

Carpet/4-Phenylcyclohexene Toxicity: The EPA Headquarters Case

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ABSTRACT

At least 122 people were adversely affected by poor indoor air quality and fumes from new carpet installed at EPA headquarters from October 1987 through April 1988. Of these, 17 were unable to work at their normal duty stations, and at least 6 appear to have acquired multiple chemical sensitivity (MCS) as a result of exposure. Reports of similar phenomena from the public, structure-activity analyses, and exposure information indicate a causal relationship between MCS and exposure to 4-phenylcyclohexene (4-PC). Hypersensitivity can occur with exposure to carpet, glues or a combination of the two. Air monitoring for 4-PC and other agents was used to estimate levels of 4-PC that caused acute irritancy and acquisition of MCS. Application of safety factor methodology gives estimates likely to establish minimal levels of exposure against the phenomena. The source of 4-PC in carpet and glues and the means of lowering 4-PC in those products are discussed.

KEYWORDS: 4-phenylcyclohexene, hypersensitivity, carpets, indoor air, building illness, multiple chemical sensitivity

INTRODUCTION

This is a paper about the interfaces among science, public policy, occupational health and labor relations. These interfaces should be apparent to the reader; space limitations prevent our expounding upon them at length.

The data used in the paper were gathered and analyzed by the union and staff scientists of the Agency during an on-going investigation of an outbreak of illnesses at the Waterside Mall facilities of EPA following installation of new carpet there. We theorize that the introduction of a source of 4-phenylcyclohexene into a marginal indoor air environment in which approximately 5000 people work for 8 to 10 hours per day is responsible for the outbreak.

BACKGROUND

Exposure/Health Complaint Data

Beginning in October, 1987 EPA installed at Waterside Mall about 27,000 square yards of Grand Entrance III and Tuff One II, manufactured by Ebsco Mills, Dalton, GA.¹

The Waterside Mall (WSM) (Figs. 1 and 2) complex covers about 480,000 square feet and houses offices for approximately 5,000 people (not all of whom are EPA employees). Table 1 shows the total areas of the various sections of the WSM office complex and the percent of those areas in which the suspect new carpet was installed.

The increase in the number of health symptoms was proportionate to the amount of new carpet installed. The symptoms listed in Table 2 were registered by employees with their management and the EPA Health Unit. By January 1988, several employees had suffered severe reactions requiring hospital treatment.^{2,3}

EPA hired an industrial hygienist to compile reports of complaints and assess them and brought in its Emergency Response Team to monitor WSM air for volatile organic compounds usually measured at Super Fund sites. Measurements of formaldehyde levels were also made.⁴ At that time, the presence of 4-phenylcyclohexene was not suspected nor were its adverse effects generally known, and it was not measured. (See Structure-Activity Considerations section.)

A list of symptoms most commonly reported by employees is given in Table 2, and Table 3 lists the number of employees reporting symptoms by location in WSM.^{2,3} There is a correlation between the number of symptomatic employees linking newly installed carpet to initiation of symptoms and the proportion of newly carpeted areas in the various sectors of WSM, especially the Southeast Mall.

Hypersensitivity to a range of environmental factors began to appear in some of the most severely affected people after several days to several weeks of exposure. The results of the ERT monitoring and the industrial hygienist's analysis of complaints were reported in April, 1988. The hygienist reported² that some 60 or so employees had complained of health effects ranging in severity from irritation of eyes, nose and throat to the apparent induction of multiple chemical sensitivity (MCS).

In May, 1988 and again in June, August and November, additional air monitoring was conducted for a range of volatile organic compounds (VOCs) in selected carpeted and uncarpeted rooms.^{5,6} 4-phenylcyclohexene was measured during these sessions. These May-November measurements complemented those taken in March, 1988 of formaldehyde levels. The formaldehyde and 4-PC results are shown in Table 4.

Results for other VOCs are shown in Table 5.^{5,6} The most remarkable finding was that 4-PC was the single chemical uniquely associated with carpet in WSM, and that 4-PC was the only chemical found whose levels declined significantly over the period of monitoring. In essence, 4-PC was the single chemical uniquely tied to the appearance of the illnesses that employees reported after the installation of the carpet. This is consistent with the findings of Crabb.⁷

The results of 4-PC measurements showed that employees who worked in carpeted areas were exposed to initial concentrations in the range of about 1-15 ppb. This is explained in Fig. 3, which shows the levels of 4-PC in SE-226 from May through August, 1988.

Employees generally did not re-enter carpeted space for about 7-10 days following carpet laying. SE-226 was carpeted in late April, 1988, one month prior to the monitoring. Extrapolating the decay curve back about 30 days gives our estimate of the likely initial exposure level in that room.

Figure 4 shows a comparison of 4-PC levels in new vs. six-month-old carpet.⁸ Figures 3 and 4 show that carpet of this type can be a continuing source of 4-PC in indoor air environments for prolonged periods.

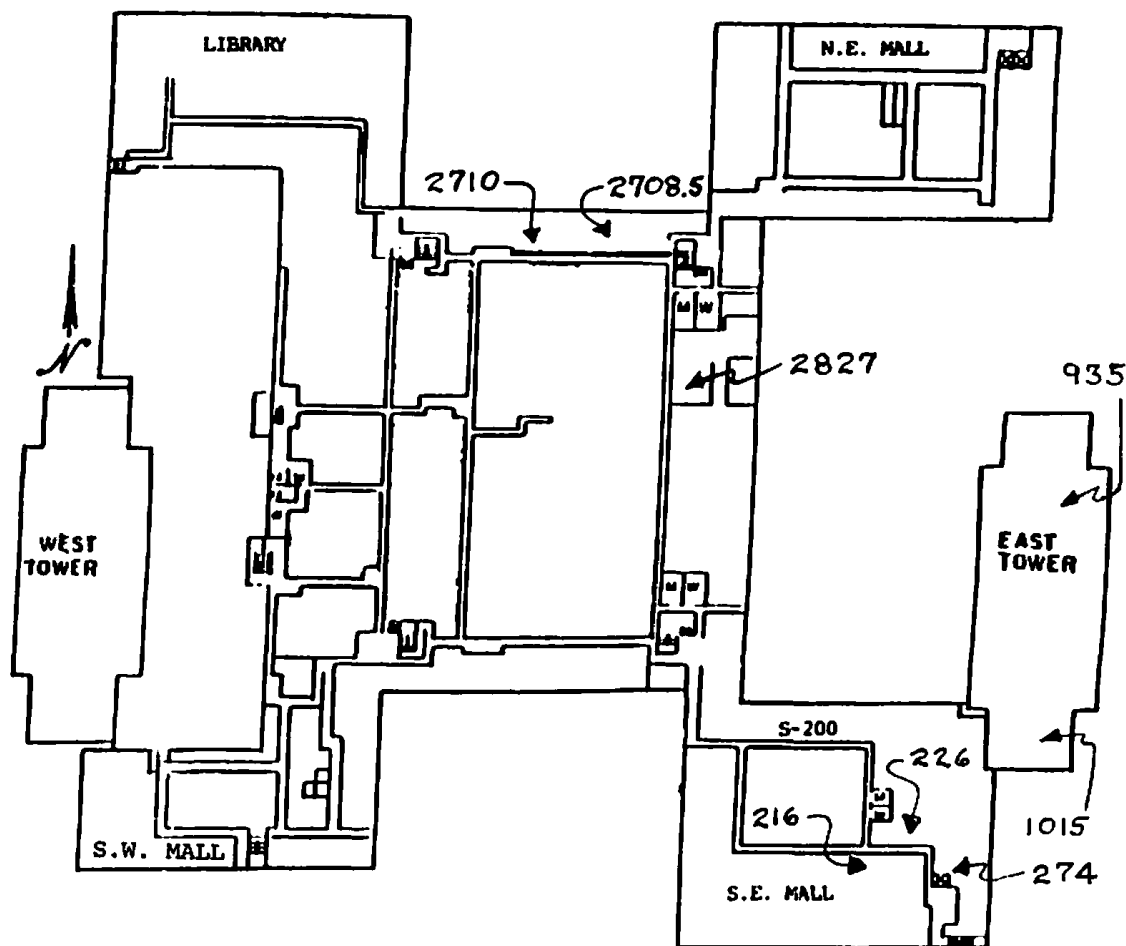


Fig. 1. Second floor of the Waterside Mall (WSM).

Structure-Activity Considerations

By April, 1988 staff of the Office of Toxic Substances (OTS) had uncovered a 1987 submission⁹ by Mark VanErt linking 4-PC to complaints about building environments and new carpeting and reporting limited toxicological testing on the compound (see Fig. 5). The Agency's OTS structure-activity team, which analyzes limited data on new chemicals submitted under the premanufacture notification program of the Toxic Substances Control Act (TSCA), reviewed VanErt's submission and literature on structural analogues of 4-PC and its likely primary metabolite, 3,4-epoxycyclohexyl-1-benzene.¹⁰ We also reviewed literature citations from TOXLINE on cyclohexene and epoxycyclohexane, and we considered the difference in carcinogenic potency between aniline (weak) and 4-aminobiphenyl (strong). This latter point suggests a steric similarity in the comparisons between cyclohexene/4-PC and aniline/4-aminobiphenyl as regards reactivity toward DNA and de-toxifying enzyme systems. These reviews lead us to conclude that the likely primary metabolite of 4-PC would be expected to be a fairly potent inhibitor of certain enzymes and to be reactive toward DNA and/or cellular proteins.¹¹

We also note the structural similarity between 4-PC and phencyclidine (a.k.a. "angel dust") and point out that neurotoxic/behavioral effects are commonly reported by affected individuals and observed by clinicians treating them.¹²

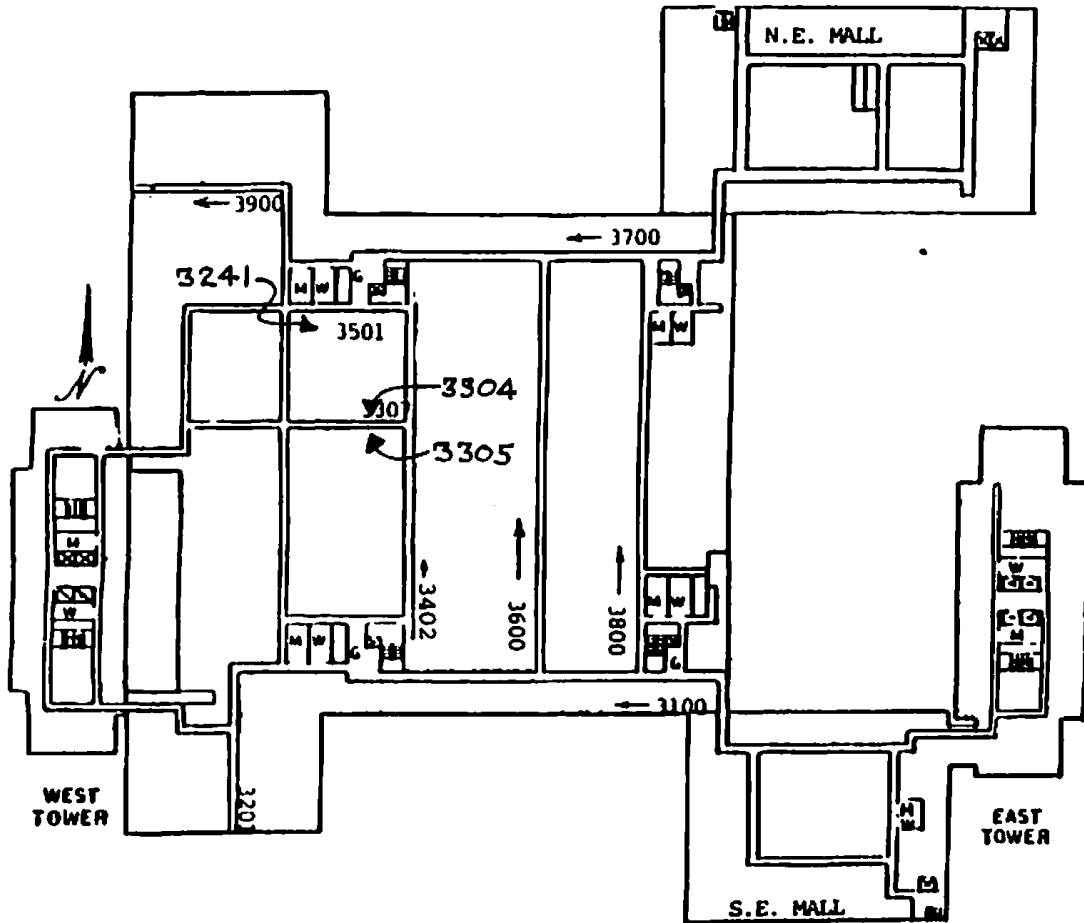


Fig. 2. Third floor of the Waterside Mall (WSM).

Table 1. Distribution of Carpet and Employees

Building Segment	Employees	Total Area ft ²	Area Newly Carpeted-ft ²
East Tower	945	240,000	56,100
West Tower	737	220,000	41,000
Mall-2	490	150,000	29,100
Mall-3	615	150,000	11,300
NE Mall	536	132,000	16,900
SE Mall	274	48,000	33,900

Table 2. Symptoms Experienced by Employees

Burning Eyes	Memory Difficulty
Chills	Unusual Fatigue
Chest Wheezing	Nausea
Runny Nose	Nervousness
Sneezing	Difficulty Concentrating
Cough	Depression
Fever	Dizziness
Chest Tightness	Lightheadedness
Hoarseness	Blurred or Double Vision
Sore Throat	Numbness
Joint Pain	Menstrual Problems

and

Hypersensitivity to environmental agents resulting in one or more of the above symptoms

Table 3. Employees with Symptoms by Location

Building Segment	Percent Newly Carpeted	Employee in New Carpet Offices	Symptomatic Employees	Carpet Linked Symptoms
East Tower	23	220	16 (198)*	10
West Tower	18	137	8 (103)	5
Mall-2	19	95	18 (98)	14
Mall-3	8	46	16 (135)	8
NE Mall	13	68	13 (70)	5
SE Mall	71	193	10 (96)	9

*Parenthetical numbers derived from February 1989 survey: "Indoor Air Quality and Work Environment Study—EPA Headquarters Buildings, Vol. 1 Employee Survey, November 1989, 19K-1003.

Table 4. Formaldehyde and 4-PC Levels in Selected Rooms
May through November 1988

Room	Carpet Laid	Formaldehyde (ppb)			4-Phenylcyclohexene (ppb)			
		May	June	Nov.	May	June	Aug.	Nov.
SE-216	none	NS	NS	NS	.04-.2	NS	NS	NS
SE-226	4/88	<4	NS	NS	3.7-6.7	0.8	0.2	NS
SE-274	4/88	7-49	NS	ND-20	0.7-1.3	NS	NS	.07
M-2710	none	ND-59	2.4	ND	ND	ND	ND	ND
M-2708.5	unk.	<4-37	NS	NS	2.6-3.9	0.6	NS	NS
M-2827	3/88	ND-46	NS	ND	0.4	NS	NS	ND-0.1
M-3304	none*	<4	NS	NS	0.2	NS	NS	NS
M-3241	4/88	6-59	NS	NS	1.7-1.8	ND	NS	NS
E-1015	none	<4	NS	NS	.03-0.3	NS	NS	NS
E-935	4/88	<4	NS	NS	0.6-0.9	NS	NS	NS

*Carpet laid across the hall, M-3305 in 3/88.

ND = not detected; NS = present, but not quantifiable.

Table 5. Volatile Organics in Selected Rooms

Room	Carpet Laid	Compound in ppb					
		CH ₂ Cl ₂		1,1,1-Cl ₃ C ₂ H ₃		C ₆ H ₆	
		May	Nov.	May	Nov.	May	Nov.
SE-216	none	.04-1.7	NS	.2-6.3	NS	0.1-0.8	NS
SE-226	4/88	2.1-4.9	NS	1.1-5.8	NS	.6	NS
SE-274	4/88	ND-1.1	.9-4.5	.5-3.	.3-1.9	.3-.5	.5-1.2
M-2710	none	.3	.9-8.	.3-3.3	.5-1.	ND	.6-1.1
M-2708.5	unk.	1.9-2.1	NS	.2-1.	NS	NQ-.2	NS
M-2827	3/88	1.2-6.3	1.5-8.9	.5-3.	.3-1.7	.3-.8	.6-.7
M-3304	none*	1.4-2.6	NS	1.7-12	NS	.3-.8	NS
M-3241	4/88	.4-1.3	NS	.3-5.1	NS	.1-.2	NS
E-1015	none	.3-9.1	NS	.3-4.	NS	.1	NS
E-935	4/88	.5	NS	.2-3	NS	.02-.1	NS

*Carpet laid across the hall in M-3305, 3/88.

ND = not detected; NS = not sampled; NQ = present, but not quantifiable.

Table 5. Continued

Room	Compound in ppb							
	CH ₂ ClCH ₂ Cl		CHClCCl ₂		C ₆ H ₅ CH ₃		CCl ₂ CCl ₂	
	May	Nov.	May	Nov.	May	Nov.	May	Nov.
SE-216	ND	NS	ND	NS	1.3-2.9	NS	.2-.5	NS
SE-226	ND	NS	.1	NS	4.9-11	NS	.6-.9	NS
SE-274	ND	ND-.4	ND-.1	NQ-.3	4.3-5.9	1.7-4.3	.8	ND-1
M-2710	ND	ND-.6	ND	ND-.3	.3-10	1.3-3	1.3-.5	NQ-.4
M-2708.5	ND-NQ	NS	ND-.1	NS	3-6.7	NS	1-5.3	NS
M-2827	ND	ND-.7	ND	ND-.4	.1-3.1	1.8-3	.4-.6	NQ-.9
M-3304	ND-.1	NS	.03-.1	NS	5-8.7	NS	1.2-13	NS
M-3241	ND	NS	ND-.1	NS	.6-8.9	NS	.1-1.5	NS
E-1015	ND	NS	ND-.3	NS	.7-4.7	NS	.7-.8	NS
E-935	ND	NS	ND	NS	5.7-5.8	NS	.8	NS

Table 5. Continued

Room	Compound in ppb					
	Xylenes*		Styrene		Other VOCs**	
	May	Nov.	May	Nov.	May	Nov.
SE-216	.9-2.5	NS	.2-.9	NS	4-22	NS
SE-226	2-2.3	NS	.2-.3	NS	37-52	NS
SE-274	2.6-3.7	1.3-3.3	.5-.6	NQ-.3	36-41	14-52
M-2710	2.1-3.2	.6-1.7	.3-.5	NQ-.3	12-13	10-38
M-2708.5	1.3-3.4	NS	.2-.5	NS	48-54	NS
M-2827	2-4	1.4-2	.4	ND-NQ	15-182	8-32
M-3304	2.6-2.7	NS	.3	NS	70-161	NS
M-3241	3.1-3.5	NS	.5-.6	NS	31-40	NS
E-1015	1.4-3.2	NS	.1-.4	NS	14-49	NS
E-935	2.4-4.2	NS	.5	NS	35-43	NS

*Includes ethylbenzene.

**Chiefly unspecified alkanes, alcohols, and < 5 ppb acetone.

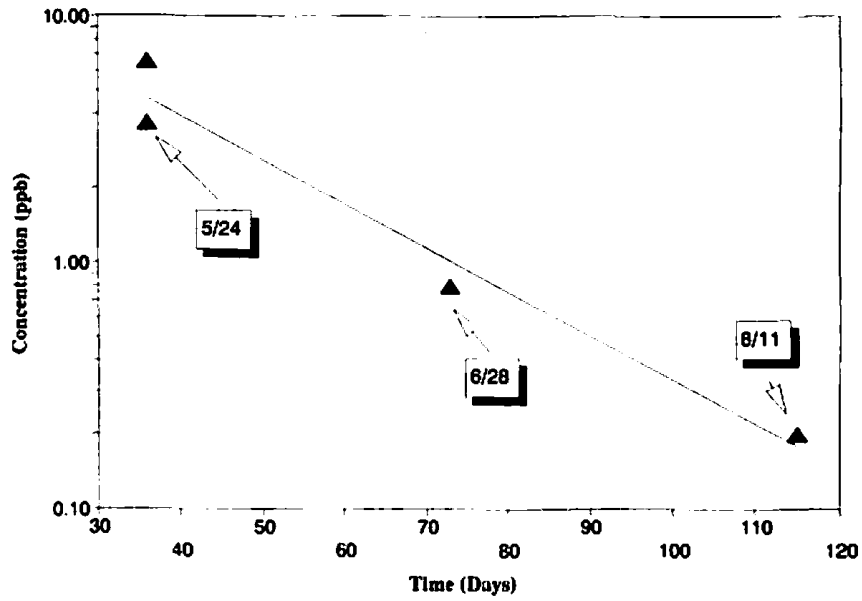


Fig. 3. 4-phenylcyclohexene levels in SE-226 - 1988.

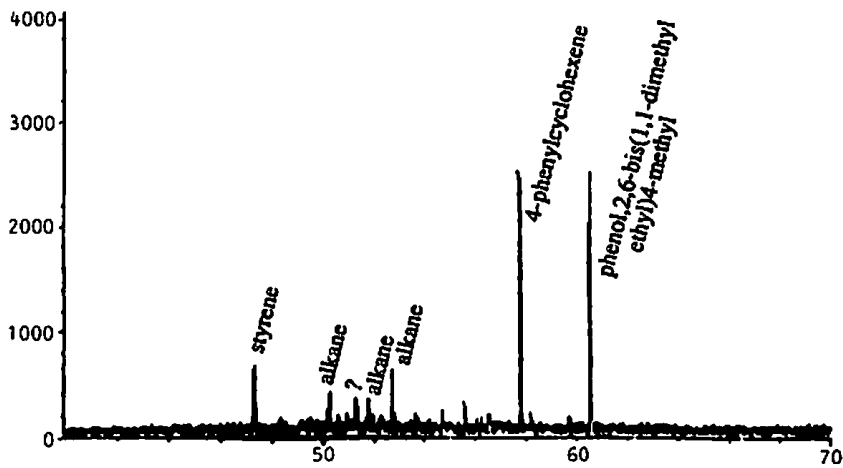
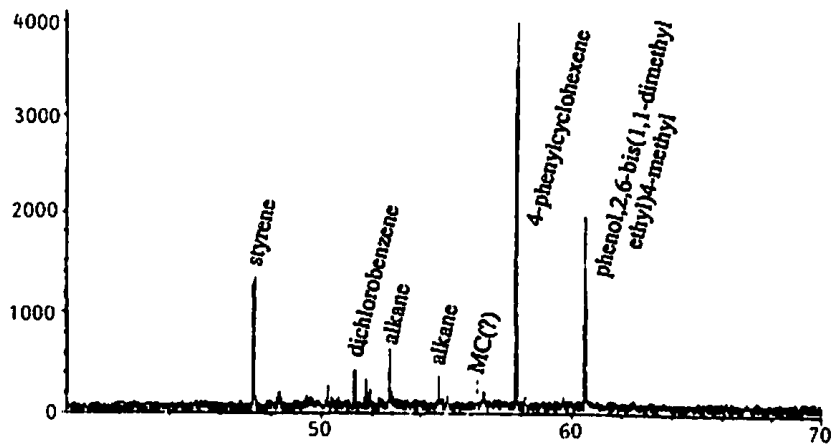


Fig. 4. Comparison of 4-phenylcyclohexene levels in new vs. old carpet

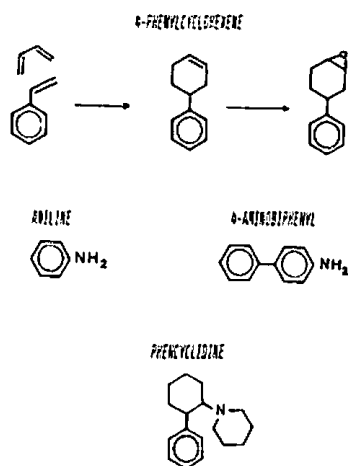


Fig. 5. Structure-activity considerations.

Recommended Risk Control

Based on the temporal and spatial link between carpet, 4-PC and employee illnesses, the initial 4-PC exposure levels, and generally accepted criteria for establishing putatively "safe" levels for toxic agents, we propose that indoor air standards be set for 4-PC that would protect against induction of MCS and against acute irritancy responses. The derivation of those recommended levels is shown below:

Recommended Indoor Air Standards for 4-Phenylcyclohexene

To Protect Against Induction of Multiple Chemical Sensitivity:

Lowest Observed Effect Level = 5 ppb
 Factor to derive No Observed Effect Level = 10
 Factor to account for more sensitive individuals = 10
 Factor to account for uncertainty re: cumulative dose effects, actual LOEL and severity of multiple chemical sensitivity effect = 10
 Derived Indoor Air Standard = .005 ppb

To Protect Against Acute Irritancy Effects:

Lowest Observed Effect Level = 5 ppb
 Factor to derive No Observed Effect Level = 10
 Factor to account for more sensitive individuals = 10
 Factor to account for uncertainty in LOEL, lesser severity of irritancy compared to MCS = 3
 Derived Indoor Air Standard = .017 ppb

In addition to the indoor air standard, we recommend, via a Toxic Substances Control Act section 21 petition that (1) testing be required on finished styrene-butadiene latex adhesive and carpeting to establish a product-content standard for 4-PC that will assure compliance with the indoor air standard; (2) quality control records be maintained and procedures put in place to assure compliance with product-content standards; and (3)

notification be given of the risks associated with 4-PC levels above those specified in the standards; and (4) products containing 4-PC at levels greater than the standards be recalled.

We do not contend that 4-PC is the cause of every case of MCS, nor do we contend that all carpet or all styrene-butadiene latex is hazardous, nor that these products cannot be manufactured, sold and used safely. We do contend that under the conditions existing at WSM in the time period in question, exposure to 4-PC at levels of around 10 ppb resulted in induction of MCS and irritancy responses in EPA employees.

ACKNOWLEDGMENTS

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