Indoor Air Quality and Children's Products: Measuring Chemical Emissions from Toys and Other Juvenile Goods

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Environmental exposure to chemicals—whether through direct contact, ingestion, or inhalation—can have myriad effects on the health and well-being of children. In fact, compared to adults, children are far more susceptible to health effects associated with chemical exposure. Children not only breathe at a faster rate (and therefore inhale more air) than adults, but they also consume more food and beverage with respect to their body size. In addition, their immune, respiratory, and neurological systems are still developing, rendering them particularly sensitive to chemical influences.

Indoor pathway exposures to airborne chemicals are especially concerning. Children spend 85 to 90-percent of their time indoors, where the overall level of key contaminants—such as formaldehyde and other volatile organic compounds (VOCs)—is higher than it is outdoors. Indoor airborne VOCs originate from the numerous construction materials, furniture, decorative furnishings, electronics, and cleaning products commonly found and used inside our buildings.

Indoor air quality experts have traditionally placed emphasis on measuring and reducing overall chemical emissions from building materials and furnishings and ensuring that individual toxic chemicals are eliminated or minimized. However, very little scientific data exists on chemical emissions from children's toys and other juvenile products—despite the fact that children spend a considerable amount of time using these products indoors.

To test the hypothesis that children's toys and other juvenile products emit VOCs, a study was commissioned to collect VOC emissions data on a limited number of widely available children's products. The products, which were purchased from a retail store, were tested in controlled environmental chambers according to ASTM standard practices and analytical methodologies. Products were tested fully assembled to simulate the way a child would be exposed to them. Products that were operational (such as those requiring electrical power) were tested while in use and fully compliant with the manufacturer's usage instructions.

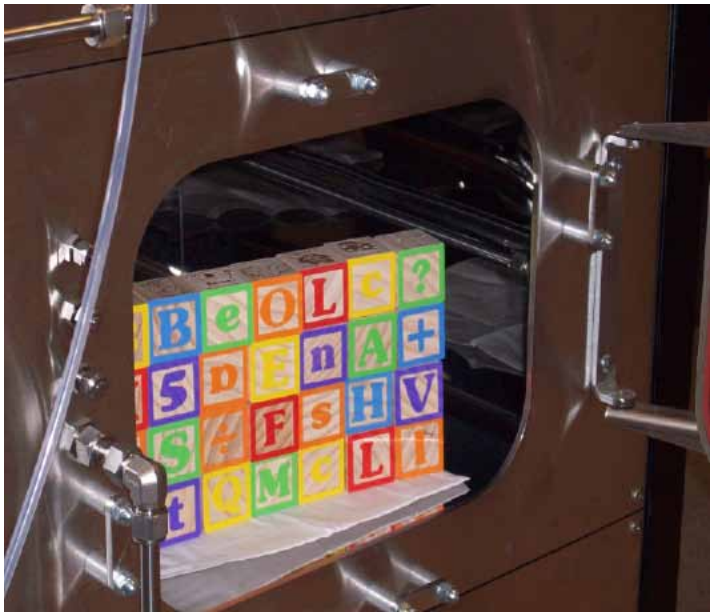
The results of this limited VOC emissions study follow.

Indoor Airborne VOCs

The health significance of exposure to airborne volatile organic compounds (VOCs) in indoor environments is a topic of ongoing discussion in the scientific community, as it appears to be related to building occupant complaints of "sick building syndrome." Hundreds of VOCs pollute the indoor air at any given time, creating a chemical "cocktail" of irritants, odorants, carcinogens, and/or reproductive toxins to which building occupants are continuously exposed. While the toxicity of individual VOCs can be evaluated when assessing human exposure and health effects, little is known about the biological impact (or synergistic reaction) of inhaling complex mixtures of low doses of VOCs. Still, science has shown a positive correlation between airborne chemical exposure and health problems like headaches; eye, nose, and throat irritation; asthma symptoms; increased respiratory irritation; fatigue; and mental confusion.

Measurement Study

The study evaluated six products intended for use by children of various ages: a doll wearing clothes; a remote-controlled car; wooden alphabet blocks; wooden puzzles; a functioning "toy" oven; and an infant bouncer seat. The fully assembled product was placed in a controlled environmental chamber with normal environmental conditions and air flow. Products were conditioned for four (4) hours after placement in the chamber. Then, chemical emissions levels were measured within four (4) inches of the actual product; this simulated the breathing zone of a child and the inhalation exposure resulting from a child's interaction with the product.



PRODUCT TYPE	TVOC LEVEL (µg/m³)	COUNT OF VOCs MEASURED	SPECIFIC VOCs MEASURED OF CONCERN
Remote Controlled Car	1,620	95	1,4-Dichlorobenzene 2-Butanone (Methyl ethyl ketone, MEK) 3,5,5-Trimethyl-2-cyclohexen-1-one Acetophenone (Ethanone,1-phenyl) Formaldehyde Naphthalene Phenol Toluene (Methylbenzene) Xylene (para and/or meta)
Wooden Blocks	3,750	111	1-Butanol (N-Butyl alcohol) 2-Butanone (Methyl ethyl ketone, MEK) 2-Butoxyethanol 2-Ethoxyethanol 2-Pentanone, 4-methyl (Methyl isobutyl ketone, MIBK) 3,5,5-Trimethyl-2-cyclohexen-1-one Acetaldehyde Ethylbenzene Formaldehyde Propanal Toluene (Methylbenzene) Xylene (para and/or meta)
Synthetic Doll	3,200	111	1,1,2-trichloroethene, (Trichloroethylene) 1-Butanol (N-Butyl alcohol) Acetophenone (Ethanone,1-phenyl) Ethylbenzene Formaldehyde Phenol Styrene Toluene (Methylbenzene) Xylene (para and/or meta) Xylene, ortho
Infant Bounce	238	45	Acetaldehyde Formaldehyde Styrene Toluene (Methylbenzene)

Table 1: Summary of chemical data of toys

PRODUCT TYPE	TVOC LEVEL (µg/m³)	COUNT OF VOCs MEASURED	SPECIFIC VOCs MEASURED OF CONCERN
Bake Oven	14,900	183	1,2-Dichloroethane 1,4-Dione-2,5-cyclohexadiene 2-Propenoic acid 3,5,5-Trimethyl-2-cyclohexen-1-one 4-Methyl-2-pentanone Acetaldehyde Acetophenone (Ethanone,1-phenyl) Benzene Cyclohexane Ethylbenzene Formaldehyde Hexane Naphthalene Phenol Propanal Styrene Toluene (Methylbenzene) Xylene, ortho Xylene (para and/or meta)
Wooden Puzzles	1,100	113	1,1'-Biphenyl 1,4-Dichlorobenzene 2-Butanone (Methyl ethyl ketone, MEK) 3,5,5-Trimethyl-2-cyclohexen-1-one Acetaldehyde Acetophenone (Ethanone,1-phenyl) Ethylbenzene Formaldehyde Naphthalene Propanal Toluene (Methylbenzene) Xylene (para and/or meta)

Table 1: Summary of chemical data of toys(contd.)

Results

Each of the six children's products emitted numerous VOCs. Table I shows the total level of VOCs released from each product, the number of individual VOCs measured from each product, and the specific chemicals found in the emissions that are of concern (reported carcinogens, reproductive toxins, and other health hazards). Except for the baby bouncer, more than 100 airborne VOCs were identified from each of the toys.

The VOCs with known chronic reference exposure levels (CRELs) as defined by the State of California, as well as those with existing threshold limit values (TLVs) as published by the American Conference of Governmental Hygienists, are listed in Table 2, along with data demonstrating how those levels compare to the target acceptance level defined by the GREENGUARD Children & Schools Certification and the Collaborative for High Performance Schools (CHPS) Program. Those VOCs identified as having values that may exceed acceptable criteria of GREENGUARD and CHPS include phenol, butylated hydroxytoluene (BHT), formaldehyde, acetaldehyde, naphthalene, and 2-methy naphthalene. For scientists and laboratories conducting emissions analysis of toys, Table 3 presents a target list of potential individual VOCs that may be expected.

TVOC LEVELS(µg/m³)

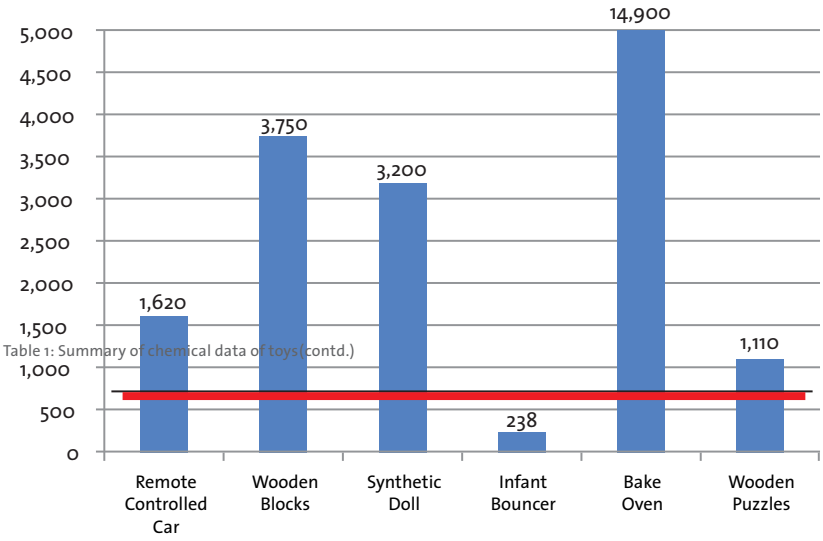


Table 1: Summary of chemical data of toys (contd.)

While TVOC may not be a predictor of potential health effects, it does illustrate the sum, or totality, of all VOCs emitting from the product —including those that may be hazardous to human health. Since comprehensive scientific data on the potential health effects of these VOCs are lacking, and since little is understood about the possible health implications of inhaling this complex mixture of VOCs, limits are recommended on TVOC as a precautionary measure.

As shown in the graph above, the total VOC (TVOC) level from each product was generally two to seven times higher than the 500 ug/m3 value considered indicative of a low-emitting product. The bake oven was an exception emitting over 14,000 ug/m3 of TVOC.

CAS NUMBER	VOCs	GREENGUARD CERTIFICATION PROGRAM LEVEL		HIGHEST MEASURED LEVEL (µg/m³)
		1/100 TLV[a] (µg/m³)	1/2 CA CREL[b] (µg/m³)	
100-41-4	Benzene, ethyl	4,340	1,000	37.7
100-42-5	Styrene	850	450	56.7
106-35-4	3-Heptanone	2,340	-	16.1
106-46-7	Benzene, 1,4-dichloro	600	400	10.4
106-51-4	2,5-Cyclohexadiene-1,4-dione (p-Benzoquinone)	4	-	39.8
107-06-2	Ethane, 1,2-dichloro	400	200	2.1
107-87-9	2-Pentanone	7,050	-	7.3
108-10-1	2-Pentanone, 4-methyl (Methyl isobutyl ketone, MIBK)	2,050	-	24.5
108-88-3	Toluene (Methylbenzene)	750	150	42.9
108-94-1	Cyclohexanone	500	-	138
108-95-2	Phenol	190	100	284
110-43-0	2-Heptanone	2,330	-	19.4
110-54-3	Hexane	1,760	3,500	20.1
110-62-3	Pentanal	1,760	-	306
110-80-5	Ethanol, 2-ethoxy	180	35	3.6
110-82-7	Cyclohexane	3,440	-	11.0
111-76-2	Ethanol, 2-butoxy	970	-	189
111-84-2	Nonane	10,500	-	29
123-38-6	Propanal	480	-	217
123-51-3 1	Butanol, 3-methyl	3,610	-	4.2
123-86-4	Acetate, butyl	7,130	-	48.5
127-19-5	Acetamide, N,N-dimethyl-	360	-	63.2
127-91-3	Pinene, ß (6,6-Dimethyl-2-methylene-bicyclo[3.1.1]heptane)	1,120	-	161
128-37-0	2,6-Di-tert-butyl-4-methylphenol (BHT)	20	-	175
1330-20-7	Xylenes (Total)	4,340	350	74.4
140-11-4	Acetic acid, phenylmethyl ester (Benzyl acetate)	610	-	2.4
141-78-6	Acetate, ethyl	14,400	-	83.0
149-57-5	Hexanoic acid, 2-ethyl	50	-	291

Table 2: Comparison to 1/100 TLV and 1/2 CREL

CAS NUMBER	VOCs	GREENGUARD CERTIFICATION PROGRAM LEVEL		HIGHEST MEASURED LEVEL (µg/m³)
		1/100 TLV[a] (µg/m³)	1/2 CA CREL[b] (µg/m³)	
25551-13-7	Trimethylbenzene (All Isomers)	1,230	-	3.2
34590-94-8	Dipropylene glycol monomethyl ether	6,060	-	7.8
4170-30-3	2-Butenal	9	-	27.9
50-00-0	Formaldehyde†	C 3.7†	16.5†	579
591-78-6	2-Hexanone	200	-	6.4
628-63-7	Acetic acid, pentyl ester	2,260	-	5.1
71-36-3	1-Butanol (N-Butyl alcohol)	610	-	13.0
71-43-2	Benzene	16	30	2.4
75-07-0	Acetaldehyde	450	70	723
78-59-1	2-Cyclohexen-1-one, 3,5,5-trimethyl	280	1,000	33.0
78-93-3	2-Butanone (Methyl ethyl ketone, MEK)	5,900	-	12.3
79-01-6	Ethene, 1,1,2-trichloro (Trichloroethylene)	2,690	300	21.8
79-09-4	Propanoic acid	300	-	7.8
79-10-7 2	2-Propenoic acid	59	-	3.7
80-56-8	Pinene, α (2,6,6-Trimethyl-bicyclo[3.1.1]hept-2-ene)	1,120	-	20.4
91-20-3	Naphthalene	520	5	98.2
91-57-6	Naphthalene, 2-methyl	30	-	257
92-52-4	1,1'-Biphenyl	13	-	2.9
98-01-1	Furfural (2-Furaldehyde)	79	-	33.0
98-86-2	Acetophenone (Ethanone, 1-phenyl)	490	-	63.0

Table 2: Comparison to 1/100 TLV AND 1/2 CREL(contd.)

a American Conference of Governmental Industrial Hygienists. Threshold Limit Values for Chemical Substances and Physical Agents. Cincinnati, OH: ACGIH, 2009.

b http://www.oehha.ca.gov/air/chronic_rels/AllChrels.html - Chronic Reference Exposure Levels (CRELs) Adopted by the State of California Office of Environmental Health Hazard Assessment (OEHHA), December 2008.

† For formaldehyde, 1/100 TLV of ceiling short term exposure level and the 1/2 CREL value is 1/2 OEHHA staff recommended indoor air limit.

1,1,2-trichloroethene, (Trichloroethylene)
1,1'-Biphenyl
1,2-Dichloroethane
1,4-Dichlorobenzene
1,4-Dione-2,5-cyclohexadiene
1-Butanol (N-Butyl alcohol)
2-Butanone (Methyl ethyl ketone, MEK)
2-Butoxyethanol
2-Ethoxyethanol
2-Pentanone, 4-methyl (Methyl isobutyl ketone, MIBK)
2-Propenoic acid
3,5,5-Trimethyl-2-cyclohexen-1-one
4-Methyl-2-pentanone
Acetaldehyde
Acetophenone (Ethanone,1-phenyl)
Benzene
Cyclohexane
Ethylbenzene
Formaldehyde
Hexane
Naphthalene
Phenol
Propanal
Styrene
Toluene (Methylbenzene)
Xylene (para and/or meta)
Xylene, ortho

Table 3: Calibration list for toys
All measured CRELs, PROP 65, CA Air Toxic Chemicals

Conclusion

While limited in scope, this study indicates the potential for inhaling VOCs that are released from toys and other children's products. Additional exposure routes, based on dermal contact or ingestion, were not evaluated in this study. This study was intended to identify potential VOCs associated with children's products. It was not intended to be a risk assessment which would include consideration of exposure routes, usage patterns, aging of products, exposure environments, and assessment to available risk values established for health impact. It is recommended that manufacturers take proactive steps to ensure that toxic or irritating chemicals are removed from product formulations and that they submit their products for independent evaluation to verify that the product's VOCs emissions qualify as low-emitting.

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