

Chapter 5

Risk Characterization

Risk characterization integrates the hazard and exposure components of a risk evaluation and presents overall conclusions. Risk characterization typically includes a description of the assumptions, scientific judgments, and uncertainties that are part of this process. This risk characterization focuses on chronic (long-term) exposure to chemicals that may cause cancer or other toxic effects, rather than on acute toxicity from brief exposures to chemicals. The focus is also on health effects from chronic exposures that could be used to measure risk.

The goals of the furniture adhesives risk characterization are to:

- ? integrate chemical hazard and exposure information to assess potential risks from ambient environmental and occupational exposures resulting from use of the adhesives selected for evaluation;
- ? use reasonable and consistent assumptions across alternatives, so potential health risks associated with one alternative can be compared with the potential health risks associated with other alternatives;
- ? present conclusions and uncertainties associated with this risk screening and comparison of chemicals used in the adhesive application process of upholstered furniture manufacture; and
- ? identify the areas of concern and differences in risk among the adhesive alternatives in a manner that facilitates decision making.

Numerical results (risk indicators) are presented whenever possible, as well as qualitative assessment of risk for effects like sensitization (which cannot be quantified) and for chemicals with no available measured toxicity data. Detailed exposure and hazard data are presented separately in the Human Health Hazards Summary (Chapter 3) and Exposure Assessment (Chapter 4), respectively.

Estimates of potential human health risk from chemical exposure are characterized here in terms of excess lifetime cancer risk, and hazard quotient (HQ) or margin of exposure (MOE) for potential non-cancer health effects. Cancer risks to nearby residents and workers are discussed first. Next, the calculation of HQs and MOEs is presented, both for nearby residents and for adhesive workers. In addition to risk indicators, estimated workplace air concentrations are compared with available occupational exposure standards and guidance levels, to further evaluate areas of concern for workers. Next the results of concern are discussed, along with uncertainties and key assumptions. Finally, an overall summary of the risk screening and comparison results is presented. When considering the results of these risk evaluations, it should be remembered that the results are intended for use in comparing relative potential risk among processes, based on a model facility, and should not be used as absolute indicators of actual health risks to adhesive workers or to the public from any specific facility.

5.1 CANCER RISK

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Cancer risks are expressed as the probability of an individual developing cancer over a lifetime from exposure to a chemical in excess of the already-existing background cancer risk. For chemicals classified as carcinogens, an upper-bound excess¹ lifetime cancer risk, expressed as a unitless probability, is estimated by the following equation:

$$\text{Cancer Risk} = C_{\text{AIR}} \times \text{unit risk}$$

where,

Cancer Risk	=	The upper-bound excess lifetime cancer risks for an individual.
C_{AIR}	=	The concentration of the chemical in air to which a person is continuously exposed. Ambient air concentrations near a model adhesives facility were estimated in the Exposure Assessment (Section 4.3).
Unit risk	=	A measure of cancer potency for air concentrations, expressed as the upper-bound excess lifetime cancer risk per $\mu\text{g}/\text{m}^3$ in air, based on default exposure conditions for continuous lifetime exposure.

5.1.1 Cancer Risk for Nearby Residents

Potential risks to residents living near a hypothetical “model” facility were evaluated on the basis of exposure to chemicals released in outdoor air by the facility. Inhalation is the only exposure route quantified. Methylene chloride-based adhesive is the only adhesive type for which cancer risk to nearby residents could be estimated; the major ingredient, methylene chloride, is a probable human carcinogen.²

The following cancer risk estimates are based on the air modeling described in Section 4.3.3 (Exposure Models and Results), which is based on several key assumptions:

- ? All the methylene chloride solvent evaporates during the application process.
- ? All air releases from adhesive application are vented to the outside, without any air pollution control.

¹Upper bound refers to the method of determining a slope factor, where the upper bound value (generated from a certain probability statement) for the slope of the dose-response curve is used. *Excess* means the estimated cancer risk is in addition to the already-existing background risk of an individual contracting cancer from all other causes.

² A cancer classification of B2, *probable human carcinogen*, has been assigned by the Environmental Protection Agency (EPA); International Agency for Research on Cancer (IARC) has classified methylene chloride as *possibly carcinogenic to humans* (Group 2B); and National Toxicology Program (NTP) has judged methylene chloride as *reasonably anticipated to be a human carcinogen* (see Section 3.1 and Table 3-1).

- ? Facility site visits provide representative average and high annual adhesive use amounts, adhesive use is evenly distributed throughout the year, and chemical ingredient formulations are constant over time.
- ? Chemicals released to air do not degrade in the environment prior to reaching the nearby population.
- ? People live as close as 25 meters from a facility (based on observations made on site visits).
- ? Meteorological data from El Monte, California; Grand Rapids, Michigan; and High Point, North Carolina, are representative of facility locations.

Results are based on the highest modeled air concentrations for three locations (El Monte, California; Grand Rapids, Michigan; and High Point, North Carolina) and, at each location, the position relative to the facility yielding the highest air concentration (of 16 different wind speed/direction vectors).

Upper-bound excess individual lifetime cancer risks for nearby residents from inhalation exposure to methylene chloride, depending on location from the model facility, are estimated as follows. For average adhesive use:

- ? at 100 meters from a model facility: from near zero to 6×10^{-5}
- ? at 25 meters from a facility: from near zero to 1×10^{-4}

For high adhesive use:

- ? at 100 meters from a facility: from near zero to 6×10^{-4}
- ? at 25 meters from a facility: from near zero to 1×10^{-3}

These estimates indicate concern for cancer risks and are interpreted to mean that, over a lifetime, an individual resident may have up to one chance in 1,000 of developing cancer from exposure to methylene chloride from a nearby facility, depending on amount of adhesive used, the resident's location, and the distance he or she lives from the facility.

5.1.2 Cancer Risk for Workers

Although the Environmental Protection Agency (EPA) has established inhalation and oral cancer potency factors for methylene chloride (used in methylene chloride-based adhesive) these factors are not appropriate for use at the concentrations estimated for worker exposure.³ At those higher concentrations, pharmacokinetic modeling is required.

³ According to the Integrated Risk Information System (IRIS), the inhalation unit risk factor should not be used if the air concentration exceeds 20 mg/m³, and the oral potency factor should not be used if the water concentration exceeds 50 mg/L (EPA, 2000).

5.1 CANCER RISK

The Occupational Safety and Health Administration (OSHA) recently conducted a quantitative assessment of methylene chloride cancer risks in the workplace, "...based on the highest-quality animal tumor data, constructing a state-of-the-art physiologically-based pharmacokinetic (PBPK) model incorporating rodent and human metabolic information." (OSHA, 1997). Results of this risk assessment include the following:

- ? 3.62 cancer deaths estimated per 1,000 workers occupationally exposed to 86 mg/m³ (25 ppm) methylene chloride for a working lifetime;
- ? 7.47 excess cancers per 1,000 workers estimated at 170 mg/m³ (50 ppm); and
- ? 126 excess cancers estimated per 1,000 workers at 1,700 mg/m³ (500 ppm).

To evaluate worker inhalation risks, estimated workplace air concentrations are compared with these risk results calculated by OSHA at the specified workplace exposure levels. Cancer risk from dermal exposure cannot be characterized at this time.

The estimated air concentration for average methylene chloride adhesive use, with average ventilation, is 160 mg/m³. This is close to the 170 mg/m³ (50 ppm) air concentration that corresponds to 7.47 excess cancers per 1000 workers as estimated by OSHA. Therefore, under the average workplace scenario, there is up to approximately a 7×10^{-3} cancer risk from inhalation of methylene chloride. Cancer risks less than 1×10^{-6} (one in 1 million) are generally considered to be of low concern. These results are significantly above this level, indicating a concern for cancer from the estimated exposure levels of methylene chloride.

The estimated air concentration for high methylene chloride adhesive use, worse-than-average (WTA) ventilation, is 6,700 mg/m³—this is much higher than the 1,700 mg/m³ (500 ppm) air concentration that corresponds to 126 excess cancers per 1000 workers as estimated by OSHA. Therefore, under the high-use/WTA-ventilation workplace exposure scenario, cancer risk from inhalation of methylene chloride could be more than 0.1, indicating high concern.

These air concentrations and resulting risks were estimated based on the assumptions that all the methylene chloride solvent evaporates during the application process, facility site visits provide representative average and high annual adhesive use amounts, adhesive use is evenly distributed throughout the year, the air in the process room is at steady state, and chemical ingredient formulations are constant over time. Also, ventilation rates are based on general ventilation (air turnover for the entire room), and do not consider the use of any additional local ventilation, such as hoods.

Available air monitoring data in one facility where methylene chloride-based adhesive was used indicated that air concentrations of methylene chloride to which workers were being exposed ranged from 1,200 to 2,520 mg/m³ (340 to 715 ppm) (OSHA, 2001). These measured values fall

between the air concentrations that were estimated by modeling for average-use/average-ventilation and high-use/WTA-ventilation scenarios. This suggests that the air concentrations estimated by modeling are not unreasonable, although the high-use/WTA-ventilation scenario is a high-end assumption that may overestimate most actual exposures. However, measured concentrations from monitoring at one facility also suggest a high concern for worker's cancer risk.

5.1.3 Other Potential Cancer Risks

Quantitative cancer potency measures, such as unit risk or slope factors, are needed to calculate estimates of cancer risk. Other adhesive ingredients are possible carcinogens, but do not have EPA-established potency factors. In addition to methylene chloride, 1,2-butylene oxide and chloroprene have been determined by the International Agency for Research on Cancer (IARC) to be possible human carcinogens (IARC Group 2B). (1,2-butylene oxide is used in the n-propyl bromide adhesive, and chloroprene is in water-based latex/synthetic adhesive, left over as unreacted monomer from the neoprene manufacturing process.) Trichloroethylene (TCE—an alternative ingredient that may be used in some n-propyl bromide formulations) has been determined by IARC to be probably carcinogenic to humans (IARC Group 2A). There are potential cancer risks to nearby residents and workers from these chemicals, and exposures have been estimated, but cancer potency and therefore cancer risks are unknown.

5.2 NON-CANCER RISKS

5.2 NON-CANCER RISKS

Non-cancer risk estimates are expressed as an HQ or MOE. HQs are generally based on a reference dose (RfD) or reference concentration (RfC) that has been established by EPA. If an RfD or RfC is available, the HQ is calculated to characterize risk from chemicals that exhibit chronic, non-cancer toxicity. (In the case of acetone, a minimum risk level (MRL) was used in place of an RfC.) The HQ is the unitless ratio of the RfD (or RfC) to the potential dose rate. For adhesive ingredient chemicals that exhibit chronic, non-cancer toxicity, the HQ was calculated by:

$$\begin{aligned} \text{HQ} &= \text{ADD}/\text{RfD} \\ &\text{or,} \\ \text{HQ} &= \text{ADD}/(\text{RfC}\times\text{CF}) \end{aligned}$$

where,

- ADD = Average daily dose rate; the amount of a chemical ingested, inhaled, or applied to the skin per unit time, averaged over the exposure duration (in mg/kg-day).
- RfD = Reference dose; an estimate (with uncertainty spanning perhaps an order of magnitude) of the daily exposure through ingestion (oral) and through skin uptake (dermal) to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious non-cancer effects during a lifetime (mg/kg-day).
- RfC = Reference Concentration; an estimate (with uncertainty spanning perhaps an order of magnitude) of the daily inhalation exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious non-cancer effects during a lifetime (mg/m³).
- CF = Conversion factor based on underlying assumptions in the RfC (20 m³/day breathing rate and 70 kg body weight), which converts the units from mg/m³ to mg/kg-day (EPA, 1989; EPA, 1994).

RfDs and RfCs are presented in the Human Health Hazards Summary, Section 3.2.1. ADDs were calculated as part of the Exposure Assessment (Section 4.4).

The HQ is based on the assumption that there is a level of exposure (i.e., the RfD or RfC) below which it is unlikely, even for sensitive subgroups, to experience adverse health effects. Unlike cancer risk, the HQ does not express *probability* and is not necessarily linear; that is, an HQ of 10 does not mean that adverse health effects are 10 times more likely to occur than for an HQ of 1. However, the ratio of estimated dose to RfD or RfC reflects the level of concern, and an HQ above 1 indicates potential concern.

For chemicals where an RfC or RfD was not available, a margin of exposure (MOE) was calculated by:

$$\text{MOE}_N = (\text{NOAEL})/\text{ADD}$$

or,

$$\text{MOE}_L = (\text{LOAEL})/\text{ADD}$$

where,

MOE_N	=	NOAEL-based Margin of Exposure (unitless).
MOE_L	=	LOAEL-based Margin of Exposure (unitless).
NOAEL	=	No-observed adverse effect level, the highest dose level in a toxicity test at which there is no statistically or biologically significant increase in the frequency or severity of adverse effects in the exposed population over its appropriate control (mg/kg-day, or mg/m ³ for inhalation).
LOAEL	=	Lowest-observed adverse effect level, the lowest experimental dose level in a toxicity test at which there are statistically or biologically significant increases in frequency or severity of adverse effects in the exposed population over its appropriate control group (mg/kg-day, or mg/m ³ for inhalation).

NOAELs and LOAELs are presented in the Human Health Hazards Summary, Section 3.2.2. In general, there is a higher level of confidence for HQs than for MOEs because the toxicity data on which RfDs and RfCs are based have passed a more thorough level of review, and test-specific uncertainty factors have been included.

As with the HQ, the MOE is not a probabilistic statement of risk. The ratio for calculating MOE is the inverse of the HQ. That is, as HQ increases, the level of concern increases, and a high HQ (exceeding 1) indicates a potential concern. However, as MOE increases, the level of concern *decreases* and a low MOE (less than 100 for a NOAEL-based MOE or 1,000 for a LOAEL-based MOE) indicates a potential concern.

Both the exposure estimates and toxicity data are specific to the route of exposure (i.e., inhalation, oral, or dermal). Very few RfDs, NOAELs, or LOAELs are available for dermal exposure. For chemicals without dermal toxicity data, oral data were used, when available.

Developmental Toxicity

For two chemicals, either a no-observed effect level (NOEL) or a NOAEL value were available for developmental toxicity. For these, a developmental toxicity MOE was calculated by:

$$\text{MOE}_{N\text{-DT}} = \text{NOEL}_{\text{DT}}/\text{ADD} \text{ or } \text{NOAEL}_{\text{DT}}/\text{ADD}$$

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where,

MOE_{N-DT} = NOEL- or NOAEL-based margin of exposure for developmental effects.
 $NOEL_{DT}$ = No-observed effect level for developmental toxicity (mg/kg-day).

5.2.1 Risk Indicators Calculated for Nearby Residents

HQs were calculated for inhalation exposure of nearby residents to chemicals with an established RfC or minimum risk level (MRL). MOEs were calculated in cases where an RfC or MRL was not available, but a NOAEL or LOAEL was. HQs and MOEs were calculated for nearby residents under both the average- and high-adhesive-use scenarios at 25 meters from a model facility. Table 5-1 presents inhalation HQ results and Table 5-2 presents inhalation MOE results for nearby residents.

Table 5-1. Inhalation HQ Results for Nearby Residents 25 Meters from a Model Facility

HQ, average-use scenario ^a	HQ, high-use scenario ^a	Ingredient	Adhesive type
1.7	17	TCE	Alternative ingredient, n-propyl bromide
0.2	2.0	Hexane	Alternative ingredient, acetone blend
0.054	0.54	Methylene chloride	Methylene chloride
0.041	0.41	1,2-Butylene oxide	n-Propyl bromide
0.0092	0.092	Ammonia	Water-based latex
0.0092	0.092	Ammonia	Water-based latex/synthetic
0.0053	0.053	Acetone	Acetone
0.0013	0.013	Acetone	Acetone/heptane

^a Bold type indicates concern (HQ > 1).

Table 5-2. Inhalation MOE Results for Nearby Residents 25 Meters from a Model Facility

MOE, average-use ^a	MOE, high-use ^a	Ingredient	Adhesive type
1,300 (L)	130 (L)	n-Propyl bromide	n-Propyl bromide
41,000 (L)	4,100 (L)	Heptane	Acetone/heptane
46,000 (L)	4,600 (L)	1,3-Dioxolane	n-Propyl bromide
120 million (L)	12 million (L)	Chloroprene	Water-based latex/synthetic
170 million (N)	17 million (N)	Irganox 1010	n-Propyl bromide
200 million (N)	20 million (N)	Irganox 1010	Methylene chloride
220 million (N)	22 million (N)	Irganox 1010	Acetone
360 million (N)	36 million (N)	Irganox 1010	Acetone/heptane
7.9 billion (N)	790 million (N)	Irganox 1010	Hot melt

^a Bold type indicates concern: LOAEL-based MOE < 1,000 (L) or NOAEL-based MOE < 100 (N).

Data limitations include the use of estimated air concentrations based on data developed for a model facility, rather than site-specific, measured concentrations, and the lack of toxicity data for many chemicals. Chemicals without sufficient data with which to calculate inhalation HQs or MOEs for nearby residents include the following:

- ? 2-Bromopropane
- ? Chlorinated alkyl phosphates
- ? Cyanox 2246
- ? Paraffin wax
- ? Surfynol 440

Of these, all but 2-bromopropane are only marginally volatile and not as likely to evaporate completely during routine use.

Although toxicity data are not considered adequate for calculating a risk indicator, laboratory studies of the effects of 2-bromopropane clearly identified reproductive tissue effects to both male and female rats. Effects were seen from repeated exposure to air concentrations as low as 300 ppm (1,510 mg/m³). Compared with estimated air concentrations for nearby residents of 0.03 to 2.3 mg/m³, this indicates some concern from inhalation exposure to 2-bromopropane (when a safety factor of 1,000—for comparing lowest-observed effect levels in laboratory animals to human exposure—is taken into account).

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5.2.2 Risk Indicators Calculated for Adhesive Workers

HQs and MOEs calculated for occupational exposure to adhesive chemicals are presented below. (It should be noted that no epidemiological studies of health effects among furniture adhesive workers were located.) As stated earlier, an HQ exceeding 1 indicates a potential concern. Unlike cancer risk, the HQ does not express probability, only the ratio of the estimated dose to the RfD or RfC, and it is not necessarily linear (an HQ of 10 does not mean that adverse health effects are 10 times more likely than an HQ of one).

Inhalation Exposure

Table 5-3 presents HQs calculated for inhalation exposure to workers for the average-use/average-ventilation and high-use/WTA-ventilation scenarios.

Table 5-3. Inhalation HQ Results for Adhesive Workers

HQ, average use/average ventilation ^a	HQ, high use/WTA ventilation ^a	Ingredient	Adhesive type
560	24,000	TCE	Alternative ingredient, n-propyl bromide
65	2,700	Hexane	Alternative ingredient, acetone blend
18	740	Methylene chloride	Methylene chloride
13	570	1,2-Butylene oxide	n-Propyl bromide
3.0	120	Ammonia	Water-based latex
3.0	120	Ammonia	Water-based latex/synthetic
1.7	72	Acetone	Acetone
0.42	18	Acetone	Acetone/heptane

^a Bold type indicates concern (HQ > 1).

In cases where an RfC or MRL was not available, but a NOAEL or LOAEL was, MOEs were calculated for inhalation exposure to workers. Table 5-4 presents inhalation MOE results for the average-use/average-ventilation and high-use/WTA-ventilation scenarios.

Table 5-4. Inhalation MOE Results for Adhesive Workers

MOE, average use/average ventilation^a	MOE, high use/WTA ventilation^a	Ingredient	Adhesive type
4.1 (L)	0.097 (L)	n-Propyl bromide	n-Propyl bromide
130 (L)	3.0 (L)	Heptane	Acetone/heptane
140 (L)	3.3 (L)	1,3-Dioxolane	n-Propyl bromide
350,000 (L)	9,200 (L)	Chloroprene	Water-based latex/synthetic
530,000 (N)	13,000 (N)	Irganox 1010	n-Propyl bromide
630,000 (N)	15,000 (N)	Irganox 1010	Methylene chloride
690,000 (N)	16,000 (N)	Irganox 1010	Acetone
1.1 million (N)	27,000 (N)	Irganox 1010	Acetone/heptane
14 million (N)	570,000 (N)	Irganox 1010	Hot melt

^a Bold type indicates concern: < 1,000 for LOAEL-based MOE (L); < 100 for NOAEL-based MOE (N).

Data limitations include the use of estimated air concentrations using data developed for a model facility, rather than site-specific, measured concentrations, and the lack of toxicity data for many chemicals. Chemicals without sufficient data with which to calculate inhalation HQs or MOEs for workers include the following:

- ? 2-Bromopropane
- ? Chlorinated alkyl phosphates
- ? Cyanox 2246
- ? Paraffin wax
- ? Surfynol 440

Of these, all but 2-bromopropane are only marginally volatile and not as likely to evaporate completely during routine use.

As stated above, although toxicity data are not considered adequate for calculating a risk indicator, laboratory studies of the effects of 2-bromopropane clearly identified reproductive tissue effects to both male and female rats. Effects were seen from repeated exposure to air concentrations as low as 300 ppm (1,510 mg/m³). A comparison with estimated air concentrations for workers of 2.7 to 113 mg/m³ does indicate some concern to workers from inhalation exposure to 2-bromopropane (when a safety factor of 1,000—for comparing lowest-observed effect levels in laboratory animals to human exposure—is taken into account).

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Dermal Exposure

Table 5-5 presents dermal HQ results for worker's skin contact.

Table 5-5. Dermal HQ Results for Adhesive Workers

Dermal HQ or MOE ^a	Ingredient	Adhesive type
HQ		
2,200	Methylene chloride	Methylene chloride
1,500	Acetone	Acetone
970	Hexane	Alternative ingredient, acetone blend
580	Acetone	Acetone/heptane
MOE		
0.51 (N)	Chlorinated alkyl phosphates	Water-based latex
0.51 (N)	Chlorinated alkyl phosphates	Water-based latex/synthetic
10 (N-DT)	Chlorinated alkyl phosphates	Water-based latex
10 (N-DT)	Chlorinated alkyl phosphates	Water-based latex/synthetic
13 (N)	Cyanox 2246	Water-based latex
13 (N)	Cyanox 2246	Water-based latex/synthetic

^a Bold type indicates concern: HQ > 1, NOAEL-based MOE < 100 (N), or NOAEL-based MOE for developmental effects < 100 (N-DT).

Limitations include lack of sufficient toxicity data specific to dermal absorption for all chemicals, and the lack of sufficient oral toxicity data (used to substitute for dermal data) for many chemicals. (All of the calculated dermal HQs and MOEs are based on oral toxicity values.) Chemicals without sufficient dermal or oral toxicity data with which to calculate dermal HQs or MOEs for workers include the following:

- ? Ammonium hydroxide/ammonia
- ? 2-Bromopropane
- ? 1,2-Butylene oxide
- ? Chloroprene
- ? 1,3-Dioxolane
- ? Heptane
- ? n-Propyl bromide
- ? Surfynol 440
- ? Tackifying resin-rosin based

? Trichloroethylene (TCE)

There is also high uncertainty from the use of oral toxicity data to substitute for dermal-specific data and with the assumption that chemicals applied to the skin are completely absorbed. Dermal absorption was assumed to be negligible for high-molecular-weight ingredients due to large molecular size (this includes ethylene vinyl acetate, Irganox 1010, latex, neoprene, nitrile rubber, and SBS block copolymer) and for all hot melt ingredients, because the high temperatures would preclude any prolonged skin contact.

5.2.3 Comparing Worker Inhalation Exposure with Occupational Exposure Levels

In addition to calculating risk indicators for workplace inhalation exposures, the estimated workplace air concentrations are compared directly with available occupational exposure standards and/or guidance levels (presented in Section 3.4). Table 5-6 presents these comparisons.

Table 5-6. Comparison of Estimated Workplace Air Concentrations with Available Occupational Exposure Standards and Guidance Levels

Adhesive Type / Chemical Ingredient ^a	Comparison with Estimated Workplace Air Concentrations (C _{AIR})				
	Occupational Exposure Standard or Guidance Level (mg/m ³) ^b	Average Use/Average Ventilation		High Use/WTA Ventilation	
		C _{AIR} (mg/m ³)	Comments	C _{AIR} (mg/m ³)	Comments
Methylene Chloride Adhesive					
Methylene chloride	<ul style="list-style-type: none"> • PEL: 86 • TLV: 175 • NIOSH: <i>lowest feasible concentration</i> 	160	Exceeds PEL	6,700	Exceeds PEL and TLV
Acetone Adhesive					
Acetone	<ul style="list-style-type: none"> • REL: 590 • TLV: 1,200 • vacated PEL: 1,800^c • PEL: 2,400 	160		6,700	Exceeds REL, TLV, vacated PEL, and PEL
Acetone/Heptane Adhesive					
Acetone	<ul style="list-style-type: none"> • REL: 590 • TLV: 1,200 • vacated PEL: 1,800^c • PEL: 2,400 	39		1,600	Exceeds REL and TLV

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Adhesive Type / Chemical Ingredient ^a	Comparison with Estimated Workplace Air Concentrations (C _{AIR})				
	Occupational Exposure Standard or Guidance Level (mg/m ³) ^b	Average Use/Average Ventilation		High Use/WTA Ventilation	
		C _{AIR} (mg/m ³)	Comments	C _{AIR} (mg/m ³)	Comments
Heptane	<ul style="list-style-type: none"> • REL: 350 • vacated PEL: 1,600^c • TLV: 1,600 • PEL: 2,000 	39		1,600	Exceeds REL; equals vacated PEL and TLV
n-Propyl Bromide Adhesive					
n-Propyl bromide	<ul style="list-style-type: none"> • Supplier-recommended: 126 	180	Exceeds supplier-recommended level	7,700	Exceeds supplier-recommended level
1,2-Butylene oxide	<ul style="list-style-type: none"> • WEEL: 6 	0.8		34	Exceeds WEEL
2-Bromopropane	<ul style="list-style-type: none"> • OEL: 5 	2.7		113	Exceeds OEL
Water-Based Latex Adhesive					
Ammonia ^d	<ul style="list-style-type: none"> • REL: 18 • TLV: 18 • PEL: 35 	0.89		37	Exceeds REL, TLV, and PEL
Water-Based Latex/Synthetic Adhesive					
Ammonia ^d	<ul style="list-style-type: none"> • REL: 18 • TLV: 18 • PEL: 35 	0.89		37	Exceeds REL, TLV, and PEL
Chloroprene	<ul style="list-style-type: none"> • vacated PEL: 35^c • TLV: 36 mg/m³ • PEL: 90 • NIOSH: <i>lowest feasible concentration</i> 	0.001		0.038	
Hot Melt Adhesive					
Paraffin wax	<ul style="list-style-type: none"> • REL, TLV: 2 (fumes) 	Unknown		Unknown	
Alternative Ingredients^e					

Adhesive Type / Chemical Ingredient ^a	Comparison with Estimated Workplace Air Concentrations (C _{AIR})				
	Occupational Exposure Standard or Guidance Level (mg/m ³) ^b	Average Use/Average Ventilation		High Use/WTA Ventilation	
		C _{AIR} (mg/m ³)	Comments	C _{AIR} (mg/m ³)	Comments
Hexane	<ul style="list-style-type: none"> • vacated PEL: 180^c • REL: 180 • TLV: 180 • PEL: 1,800 	39		1,600	Exceeds REL, TLV, and vacated PEL
TCE	<ul style="list-style-type: none"> • REL: 135 • vacated PEL: 270^c • TLV: 270 • PEL: 540 • NIOSH: <i>lowest feasible concentration</i> 	67		2,800	Exceeds REL, PEL, TLV, and vacated PEL

^a This only includes those ingredients for which occupational exposure levels are available.

^b Time-weighted average (TWA). See Table 3-3 in Human Health Hazards Summary chapter.

^c Vacated 1989 PEL, still enforced in some states.

^d Ammonium hydroxide is the chemical form in solution in water-based adhesives. This converts to ammonia during application. A 100-percent conversion of ammonium hydroxide to ammonia is assumed.

^e Alternative adhesive ingredients not included in typical adhesive formulations; hexane may be used in some acetone-blend formulations and TCE in some n-propyl bromide formulations.

PEL: Permissible exposure level

REL: Recommended exposure level

TLV: Threshold limit value

WEEL: Workplace environmental exposure level

NIOSH: National Institute for Occupational Safety and Health

5.3 DISCUSSION OF RESULTS, UNCERTAINTIES, AND KEY ASSUMPTIONS

5.3 DISCUSSION OF RESULTS, UNCERTAINTIES, AND KEY ASSUMPTIONS

5.3.1 Nearby Residents

Cancer risk results indicate potential concern for nearby residents exposed to methylene chloride, with cancer risks estimated at up to 1 in 1,000. HQ results do not indicate concern for noncancer health effects. However, the MOE for n-propyl bromide for high adhesive use does indicate concern for that chemical.

Key assumptions related to nearby resident exposure include the following:

- ? 100 percent of all volatile ingredients evaporates during the adhesive application process;
- ? All air releases from adhesive application are vented to the outside, without any air pollution control.
- ? Facility site visits provide representative average and high annual adhesive use amounts;
- ? Adhesive use is evenly distributed throughout the year.
- ? Chemical ingredient formulations are constant over time.
- ? Chemicals released to air do not degrade in the environment prior to reaching the nearby population.
- ? People live as close as 25 meters from a facility (based on site-visit observations).
- ? Meteorological data from El Monte, California; Grand Rapids, Michigan; and High Point, North Carolina, are representative of facility locations. Results are based on the highest modeled air concentrations for those three locations and of 16 different wind speed/direction vectors at each location.

Other assumptions used in the exposure modeling are discussed in Section 4.4.

5.3.2 Worker Inhalation

Adhesive ingredients that pose a concern from worker inhalation are presented in Tables 5-7 and 5-8. These include chemicals of potential concern based on cancer risks, HQ, and MOE results and comparison with occupational exposure standards and/or guidance levels.

Table 5-7. Results of Concern for Worker Inhalation of Chemical Ingredients in the Average Adhesive Use / Average Ventilation Scenario

Chemical Ingredient of Concern	Results of Concern, by Adhesive Type ^a					
	Methylene Chloride-based	Acetone-based	Acetone/Heptane-based	n-Propyl Bromide-based	Water-based Latex	Water-based Latex/Synthetic
Acetone	NA	HQ = 1.7	NA	NA	NA	NA
Ammonia ^b	NA	NA	NA	NA	HQ = 3.0	HQ = 3.0

5.3 DISCUSSION OF RESULTS, UNCERTAINTIES, AND KEY ASSUMPTIONS

Chemical Ingredient of Concern	Results of Concern, by Adhesive Type ^a					
	Methylene Chloride-based	Acetone-based	Acetone/Heptane-based	n-Propyl Bromide-based	Water-based Latex	Water-based Latex/Synthetic
1,2-Butylene oxide	NA	NA	NA	HQ = 13	NA	NA
1,3-Dioxolane	NA	NA	NA	MOE _L = 140	NA	NA
Heptane	NA	NA	MOE _L = 130	NA	NA	NA
Latex	NA	NA	NA	NA	Sensitizer	Sensitizer
Methylene chloride	Cancer risk = 7×10^{-3} ; HQ = 18; PEL exceeded.	NA	NA	NA	NA	NA
n-Propyl bromide	NA	NA	NA	MOE _L = 4.1; supplier-recommended level exceeded.	NA	NA
Alternative Ingredients^c						
Hexane	NA	HQ = 65	NA	NA	NA	NA
TCE	NA	NA	NA	HQ = 560	NA	NA

^a Results of concern include any of the following: cancer risk $> 1 \times 10^{-6}$; HQ > 1 ; MOE_N < 100 ; MOE_L $< 1,000$; and/or estimated workplace air concentration that exceeds 1 or more occupational standard or guidance level. There were no results on concern for acetone/heptane or hot melt adhesives.

^b Ammonium hydroxide is the chemical form in solution in water-based adhesives. This converts to ammonia during application. A 100-percent conversion of ammonium hydroxide to ammonia is assumed.

^c Alternative adhesive ingredients not included in typical adhesive formulations; hexane may be used in some acetone-blend formulations and TCE in some n-propyl bromide formulations.
NA = not applicable.

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Table 5-8. Results of Concern for Worker Inhalation of Chemical Ingredients in the High-Adhesive Use / WTA-Ventilation Scenario

Chemical Ingredient of Concern	Results of Concern, by Adhesive Type ^a					
	Methylene Chloride-based	Acetone-based	Acetone/Heptane-based	n-Propyl Bromide-based	Water-based Latex	Water-based Latex/Synthetic
Acetone	NA	HQ = 72; REL, TLV, vac.PEL, PEL exceeded	HQ = 18; REL, TLV exceeded	NA	NA	NA
Ammonia ^b	NA	NA	NA	NA	HQ = 120; REL, TLV, PEL exceeded	HQ = 120; REL, TLV, PEL exceeded
2-Bromo-propane	NA	NA	NA	OEL exceeded	NA	NA
1,2-Butylene oxide	NA	NA	NA	HQ = 570; WEEL exceeded	NA	NA
1,3-Dioxolane	NA	NA	NA	MOE _L = 3.3.	NA	NA
Heptane	NA	NA	MOE _L = 3.0; REL exceeded	NA	NA	NA
Latex	NA	NA	NA	NA	Sensitizer	Sensitizer
Methylene chloride	Cancer risk > 0.1; HQ = 740; PEL, TLV exceeded	NA	NA	NA	NA	NA
n-Propyl bromide	NA	NA	NA	MOE _L = 0.1; supplier-recommended level exceeded	NA	NA

5.3 DISCUSSION OF RESULTS, UNCERTAINTIES, AND KEY ASSUMPTIONS

Chemical Ingredient of Concern	Results of Concern, by Adhesive Type ^a					
	Methylene Chloride-based	Acetone-based	Acetone/Heptane-based	n-Propyl Bromide-based	Water-based Latex	Water-based Latex/Synthetic
Alternative Ingredients^c						
Hexane	NA	HQ = 2,700; REL, TLV, vac. PEL exceeded	NA	NA	NA	NA
TCE	NA	NA	NA	HQ = 24,000; PEL, REL, TLV, vac. PEL exceeded	NA	NA

^a Results of concern include any of the following: cancer risk $>1 \times 10^{-6}$; HQ > 1 ; $MOE_N < 100$; $MOE_L < 1,000$; and/or estimated workplace air concentration that exceeds 1 or more occupational standard or guidance level. There were no results on concern for hot melt adhesive.

^b Ammonium hydroxide is the chemical form in solution in water-based adhesives. This converts to ammonia during application. A 100-percent conversion of ammonium hydroxide to ammonia is assumed.

^c Alternative adhesive ingredients not included in typical adhesive formulations; hexane may be used in some acetone-blend formulations and TCE in some n-propyl bromide formulations.

NA = not applicable.

Key assumptions for worker inhalation include the following:

- ? 100 percent of all volatile ingredients evaporate during the adhesive application process.
- ? Facility site visits provide representative average and high annual adhesive use amounts.
- ? Adhesive use is evenly distributed throughout the year.
- ? Chemical ingredient formulations are constant over time.
- ? Mixing of air in the process room is at steady state.
- ? Ventilation rates are based on general ventilation (air turnover for the entire room) and do not consider the use of any additional local ventilation, such as hoods. (The use of local ventilation for adhesive application areas could reduce worker exposure significantly.)

Other assumptions used in the exposure modeling are discussed in Section 4.4.

5.3.3 Skin Contact for Adhesive Workers

Dermal risk indicators of concern are presented in Table 5-9. This includes chemicals of potential concern based on HQ, MOE, and potential for cancer risk.

5.3 DISCUSSION OF RESULTS, UNCERTAINTIES, AND KEY ASSUMPTIONS

Table 5-9. Results of Concern for Worker Skin Contact with Chemical Ingredients

Chemical Ingredient of Concern	Results of Concern, by Adhesive Type ^a				
	Methylene Chloride-based	Acetone-based	Acetone/Heptane-based	Water-based Latex	Water-based Latex/Synthetic
Acetone	NA	HQ = 1,500	HQ = 580	NA	NA
Chlorinated alkyl phosphates	NA	NA	NA	MOE _N = 0.51; MOE _{N-DT} = 10	MOE _N = 0.51; MOE _{N-DT} = 10
Cyanox 2246	NA	NA	NA	MOE _N = 13	MOE _N = 13
Latex	NA	NA	NA	Sensitizer	Sensitizer
Methylene chloride	HQ = 2,200; cancer risk ^b	NA	NA	NA	NA
Alternative Ingredients^c					
Hexane	NA	HQ = 970	NA	NA	NA

^a Results of concern include any HQ > 1, MOE_N <100, or MOE_L <1,000.

^b Although some cancer risk is expected from contact with methylene chloride, it could not be quantified.

^c Alternative adhesive ingredients not included in typical adhesive formulations; hexane may be used in some acetone-blend formulations and TCE in some n-propyl bromide formulations.

NA = not applicable.

Key assumptions for worker dermal include the following:

- ? Hands and forearms are routinely in contact with spray adhesive.
- ? Workers do not wear long sleeves or gloves.
- ? Chemicals applied to the skin are completely absorbed.
- ? Oral toxicity values are used in lieu of any available dermal RfDs, NOAELs, or LOAELs.

Other assumptions used in the exposure modeling are discussed in Section 4.4.

5.3.4 Potential Health Effects from Chemicals of Concern

Table 5-10 provides a summary of the potential health effects for the chemicals of concern. It should be noted that Tables 5-7, 5-8, and 5-9 do not include chemicals for which toxicity data were unavailable.

Table 5-10. Summary of Potential Human Health Effects for Chemicals of Concern

Chemical of Concern	Potential Health Effects ^a
Acetone	Acetone is irritating to the skin, respiratory tract, and eyes. It can affect the central nervous system, and repeated exposure may damage the liver and kidneys. High exposures can cause confusion, headaches, dizziness, drowsiness, and unconsciousness.
Ammonium hydroxide/ammonia ^b	Ammonia fumes are extremely irritating to skin, eyes, and respiratory passages. Inhaling ammonia can damage the respiratory tract and at high concentrations can lead to blurred vision, unconsciousness, and brain effects. Dermal exposures can also result in gastrointestinal and respiratory effects. People with asthma are especially sensitive to ammonia's effects.
2-Bromopropane	2-Bromopropane can cause reproductive effects in both males and females and can affect the hematopoietic (blood forming) system.
1,2-Butylene oxide	1,2-Butylene oxide is irritating to the skin, respiratory tract, and eyes. Inhaling 1,2-butylene oxide can cause confusion, dizziness, headache, nausea, and unconsciousness and can damage the mucous membranes and upper respiratory tract. Inhalation of high amounts can damage the respiratory system and is potentially fatal. Repeated exposures may affect the nervous system, spleen, thymus, and kidneys. Repeated dermal exposure can damage the skin.
Chlorinated alkyl phosphates	Chlorinated alkyl phosphates are slightly irritating to the skin. Exposure is associated with effects to the liver, kidneys, testes, and adrenal gland.
Chloroprene	Chloroprene may cause skin and lung cancer; it is a suspected, but not recognized, carcinogen. Inhaling chloroprene can irritate the skin and mucous membranes. It can also affect the nervous system, liver, kidneys, and respiratory tract and possibly have reproductive effects. Repeated exposures can affect the liver, central nervous system, circulatory system, and immune system.
Cyanox 2246	Limited toxicity data. Long-term, repeated exposure of male rats caused severe effects to the testes. One study "identifies testicular effects as a critical target."
1,3-Dioxolane	1,3-Dioxolane is irritating to the skin and severely irritating to the eyes. Exposure is associated with blood and reproductive effects.
Heptane	Heptane is irritating to the eyes, skin, and lungs. It can affect the central nervous system, with the potential for brain damage from repeated exposure. It may also damage the liver.

5.3 DISCUSSION OF RESULTS, UNCERTAINTIES, AND KEY ASSUMPTIONS

Chemical of Concern	Potential Health Effects ^a
Hexane	Exposure to hexane can damage the sensory and motor nerves (peripheral neuropathy). The most common symptoms include numbness and loss of feeling, usually in the feet and hands.
Latex	Latex is a sensitizer; repeated exposure to latex can cause a substantial proportion of exposed people to develop an allergic reaction. The type and severity of allergic reaction can vary, including skin irritation, dermatitis, hives, and other allergic reactions; asthma; and rarely, life-threatening anaphylaxis (swelling of lips and airways that may progress to shock and death) (OSHA, 1999).
Methylene chloride	Methylene chloride is irritating to the skin, eyes, and respiratory tract. Repeated exposures can affect the central nervous system, heart, liver, kidneys, and bone marrow. In the body, it metabolizes to carbon monoxide, which can cause oxygen deprivation. Because of this, high exposure to methylene chloride can result in unconsciousness and death. It is a probable human carcinogen.
n-Propyl bromide	Although the toxic properties of n-propyl bromide have not yet been extensively studied, there is concern that it may cause reproductive effects and nerve damage.
Trichloroethylene (TCE)	Exposure to TCE can affect the nervous system, immune system, liver, kidneys, and endocrine system. It is also associated with developmental effects and several forms of cancer. TCE is considered “highly likely to produce cancer in humans.”

^a In general, the severity of effects depends on the amount and duration of exposure.

^b Ammonium hydroxide is the chemical form in solution in water-based adhesives. This converts to ammonia during application. A 100-percent conversion of ammonium hydroxide to ammonia is assumed.

5.3.5 Data Gaps

Data gaps for cancer risks include 1,2-butylene oxide, chloroprene, and Trichloroethylene (TCE), which are possible carcinogens, but no established cancer potency factors are available with which to calculate cancer risks. For non-cancer effects, Table 5-11 presents an overview of data availability for characterizing non-cancer risk.

5.3 DISCUSSION OF RESULTS, UNCERTAINTIES, AND KEY ASSUMPTIONS

Table 5-11 Data Gaps for Chronic Non-Cancer Health Effects

Adhesive Type / Chemical Ingredient	Inhalation Exposure ^a			Dermal Exposure ^b		
	Potential Exposure ^c	Available Toxicity Data/OEL ^d	Data Gap ^e	Potential Exposure ^f	Available Toxicity Data ^g	Data Gap ^e
Methylene Chloride						
Irganox 1010	Yes ^h	Yes / No	NA	No	Yes	NA
Methylene chloride	Yes	Yes / Yes	NA	Yes	Yes	NA
SBS block copolymer	No	No / No	NA	No	No	NA
Tackifying resin-rosin based	No	No / No	NA	Yes	No	X
Acetone						
Acetone	Yes	Yes / Yes	NA	Yes	Yes	NA
Irganox 1010	Yes ^h	Yes / No	NA	No	Yes	NA
Nitrile rubber	No	No / No	NA	No	No	NA
Tackifying resin-rosin based	No	No / No	NA	Yes	No	X
Acetone/Heptane						
Acetone	Yes	Yes / Yes	NA	Yes	Yes	NA
Heptane	Yes	Yes / Yes	NA	Yes	No	X
Irganox 1010	Yes ^h	Yes / No	NA	No	Yes	NA
SBS block copolymer	No	No / No	NA	No	No	NA
Tackifying resin-rosin based	No	No / No	NA	Yes	No	X
n-Propyl Bromide						
2-Bromopropane	Yes	No / Yes	No HQ or MOE	Yes	No	X
1,2-Butylene oxide	Yes	Yes / Yes	NA	Yes	No	X
1,3-Dioxolane	Yes	Yes / No	NA	Yes	No	X
Irganox 1010	Yes ^h	Yes / No	NA	No	Yes	NA
n-Propyl bromide	Yes	Yes / Yes	NA	Yes	No	X
SBS block copolymer	No	No / No	NA	No	No	NA
Tackifying resin-rosin based	No	No / No	NA	Yes	No	X
Water-Based Latex						

5.3 DISCUSSION OF RESULTS, UNCERTAINTIES, AND KEY ASSUMPTIONS

Adhesive Type / Chemical Ingredient	Inhalation Exposure ^a			Dermal Exposure ^b		
	Potential Exposure ^c	Available Toxicity Data/OEL ^d	Data Gap ^e	Potential Exposure ^f	Available Toxicity Data ^g	Data Gap ^e
Ammonium hydroxide/ammonia	Yes	Yes / Yes	NA	Yes	No	X
Chlorinated alkyl phosphates	Yes ^h	No / No	X	Yes	Yes	NA
Cyanox 2246	Yes ^h	No / No	X	Yes	Yes	NA
Latex	No	No / No	NA	No	No	NA
Surfynol 440	Yes ^h	No / No	X	Yes	No	X
Tackifying resin-rosin based	No	No / No	NA	Yes	No	X
Water-Based Latex Synthetic						
Ammonium hydroxide/ammonia	Yes	Yes / Yes	NA	Yes	No	X
Chloroprene	Yes	Yes / Yes	NA	Yes	No	X
Chlorinated alkyl phosphates	Yes ^h	No / No	X	Yes	Yes	NA
Cyanox 2246	Yes ^h	No / No	X	Yes	Yes	NA
Latex	No	No / No	NA	No	No	NA
Neoprene	No	No / No	NA	No	No	NA
Surfynol 440	Yes ^h	No / No	X	Yes	No	X
Tackifying resin-rosin based	No	No / No	NA	Yes	No	X

5.3 DISCUSSION OF RESULTS, UNCERTAINTIES, AND KEY ASSUMPTIONS

Adhesive Type / Chemical Ingredient	Inhalation Exposure ^a			Dermal Exposure ^b		
	Potential Exposure ^c	Available Toxicity Data/OEL ^d	Data Gap ^e	Potential Exposure ^f	Available Toxicity Data ^g	Data Gap ^e
Hot Melt						
Ethylene vinyl acetate	No	No / No	NA	No	No	NA
Irganox 1010	Yes ^h	Yes / No	NA	No	Yes	NA
Microcrystalline wax	No	No / No	NA	No	No	NA
Paraffin wax	No ⁱ	No / Yes	NA	No	No	NA
Tackifying resin-rosin based	No	No / No	NA	No	No	NA
Alternative Ingredients^j						
Hexane	Yes	Yes/Yes	NA	Yes	Yes	NA
TCE	Yes	Yes/Yes	NA	Yes	No	X

^a Inhalation data gaps apply to both nearby residents and to adhesive workers.

^b Dermal data gaps apply only to adhesive workers.

^c “Yes” indicates that exposure is expected to occur and was quantified in the exposure assessment; “No” indicates that exposure is expected to be negligible for inhalation due to the chemical’s low volatility and its use as an adhesive ingredient.

^d Indicates whether available toxicity data were sufficient to calculate an HQ or MOE, or whether an occupational exposure standard or guidance level for workplace air was available for this chemical.

^e **X** indicates a data gap, where exposure is expected to occur but toxicity data were not available to calculate an HQ or MOE. “NA” indicates that a data gap did not occur, either because data were sufficient to calculate an HQ or MOE or because exposure is expected to be negligible. “No HQ or MOE” indicates that an HQ or MOE could not be calculated, but estimated workplace air concentrations could be compared with occupational exposure standards or guidance levels.

^f “Yes” indicates that exposure is expected to occur and was quantified in the exposure assessment; “No” indicates that exposure is expected to be negligible from skin absorption due to the chemical’s large molecular size (e.g., the polymers) or due to the high operating temperatures (for all hot melt ingredients).

^g Indicates whether available data were sufficient to calculate an HQ or MOE. For dermal exposure, in all cases an oral toxicity value was used in lieu of dermal toxicity data.

^h Only marginally volatile and not as likely to evaporate completely during routine use.

ⁱ Only marginally volatile, not quantified in exposure assessment.

^j Alternative adhesive ingredients not included in typical adhesive formulations; hexane may be used in some acetone-blend formulations and TCE in some n-propyl bromide formulations.

5.3.6 Uncertainties

An important component of any risk characterization is the identification and discussion of uncertainties. There are uncertainties involved in the measurement and selection of hazard data and in the data, models, and scenarios used in the exposure assessment. Any use of the risk characterization should include consideration of these uncertainties.

5.3 DISCUSSION OF RESULTS, UNCERTAINTIES, AND KEY ASSUMPTIONS

In addition to data and modeling limitations, discussed in Section 4.4, uncertainties in the exposure assessment include the following:

- ? Accuracy of the description of exposure setting: how well the model facility used in the assessment characterizes an actual facility; the likelihood of exposure pathways actually occurring (i.e., scenario uncertainty).
- ? Missing data and limitations of data on workplace practices: this includes possible effects of any chemicals that may not have been included (e.g., minor ingredients and/or variations in the formulations).
- ? Estimating exposure levels from averaged data and modeling in the absence of measured, site-specific data.
- ? The applicability of the chemical fate and transport model and the assumptions on which it is based: how well the models and assumptions represent the situation being assessed and the extent to which the models have been validated or verified (i.e., model uncertainty).
- ? The uncertainty of parameter values, including measurement error, sampling error, parameter variability, and professional judgement.
- ? Uncertainty in combining pathways for an exposed individual.

Key assumptions made in the exposure assessment are discussed in Sections 4.4 and 4.5.

Uncertainties in the hazard data (typically encountered in a hazard assessment) include the following:

- ? Using dose-response data from high-dose studies to predict effects that may occur at low levels.
- ? Using data from short-term studies to predict the effects of long-term exposures.
- ? Using dose-response data from laboratory animals to predict effects in humans.
- ? Using data from homogeneous populations of laboratory animals or healthy human populations to predict the effects on the general human population, with a wide range of sensitivities (uncertainty due to natural variations in human populations).
- ? Using NOAELs and LOAELs in the absence of peer-reviewed RfCs and RfDs.
- ? Assuming a linear dose-response relationship for cancer risk (in this case for methylene chloride).
- ? Possible increased or decreased toxicity resulting from chemical interactions.
- ? Possible effects of substances not evaluated because of a lack of sufficient toxicity data.

Uncertainties in assessing risk from dermal exposure come from the use of oral reference doses, a route of exposure different from the one under evaluation (dermal absorption from skin contact). This was done for five chemicals with dermal HQs (including acetone, ammonia, chloroprene, hexane, and methylene chloride); and two chemicals with dermal MOEs (chlorinated alkyl phosphates and Cyanox 2246). Uncertainties in dermal risk estimates also stem from the assumption that 100 percent of chemical applied to the skin is absorbed into the body, which may overestimate exposure to some ingredients.

5.3 DISCUSSION OF RESULTS, UNCERTAINTIES, AND KEY ASSUMPTIONS

Finally, the risk characterization does not address the potential adverse health effects associated with acute exposure to peak levels of chemicals, as might occur from a spill. This type of exposure is especially important when evaluating developmental risks associated with exposure.

5.4 OVERALL RISK SCREENING AND COMPARISON SUMMARY

5.4 OVERALL RISK SCREENING AND COMPARISON SUMMARY

Table 5-12 presents an overall comparison of human health concerns for the adhesive formulations evaluated.

Table 5-12. Overall Comparison of Potential Worker Health Risks for Baseline and Alternative Adhesive Types

Adhesive Type	Chemicals of Concern					
	Potential Carcinogen ^a	Inhalation Concern ^b		Dermal Concern ^c	Inhalation Data Gaps ^d	Dermal Data Gaps ^e
		Average Use/Average Ventilation	High Use/WTA Ventilation			
Methylene Chloride (Baseline)	Methylene chloride	Methylene chloride	Methylene chloride	Methylene chloride	(none)	Tackifying resin
Acetone	(none)	Acetone	Acetone	Acetone	(none)	Tackifying resin
Acetone/Heptane	(none)	Heptane	Acetone Heptane	Acetone	(none)	Heptane Tackifying resin
n-Propyl Bromide	1,2-Butylene oxide	1,2-Butylene oxide 1,3-Dioxolane n-Propyl bromide	2-Bromopropane 1,2-Butylene oxide 1,3-Dioxolane n-Propyl bromide	(none)	2-Bromopropane ^f	2-Bromopropane 1,2-Butylene oxide 1,3-Dioxolane n-Propyl bromide Tackifying resin
Water-based Latex	(none)	Ammonia ^g Latex	Ammonia ^g Latex	Latex Chlorinated alkyl phosphates Cyanox 2246	Chlorinated alkyl phosphates Cyanox 2246 Surfynol 440	Ammonia Surfynol 440 Tackifying resin
Water-based Latex/Synthetic	Chloroprene	Ammonia Latex	Ammonia Latex	Latex Chlorinated alkyl phosphates Cyanox 2246	Chlorinated alkyl phosphates Cyanox 2246 Surfynol 440	Ammonia Chloroprene Surfynol 440 Tackifying resin
Hot Melt	(none)	(none)	(none)	(none)	(none)	(none)

5.4 OVERALL RISK SCREENING AND COMPARISON SUMMARY

Adhesive Type	Chemicals of Concern					
	Potential Carcinogen ^a	Inhalation Concern ^b		Dermal Concern ^c	Inhalation Data Gaps ^d	Dermal Data Gaps ^e
		Average Use/Average Ventilation	High Use/WTA Ventialtion			
Alternative Ingredients	TCE	Hexane TCE	Hexane TCE	Hexane	(none)	TCE

^a The chemicals with an EPA cancer weight of evidence (WOE) of B2 and/or an IARC WOE of 2B (see Table 3-1).

^b The chemicals for which the inhalation cancer risk is greater than 1×10^{-6} ; HQ for worker inhalation exceeds 1; MOE_N is less than 100; MOE_L is less than 1,000; or estimated workplace air concentrations exceed one or more occupational exposure standards or guidance levels. See Tables 5-7 and 5-8 for more detailed results.

^c The chemicals for which the HQ for dermal contact by workers exceeds 1; MOE_N is less than 100; or MOE_L is less than 1,000. See Table 5-9 for detailed results.

^d The chemicals for which worker inhalation exposure is possible but for which appropriate toxicity data are not available for calculating an HQ and no occupational exposure standard or guidance level is available with which to compare estimated air concentrations.

^e The chemicals for which worker dermal contact is possible but appropriate toxicity data are not available for calculating a risk indicator.

^f No HQ or MOE could be calculated, although estimated air concentrations could be compared with occupational exposure guidance levels.

^g Ammonium hydroxide is the chemical form in solution in water-based adhesives. This converts to ammonia during application. A 100-percent conversion of ammonium hydroxide to ammonia is assumed.

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REFERENCES

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