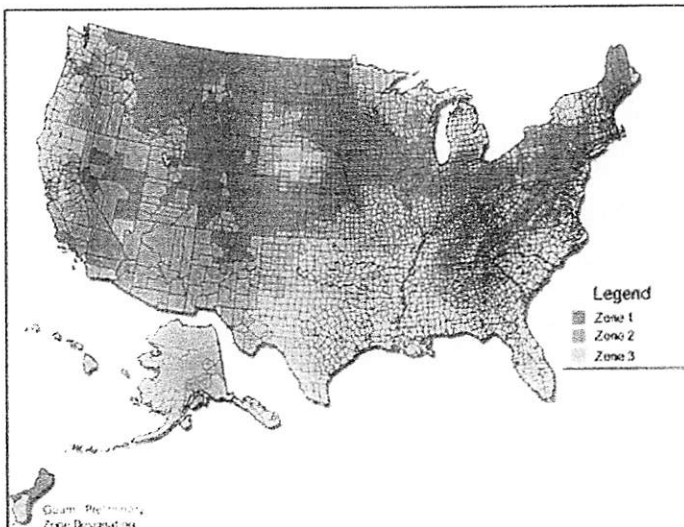

Figure 5.5. EPA Map of Radon Zones [43]

Zone 1: predicted average indoor radon screening level greater than 4 pCi/L [picocuries per liter]

Zone 2: predicted average indoor radon screening level between 2 and 4 pCi/L

Zone 3: predicted average indoor radon screening level less than 2 pCi/L

Important: Consult the EPA Map of Radon Zones document [EPA-402-R-93-071] before using this map. This document contains information on radon potential variations within counties.

EPA also recommends that this map be supplemented with any available local data to further understand and predict the radon potential of a specific area.

APPENDIX I

REDUCE ALL VOC'S, NOT JUST FORMALDEHYDE

We have known of the existence of other volatiles in wood products for at least 20 years, but are only now recognizing potential for harmful effects for the general public and the environment. The CMHC has been working for some time to improve the indoor air of homes, and for individuals with acquired sensitivities. At a recent roundtable on developing a national guide to product selection the CMHC speaker recommend using the reference Building Materials for the Environmentally Hypersensitive as a guide for materials source control for the general public.
"Emissions from cabinet and countertop materials ... can be a significant source of volatile organic compounds in the living space. ... Common emissions associated with cabinets and countertops are wood terpenes and plastic resin vapour from sheet materials, and emissions from wood binders."
Building Materials for the Environmentally Hypersensitive, page 44

"While the greatest IAQ problems caused by pressed-wood furnishings come from formaldehyde, pressed-wood products emit a large number of other VOCs that may have potential adverse health effects. Nelms, Mason, and Tichenor (1986) identified the following compounds in a gas chromatography/mass spectrometry analysis of the emissions from particleboard:

- Acetonitrile
- Acetone
- 2-propanol
- Methyl acetate
- Butanal
- 2-batanone
- Acetic acid
- Methylpentane
- pentene
- 2 Furaldehyde
- Hexanal
- Toluene
- Heptane
- Octane
- Benzaldehyde
- Dimethylhexadiene

Cutter Information Corporation 1992

APPENDIX J

[redacted]

Chemcraft Atlantic Ltd.

31 Ilsley Ave., Dartmouth, Nova Scotia Canada B3B 1L5
Tel (902) 468-6844 Fax (902) 468-2642

To: Mike	Date: November 4, 2002
Co: Ven-Rez Products Ltd.	
Fax No.: (902) 875-3371	
From: Sam Sorensen	No. of pages: 9

FAXED

Resend top page

Attn: Mike at Ven-Rez Products Ltd.

RE: Coating Schedule for Furniture at Halifax Mainland North High School

<u>Item No. 1:</u> <u>Tables with Exposed MDF Board Edges</u>

2 Coats Air-dry Alkyd # 544-002 (Clear)

2 Coats of Aquatech 423-1650

<u>Item No. 2:</u> <u>Plywood/ Wood Cabinet Work</u>

1 Coat sealer 401-004 Vinyl

2 Coats Aquatech 423-1650 (Clear)

<u>Note:</u> The above products do not release any formaldehyde or isocyanate, therefore our conclusion is that the finished products meet the criteria for no off-gassing in service.

Best regards,

Sam Sorensen

/om

APPENDIX K

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VOC Emissions: IAQUEST Applied

HIP Workshop – Feb.6th, 2007

- Bob Magee, Indoor Environment Program, IRC

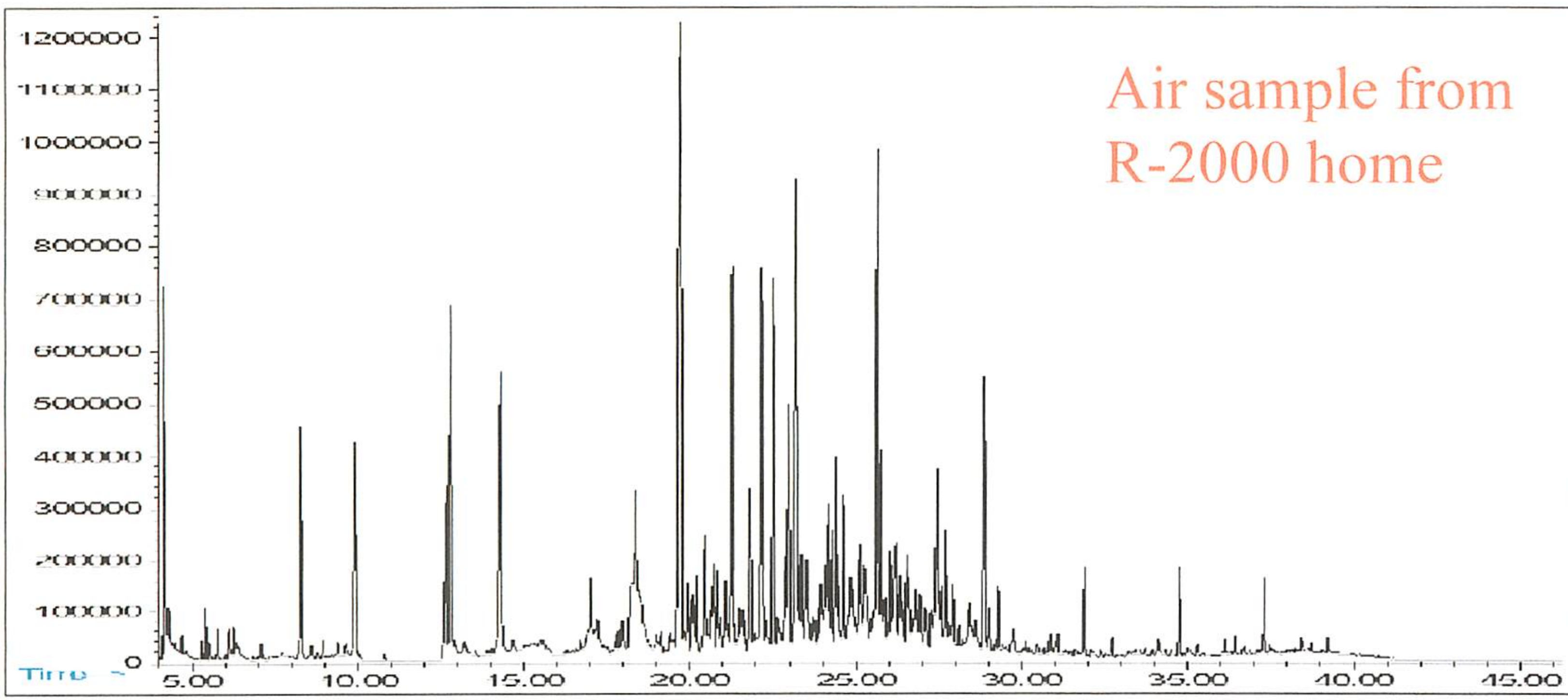
National Research Council Canada | Conseil national de recherches Canada

Canada

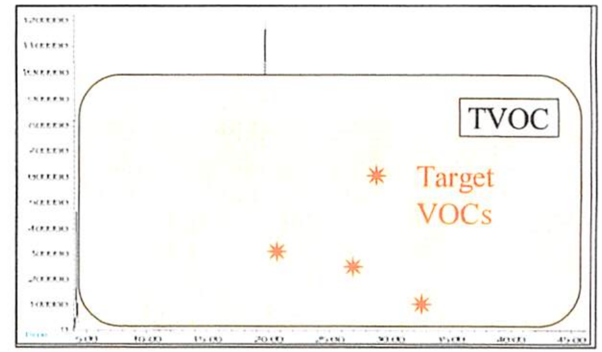
Product Emissions & IAQ

Some Background Issues:

Reality: Chemical emissions are complex



Product Emissions & IAQ



Does TVOC correlate with IAQ?

- *Mølhave (2003): TVOC indicator is and has been widely <u>misused</u>; TVOC 's usefulness for health prediction is <u>undocumented</u>; there is <u>no true standardized measure</u> for TVOC; TVOC <u>cannot</u> be used for normal regulatory risk assessment*

Which compounds <u>are</u> important?

- *Focus must be shifted to (health-relevant)* ***<u>individual VOCs</u>****, and other compounds (**SVOCs**; **reactive species**;* …?)

<u>Acute</u> vs. <u>Chronic</u> exposures?

- ***VOC Decay rates*** *vary enormously (thus impact on chronic exposure)*
- ***<u>Small</u>*** *surface area materials <u>can</u> release strong long-term emissions*

Odour and Irritation:

- *<u>Are</u> important aspects of IAQ and thus for assessment of product emissions*
- *But: Odour & Irritancy thresholds are often <u>above</u> health effect levels, thus detailed chemical analysis coupled with toxicological assessment is <u>needed</u>*

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CMEIAQ:

Consortium for Material Emission & IAQ Modelling

National Research Council Canada / Conseil national de recherches Canada

Public Works and Government Services Canada / Travaux publics et Services gouvernementaux Canada

Health Canada / Santé Canada

CMHC SCHL

Natural Resources Canada / Ressources naturelles Canada

- Australia Commonwealth Scientific & Industrial Research Organization (CSIRO)
- Saskatchewan Research Council (SRC)
- The Building Center of Japan
- U.S. Environmental Protection Agency (EPA)
- U.S. National Institute of Standards and Technology (NIST)

- Canadian Composite Panel Association
- Canadian Wood Council
- Chemical Manufactures Association
- Gypsum Board Association
- USG Corporation

- Carleton University
- Cheng-Kung University, Taiwan
- Dalhousie University
- Massachusetts Institute of Technology (MIT)
- University of Calgary
- University of Miami
- University of Syracuse
- Virginia Polytechnic Institute & State University

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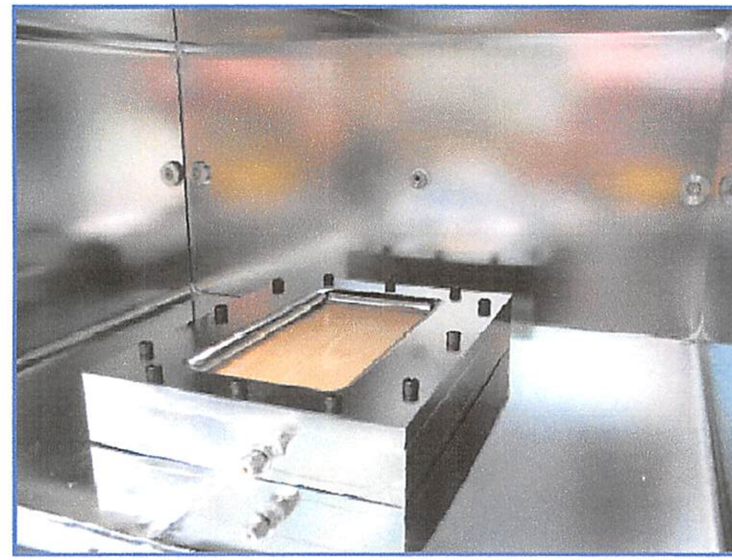
CMEIAQ:

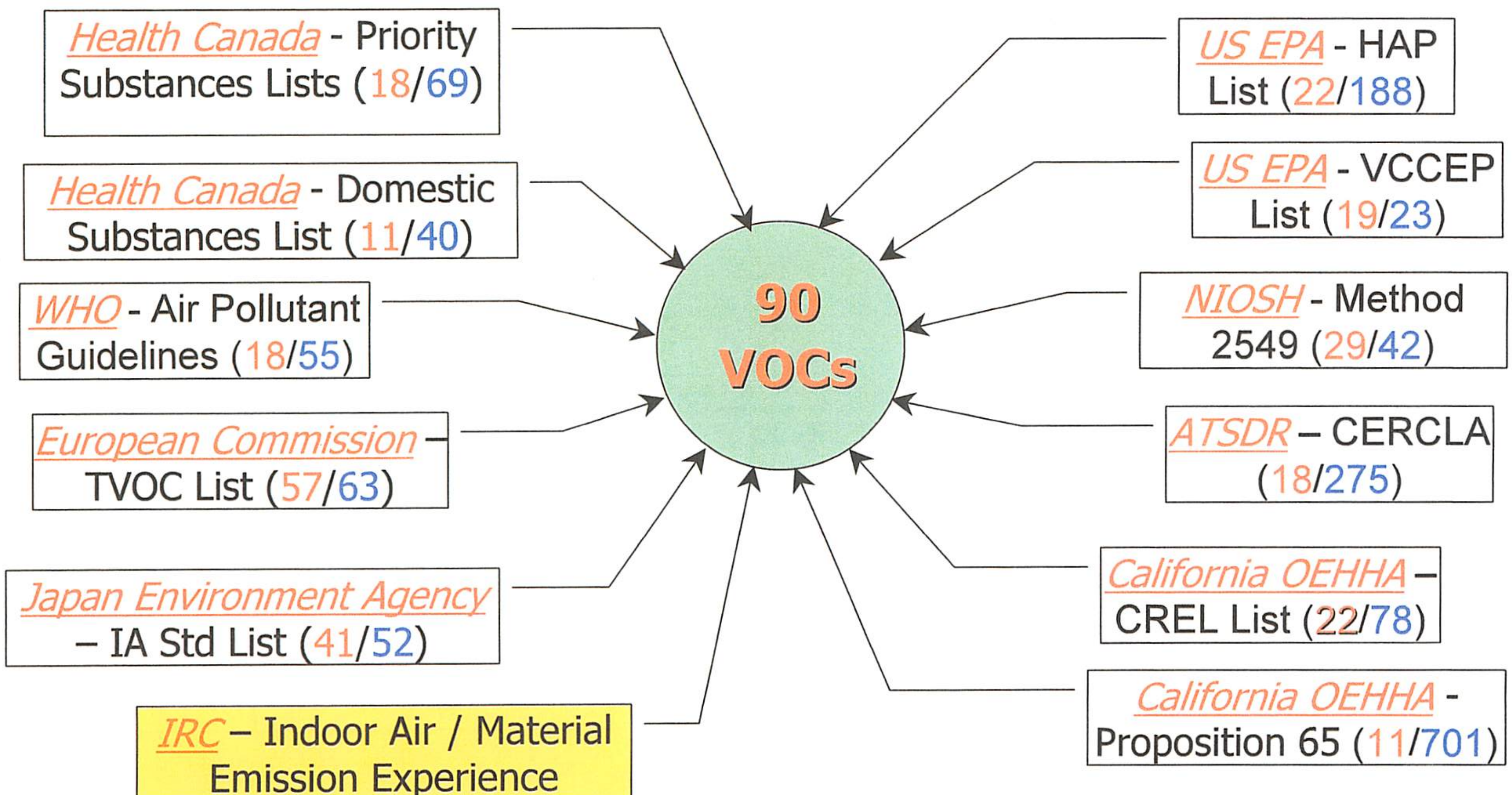


CMEIAQ Outputs include:

- Test procedures for emissions testing:
  - Sample selection / preparation
  - Emissions testing – Chambers
  - Chemical sampling / analysis
  - Data analysis / reporting
- Target List: 90 relevant VOCs (Health & End-User Advisory Committee)
- IA-QUEST Tool (DataBase / Simulation)

Target VOCs: *CMEIAQ List*

(Used in CMEIAQ List /on Agency List)



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IA-QUEST

2 Sides of IA-QUEST

Database

- material emission tests with defined:
  - specimen collection,
  - handling,
  - testing,
  - analysis
- VOC emission coefficients for ***Abundant*** + ***90 Target VOCs***

Simulation Tool

- single zone model
- inputs:
  - room volume,
  - air change rate(s) & schedule,
  - **materials** + emitting area,
  - material entry / removal times
- ***prediction of VOC concentrations***

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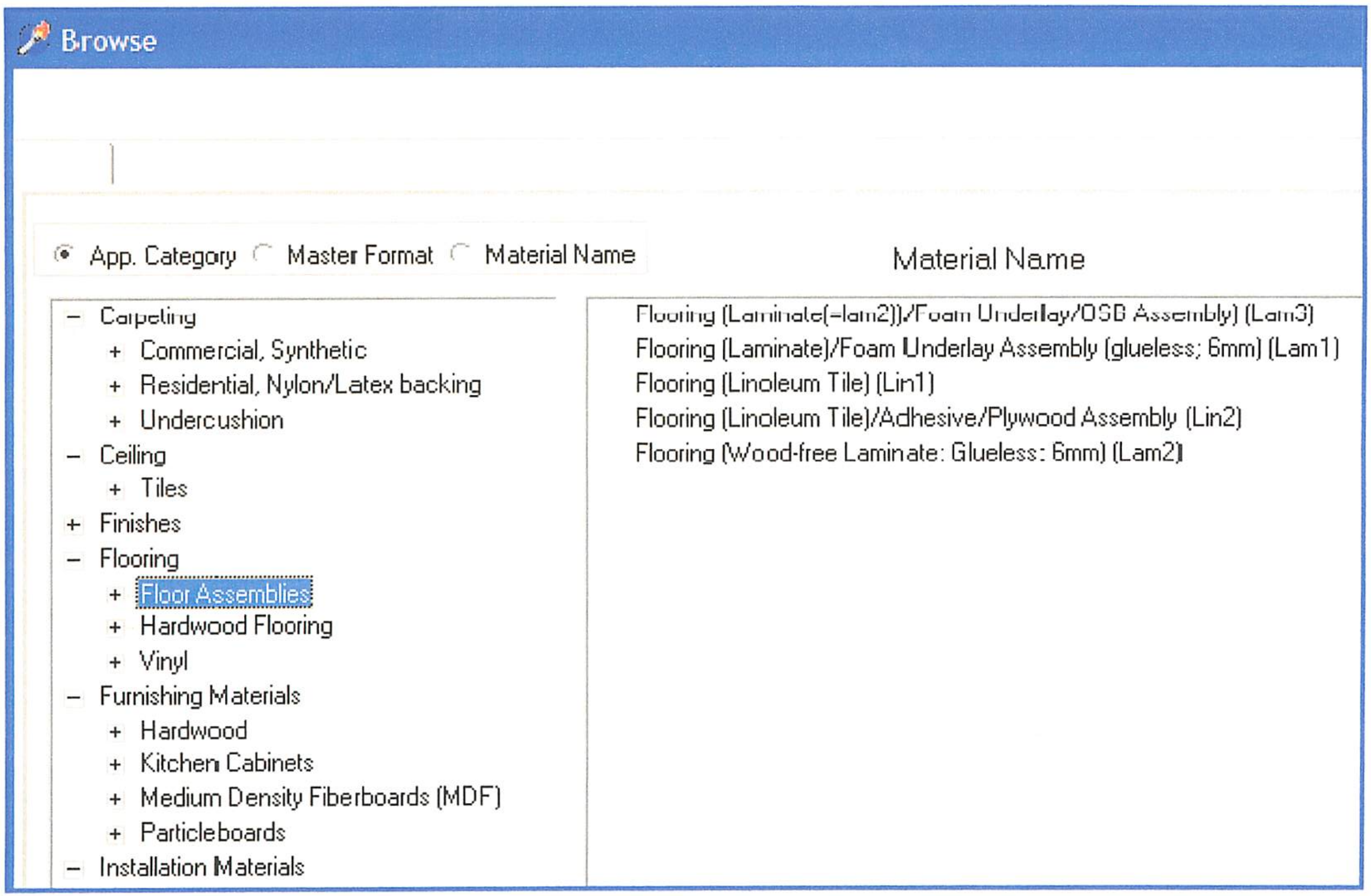
IA-QUEST: the Database



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IA-QUEST: the Database

Contaminant Properties and Health Effects

Contaminant: 1,3-Dimethylbenzene **CAS #: 108-38-3**

Type: Target Compound Sub-type: Aromatic Hydrocarbons

Physical Properties:

Molecular weight (g/mol):	106.167
Boiling point (°C):	139.27
Vapor pressure @23°C (mmHg):	7.522

Health Effect Data:

Odor detection threshold (mg/m^3):	1.41
Permissible exposure level, OSHA (mg/m^3):	435
Occupational exposure limit, USA (mg/m^3):	434.47
Occupational exposure limit, Denmark (mg/m^3):	152.064
Mucous membrane irritation threshold (mg/m^3):	
Non-cancer chronic referenace exposure level, California (mg/m^3):	.7

Alternate Names
- Benzene, 1,3-dimethyl-
- 1,3-dimethylbenzene
- 1,3-Xylene
- m-dimethylbenzene

Print

Notes:

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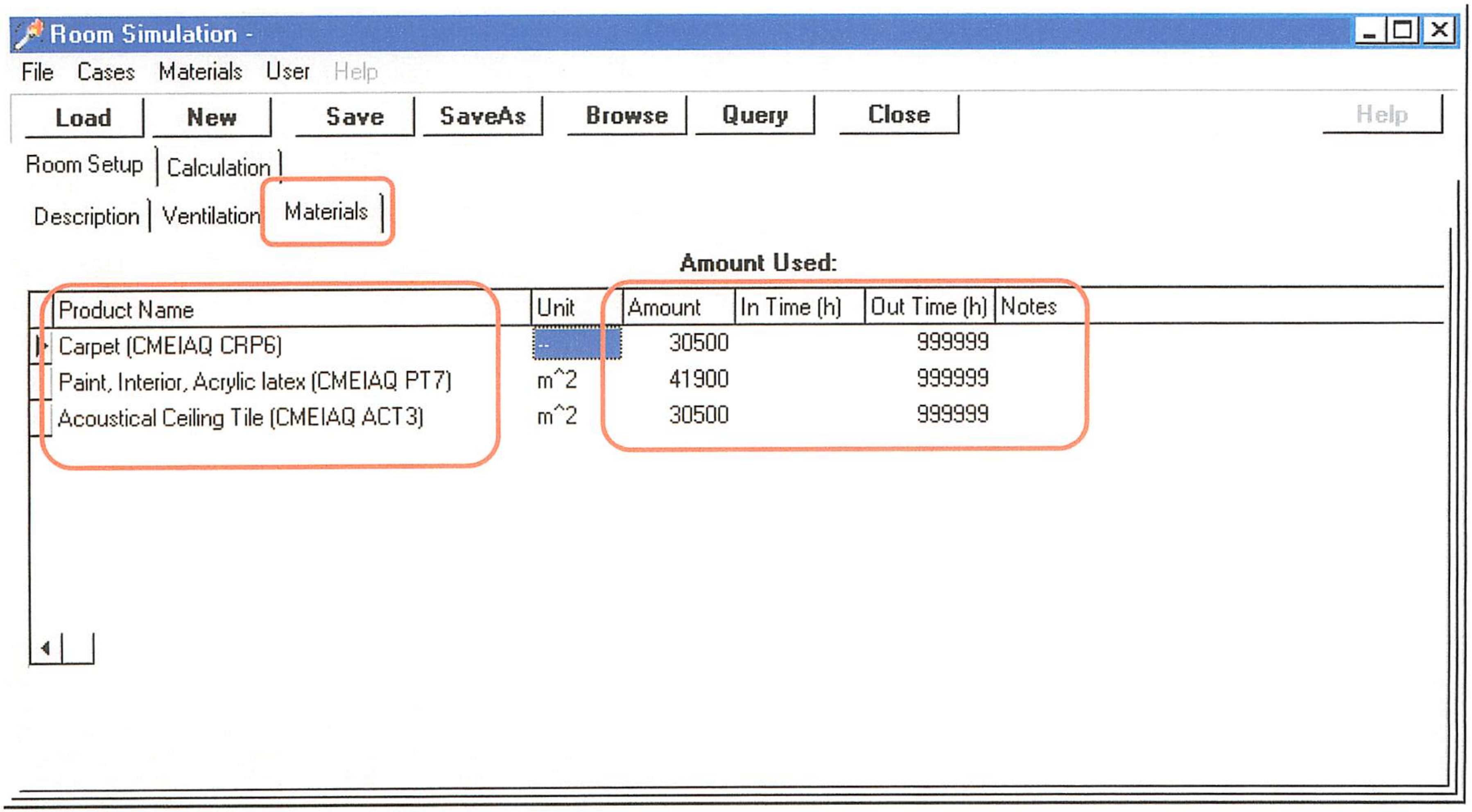
IA-QUEST :
Materials Selection



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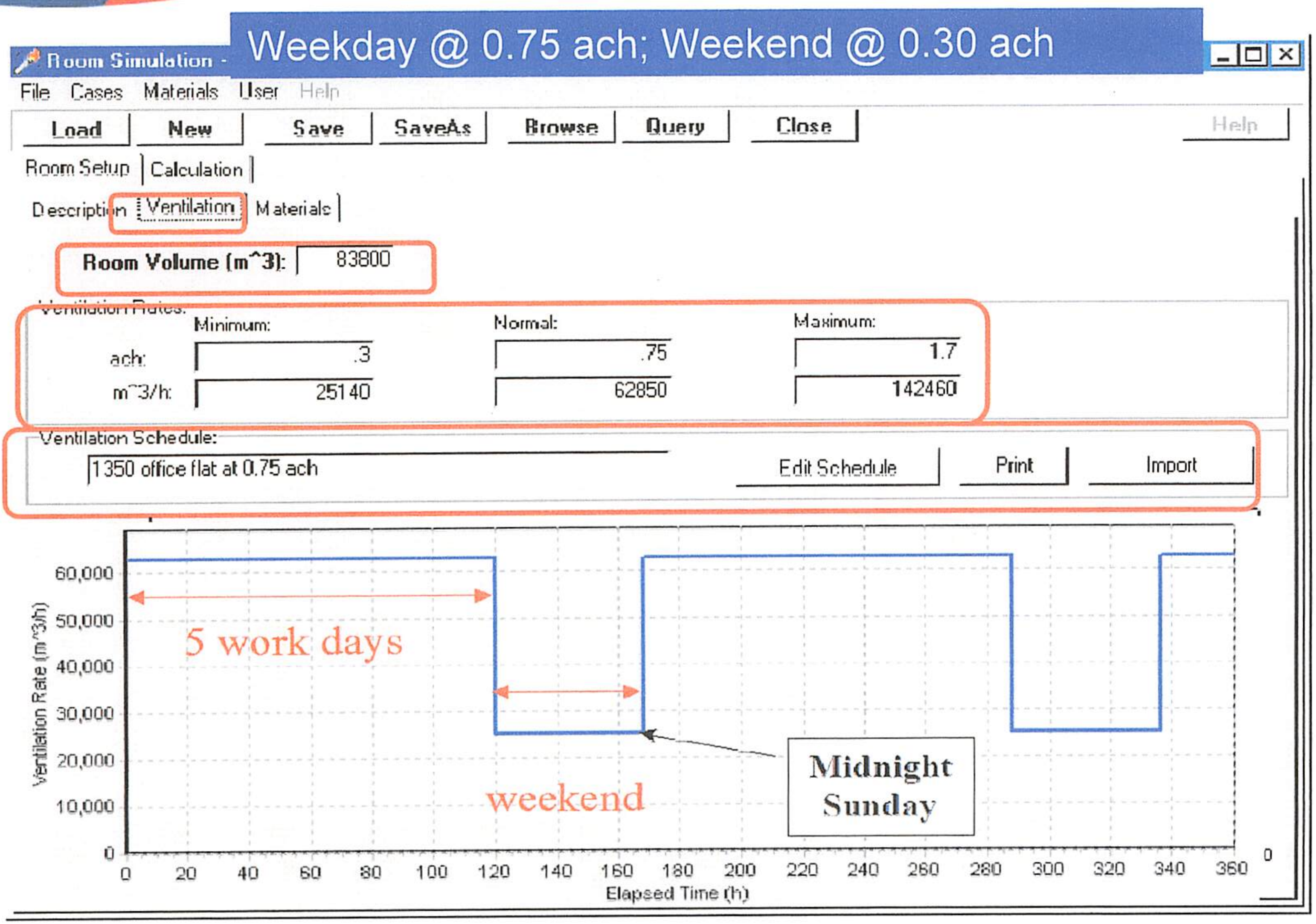
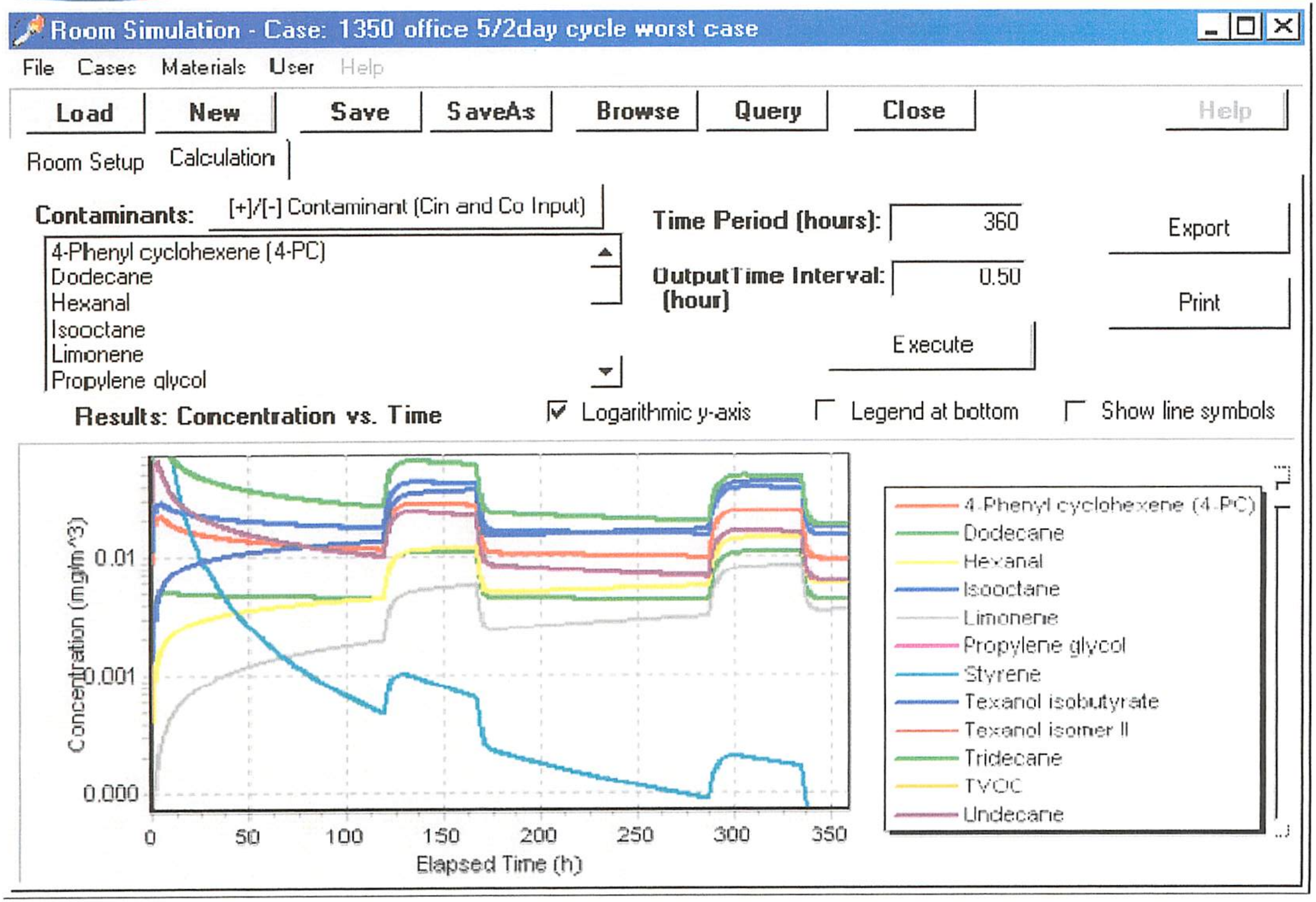
IA-QUEST: Simulation Tool



IA-QUEST: Simulation Tool



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Low VOC Materials?

VOC-"Free"

"Low-Formaldehyde"

"Low-emitting"

"SAFE"

Basis for Material Selection?

"IAQ-Friendly"

"Green"

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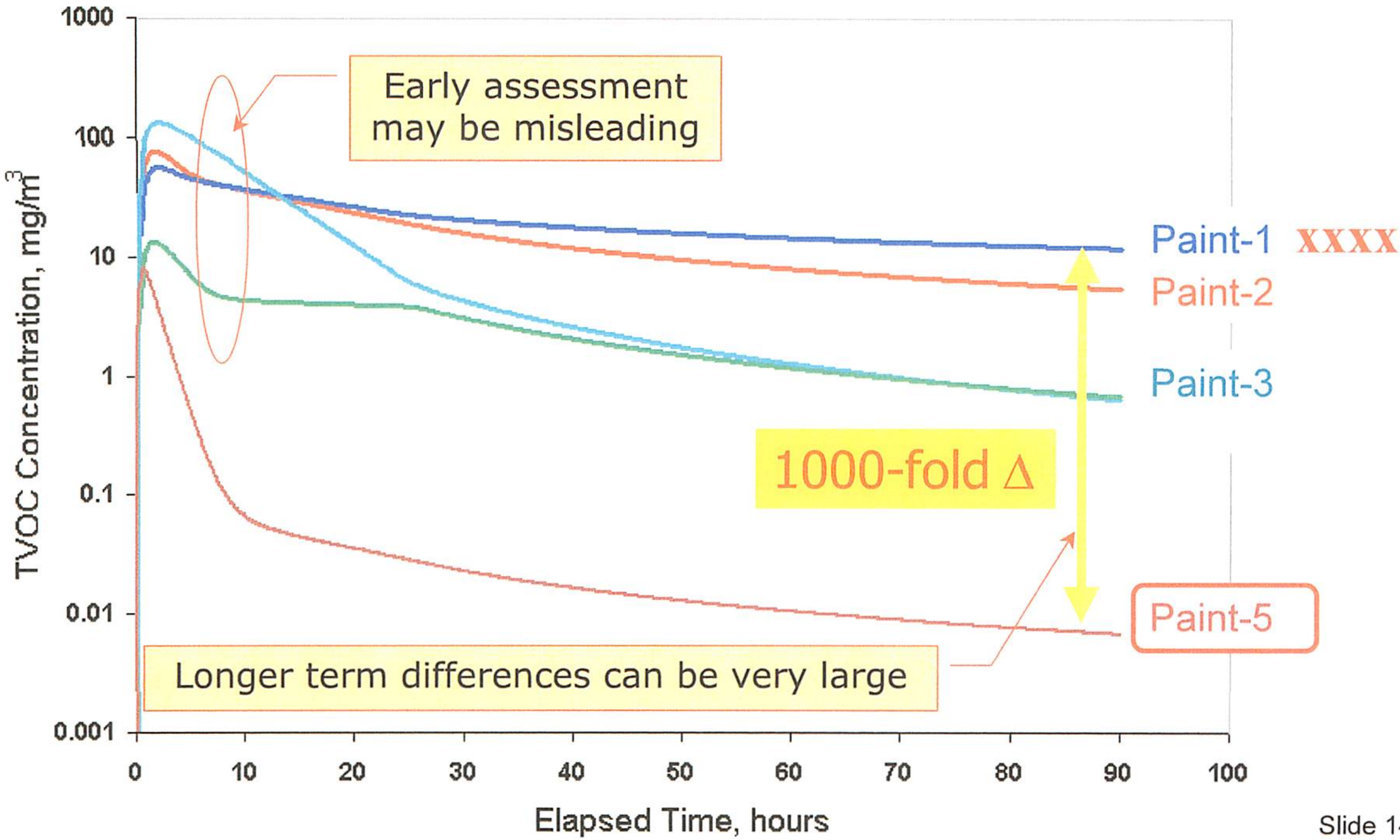
IA-QUEST: Product – Product Comparisons



Product Certification

Summary:

1. Need accepted list of health-relevant Target compounds to support product labelling
2. Detailed emission testing is needed with defined test methods:
   specimen handling,
   chamber operation,
   chemical sampling/analysis,
   data analysis/interpretation
3. Material Impact assessment needed (VOC concentration prediction)
4. Balance needed: required sophistication/detail of emission testing

= Basis for improved labeling / product certification system

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Thankyou

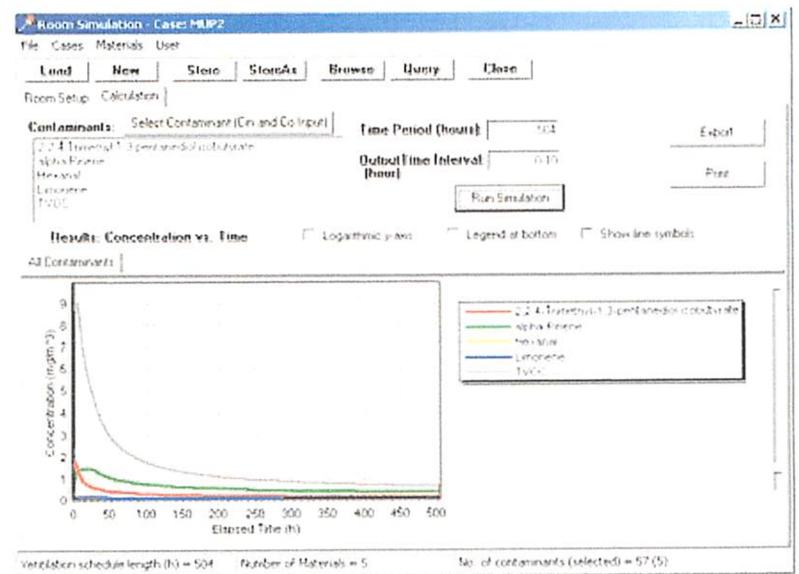
More info: http://irc.nrc-cnrc.gc.ca/ie/iaq/iaquest_e.html

Indoor Air Quality Emission Simulation Tool (IA-QUEST) – Version 1.1

National Research Council Canada (NRC/IRC) launched a series of projects called "Consortium of Material Emissions and Indoor Air Quality Modeling (CMEIAQ)" with the overall goal of developing guidelines for indoor material selection and ventilation strategies to meet specific indoor air quality requirements. One of the major outcomes of the project was an Indoor Air Quality Emission Simulation Tool (IA-QUEST).

Additional info...

- IA-QUEST Download
- IA-QUEST FAQs
- IA-QUEST Partners
- IA-QUEST Publications
- IA-QUEST Disclaimer



APPENDIX L

PHTHALATES/PLASTICS AND HEALTH

"In the largest and most extensive survey of American body burdens of environmental chemicals ever undertaken, the Centers for Disease Control found widespread low-level contamination in a random sample of Americans in 1999-2000...Some chemicals are present at levels associated with health effects. Among the most troubling findings are... confirmation of an earlier, smaller CDC study that documented widespread exposure to phthalates. Levels of phthalates are highest in children and women of reproductive age, creating the potential for developmental effects on the fetus and children."

Protecting our Health: 2003 CDC Report on body burden. *http://www.cdc.gov/exposurereport/pdf/thirdreport_summary.pdf*

"Phthalates are ingredients in nearly all personal care and cleaning products that contain fragrances and are added to polyvinyl chloride to make it flexible." *University of California, San Francisco, and the Collaborative on Health & the Environment (CHE) cross-disciplinary conference, January, 2007.*

"Eliminate trim made from manufactured wood (MDF) containing formaldehyde and plastic trim containing VOCs."
The Environmentally Responsible Construction and Renovation Handbook - Second Edition, March, 2000.

"Eleven organophosphorus compounds (OPs) that are used as plasticizers and flame retardants were analysed in duplicate samples of indoor air from 17 domestic and occupational environments. Solid-phase extraction (SPE) columns were used as adsorbents and analysis was performed using GC with a nitrogen phosphorus selective detector...
Public buildings tended to have about 3-4 times higher levels of OPs than domestic buildings. The relative amounts of individual OPs varied between the sites and generally reflected the building materials, furniture and consumer products used in the sampled environments... Potential sources of these compounds include, inter alia, acoustic ceilings, upholstered furniture, wall coverings, floor polish and polyvinylchloride floor coverings...
Based on estimated amounts of indoor air inhaled and dust ingested, adults and children in the sampled environments would be exposed to up to 5.8 microg kg(-1) day(-1) and 57 microg kg(1) day(-1) total OPs, respectively."
Organophosphorus flame retardants and plasticizers in air from various indoor environments Marklund A, Andersson B, Haglund P., Department of Chemistry, Environmental Chemistry, Umea University, Sweden. J Environ Monit. 2005 Aug;7(8):814-9.

"Shanna H. Swan, professor of obstetrics and gynecology at the University of Rochester School of Medicine & Dentistry, also cited data that show a decline in men's reproductive health. 'Earlier studies found a 1% per year decrease in sperm count in North America and Western Europe over the past 40 to 50 years,' she said. New studies show that testosterone levels declined at similar rates in Boston and Copenhagen over that same period, she said. 'The two trends taken together increase the plausibility of a significant decrease in male reproductive function.'
One type of chemical exposure that could be responsible for this decline in men's reproductive health involves phthalates. Swan said. Several studies show that prenatal exposure to phthalates leads to a

decrease in anogenital distance in male rodents. In a new human study Swan conducted, 'higher levels of five phthalate metabolites in a pregnant mother's urine predicted a shorter anogenital distance in her male offspring,' she said. Also, by looking at levels of phthalates in babies' urine samples, 'we have shown that all babies, male and female, are exposed to these ubiquitous chemicals and that the more baby care products a mother applies, the higher the levels of phthalates in her baby's urine.' Phthalates are ingredients in nearly all personal care and cleaning products that contain fragrances and are added to polyvinyl chloride to make it flexible." *University of California, San Francisco, and the Collaborative on Health & the Environment (CHE) cross-disciplinary conference, January, 2007.*

Burning PVC produces Dioxin

"Many plastics, particularly PVC when burned result in emissions of the deadly poison named Dioxin. Dioxin is a toxic organic chemical that contains chlorine and is produced when chlorine and hydrocarbons are heated at high temperatures. To inhale dioxin or to be exposed anyway to its fumes can cause many deadly results...Some types of plastic contain elements besides the standard carbon, hydrogen, and oxygen. Nylons contain nitrogen, and polyvinyl chloride (PVC) contains, of course, chlorine. These constituents also find their way into the combustion products. Probably the particular component you have heard about most is TCDD, which is an abbreviation for the chemical name tetrachloro-dibenzo-dioxin. This compound contains four chlorine atoms, and is inevitably formed when polyvinyl chloride plastics are burned... it is the material leading to the highest levels of TCDD. The toxicity of TCDD to animals is well-established. It is often considered to be the man-made compound most toxic to animals. Its toxicity to humans, however, is not as well-established. The only absolutely confirmed human health effect from exposure to TCDD is a skin rash called chloracne. Other health effects are suspected. It is considered a carcinogen on the basis of animal studies. "
Richard E. Barrans Jr., Ph.D., PG Research Foundation, Darien, Illinois.
from "Ask a Scientist", http://www.newton.dep.anl.gov/askasci/chem00/chem00031.htm

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National Research Council Canada

A Material emission database for 90 target VOCs

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APPENDIX M

A MATERIAL EMISSION DATABASE FOR 90 TARGET VOCS

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ABSTRACT
To keep the level of volatile organic compounds (VOCs) as low as possible indoors, one of the most effective measures is source control. Characterization of emissions from building materials is an important step towards source control. In this research, 69 building material specimens commonly used in Canada were tested in accordance with an ASTM standard for their emissions for 90 "Target" VOCs and "Abundant" VOCs. The target VOC selection was based on 11 published lists by national and international organizations. The emission characteristics of each material were assembled into a material emission database that is linked to a simulation program such that indoor air levels can be simulated. This combined database and simulation program will provide the basis for a screening method to compare materials and for identifying sources of individual, health-relevant VOCs.

INDEX TERMS
Volatile organic compounds, Building materials, Indoor air quality, Material emissions

INTRODUCTION
Selecting low emission materials has become a major source control strategy to keep the levels of volatile organic compounds indoors as low as possible. As a consequence, material emission testing is gaining acceptance as a source of emission information and/or a marketing tool. Since absolute health-relevant concentration information is extremely sparse, that can label a building material as a low emission product, it is important to compare the emission level of a product to others.

National Research Council Canada (NRC/IRC) launched a series of projects called "Consortium of Material Emissions and Indoor Air Quality Modeling (CMEIAQ)" with the overall goal of developing guidelines for indoor material selection and ventilation strategies to meet specific indoor air quality requirements. One of the major outcomes of the project was a Material Emission DataBase and single-zone Indoor Air Quality simulation program (MEDB-IAQ). The database contains specimen details, test conditions, and emission information on 90 "Target" VOCs, "Abundant" VOCs and TVOC (total volatile organic compound) from 69 building materials commonly used in Canada. In this paper, an overview is given for the criteria used for developing the "Target" VOC list and the procedure of obtaining input data for the database. The structure and functionality of the database and simulation program are not discussed here, as they have been described previously (Zhang et al., 1999).

METHODS AND RESULTS
Target VOC List: To aid the chemical identification and quantification, a target VOC list was assembled. The "Target" VOCs were selected from 11 published lists by national and international agencies such as the World Health Organization and Health Canada (see References) coupled with experience gained from emission tests at NRC. The target VOC list

for material emissions was intended to include chemicals that were: 1) known or suspected to have health or irritation concerns (health criterion); 2) known to be emitted from the building materials (building material); 3) often found in indoor air (indoor air), and 4) suitable for sorbent sampling and analysis with GC/MS or carbonyl analysis with HPLC (analysis).

A preliminary list of 120 compounds was first compiled based on the abundance in indoor air and the relevance to material emissions (#1, #2 in References and the NRC's internal list). After comparing with nine published lists compiled by national and international organizations (#3 to #11 in References), the list was reduced, in consultation with an advisory committee comprised of health experts, to 90 compounds by eliminating those compounds that either have no known health risk, or were not typically emitted from building materials.

The 90 compounds on the "Target" VOC list are summarized in Table 1. The chemicals are grouped into 10 chemical groups. The cross referencing with existing lists are given in the next columns. The value under "sum" indicates the number of lists in References in which that chemical appears. Most of the chemicals on the "Target" VOC list are found in at least one of the referenced lists. Exceptions are 16 compounds that are known to be emitted in a large amount from building materials based on NRC's experience gained from its material emissions testing. Out of 90 compounds, half of the compounds are considered as compounds with health implications as they are listed once or more on the health-relevant existing lists (#3 to #10 in Reference). The other half is mainly associated with large emissions from building materials.

Guideline values are also summarized in the last five columns of Table 1 for acute and/or chronic exposures mainly through inhalation. Permissible Exposure Levels (PELs) are regulatory limits for occupational settings (OSHA, 2005), while the first two levels are recommended guideline values for non-occupational (office and residential) settings. PELs are for short-term exposures with the averaging time of 8 hours for most substances. WHO guidelines cover both short-term (30 minutes to 1 week) and long-term (1 year) exposures depending on individual compounds. Chronic Reference Exposure Levels (CRELs) are for long-term exposures producing chronic health effects. The last column shows that there are reported odor threshold limits for most VOCs on the target list. These guideline levels are also included in the database to aid decision-making procedures for material selection.

In addition to "Target" VOCs, GC/MS chromatographs were analyzed for additional "Abundant" VOCs outside of the target list. "Abundant" VOCs were defined as compounds whose level is more than 1% of TVOC at 24 hour and those quantified based on toluene.

Emission Testing: A total of 69 specimens (Table 2) were subjected to emission testing in a flow-through chamber system in accordance with ASTM Standard D5116-97. Material tests were done in two different phases as shown in Table 2. The materials were selected to represent building materials commonly used in Canada. The focus of Phase II was particularly on obtaining emission characteristics of assemblies.

The testing period ranged from 72 – 362 hours for dry materials and 78 to 440 hours for wet materials to capture the concentration decay portion properly. Therefore, the number of chamber air samples also varied from 6 to 22 for dry materials and from 16 to 40 for wet materials. Exceptions are associated with two OSB specimens whose tests lasted for 1 year to investigate long-term emission behaviors. For long-term tests, a total of 40 samples were taken for each test.

Table 1. "Target" VOC List and Reference Levels

VOC #	Group	CAS #	Chemical Compound	Existing List (see References)											Sum	Reference Levels (µg/m³)				
				1	2	3	4	5	6	7	8	9	10	11		WHO Guidelines [1] (ug/m³)	WHO Guidelines [1] (avg. time)	CREL[2]	OSHA PEL [3]	Odor Detect. Threshold [4]
1	Aldehydes	75-07-0	Acetaldehyde			1		1		1	1	1			5	50	(1 yr)	9	3.6E+05	3.4E+02
2		107-02-8	Acrolein			1			1	1	1	1			5	50	(30 min)	0.06	2.3E+02	4.1E+02
3		100-52-7	Benzaldehyde	1										1	2					1.9E+02
4		123-72-8	Butanal	1											1					2.8E+01
5		112-31-2	Decanal		1										1					5.9E+00
6		50-00-0	Formaldehyde			1		1	1	1	1	1			6	100	(30 min)	3	9.2E+02	1.1E+03
7		98-01-1	Furfural												0				2.0E+04	2.5E+02
8		111-71-7	Heptanal												0					2.3E+01
9		66-25-1	Hexanal	1										1	2					5.8E+01
10		124-19-6	Nonanal	1	1									1	3					1.4E+01
11		124-13-0	Octanal												0					7.2E+00
12		110-62-3	Pentanal	1											1					2.2E+01
13	Ketones	78-93-3	Methyl ethyl ketone	1	1		1		1	1			1	1	7				5.9E+05	8.7E+02
14		67-64-1	Acetone		1		1		1		1		1	1	6	n.p.			2.4E+06	1.4E+04
15		98-86-2	Acetophenone	1						1					2					1.8E+03
16		108-94-1	Cyclohexanone	1										1	2				2.0E+05	8.3E+01
17		108-10-1	Methyl isobutyl ketone	1	1		1		1	1				1	6				4.1E+05	5.4E+02
18	Alcohols, Glycols, GlycoEthers	107-21-1	1,2-Ethanediol			1				1		1			3			400		6.3E+04
19		57-55-6	1,2-Propanediol												0					
20		71-36-3	1-Butanol	1	1		1							1	4				3.0E+05	9.0E+01
21		107-98-2	1-Methoxy-2-propanol	1								1			2			7000		1.2E+01
22		71-23-8	1-Propanol		1						1				2	n.p.			5.0E+05	6.0E+03
23		111-76-2	2-Butoxyethanol	1		1				1	1			1	5	13100	(1 wk)		2.4E+05	5.1E+00
24		112-34-5	2-Butoxyethoxyethanol	1											1					9.2E+00
25		110-80-5	2-Ethoxyethanol	1		1		1			1	1			5	n.p.		70	7.4E+05	4.6E+03
26		104-76-7	2-Ethyl-1-hexanol												0					5.0E+02
27		109-86-4	2-Methoxyethanol	1		1		1			1	1			5	n.p.		60	8.0E+04	3.6E+03
28		75-65-0	2-Methyl-2-propanol												0				3.0E+05	7.1E+04
29		67-63-0	2-Propanol	1	1		1				1	1		1	6	n.p.		7000	9.8E+05	1.2E+03
30		64-17-5	Ethanol	1	1									1	3				1.9E+06	2.8E+02
31		108-95-2	Phenol			1			1	1		1		1	5			200	1.9E+04	4.3E+02
32	Esters	108-21-4	1-Methylethyl acetate	1											1				1.0E+06	1.0E+04
33		111-15-9	2-Ethoxyethyl acetate	1				1				1			3	n.p.		300	5.4E+05	1.0E+03
34		123-86-4	Butyl acetate	1	1									1	3				7.1E+05	4.7E+01
35		141-78-6	Ethyl acetate	1	1									1	3				1.4E+06	2.4E+03
36		6846-50-0	TM-PD-DIB**	1											1					
37	Halo-Carbons	95-50-1	1,2-Dichlorobenzene			1			1				1	1	4				3.0E+05	4.5E+02
38		106-46-7	1,4-Dichlorobenzene	1	1	1		1	1	1	1	1	1	1	10	1000	(1 yr)	800	4.5E+05	3.0E+02
39		75-09-2	Dichloromethane			1		1	1	1		1		1	6			400	8.7E+04	3.4E+03
40		79-01-6	Trichloroethylene	1	1	1			1	1	1	1	1		8	n.v.		600	5.4E+05	8.0E+03
41	Aliphatic Hydrocarbons	107-83-5	2-Methylpentane	1											1					2.9E+02
42		96-14-0	3-Methylpentane	1											1					
43		124-18-5	Decane	1	1		1						1	1	5					4.4E+03
44		112-40-3	Dodecane	1	1								1		3					1.5E+04
45		142-82-5	Heptane	1	1									1	3				2.1E+06	4.1E+04
46		544-76-3	Hexadecane	1	1										2					
47		110-54-3	Hexane	1	1					1		1		1	5			7000	1.8E+06	7.9E+04
48		111-84-2	Nonane	1	1										2					6.8E+03
49		111-65-9	Octane	1	1									1	3				2.3E+06	2.8E+04
50		629-62-9	Pentadecane	1	1										2					
51		629-59-4	Tetradecane	1	1										2					
52		629-50-5	Tridecane	1	1										2					1.7E+04
53		1120-21-4	Undecane	1	1								1		3					7.8E+03
54	Aromatic Hydrocarbons	95-93-2	1,2,4,5-Tetramethylbenz		1										1					1.5E+02
55		611-14-3	2-Ethyltoluene	1	1										2					
56		620-14-4	3-Ethyltoluene		1										1					
57		622-96-8	4-Ethyltoluene		1										1					
58		4994-16-5	4-Phenylcyclohexene	1											1					
59		71-43-2	Benzene	1	1	1		1	1	1	1	1	1	1	10	n.v.		60	3.2E+04	3.3E+04
60		526-73-8	1,2,3-Trimethylbenzene		1										1					
61		95-63-6	1,2,4-Trimethylbenzene	1	1		1						1		4					7.8E+02
62		95-47-6	1,2-Dimethylbenzene	1	1	1			1	1	1	1	1	1	9	870 *	(1 yr)	700 *	4.3E+05 *	3.8E+03
63		108-67-8	1,3,5-Trimethylbenzene	1	1										2					1.2E+03
64		108-38-3	1,3-Dimethylbenzene	1	1	1			1	1	1	1	1	1	9	870 *	(1 yr)	700 *	4.3E+05 *	1.4E+03
65		106-42-3	1,4-Dimethylbenzene	1	1	1			1	1	1	1	1	1	9	870 *	(1 yr)	700 *	4.3E+05 *	2.1E+03
66		98-82-8	Isopropylbenzene							1			1		2				2.5E+05	1.2E+02
67		103-65-1	Propylbenzene	1											1					4.8E+01
68		100-41-4	Ethylbenzene	1	1		1		1	1	1	1	1		8	22000	(1 yr)	2000	4.3E+05	1.0E+04
69		91-20-3	Naphthalene	1			1	1	1	1		1	1		7			9	5.5E+04	7.9E+01
70		99-87-6	Isopropyltoluene												0					1.2E+01
71		100-42-5	Styrene	1	1	1			1	1	1	1	1		8	260	(1 wk)	900	4.3E+05	1.6E+02
72		108-88-3	Toluene	1	1	1		1	1	1	1	1	1	1	10	260	(1 wk)	300	7.5E+05	6.4E+02
73	Cyclo-Alkanes	110-82-7	Cyclohexane	1			1								2				1.0E+06	3.2E+05
74		1678-93-9	Butylcyclohexane												0					
75		1678-91-7	Ethylcyclohexane												0					
76		1678-92-8	Propylcyclohexane												0					
77		91-17-8	Decahydronaphthalene												0					5.7E+05
78	Terpenes	80-56-8	alpha-Pinene	1	1								1	1	4					3.9E+03
79		99-86-5	alpha-Terpinene												0					2.3E+03
80		127-91-3	beta-Pinene	1	1									1	3					
81		99-85-4	gamma-Terpinene												0					1.5E+03
82		13466-78-9	3-Carene	1											1					
83		79-92-5	Camphene				1								1					
84		138-86-3	Limonene	1	1									1	3					2.5E+03
85	Other	3777-69-3	2-Pentylfuran	1											1					
86		872-50-4	1-Methyl-2-pyrrolidinone					1							1					
87		64-19-7	Acetic acid												0				2.5E+04	4.3E+01
88		142-62-1	Hexanoic acid	1											1					6.0E+01
89		142-96-1	n-Butyl ether												0					3.0E+01
90		109-52-4	Pentanoic acid												0					2.0E+01

[1] #8 in References, n.p (not provided), n.v. (no value is available for chemicals with cancer health endpoints); [2] # 9 in References; [3] PEL: permissible exposure level by OSHA (OSHA, 2005); [4] VOCBASE: database with properties of 808 VOCs, B.Jensen, P.Wolkoff, Nat. Inst. Occup. Health, Denmark, 1996; * Dimethylbenzenes (mixture of 1,2-, 1,3- & 1,4-dimethylbenzene); **2,2,4-Trimethyl-1,3-pentanediol diisobutyrate

The main chemical analysis method involves air sampling on multi-layered sorbent tubes and the thermal desorption/GC/MS analysis. Although the analytical focus was on "Abundant" VOCs for Phase I, the GC/MS chromatograms were reanalyzed for "Target" VOCs. For six tests involving three woodstain and three particleboard specimens in Phase I, no reanalysis was done for "Target" VOCs since original samples were analyzed with GC/FID. Twenty specimens tested in Phase II were intended for both "Target" and "Abundant" VOCs. The HPLC analysis in combination with DNPH cartridge sampling was added to Phase II for carbonyls such as acetaldehyde, butanal, formaldehyde, hexanal, pentanal and acetone.

Table 2. List of Materials tested for MEDB-IAQ

Category	Phase I Materials (49)*	Phase II Materials (20)*
Solid and Engineered Wood Materials	• Oriented Strand Board (3) • Particleboard (3) • Plywood (3) • Solid Wood (Oak, Pine, Maple)	• Medium Density Fiberboard (MDF) • Oriented Strand Board (9 for variability tests and long-term tests)
Installation Materials	• Adhesives (3) • Caulking/Sealants (3)	
Flooring	• Carpet (6)** • Vinyl Flooring (2 Tile; 1 Sheet)** • Underpad (2)**	• Carpet & Carpet/Adhesive/Concrete • Laminate (Lam1), Laminate/Underlay (Lam2) & Laminate/Underlay/OSB (Lam3) • Linoleum (Lin1) & Linoleum/Adhesive/ Plywood (Lin2)
Walls	• Gypsum Panels (3)	• Vinyl-Faced Wall Panel (VWB)
Ceilings	• Acoustical Ceiling Tile (3)**	
Interior Finishing	• Floor Wax (2 oil; 1 water) • Polyurethane (3 oil) • Paint (2 water, 1 oil) • Woodstain (4 oil. 1 rep)	
Furnishings		• Countertop (2: upper laminate surface only, all surfaces)

* The value indicates the number of test specimens.
** One DNPH sample was taken at 24 h for these materials in Phase-I.

Emission Database: Concentration versus time (C-t) profiles from a chamber test were converted to emission factor versus time (EF-t) profiles, which were used to determine model coefficients of two empirical emission models through curve fitting. It was observed that the EF-t profiles generally follow a power-law or peak type of decay functions.

Due to the space limitation, no information is given for the model coefficients in this paper. An example of the contents of the database was reported in Won et al. (2003) for 5 –6 most abundant VOCs resulting from Phase I. In addition to emission coefficients, the emission factor at 24 h is included in the database to show the early emissions for a broad range of chemicals. The range of emission factors are given in Table 3 for selected materials.

The current database contains emission characteristics of more than 2,300 combinations of chemicals and materials. All chemicals on the target VOC list were found in at least one material specimen with five exceptions of acrolein, 1-methoxy-2-propanol, 2-butoxyethanol, 2-methoxyethanol and 2-methyl-2-propanol. The most frequently detected chemical categories are aliphatic and aromatic hydrocarbons. The chemicals with the least detection frequency are from the category of alcohols/glycols/glycol ethers and that of esters.

The number of "Target" VOCs emitted from a material ranged from 3 to 53 with an average of 31 compounds. Specimens of maple solid wood and OSB emitted more than 50 "Target" VOCs. No "Abundant" VOCs were detected outside the "Target" VOC list from 38

Table 3. Range of Emission Factors of Selected Materials (µg/m²/h) at 24 h

Group	VOC #	Solid & Engineered Wood Materials							Flooring								Installation Materials				% (Detection)
		OSB		Plywood		Solid wood		MDF	Carpet/ Assembly		Underpad		Laminate/ Assembly		Linoleum/ Vinyl Flooring		Adhesive		Caulking		
		Min	Max	Min	Max	Min	Max		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	
Aldehydes	1	41.8	285.5					89.9	1.67	20.85			3.68	11.49	2.0	28.5					48
	2																				0
	3	0.1	2.6			0.2	0.2	0.2	0.08	1.41	0.21	1.42	0.01	0.09	0.90	1.55			6057	6057	60
	4	2.7	59.6	2.1	6.0	0.3	1.7	6.0	0.19	0.48	0.21	0.93	2.33	2.33	0.15	0.15			361	361	52
	5	0.6	44.6	3.3	25.4	1.9	10.4	0.9	13.45	13.45	1.08	7.42	0.53	0.53	0.53	0.71			225	757	63
	6	11.1	53.7					441.6	6.17	40.46	6.70	76.57	1.32	37.66	1.2	19.0					54
	7	4.3	4.3			0.3	0.3														3
	8	0.3	6.5	0.9	3.6	0.7	0.7	1.4			0.15	0.15	0.03	1.62	0.9	1.3					46
	9	29.4	1256.7	12.3	33.0	0.4	5.7	135.7			0.25	0.25	12.67	12.67	21.7	26.2					56
	10	1.1	47.3	3.3	24.7	1.6	12.4	2.5	0.60	0.90	3.03	6.37	0.50	0.50	0.3	1.9	89	89	170	742	67
	11	0.6	6.7	1.0	12.8	0.4	3.6	2.6	0.46	2.43	0.60	0.60	0.30	0.30	1.3	1.6					52
	12	12.9	354.1	3.4	12.2	0.4	4.4	29.0					7.70	7.70	15.5	15.5			762	762	49
Ketones	13	0.7	1.9	2.6	2.6	0.4	0.4		0.04	0.77	3.04	4.58							1564	1564	27
	14	6.0	338.4	4.5	24.3	3.4	4.2	7.8	0.39	93.23	0.99	3.41	21.4	290.2	0.3	271.5	25	25	109	4986	79
	15	0.1	0.8			0.1	0.1		0.21	1.26					0.32	0.32			1106	1106	33
	16																				2
	17								0.24	0.24											6
Alcohols, Glycols, GlycoEthers	18												0.44	0.44							2
	19								3.72	3.98	3.11	3.11									8
	20	2.1	2.1			0.5	0.5				1.75	4.46			0.6	2.0					13
	21																				0
	22																				2
	23																				0
	24																				2
	25																				2
	26	0.5	5.3			0.5	0.5	1.5	0.28	0.28	3.73	3.73	0.01	2.00	0.4	2.3					37
	27																				0
	28																				0
	29								230.7	230.7											3
	30			2.5	2.5	0.4	0.4										2694	2694			5
	31					7.5	7.5								64.1	64.1					5
Esters	32					1.3	1.3								4.2	4.2					5
	33	1.8	1.8			3.1	3.1														6
	34										0.87	0.87									3
	35					1.8	1.8										2235	2235	13415	15146	8
	36										44.90	44.90			418.7	418.7					11
Halo-Carbons	37								0.10	1.4	0.32	0.32									11
	38	0.25	26.6	0.43	0.89	0.12	0.12	0.04	0.08	0.5	0.36	0.89	0.003	0.08	0.05	2.77	6	48	145	191	71
	39	0.05	0.3	2.68	2.68	0.02	0.02		0.16	0.8	0.46	0.46			0.16	0.34	604	604			24
	40	1.35	1.4	0.28	0.28	0.42	0.42		0.17	0.2											16
Aliphatic Hydrocarbons	41	0.48	6.1	0.17	0.17	0.05	26.45		0.04	1.3					0.09	0.09	13	67750	649	649	40
	42	0.25	1.8	0.26	0.26	0.03	0.03		0.03	0.3							60	40481	385	385	30
	43	1.13	11.4	0.28	1.07	0.31	7.99	0.31	0.26	78433	1.56	2.71	0.01	0.38	0.09	6.5	9	334	1213	456853	84
	44	0.14	4.1	0.14	0.49	0.09	4.86	0.09	0.12	398	6.95	9.58	0.19	0.19	0.04	181.5	42	42	40	39882	86
	45	0.51	8.2	0.34	1.45	0.02	1.03	1.04	0.13	207			0.45	11.60	0.02	61.5			322	322	51
	46	0.07	0.3	0.15	0.29	0.05	0.05		0.07	1066	3.22	3.22	0.22	0.22	0.11	4.0	2070	2070			49
	47	0.18	2.3	0.43	0.45	0.07	5.34		0.05	0.6	0.16	0.16	2.46	2.46	0.02	0.0	170	634	805	805	60
	48	1.08	7.8	0.26	0.39	0.08	0.08	0.52	0.19	26322			3.50	3.50	0.03	1.3	9	9	3843	115166	65
	49	1.06	7.1	0.57	2.89	0.03	1.00	0.79	0.05	156.1			29.78	29.78	0.44	0.7	56	56	167	355	63
	50	0.14	1.4	0.28	0.39	0.07	0.08		0.05	10.2	19.85	19.85	0.08	0.08	0.07	35.2	22676	22676			57
	51	0.16	3.5	0.60	0.79	0.15	1.79	0.26	0.14	32.5	5.54	87.97			1.17	443.5	37609	37609			70
	52	0.07	1.2	0.19	0.22	0.05	0.28		0.41	40.1	14.56	64.77			0.17	496.0	3363	3363	49	49	63
	53	0.31	3.6	0.33	0.79	0.29	2.03	0.23	0.85	19536	2.99	8.11	0.10	0.10	0.05	8.42	20	134	79	271976	90
Aromatic Hydrocarbons	54	0.00	0.0			0.01	0.01		0.31	493	1.22	3.23			0.08	0.08			149	149	33
	55	0.02	0.4			0.01	0.01	0.02	0.04	4787	0.14	1.95	0.06	0.06	0.01	0.73	2	2	527	5375	65
	56	0.02	0.9			0.02	0.02	0.03	0.25	1215	0.49	0.65	0.05	0.05	0.06	1.88	8	8	1462	72255	68
	57	0.09	0.1			0.01	0.01	0.14	0.15	9571	0.28	0.29			0.03	0.93	3	3	752	27175	52
	58								0.06	74.6	1.03	19.08			0.19	0.19					21
	59	0.53	3.5	0.26	0.73	0.09	1.29	1.11	0.11	0.7	0.12	0.34	0.05	1.68	0.08	3.95	11	252	146	905	89
	60	0.01	0.5						0.12	6561	0.69	2.38	0.01	0.01	0.05	2.72			892	1049	57
	61	0.05	1.7			0.05	0.05	0.06	0.07	14202	1.14	2.55	0.04	0.04	0.03	4.44			2571	24232	88
	62	0.15	2.7	0.12	0.17	0.02	0.26	0.08	0.09	1942	0.28	0.44	0.002	0.12	0.05	0.12	3	3	601	2151650	83
	63	0.01	0.2			0.01	0.01	0.03	0.04	5023	0.23	0.33	0.02	0.02	0.02	1.18	2	2	956	21762	70
	64	0.26	3.9	0.50	0.54	0.09	2.38	0.10	0.19	1548	0.96	1.46	0.01	0.28	0.10	0.28	14	79	833	3521988	89
	65	0.06	2.3	0.34	0.37	0.06	1.64	0.10	0.13	514	0.66	1.00	0.002	0.10	0.05	0.13	10	48	572	2421367	84
	66	0.03	0.1	0.09	0.09	0.01	0.01		0.06	6218	0.09	0.09			0.04	0.19			31103	31103	41
	67	0.06	0.5			0.01	0.01		0.20	4790	0.13	0.17	0.06	0.06	0.02	0.39	3	3	543	12697	62
	68	0.13	1.3	0.05	0.09	0.03	0.28	0.94	0.03	291	0.21	0.23	0.01	0.20	0.04	0.11	5	5	151	4457281	88
	69	0.02	0.2	0.07	0.07	0.19	0.19		0.04	164.8	2.12	9.87	0.001	0.001	0.09	0.57	1	1	310	310	59
	70	0.03	0.7	2.82	34.10	0.38	211.6	0.05	0.06	1091.1	0.21	0.21	0.003	0.01					365	365	49
	71	0.08	1.1			0.02	0.02		0.16	16.7	0.44	0.66	0.06	0.06			43	43			40
	72	0.40	6.8	0.80	2.92	0.15	3.45	2.10	0.22	7.3	1.43	1.73	0.08	1.06	0.2	2.4	16	127	32	45800	97
Cyclo-Alkanes	73	0.19	0.2			2.62	2.62		0.30	1.3			1.70	2.54	322.2	322.2	1	372	2739	5448	27
	74								0.11	8334					0.7	0.7			305	45975	21
	75								509.0	509							11	11	1636	1851	19
	76	0.17	0.4						0.09	9564									859	54261	29
	77								2947.3	2947									774	19813	19
Terpenes	78	0.56	14.2	30.9	172.4	2322.5	2322.5	0.10	0.11	0.43			1.08	7.94					712	712	51
	79			6.2	14.8	222.0	222.0														6
	80	0.16	9.1	32.5	75.0	1152.9	1152.9	0.18					0.27	1.92							37
	81			0.1	3.9	113.2	113.2						0.0012	0.0012							11
	82	0.85	2.5	8.4	114.4	14.5	14.5	0.09					0.09	1.09							24
	83	0.03	1.2	3.5	29.7	512.3	512.3						0.17	0.32					1533	1533	35
	84	0.26	1.6	7.1	63.8	0.1	659.7	0.29	0.28	2.69	1.75	1.77	0.02	0.29					16649	16649	56
Other	85	6.39	112.5	1.6	5.0	0.1	0.1	0.67					4.35	4.35	0.1	0.1					37
	86														2.0	3.7					3
	87	18.9	460.3	11.9	23.3	37.4	141.1	178.6	1.74	9.65	2.66	3.01	0.81	3.88	0.8	39.7	65	65	445693	445693	59
	88	13.9	155.7												10.6	10.6					16
	89																				3
	90	3.2	3.2																		2

Note: Refer to Table 1 for chemical compounds.
The same value for "Min"and "Max" indicates there is only one data point.
No data are given for TVOC and additional abundant VOCs.
The numbers of the column of "% detection" are based on all data.

materials. Less than 5 compounds were additionally identified as "Abundant" VOCs from the remaining materials. Two assemblies (Lam3 and Lin2) emitted more than 10 "Abundant" VOCs. This indicates that for the materials tested thus far, the current target VOC list can cover "Abundant" VOCs relatively well. However, it is important to recognize that the "Target" VOC list needs to be flexible enough to accommodate both new products entering markets and new knowledge regarding chemical contaminants with health-relevance.

SUMMARY AND IMPLICATIONS

A "Target" VOC list of 90 compounds were developed based on 11 published lists by national and international organizations combined with NRC's experience from emission testing. The emission characteristics of "Target" VOCs were obtained from 69 building specimens that are commonly used in Canada. A material emission database was developed to facilitate the handling of the extensive data sets. The database as well as the target VOC list will continue to evolve by responding to new products, knowledge and future needs. The database linked to a simulation program will provide the basis for a screening method to compare materials and for identifying sources of individual, health-relevant VOCs.

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Truro West
(+ Shipyard)

PART 1 - GENERAL

1.1 Related Work

.1 Metal Fabrication — Section 05500
.2 Finish Carpentry — Section 06200
.3 Laminated Plastic — Section 06240

1.2 Description

.1 Work included but not restricted to the supply and installation of the following;
.1 Hallway shelves and hooks
.2 All casework
.3 Coat rods and pegs
.4 Shelves and display cases
.5 Vanities
.6 Change Room benches and hooks
.7 Stage Construction

1.3 Quality Assurance

.1 The fabrication and installation of Architectural woodwork shall be completed by a manufacturer with a minimum of 5 years experience. The manufacturer is responsible to obtain all site and roughing in dimensions and shall supply to other related trades all necessary information to coordinate the requirements of the work specified in this section.

.2 Do architectural Woodwork to Millwork Standards of the Architectural Woodwork Manufacturers Association of Canada AWMAC 1987, except where specified otherwise.

1.4 Samples

.1 Submit samples in accordance with Section 01340 - Shop Drawings, Product Data, Samples and Mock-ups.

.2 Submit duplicate samples of:
.1 Each counter top material, to match cabinet.
.2 Each standard colour of cabinet finish, full size.

.3 Submit duplicate colour samples of laminated plastic for colour selection

.4 Submit duplicate samples of laminated plastic joints, edging, cutouts and post formed profiles.

.5 Submit full range of colours and profiles for selection by Architect prior to shop drawings submittal.

1.5 Shop Drawings

.1 Submit shop drawings in accordance with Section 01340 - Shop Drawings, Product Data, Samples and Mock-ups.

.2 Indicate:
.1 Details of Architectural woodwork construction and related and dimensional position, with sections.
.2 Location of each casework unit.
.3 Location for roughing-in of plumbing, including sinks, faucets, and electrical services.

.4 Indicate all materials, thicknesses, finishes and hardware

.5 Indicate typical and special installation conditions, and all connections, attachments, anchorage and location of exposed fastening.

1.6 Maintenance <u>Data</u>

.1 Provide operation and maintenance data for casework .

1.7 Product Delivery, <u>Storage and Handling</u>

.1 Protect millwork against dampness during and after delivery.

.2 Store millwork in ventilated areas, protected from extreme changes of temperature or humidity.

<u>PART 2 - PRODUCTS</u>

<u>2.1 Materials</u>

.1 All Cabinet construction in the Library, Library Office, Administration and related offices shall be maple veneer plywood.

.2 Cabinets in the Learning Support & Resource Rooms shall be constructed using hardwood faced plywood complete with solid hardwood doors.

.3 Cabinet construction in all other teaching spaces (i.e. classrooms) to be hardwood faced plywood with solid hardwood doors. Finish to be clear urethane. (48lb/cu.ft.) or maple veneer plywood.

.4

.1 Moisture content of wood at time of installation shall be for interior locations 7%, and for exterior locations 12%.

.2 Use only adhesives and fastenings that develop sufficient strength for intended use, are non-staining, and are unaffected by the environment to which exposed.

.3 Wood: Grade mark softwood and hardwood lumber by the appropriate association under authority of the National Lumber Grades Authority. Where not exposed to view, use wood of grades suitable for fabrication, utility and structural needs. Where exposed to view, use wood to meet requirements of AWMAC Quality Grade Standard.

.4 Hardwood plywood: to CSA 0115-M1982 of species and thickness indicated, rotary veneer. Use veneer core with Type II bond. Good grade where exposed to view and sound grade where not.

.5 Canadian softwood plywood: to CSA 0151-1978. Sanded exterior grade, solid two sides where both sides are exposed to view and good one side where only one side exposed to view.

.6 Douglas fir plywood: to CSA 0121-M1978, exterior grade, good two sides where both sides are exposed to view and good one side where only one side exposed to view.

.7 Maple plywood: to CSA 0153-1976.

.8 Plastic Laminate: commercial grade to meet specified requirements of CSA Standard A172-M79.
.9 Plastic laminate for cabinets u.n.o.

.4 Fastening
.1 Fasten work with nails generally, but use screws or special fasteners at critical joints, and where required by specified quality grade standards.
.2 Glue built-up work as well as nailing and screwing.
.3 Blind nail unless impossible.
.4 Set finishing nails below finished surfaces to receive putty.

.5 Finishing
.1 Finish each surface of Work of specified quality grade standard where exposed or semi-exposed.
.2 Fine sand surfaces level and smooth after fabrication.

.6 Corridor Shelves and Hooks
.1 Maple slat shelf as detailed
.2 Maple support and coat hook dowels as detailed

.7 Locker Room Coat Hooks and Benches
.1 Maple support and coat hook dowels as detailed
.2 Maple slat benches as detailed

.8 Fixed Wall Mounted Bench
.1 Provide fixed wall mounted bench with heavy wood dowels for hanging clothes, provide hanging and seating for 20 persons in the Change and Shower Rooms of Elementary Schools.

.9 Permanent Stage Construction
.1 2x6 @ 24" o.c. framing material or 2x4 framing material @ 16" o.c. on concrete deck with
.2 3/4" T&G select spruce plywood, base sheet with layer of bldg paper between plywood layers
.3 3/4" square edge poplar plywood, finished sheet, screwed in place and painted black.
.4 4 foot wide strip of hardwood is required at front edge of stage on all performing sides.

.10 Storage Rooms (Building Support Services) Shelving
.1 Wood/metal Shelving Units
.1 built-in wood/metal shelving to suit room
.2 layout 5 shelves high minimum amount.
.3 Teacher storage: 40 linear feet x 24" wide
.4 General storage: 16 linear feet x 24" wide
.5 Art Storage: 23 linear feet x 24" wide
.6 General Storage: 30 linear feet x 18" wide

2.3 Countertop Materials

.1 Solid plastic laminate: to CAN3-A172, Type 3, 1.6mm thick, colour to be selected matt. See Section 06240.

.2 Post formed one piece, factory laminated to CAN3-0188.1.

.3 Draw bolts and splines: as recommended by fabricator.

2.4 Cabinet Hardware

.1 Cabinet Hardware items listed below shall comply with ANS1/BHMA A 1S6.6-1982.
   - .1 Hinges: BHMA BOO1421 or BO 1441 as required.
   - .2 Magnetic catches: BHMA BO 3151.
   - .3 Drawer slides: BHMA BO 5051.
   - .4 Drawer or door lock: BHMA E07042/E07122 C26D finish - Cyl.
   - .5 Adjustable shelving standards: BHMA B04061.
   - .6 Shelf rests: BHMA B04091.

.2 Acceptable products for door and drawer pulls:
   - .1 Hager HA 2652-88.9 mm C26D.
   - .2 Canadian Builder's Hardware Manufacturing Ltd. CBH 220 88.9 mm C260.
   - .3 Standard Metal Hardware Manufacturing Ltd. SM 302A.
   - .4 Richelieu #33205 Bright Chrome "D" pull

2.5 Fabrication

.1 Set nails and countersink screws, apply stained or plain wood filler to indentations, sand smooth and leave ready to receive finish.

.2 Shop install cabinet hardware for doors, shelves and drawers. Recess shelf standards unless noted otherwise.

.3 Shelving to cabinetwork to be adjustable unless otherwise noted.

.4 Provide cutouts for plumbing fixtures, inserts, appliances, outlet boxes and other fixtures.

.5 Shop assemble work for delivery to site in size easily handled and to ensure passage through building openings.

2.6 Finishing

.1 Shop apply all specified finishes in accordance with relevant Sections.

.2 All M.D.F. P.25.B board to be sealed on all edges and backs and fronts.

.3 To reduce emissions all plywood and fibreboard surfaces including edges and all surfaces hidden from view to be sealed with a Sealer Coat.
   .1 Acceptable product is "Lucido washcoat" as supplied by Chemcraft.

.4 Clear finish on exposed woodwork as noted

PART 3 - EXECUTION

3.1 Installation

.1 Install casework plumb with countertops level to 1.5 mm in 3 m.
.2 Level base cabinets by adjusting levelling screws.
.3 Fit closure strips and scribe to irregularities of adjacent surfaces, maximum gap opening 0.5 mm.
.4 Support wall cabinets on continuous galvanized steel hanging brackets or by bolting directly to wall.
.5 Bolt adjoining cabinets together, maximum width of joint 1 mm.
.6 Apply small bead of sealant at junction of counter top and adjacent wall finish.
.7 After installation, adjust operating hardware.

3.2 Colour Schedule by Use

1. Finish wood panels indicated on the drawings are to be sealed stained and protected with a clear coat.
   1. Acceptable Clear Coat ; Lucido #634 -XXX, as produced by Chemcraft Ltd.
   2. Stain grade to be selected from sample pieces to be provided by contractor.
2. MCP colour to be from Manufacturers standard range.
3. Cover and protect finish work until final cleaning.

3.2 Cleaning

.1 On completion, touch up marred or abraded finished surfaces.
.2 Wipe down surfaces to remove fingerprints and markings and leave in clean condition.

END OF SECTION 06400

APPENDIX O

THE ECONOMICS OF GOOD IAQ

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INTRODUCTION

Salary dollars are the single, most important cost in an office building, being more than two orders of magnitude (100 times) more than energy costs and more than ten times building design and construction costs. It would therefore seem reasonable that the benefits of providing a comfortable and productive workplace should be compared against the cost of designing, constructing, operating and maintaining a building with an optimum indoor environment. While it is probably not possible to have a building where occupants never complain, there are simple, cost-effective means to reduce dissatisfaction with their environment.

FACTORS LEADING TO HAPPINESS

There are many individual and collective influences on building occupants affecting their well-being, comfort and tolerance at work. While IAQ and building design operation and maintenance issues will be elaborated on, there are many other factors which influence perception of the work environment. These can include environmental stressors such as lighting, noise, vibration, overcrowding, factors such as ergonomics interior design, and psychosocial issues such as company organization, culture, job satisfaction, security, health and family-related problems. To attempt to understand and improve the occupants' perception of the work environment truly requires a multi-disciplinary approach.

The external and internal factors that influence the indoor air quality of a building also depend on the different roles and responsibilities of the building owner, architect, systems engineer, manager, operator and tenant. Some factors influencing IAQ include:

- building design and location
- the outside air quality
- supply temperature and relative humidity
- system design and capacity
- ventilation, air supply rate
- system control strategy

- filtration performance
- hours of system operation
- system maintenance and cleaning
- office cleaning routines, cleaning compounds
- office furnishings (walls, partitions, carpets, etc.)
- pollution migration and entrainment
- occupancy levels
- work activity

FACTS AND FIGURES

At an approximate value of $2727 per square metre per year [$30,000 average salary plus 30% benefits divided by 14.3 m^2] [$273/$Ft.^2$] salary is far more expensive than building site purchase, design and construction costs at $160/$m^2$ [$16/$Ft.^2$] per year, and heating and cooling cost at $15/$m^2$ per year [*Indoor Air Quality Update*, August 1989, pp 13-15, Cutter Information Corp. MA.].

While building owning and operating costs and salary costs are tangible, productivity losses or gains are not readibly apparent. It is clear however that a small decrease in productivity can be costly; a 1% loss is almost double the total building heating and cooling cost.

Building productivity surveys and questionnaires aside, it should be patent that working in less that optimal conditions or in the extreme, working in a building labelled as "sick", will negatively affect productivity. How productive are workers in a building where over 20% of them complain about their work environment? Do occupants need more time away from their office and take longer coffee breaks or lunch times? Are people working effectively? Has absenteeism increased?

WHAT THINGS CAN WORK?

A Study done by Dorgan Associates for the National Energy Management Institute, Alexandria, Virginia, estimates that improving IAQ in buildings could result in a payback in terms of improved productivity and decreases in medical costs in less than two years [*IAQ Update*, May 1994].

Some of the beneficial modifications include:

- increase minimum ventilation rate to ASHRAE Standard 62-1989
- improve thermal comfort to ASHRAE Standard 55-1992 Standard
- provide contaminant source control (exhaust or product selection)
- increase air circulation and ventilation effectiveness
- design systems with an economizer cycle
- maximize filtration system performance
- provide individual control over thermal comfort

- improve system operations and maintenance
- assess system retrofit and rebalance requirements when office layout/functions change
- monitor and regularly audit the IAQ; have a proactive program

Implicit in the provision of good IAQ is the assumption that the building and its systems are properly designed and performing as intended. It is therefore necessary to follow a proper "commissioning" process during the building delivery cycle. Commissioning will not be addressed in this paper suffice to note that it is an important and vital process that has many benefits and ASHRAE Guideline 1-1989, *Guideline for Commission of HVAC Systems*, is a good place to start.

Ventilation-energy programs have been run for various North American cities and depending on the system, an increase in the ventilation rate from 2.4 to 10 L/s/person can increase the annual energy cost between 5 to 10%.

Increasing filter efficiency will result in a proportionally much higher increase in the collection of small respirable particulates, between 0.1 to 10 micron diameter. This is the size range of concern for IAQ. For example, a 70-75% dust spot efficiency filter collects only 15% of 0.3μ particles while a 90-95% filter collects 83%. The difference in initial resistance is minimal. High efficiency filters not only reduce indoor particulate levels they also result in cleaner system components (heating/cooling coils, fans), ducts and interior office surfaces (walls and ceilings).

Finally, proposed new regulations for the Canada Labour Code sets out procedures for a proactive approach to IAQ and systems for buildings under Federal jurisdiction. This will include the appointment of a "qualified person" who will investigate IAQ problems, keep records and document the design, operation and maintenance procedures of the heating, ventilating and air conditioning system.

CONCLUSIONS

To quote Mark Mendell of the National Institute of Occupational Safety and Health (NIOSH): "Until we identify specific causes [of SBS], appropriate mitigation and prevention of building-related symptoms may need to be at the level of prudent design, operation, and maintenance practices, focused on factors which reduce the likelihood of problem indoor exposures and conditions" (*Indoor Air,* December 1993, Munksgaard, Copenhagen).

There are cost-effective ways to improve the indoor environment in office buildings. While it is best to incorporate good IAQ practices in the building design and construction, existing facilities can be retrofitted to provide a more comfortable and productive workplace. Working together in a total building approach, the many disciplines involved can indeed provide a most satisfactory environment.

APPENDIX P

DEFINITIONS

Volatile Organic Compound (VOC): One of a class of chemical compounds that contains one or more carbon atoms, and usually is defined as tending to evaporate at room temperature and at normal atmospheric pressure. Semi-volatile and non-volatile organic compounds can also contribute to indoor air pollution, and are included in this document's broad definition of VOC. In indoor air, VOCs are emitted by such things as cleaning materials, tobacco smoke, combustion, building materials, furnishings, plastics, office supplies, and solvents. Some are suspected carcinogens, but others can cause symptoms such as headaches, eye, nose and throat irritation, dizziness, neurological effects, and more. Some sources limit the definition of VOCs to solvents only, and as compounds that contribute to ground-level ozone. Some sources include mold toxins as natural VOCs. Research on health impacts from VOCs is ongoing, but health impacts can result from high exposures, from long term low-level exposures, or when individuals have preexisting sensitivity to the material.

Semi-volatile organic compound: A subset of VOCs that can be in solid or gaseous form at room temperature and normal air pressure.

Toxicant: A substance that may cause tissue or organ damage in the body. Some damage may be temporary, while some can be lasting.
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