A Material emission database for 90 target VOCs

Won, D. Y.; Magee, R. J.; Yang, W.; Lusztyk, E.; Nong, G.; Shaw, C. Y.

Publisher's version / Version de l'éditeur:

Indoor Air 2005, The 10th International Conference on Indoor Air Quality and Climate [Proceedings], 2, pp. 2070-2075, 2005-09-01

NRC Publications Archive Record / Notice des Archives des publications du CNRC :
https://nrc-publications.canada.ca/eng/view/object/?id=68dda0fe-cb9f-4afd-beb0-50cf817cc5d4
https://publications-cnrc.canada.ca/fra/voir/objet/?id=68dda0fe-cb9f-4afd-beb0-50cf817cc5d4

NRC·CNRC Institute for Research in Construction
CNRC·NRC Institut de recherche en construction
http://irc.nrc-cnrc.gc.ca

National Research Council Canada

A Material emission database for 90 target VOCs

NRCC-48314

Won, D.; Magee, R.J.; Yang, W.; Lusztyk, E.; Nong, G.; Shaw, C.Y.

A version of this document is published in / Une version de ce document se trouve dans:
Indoor Air 2005, The 10th International Conference on Indoor Air Quality and Climate, Beijing, China, Sept. 4-9, 2005, pp. 1-6

A MATERIAL EMISSION DATABASE FOR 90 TARGET VOCS

D Won*, RJ Magee, W Yang, E Lusztyk, G Nong and CY Shaw

Institute for Research in Construction, National Research Council Canada,
1200 Montreal Road, Ottawa, Ontario K1A 0R6, Canada

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)												Reference Levels (µg/m³)				
				1	2	3	4	5	6	7	8	9	10	11	Sum	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	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	265.5					89.9	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	39882	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	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	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	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	86
	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	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			1.08	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.

REFERENCES

References for the target VOC list

1. European Commission (EC). 1997. Total volatile organic compounds (TVOC) in indoor air quality investigations, Report No19, EUR 17675 EN, European Commission/Joint Research Centre - Environment Institute.
2. Sigma-Aldrich. 2004. http://www.sigmaaldrich.com
3. Health Canada (HC). 2003a. http://www.hc-sc.gc.ca/hecs-sesc/exsd/psl1.htm.
   Health Canada (HC). 2003b, http://www.hc-sc.gc.ca/hecs-sesc/exsd/psl2.htm.
4. Health Canada (HC). 2003c, http://www.hc-sc.gc.ca/hecs-sesc/exsd/screening3.htm.
5. California Environmental Protection Agency, Office of Environmental Health Hazard Assessment (OEHHA). 2004. http://www.oehha.org/prop65/prop65_list/Newlist.html.
6. Agency for Toxic Substances and Disease Registry (ATSDR). 2003. http://www.atsdr.cdc.gov/clist.html.
7. U.S. Environmental Protection Agency. 2003a. http://www.epa.gov/ttn/atw/188polls.html.
8. World Health Organization. 1999. http://www.who.int/environmental_information/Air/Guidelines/Chapter3.htm#3.2.
9. California Environmental Protection Agency, Office of Environmental Health Hazard Assessment (OEHHA). 2003. http://www.oehha.org/air/chronic_rels/51702chrel.html.
10. U.S. Environmental Protection Agency. 2003b. http://www.epa.gov/chemrtk/vccep/.
11. National Institute of Occupational Safety and Health. 2003. http://www.cdc.gov/niosh/nmam/pdfs/2549.pdf.

References for others

U.S. Department of Labor, Occupational Safety & Health Administration (OSHA). 2005. http://www.osha.gov/SLTC/pel/.

Won D. Magee RJ, Lusztyk E, Nong G, Zhu JP, Zhang JS, Reardon JT, and Shaw CY. 2003. "A comprehensive VOC emission database for commonly-used building materials," *Proceedings of the 7th International Conference of Healthy Buildings*, Singapore: Healthy Buildings 2003, Vol 1, pp 253-258.

Zhang JS; Shaw CY, An Y, and Huang YT. 1999. "MEDB-IAQ: a material emission database and indoor air quality simulation program," *Proceedings of the 8th International Conference on Indoor Air Quality and Climate,* Edinburgh, Vol 4, pp 634-639.