

Chapter 3

Human Health Hazards Summary

This section presents a summary of the human health hazards data used in the risk characterization. This information is summarized for chemical ingredients in the typical adhesive formulations, plus two alternative ingredients. The chemical ingredients selected for each typical adhesive formulation are listed in Section 2.3. See Chapter 6 for further discussion of other possible adhesive formulations and ingredients.

In this cleaner technologies substitutes assessment (CTSA) risk evaluation, three types of potential human health effects are considered:

- ? cancer,
- ? chronic, systemic toxicity, and
- ? developmental toxicity.

Each of these is discussed in the sections following.

Chemical ingredients were evaluated based on toxicity measures for the above health effects as well as occupational exposure standards and guidance levels. In addition, safety information from material safety data sheets (MSDSs) is summarized and used to evaluate potential hazards posed by adhesives.

3.1 CARCINOGENIC EFFECTS

The potential for a chemical to cause cancer in humans is evaluated by cancer weight-of-evidence (WOE) classifications and by cancer potency factors, typically determined from laboratory or epidemiological studies. There are a large number of chemicals in commerce, however, (approximately 15,000 non-polymeric chemicals produced in amounts greater than 10,000 lb/year), and many of these chemicals have not yet been tested or assigned carcinogenicity classifications.

3.1.1 Weight of Evidence

In assessing the carcinogenic potential of a chemical, the Environmental Protection Agency (EPA) classifies the chemical into one of the following groups, according to the WOE from epidemiologic, animal, and other supporting data, such as genotoxicity test results. EPA categories are listed below:

- ? Group A: Human Carcinogen (sufficient evidence of carcinogenicity in humans).
- ? Group B: Probable Human Carcinogen (B1—limited evidence of carcinogenicity in humans; B2—sufficient evidence of carcinogenicity in animals with inadequate or lack of evidence in humans).

3.1 CARCINOGENIC EFFECTS

- ? Group C: Possible Human Carcinogen (limited evidence of carcinogenicity in animals and inadequate or lack of human data).
- ? Group D: Not Classifiable as to Human Carcinogenicity (inadequate or no evidence).
- ? Group E: Evidence of Non-Carcinogenicity for Humans (no evidence of carcinogenicity in adequate studies).

EPA has proposed a revision of its guidelines that would eliminate the above discrete categories while providing a more descriptive classification.¹

The International Agency for Research on Cancer (IARC) uses a similar WOE method for evaluating potential human carcinogenicity based on human data, animal data, and other supporting data. (IARC classifications predate those developed by EPA, who modeled their classifications in the 1986 cancer guidelines on the IARC scheme.) A summary of the IARC carcinogenicity classification system includes:

- ? Group 1: Carcinogenic to humans.
- ? Group 2A: Probably carcinogenic to humans.
- ? Group 2B: Possibly carcinogenic to humans.
- ? Group 3: Not classifiable as to human carcinogenicity.
- ? Group 4: Probably not carcinogenic to humans.

Both classification schemes represent judgments regarding the likelihood of human carcinogenicity (i.e., the extent to which the available data support the hypothesis that a substance causes cancer in humans). In this CTSA, both EPA and IARC classifications are used wherever information is available. Table 3-1 lists all furniture adhesive chemicals classified by EPA or IARC.

The National Toxicology Program (NTP) was established in 1978 by the U.S. Secretary of Health and Human Services to coordinate toxicology research and testing activities within the department, to provide information about potentially toxic chemicals to regulatory and research agencies and the public, and to strengthen the science base in toxicology. NTP classifies agents, substances, mixtures, or exposure circumstances as either:

- ? Known To Be Human Carcinogens, or
- ? Reasonably Anticipated to be Human Carcinogens.

The 9th Annual/Biennial Report on Carcinogens has recently been published (NTP, 2001). Any available NTP evaluations for the adhesive ingredients are also included in Table 3-1.

¹ The "Proposed Guidelines for Carcinogen Risk Assessment" (EPA, 1996) proposes the use of WOE descriptors, such as "Likely" or "Known," "Cannot be determined," and "Not likely," in combination with a hazard narrative, to characterize a chemical's human carcinogenic potential, rather than the classification system described above.

Table 3-1. Available Cancer Weight-of-Evidence Information

Chemical Name ^a	Comments/Classification
Probable or Possible Human Carcinogens	
1,2-Butylene oxide	<i>Possibly carcinogenic to humans</i> (IARC Group 2B: IARC, 2000).
Chloroprene	<i>Possibly carcinogenic to humans</i> (IARC Group 2B: IARC, 2000). <i>Reasonably anticipated to be a human carcinogen</i> based on evidence of benign and malignant tumor formation at multiple tissue sites in multiple species of experimental animals (NTP 467, 1998, as cited in 9th Report on Carcinogens [NTP, 2001]).
Methylene chloride	<i>Probable Human Carcinogen</i> : sufficient evidence of carcinogenicity in animals with inadequate or lack of evidence in humans (EPA Class B2: EPA, 2000). <i>Possibly carcinogenic to humans</i> (IARC Group 2B: IARC, 2000). <i>Reasonably anticipated to be a human carcinogen</i> based on sufficient evidence in experimental animals (NTP 306, 1986, as cited in 9th Report on Carcinogens [NTP, 2001]).
Trichloroethylene (TCE)^b	<i>Probably carcinogenic to humans</i> (IARC Group 2A; IARC, 2000). <i>Reasonably anticipated to be a human carcinogen</i> based on limited evidence of carcinogenicity in humans, sufficient evidence in experimental animals, and convincing relevant information that it acts through mechanisms indicating it would likely cause cancer in humans (NTP, 9th Report on Carcinogens [NTP, 2001]).
Other WOE Available	
Acetone	<i>Not classifiable as to human carcinogenicity</i> (EPA Class D: EPA, 2000).
Heptane	<i>Not classifiable as to human carcinogenicity</i> (EPA Class D: EPA, 2000).
Neoprene	<i>Not classifiable as to its carcinogenicity to humans</i> (IARC Group 3: IARC, 2000).
SBS block copolymer	<i>Not classifiable as to its carcinogenicity to humans</i> (IARC Group 3: IARC, 2000).

^a Only those chemicals with available data or classifications are listed.

^b An alternative ingredient; not included as an ingredient in typical formulations, but TCE has been used in some n-propyl bromide formulations.

n-Propyl bromide (1-bromopropane) was selected for carcinogenicity and other toxicity testing by the NTP Interagency Committee for Chemical Evaluation and Coordination in December 1999, following nomination for testing by the Occupational Safety and Health Administration (OSHA) and the National Institute for Occupational Safety and Health (NIOSH) (OSHA, 1999a).

3.1 CARCINOGENIC EFFECTS

3.1.2 Cancer Potency

For low-dose carcinogenic effects, there is presumably no level of exposure that does not pose a small, but finite, probability of causing a cancer response. This type of mechanism is called “non-threshold.” When the available data are adequate and sufficient for quantification, EPA develops an estimate of the chemical’s carcinogenic potency expressed as either a slope factor or unit risk value. The slope factor (q_1^*) is a measure of an individual’s excess lifetime risk or increased likelihood of developing cancer if exposed to a chemical, expressed in units of $(\text{mg}/\text{kg}\text{-day})^{-1}$ over a lifetime. More specifically, q_1^* is an approximation of the upper bound of the slope of the dose-response curve using the linearized, multistage procedure at low doses. “Unit risk” is an equivalent measure of potency for air or drinking water concentrations. Unit risk is expressed as the upper bound excess lifetime cancer risk per $\mu\text{g}/\text{m}^3$ in air, or as risk per $\mu\text{g}/\text{L}$ in water, based on default exposure conditions for a continuous lifetime exposure. Slope factors and unit risks can be viewed as quantitatively-derived judgements of the magnitude of carcinogenic effect.

EPA risk characterization methods require a cancer potency value (slope factor or unit risk) to quantify the upper bound, excess lifetime cancer risk from exposure to a known or suspected carcinogen. At the time of this report, only one chemical ingredient, methylene chloride, had an EPA-established potency factor. Therefore, this is the only chemical for which cancer risk is quantitatively characterized (see Chapter 5, Risk Characterization).

Methylene chloride has an inhalation unit risk factor of $4.7\text{E-}7$ per g/m^3 and an oral cancer slope factor of $7.5\text{E-}03$ per $\text{mg}/\text{kg}\text{-day}$ (EPA, 2000). These factors were developed, however, for much lower exposure levels than are estimated for adhesive workers. According to EPA’s Integrated Risk Information System (IRIS), the inhalation unit risk factor should not be used if the air concentration exceeds $20 \text{ mg}/\text{m}^3$ (69 ppm). Therefore, the IRIS inhalation unit risk factor is not used here for workplace exposures, because the estimated air concentrations are much higher than the $20 \text{ mg}/\text{m}^3$ limit.² IRIS also states that the oral potency factor should not be used if the water concentration exceeds $50 \text{ mg}/\text{L}$. Similarly, worker cancer risks are not estimated for skin contact, since the concentration of methylene chloride, at 68 percent, greatly exceeds the concentration limit in water stated in IRIS of $50 \text{ mg}/\text{L}$.³

² Air concentrations for average use, average ventilation are estimated at $160 \text{ mg}/\text{m}^3$ in workplace air, and for high use, worse-than-average ventilation, at $6,700 \text{ mg}/\text{m}^3$ in air (see Chapter 4, Exposure Assessment.)

³ Adhesive concentrations to which workers are exposed on their skin is 68 percent in the methylene chloride formulation. Although the oral cancer potency factor was developed for ingestion of methylene chloride in drinking water, the limit of $50 \text{ mg}/\text{L}$ in drinking water indicates that the exposure concentrations for workers greatly exceed those for which the cancer potency factors were developed.

3.1 CARCINOGENIC EFFECTS

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). For this evaluation of worker inhalation risks, estimated workplace air concentrations are compared with the risks calculated by OSHA at specified workplace exposure levels. Cancer risks from methylene chloride are not estimated for worker dermal exposure.

For the neighboring population, estimated air concentrations are below 20 mg/m³ (69 ppm), and the IRIS unit risk factor is used to estimate cancer risk from methylene chloride air releases⁴ (see Chapter 5, Risk Characterization).

⁴ Estimated ambient air concentrations are from 0.23 mg/m³ to 2.3 mg/m³ at 25 meters from the facility (see Chapter 4, Exposure Assessment).

3.2 CHRONIC, SYSTEMIC TOXICITY

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Systemic toxicity means an adverse effect on any organ system following absorption and distribution of a chemical throughout the body. Adverse effects other than cancer and gene mutations are generally assumed to have a dose or exposure threshold. Therefore, the evaluation for systemic toxicity is based on comparing this threshold amount with the estimated amount of exposure.

3.2.1 Reference Dose/Reference Concentration

A reference dose (RfD) is 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. RfDs are expressed in units of mg/kg-day. Similarly, a reference concentration (RfC) is 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 (Barnes and Dourson, 1988). RfCs are expressed in air concentration units (e.g., mg/m³). RfD and RfC values from IRIS are derived from EPA peer-reviewed study results, together with uncertainty factors regarding their applicability to human populations. Table 3-2 presents a summary of the available RfC and RfD information for adhesive ingredients. A minimal risk level (MRL) is a similar measure developed by the Agency for Toxic Substances and Disease Registry (ATSDR). Because an RfC for acetone was not available, an MRL is used instead.

Table 3-2. Summary of RfC and RfD Information Used in the Risk Characterization

Chemical Name ^a	Inhalation RfC ^b (mg/m ³)	Comments ^c (Inhalation)	Oral/Dermal RfD ^b (mg/kg/day)	Comments ^c (Oral/Dermal)
Acetone	31 (MRL)	ATSDR chronic MRL, UF = 100, neurological endpoint (ATSDR, 2000).	0.1 (IRIS)	UF = 1,000; low confidence; oral subchronic rat study, liver and kidney effects (EPA, 2000). Quickly penetrates skin.
Ammonium hydroxide/ ammonia	0.1 (IRIS)	For ammonia, UF = 30, medium confidence level, subchronic rat inhalation study, respiratory effects (EPA, 2000).	ND	
1,2-Butylene oxide	0.02 (IRIS)	UF = 300, medium confidence level, 2-year mouse inhalation study, nasal effects (EPA, 2000).	ND	
Hexane ^{d,e}	0.2 (IRIS)	UF = 300, medium confidence level, epidemiological inhalation study, neurotoxicity and electrophysical alterations (EPA, 2001).	0.06 (HEAST)	UF = 10,000; oral, rat, 90 day study, neuropathy and testicular atrophy (EPA, 1997).
Methylene chloride	3.0 (HEAST)	UF = 100, 2-year rat inhalation study, liver effects (EPA, 1997).	0.06 (IRIS)	UF = 100, medium confidence, rat, drinking water, liver toxicity (EPA, 2000). Absorbed through skin.

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Chemical Name ^a	Inhalation RfC ^b (mg/m ³)	Comments ^c (Inhalation)	Oral/Dermal RfD ^b (mg/kg/day)	Comments ^c (Oral/Dermal)
Trichloroethylene ^d	0.04 (Draft IRIS)	Based on critical effects in central nervous system, liver, and endocrine system (Cogliano, 2001).	ND	

^a Only those chemicals with available data are listed.

^b The type of value is noted in parentheses:

IRIS: EPA-derived and peer-reviewed values listed in the Integrated Risk Information System. IRIS values are preferred and used whenever available.

HEAST: EPA-derived RfD or RfC listed in the Health Effects Assessment Summary Tables. These values have not undergone the same level of review as IRIS values.

MRL: Minimal risk level, developed by the ATSDR in a manner similar to EPA-derived values.

^c Comments may include exposure route, test animal, duration of test, adverse effects noted, and source of data.

UF = uncertainty factor.

^d An alternative ingredient; not included in the typical formulations, but hexane may be used in some acetone-blend formulations, and trichloroethylene (TCE) in some n-propyl bromide formulations.

^e Toxicity data were collected for a specific, representative compound (n-hexane, CAS No. 110-54-3). Hexane used as a solvent may actually include other related compounds such as methylcyclopentane; 2-methylpentane; 3-methylpentane; 2,3-dimethylbutane; 2,2-dimethylbutane; diethylmethylethane; 2,3-dimethylbutane; and isohexane.

ND: No data; RfC, RfD, or similar value not available.

3.2.2 Adverse Effect Levels for Systemic Effects

When an RfD, RfC, or appropriate MRL was not available for a chemical, other toxicity values were used, preferably in the form of a “no-observed-adverse-effect level” (NOAEL) or “lowest-observed-adverse-effect level” (LOAEL). These toxicity values were obtained from the published scientific literature, as well as unpublished data submitted to EPA on chemical toxicity in chronic or subchronic studies. Typically, the lowest NOAEL or LOAEL value from a well-conducted study was used. If study details were not presented or the study did not appear to be valid, the reported NOAEL/LOAELs were not used. Unlike RfDs and RfCs, NOAELs and LOAELs do not incorporate uncertainty or modifying factors.

The LOAEL is 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 (in mg/kg-day, or mg/m³ for inhalation). The NOAEL is 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 (in mg/kg-day, or mg/m³ for inhalation). Available LOAEL values are used only when NOAELs were not available. Table 3-3 presents a summary of the available NOAEL and LOAEL values.

3.2.3 Other Concerns

Water-based latex and water-based latex/synthetic adhesives contain natural latex.⁵ Latex is a sensitizer; repeated exposure to latex can cause a substantial proportion of exposed people to develop an allergic reaction. Around 6 to 17 percent of the exposed health care workforce is allergic to natural rubber latex, and approximately 1 to 6 percent of the general population (OSHA, 1999b). 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, 1999b).

⁵ Natural latex is actually a mixture of chemical compounds. A single, representative chemical was selected for toxicity data collection (2-methyl-1,3-butadiene homopolymer).

3.2 CHRONIC, SYSTEMIC TOXICITY

Table 3-3. NOAEL/LOAEL Values Used in Risk Characterization

Chemical Name ^a	Inhalation NOAEL/LOAEL ^b (mg/m³)	Comments ^c (Inhalation)	Oral/Dermal NOAEL/LOAEL ^b (mg/kg-day)	Comments ^c (Oral/Dermal)
2-Bromopropane	ND ^d		ND	
Chlorinated alkyl phosphates ^f	ND		5 (N) ^e	Rat, diet, 24 months, chronic toxicity and benign tumor induction (Freudenthal and Heinrich, 2000).
Chloroprene	116 (L) ^g	Rats and mice, repeated dose inhalation, 16 days, effects on nasal lining in rats (NTP, 1998)	ND	
Cyanox 2246	ND		12.7 (N)	Rat, diet, 18 months, reduced body weight gain, liver effects, severe testicular effects (Takagi <i>et al.</i> , 1994).
1,3-Dioxolane	379 (L) ^h	One-generation reproductive study, rats, 24 weeks, reduced litter size (Dioxolane Manufacturers Consortium, 2000).	ND	
Heptane	1,630 (L)	Rats, 26 weeks (Holdsworth, 1980).	ND	
Irganox 1010	480,000 (N) ^e	Two studies: Beagle dogs, diet, 13 weeks, no adverse effects related to treatment; rats, diet, 10 months, no reproductive effects seen (1981; 1984: both studies reported in Ciba, 2001 HPV submission).	ND	(See Table 3.4)

3.2 CHRONIC, SYSTEMIC TOXICITY

Chemical Name ^a	Inhalation NOAEL/ LOAEL ^b (mg/m ³)	Comments ^c (Inhalation)	Oral/ Dermal NOAEL/ LOAEL ^b (mg/kg-day)	Comments ^c (Oral/Dermal)
n-Propyl bromide	250 (L) ^g	Rats, repeated dose inhalation, 8 weeks, liver effects (Kim <i>et al.</i> , 1999).	ND	

^a Only those chemicals with available data or classifications are listed.

^b (N) = NOAEL; (L) = LOAEL. When more than one NOAEL and/or LOAEL was available, only the lowest available NOAEL or LOAEL was used and is listed here. If both NOAEL and LOAEL data are available, the NOAEL is used and is listed here. If a chronic NOAEL or LOAEL was not available, other values (e.g., from shorter-term studies) were used as noted.

^c Comments may include exposure route, test animal, duration of test, effects, and source of data.

^d Data inadequate, although effects seen at ≥ 1510 mg/m³ (≥ 300 ppm).

^e No-observed adverse effect level (NOEL)—used as a NOAEL in this evaluation.

^f This ingredient could include two different chlorinated alkyl phosphate compounds. The value presented here is for CAS No. 13674-87-8.

^g Shorter term study.

^h 125 ppm was considered the NOAEL by the study authors, but it is possible that 125 ppm represents a LOAEL for reproduction. For this CTSA, the value is used as a LOAEL.

ND: No Data. A NOAEL or LOAEL was not available for this chemical.

3.3 DEVELOPMENTAL TOXICITY

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The risk of developmental effects is typically evaluated separately from other types of chemical hazards. Developmental toxicity refers to adverse effects produced in offspring from chemical exposure prior to conception, during pregnancy, or during childhood. These effects may be observed as stillbirths, malformations, early postnatal mortality, reduced birth weight, mental retardation, sensory loss, and other adverse functional or physical changes that appear in offspring. Developmental toxicity is different from reproductive toxicity (e.g., effects on reproductive tissues or reproductive success), which is addressed as a component of systemic toxicity, in the previous section.

Two chemicals having potential developmental toxicity were identified based on the data provided in the toxicity profiles. No RfCs or RfDs based on developmental effects (RfC_{DT} or RfD_{DT}) are available; the available data are in the form of NOAELs or no-observed effect levels (NOELs). These data are summarized in Table 3-4.

Table 3-4. Developmental Toxicity Values Used in the Risk Characterization

Chemical Name ^a	Inhalation (mg/m³)	Oral/Dermal NOAEL or NOEL ^b (mg/kg-day)	Comments ^c (Oral/Dermal)
Chlorinated alkyl phosphates ^d	ND	100 (NOAEL)	Rat, gavage, GD 6-15, developmental toxicity (bone formation effects) (Akzo Nobel Chemicals Inc., 2001).
Irganox 1010	ND	1,000 (NOEL)	Two studies: rats, gavage, GD 6-15, no teratogenic or maternal toxicity (Ciba Geigy, 1975a); mice, gavage, GD 6-15, no teratogenic or maternal toxicity (Ciba Geigy, 1975b).

^a Only those chemicals with available data are listed.

^b NOAEL: no-observed adverse effect level; NOEL: no-observed effect level. A NOEL is used in the same way as a NOAEL in this evaluation.

^c Comments may include test effects, test animal, duration during time of gestation, exposure route, and source of data. GD: Gestational day.

^d This ingredient could include two different chlorinated alkyl phosphate compounds. The value presented here is for CAS No. 13674-87-8.

ND: No data available.

3.4 OCCUPATIONAL EXPOSURE STANDARDS AND GUIDANCE

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Additional information about chemical hazards, especially as they pertain to the workplace, is available in the form of occupational exposure standards and guidance. Various agencies and groups develop recommendations or standards for workplace exposure levels in order to protect worker health. The U.S. agencies and other organizations, and the types of limits they develop are described in this section. Available values for furniture adhesive ingredients are presented in Table 3-5.

The occupational exposure limits collected for furniture adhesive ingredients were limited to agencies or independent groups within the United States. Occupational exposure standards that have been developed in other countries have not been included, with the exception of 2-bromopropane. The United States has not developed occupational standards or guidance levels, to date, but South Korea has developed an occupational exposure level (OEL) for this substance, which is considered in this evaluation and included in Table 3-5.

Also, no standards or guidance were available for n-propyl bromide from any government agency or independent organization concerned with worker health. However, industry has recommended exposure levels for this chemical which are included here in lieu of any other established value.

3.4.1 Occupational Safety and Health Administration

OSHA was established in 1970 to assure safe and healthful working conditions by establishing and enforcing health and safety standards, and by providing for research, information, education, and training in the field of occupational safety and health. This mandate involves the application of a set of tools by OSHA (e.g., standards development, enforcement, compliance assistance), which enables employers to maintain safe and healthful workplaces. OSHA standards for exposure to airborne chemicals or substances in workplace air are in the form of permissible exposure limits (PELs).

The PEL is an enforceable standard promulgated by OSHA to represent the 8-hour time-weighted average concentration of a substance above which workers may not be exposed. PELs are often derived from threshold limit values (TLVs) or may be revised based on a recommended exposure level (REL) suggested by the NIOSH (see below). Some vacated PELs are also listed in the table. A court decision in 1992 (AFL-CIO v. OSHA, 11th Circuit Court of Appeals) vacated more protective PELs set by OSHA in 1989 for 212 substances, moving them back to PELs established in 1971. The appeals court also vacated new PELs for 164 substances that were not previously regulated. Vacated PELs are enforced in some states and therefore included in the table.

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3.4.2 National Institute for Occupational Safety and Health

The National Institute for Occupational Safety and Health (NIOSH) is a Federal agency established by the Occupational Safety and Health Act of 1970 to protect the safety and health of American workers by conducting scientific research, recommending safety and health standards, and disseminating prevention information. NIOSH is responsible for making recommendations for standards to OSHA. NIOSH levels are in the form of RELs and levels that are immediately dangerous to life or health (IDLH).

A REL is defined as the 8-hour time weighted average concentration of a substance above which it is recommended that a worker may not be exposed. A REL is the recommended standard by NIOSH for promulgation by OSHA as a PEL. (There are also some short-term RELs, e.g., for 15 minutes.)

IDLH is the concentration of a substance in air that is recognized to pose an exposure that is likely to cause death or immediate or delayed permanent adverse health effects, or prevent an escape from such an environment. IDLHs were established as part of the NIOSH respirator decision logic to ensure that a worker can escape the contaminated environment in the event of failure of the respiratory protection equipment.

3.4.3 American Conference of Governmental Industrial Hygienists

American Conference of Governmental Industrial Hygienists (ACGIH) is an organization of industrial hygiene professionals founded to encourage the interchange of experience among industrial hygiene workers and to collect and make accessible information and data that might assist industrial hygienists in their professional duties. They are responsible for establishing TLVs, among other things. The TLV is the airborne concentration of a substance representing a condition under which it is believed that nearly all workers may be repeatedly exposed, day after day, without adverse effect. TLVs are consensus values and not enforceable.

3.4.4 American Industrial Hygiene Association

American Industrial Hygiene Association (AIHA) is an association of occupational and environmental health professionals dedicated to the protection of workers and members of the community from workplace related hazards. They develop Workplace Environmental Exposure Levels (WEELs). A WEEL is the workplace exposure level to which it is believed nearly all individuals could be repeatedly exposed without experiencing adverse health effects. WEELs can be expressed as either time-weighted average (TWA) concentrations or ceiling values; however, different time periods are specified depending on the properties of the agent.

3.5 SUMMARY OF AVAILABLE HAZARDS DATA

A summary of the available hazards data for the adhesive ingredient chemicals is presented in Table 3-6. These data are used in the risk characterization (Chapter 5). Risk indicators are calculated for chemicals with an applicable cancer potency factor (cancer risk) and for chemicals with an inhalation RfC, oral RfD, MRL, NOAEL, or LOAEL (hazard quotient [HQ] or margin of exposure [MOE]). These risk indicators are then compared to EPA concern levels. For chemicals with occupational exposure standards or guidance levels, estimated workplace air concentrations are compared to those standards or guidance levels. Quantitative comparisons cannot be done for chemicals without hazards data.

Table 3-6. Overview of Available Toxicity Data and Occupational Exposure Levels

Chemical Name	Cancer Potency Factor (CPF), Weight-of-Evidence (WOE) Classification	Available Chronic Toxicity Data (RfC, RfD, MRL, NOAEL, or LOAEL) ^a		Available Occupational Standard or Guidance Level ^b
		Inhalation	Oral/Dermal	Inhalation
Acetone	WOE	MRL	O-RfD	PEL, vPEL, REL, TLV
Ammonium hydroxide / ammonia	ND	RfC	ND	PEL, REL, TLV
2-Bromopropane	ND	ND	ND	South Korean OEL ^c
1,2-Butylene oxide	WOE	RfC	ND	WEEL
Chlorinated alkyl phosphates	ND	ND	O-NOEL; NOAEL _{DT}	ND
Chloroprene	WOE	LOAEL (st)	ND	PEL, vPEL, TLV
Cyanox 2246	ND	ND	O-NOAEL	ND
1,3-Dioxolane	ND	LOAEL	ND	ND
Ethylene vinyl acetate	ND	ND	ND	ND
Heptane	WOE	ND	ND	PEL, vPEL, REL, TLV
Hexane	ND	RfC	ND	PEL, vPEL, REL, TLV
Irganox 1010	ND	NOEL	NOEL _{DT}	ND
Latex	ND	ND	ND	ND

3.5 SUMMARY OF AVAILABLE HAZARDS DATA

Chemical Name	Cancer Potency Factor (CPF), Weight-of-Evidence (WOE) Classification	Available Chronic Toxicity Data (RfC, RfD, MRL, NOAEL, or LOAEL) ^a		Available Occupational Standard or Guidance Level ^b
		Inhalation	Oral/Dermal	Inhalation
Methylene chloride	WOE; I-CPF; O-CPF	RfC	O-RfD	PEL, TLV
Microcrystalline wax	ND	ND	ND	ND
Neoprene	WOE	ND	ND	ND
Nitrile rubber	ND	ND	ND	ND
Paraffin wax	ND	ND	ND	REL, TLV (fumes)
n-Propyl bromide	ND	LOAEL (st)	ND	Supplier-recommended exposure guidelines.
SBS block copolymer	WOE	ND	ND	ND
Surfynol 440	ND	ND	ND	ND
Tackifying resin, rosin-based	ND	ND	ND	ND
TCE ^d	WOE	draft RfC	ND	PEL, vPEL, REL, TLV

^a RfC = EPA reference concentration, RfD = EPA reference dose, MRL = ATSDR minimal risk level, NOAEL = no-observed adverse effect level, LOAEL = lowest-observed adverse effect level; st: value is from shorter term study; _{DT} indicates a developmental toxicity value.

^b OEL = occupational exposure level, PEL = OSHA permissible exposure limit, vPEL = vacated PEL, REL = NIOSH recommended exposure limit, TLV = ACGIH threshold limit value.

^c Chemicals may have exposure standards from other countries. Only U.S. levels are used in this evaluation, with the exception of 2-bromopropane, where the S. Korean value is the only one established at this time.

^d An alternative ingredient; not included in typical formulations, but hexane may be used in some acetone-blend formulations, and TCE in some n-propyl bromide formulations.

ND = no data

I = Inhalation

O = Oral

3.6 SUMMARY OF HAZARDS ASSESSMENT

For human health hazards, toxicity data in the form of RfDs, RfCs, MRLs, NOAELs, LOAELs, and cancer potency factors were compiled for inhalation and dermal pathways. A total of 22 chemicals are considered as part of the furniture adhesive use cluster, plus two alternative ingredients of special concern.

Methylene chloride is the only chemical ingredient with EPA-established cancer potency factors. Other adhesive ingredients are carcinogens or suspected carcinogens, but do not have EPA-established potency factors. 1,2-Butylene oxide and chloroprene have been determined by IARC to be possible human carcinogens (IARC Group 2B). 1,2-Butylene oxide is used in the n-propyl bromide adhesive. Chloroprene is present in polychloroprene, used in water-based latex/synthetic adhesive. (Chloroprene is leftover as unreacted monomer from the polychloroprene manufacturing process). TCE has been determined by IARC to be probably carcinogenic to humans (IARC Group 2A). TCE is an alternative ingredient that may be used in some n-propyl bromide formulations.

For non-cancer health effects from inhalation, five adhesive chemicals have inhalation RfCs available from which to calculate HQs in the risk characterization and one chemical has an MRL, which is also used as an RfC to calculate an HQ. In addition, four adhesive chemicals have inhalation NOAELs or LOAELs available from which to calculate MOEs. Additionally, eleven chemical ingredients have occupation exposure standards or guidance levels for air; estimated workplace air concentrations are compared to these levels in the risk characterization. For dermal exposure, two adhesive chemicals have oral RfDs from which to calculate HQs. In addition, two adhesive chemicals have oral NOAELs, and two chemicals have oral developmental NOAELs from which to calculate MOEs.

In some cases, appreciable inhalation or skin exposure is expected for a chemical ingredient, but toxicity values are not available to calculate risk indicators, or occupational exposure levels are not available with which to compare workplace air concentrations. In these cases, there may be a risk to workers, but it cannot be characterized. Uncertainties due to missing hazard data are addressed in the Risk Characterization.

3.7 PROCESS SAFETY/ACUTE EFFECTS

3.7 PROCESS SAFETY/ACUTE EFFECTS

Process safety is a concern and responsibility of employers and employees alike. Each company has the obligation to provide its employees with a safe and healthy work environment, while each employee is responsible for his/her own safe personal work habits. Adhesives used during the adhesives application process may present potential process safety hazards, requiring that they be handled and stored properly, using appropriate personal protective equipment and safe operating practices.

The U.S. Department of Labor and OSHA have established safety standards and regulations to assist employers in creating safe working environments and protecting workers from potential workplace hazards. In addition, individual states may also have safety standards regulating chemical and physical workplace hazards for many industries. Federal safety standards and regulations affecting manufacturing industries can be found in the Code of Federal Regulations (CFR) Title 29, Part 1910, and are available by contacting your local OSHA field office. State and local regulations are available from the appropriate state office.

3.7.1 Chemical Safety Hazards

Chemical safety hazards associated with the use and application of adhesives under typical operating conditions, as well as the concerns that may arise from unusual operating conditions, are described below. Relevant concerns were identified during a review of MSDSs using definitions/criteria established by OSHA [29 CFR 1910], which have been summarized and included in Appendix A. OSHA health-based reporting criteria have been omitted from this list. Refer to the risk characterization in Chapter 5 for information on the risk to human health from adhesives.

Methylene Chloride Adhesive

The methylene chloride-based adhesive is both non-flammable and non-explosive under typical operating conditions. However, vapors from the adhesive are heavier than air and can form high concentrations in confined or poorly ventilated areas, which may then be ignited by a nearby high intensity energy source, such as a pilot light or spark heater. Methylene chloride will thermally decompose under fire conditions to form toxic gases, including hydrochloric acid (HCl) fumes, chlorine gas, and phosgene. Exposure to adhesive fumes may cause minor eye or skin irritation.

Methylene chloride adhesive is incompatible with both strong acids and strong alkalis, and can react with some metals including aluminum. Prolonged contact with aluminum or its alloys during usage, and especially during storage, should be avoided.

Acetone and Acetone-Blend Adhesives

Adhesives containing acetone are both highly volatile and flammable (adhesive flashpoint below 20°F) at room temperatures. Both acetone and acetone/heptane (or acetone/hexane) adhesives pose a fire hazard unless the proper precautions are taken during the adhesives use and storage. In areas where adhesives are used, sufficient ventilation should be provided to prevent the build-up of vapors, which are heavier than air and will collect to form explosive concentrations. Open flames, such as pilot lights, should be avoided along with other ignition sources such as motors, spark heaters, and areas of smoking. The solid portions of the adhesives are combustible, and will thermally decompose to form carbon monoxide, carbon dioxide, and various hydrocarbons.

Adhesives with acetone are incompatible with strong acids and oxidizing chemicals. Acetone-based adhesives will not undergo any hazardous polymerization. Exposure to adhesive fumes may cause minor eye or skin irritation.

n-Propyl Bromide Adhesive

The n-propyl bromide adhesive is not flammable or explosive under normal operating conditions, and does not present a fire hazard. Although fumes from the adhesive are heavier than air and will tend to concentrate in confined spaces, under poor ventilation conditions, they are much less likely to form explosive concentrations than the other solvent-based adhesives. However, good ventilation should be maintained as the fumes may pose a health threat to workers at higher concentrations. Under high temperature conditions, the adhesive will thermally decompose to give hydrobromic acid fumes and carbon monoxide. Exposure to adhesive fumes may cause minor eye or skin irritation.

Incompatibilities for n-propyl bromide adhesives include strong alkalis, oxidizers, and reactive metals such as aluminum. Prolonged contact with aluminum during usage or storage should be avoided. n-Propyl bromide adhesives will not undergo hazardous polymerization.

Water-Based Latex & Water-Based Latex/Synthetic Adhesive

Water-based adhesives are not flammable and pose no unusual fire or explosion hazards. After water evaporation, remaining solids may combust to form carbon monoxide, carbon dioxide, and organic acids and aldehydes. The latex/synthetic adhesive may also thermally decompose to form HCl. The adhesives will not undergo hazardous polymerization, but they are incompatible with strong oxidizing agents and acids, and should be used and stored away from these chemicals to prevent contact. Avoid contact with eyes, as both the liquid and adhesive vapors may cause eye or skin irritation.

3.7 PROCESS SAFETY/ACUTE EFFECTS

Hot Melt Adhesive

Hot melt adhesives are solids at room temperature, and as such are not readily volatile. Hot melts pose no unusual fire or explosion hazards under typical operating conditions, and will not polymerize into hazardous substances. Once melted, care should be taken to avoid contact with skin to prevent burns. Keep area well ventilated to prevent fumes from causing eye irritation.

Summary

Table 3-7 presents a summary of chemical safety hazards for each of the adhesive types.

Table 3-7. Hazardous Properties of Adhesive Chemical Ingredients

Adhesive Type	Types of Hazardous Properties Reported on MSDS
Methylene chloride	Hazardous decomposition, skin or eye irritant
Acetone	Flammable, explosive, fire hazard, sudden release of pressure, hazardous decomposition, skin or eye irritant
Acetone/heptane	Flammable, explosive, fire hazard, sudden release of pressure, hazardous decomposition, skin or eye irritant
n-Propyl bromide	Hazardous decomposition, skin or eye irritant
Water-based latex	Skin or eye irritant
Water-based latex/synthetic	Hazardous decomposition, skin or eye irritant
Hot melt	None noted

3.7.2 Storing and Handling Adhesives

It is important that workers know and follow the correct procedures for adhesive handling and storage, especially for the solvent-based adhesives. Much of the use, disposal, and storage information about adhesives may be obtained from the MSDSs provided by the adhesive manufacturer. Safe chemical storage and handling involves keeping chemicals in their proper place, protected from adverse environmental conditions, separated from chemicals with which they may react. Storage requirements and handling recommendations for adhesives include:

- ? Store adhesive containers in a cool, dry place away from direct sunlight and other sources of heat. Containers of acetone-based adhesives may burst if stored at temperatures higher than 130° F.
- ? Large containers (5 gallons or greater) including tank cars and trucks should be bonded or grounded when transferring acetone-based adhesives.
- ? Adhesives should be stored separately from chemicals with which they react such as strong oxidizers, acids, or alkalies. Prolonged contact with aluminum during storage is also to be avoided for several of the adhesives.
- ? Solvent-based adhesives, especially those containing acetone, should be stored away from ignition sources or in a flammable liquid storage cabinet.
- ? Adhesives should only be stored in their properly sealed original containers with appropriate labels. Refer to the CFR for OSHA chemical labeling requirements [29 CFR 1910.1200 (f)].

Each chemical product should be stored in a manner consistent with the recommendation on the MSDS. In addition, chemical storage facilities must be designed to meet any local, state, and federal requirements that may apply.

3.7.3 Worker Safety

An effective worker safety program identifies potential workplace hazards and, where possible, seeks to eliminate or at least reduce their potential for harm. An employee training program and personal protective equipment requirements are key elements of any worker safety program.

Employee Training

A critical element of workplace safety is a well-trained workforce. To help achieve this goal, the OSHA Hazard Communication Standard [29 CFR 1910.1200(h)] requires that all employees at manufacturing facilities (regardless of the size of the facility) be trained in the use of hazardous chemicals to which they are exposed. A training program should be instituted for workers, especially those applying or working directly with adhesives, who may become exposed to the adhesives or adhesive fumes. Training may be conducted by either facility staff or outside parties who are familiar with the adhesives application process and the pertinent safety concerns.

3.7 PROCESS SAFETY/ACUTE EFFECTS

The training should be held for each new employee, as well as periodic retraining sessions when necessary (e.g., when a new adhesive or a new application method is used), or on a regular schedule. The training program should inform the workers about the types of chemicals with which they work and the precautions to be used when handling or storing them, when and how personal protection equipment should be worn, how to operate and maintain equipment properly, and emergency response and chemical spill procedures.

Use of Personal Protective Equipment

OSHA has developed several personal protective equipment standards that are applicable to upholstered furniture and mattress manufacturing and foam fabrication industries. These standards address general safety and certification requirements (29 CFR Part 1910.132), the use of eye and face protection (Part 1910.133), head protection (Part 1910.135), foot protection (Part 1910.136), and hand protection (Part 1910.138). The standards for eye, face, and hand protection are particularly important for the workers applying adhesives where there is close contact with a variety of chemicals, of which nearly all irritate or otherwise harm the skin and eyes. In order to prevent or minimize exposure to such chemicals, workers should be trained in the proper use of personal safety equipment.

The recommended personal protective equipment for a worker handling chemicals is also indicated on the MSDS. For the majority of adhesive chemicals, the appropriate protective equipment indicated by the MSDS includes the following:

- ? goggles with side shields or a face shield to prevent the spraying of adhesives into the eyes;
- ? chemical aprons or other impervious clothing to prevent the over-spray of adhesives onto workers clothing; and
- ? gloves to prevent dermal contact with adhesives.

Items less frequently suggested include chemically resistant boots and coveralls. In addition to the personal protective equipment listed above, some MSDSs recommend that other safety equipment be readily available. This equipment includes an eye wash station, emergency showers, and fire extinguishers.

Other personal safety considerations are the responsibility of the worker. Workers should not eat or keep food near the adhesives application area, and should not smoke near the adhesives application or storage areas.

3.8 OZONE DEPLETION

In 1974, the mechanism of ozone depletion was first proposed. It involved synthetic substances containing chlorine and bromine that have long atmospheric lifetimes. These long-lived substances do not decompose in the lower atmosphere and, over time, make their way to the upper atmosphere or stratosphere. Once there, ultraviolet light causes the chlorine or bromine atoms to be liberated and they are then available to catalytically react with the ozone, depleting the protective ozone layer. Depletion of stratospheric ozone allows more UV-B radiation to reach the earth. Increased radiation has been linked to higher incidence of various types of skin cancer and cataracts, suppression of the immune system, damage to crops and aquatic organisms, and increased formation of ground level ozone. The mechanism of ozone depletion and potential consequences are described in detail by the World Meteorological Organization (WMO, 1989).

In 1987, the United States and twenty-three other nations signed the Montreal Protocol on Substances that Deplete the Ozone Layer in response to concerns about ozone depletion. The agreement established a timetable for reducing the production and use of specific ozone-depleting substances including the chlorofluorocarbons CFC-11, CFC-12, CFC-113, CFC-114, CFC-115, and various bromine-containing halons. EPA developed regulations that allocated production and consumption allowances equal to the total amount of production and consumption granted to the United States under the Protocol.

In 1990, the Parties to the Protocol met in London to consider amendments to the Protocol. Scientific evidence at the time indicated that ozone depletion was more serious than had been previously thought. The Parties agreed to accelerate the phaseout schedules for the substances already covered by the Protocol and agreed to add additional substances to the phaseout schedule. These included 1,1,1-trichloroethane (TCA), carbon tetrachloride, and other fully halogenated CFCs. On November 15, 1990, then-President Bush signed the Clean Air Act Amendments (CAAA) of 1990. Title VI of the CAAAs requires a phaseout of the substances specified in the London Amendments to the Protocol. It defined Class I substances to include the CFCs, halons, carbon tetrachloride, and TCA.

In October 1991, the National Aeronautics and Space Administration (NASA) announced new findings documenting ozone depletion over the last decade that was more severe than had been earlier predicted. In response to these findings, then-President Bush announced an accelerated schedule for phaseout of the Class I substances. It specified a production phaseout of these substances in 1996.

The ozone depletion potential (ODP) is a measure of the ability of a substance to deplete ozone relative to the ability of CFC-11 and CFC-12 to deplete ozone. CFC-11 and CFC-12 have

3.8 OZONE DEPLETION

defined ODPs of 1.0. The ODP for TCA is lower, at about 0.1. Production of TCA was banned on January 1, 1996, but a significant amount of inventory remained. To discourage the use of ozone depleting substances further, Congress placed an accelerating tax on the Class I substances. The tax made it much more expensive to use TCA and, in applications where there were alternatives, formulators and users adopted them. It has been predicted that the inventory of TCA would be exhausted by about the end of 2000.

TCA-based adhesives were used widely by the upholstered furniture industry. TCA is exempt from VOC regulations and it is relatively low in toxicity. When the Congressional tax on TCA became effective, adhesive formulators began offering adhesives based on other alternatives. The alternatives included methylene chloride-based adhesives, water-based adhesives and, somewhat later, n-propyl bromide-based adhesives.

Under Section 612 of the CAAAs, EPA was charged with developing a program for evaluating alternatives to ozone depleting substances. This program, called the Significant New Alternatives Policy, or SNAP program, requires EPA to promulgate rules making it unlawful to replace any Class I substance with a substitute the Administrator determines may present adverse effects to human health or the environment in cases where the Administrator has identified an alternative that reduces the overall risk to human health and the environment and is currently or potentially available. EPA periodically publishes lists of alternatives that have been deemed to be acceptable, acceptable with certain limits, or unacceptable in a variety of applications.

EPA is in the process of reviewing n-propyl bromide as a potential alternative to ozone-depleting substances in cleaning and adhesive applications under the SNAP program. On December 18, 2000, EPA provided a review of the status of the chemical in the Federal Register. n-Propyl bromide contains bromine, which is a more potent ozone depleter than chlorine. Even so, EPA estimates that the ozone depletion potential of the chemical is relatively low. The ODP averaged for all global emissions is estimated to range from 0.033 to 0.040, but the ODP for emissions from the tropics is estimated to be much larger, from 0.87 to 0.105. Assuming that emissions occur only over the contiguous U.S., the ODP is estimated to range from 0.016 to 0.019. No information on the ODP of 2-bromopropane, a contaminant in n-propyl bromide, was provided in the review. EPA is waiting to issue a final proposed rule on n-propyl bromide until more information on the chemical's reproductive and developmental toxicity is available.

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