3.3 HUMAN HEALTH AND ECOLOGICAL HAZARDS SUMMARY

This section presents a summary of the human health and ecological hazards data that were used in the risk characterization.[8] This information is summarized from toxicity profiles prepared for non-proprietary chemicals identified as constituents in the baths for the MHC technologies evaluated. Table 3.23 lists these chemicals and identifies the MHC process or processes in which these chemicals are used. The electroless copper process is the predominant method now used in MHC. Section 2.1.4 includes more detailed information on bath constituents and concentrations. Throughout this section, toxicity data for proprietary chemicals are not presented in order to protect proprietary chemical identities.

Table 3.23 Known Use Cluster Chemicals and Associated MHC Processes

Chemical List	Electroless Copper	Carbon	Conductive Ink	Conductive Polymer	Graphite	Non-Formaldehyde Electroless Copper	Organic-Palladium	Tin-Palladium
2-Ethoxyethanol	✔							
1,3-Benzenediol								✔
1H-Pyrrole				✔				
2-Butoxyethanol Acetate; Butylcellusolve Acetate			✔					
Ammonia					✔			
Ammonium Chloride	✔							
Benzotriazole	✔							
Boric Acid	✔							
Carbon Black		✔	✔					
Copper (I) Chloride; Copper	✔		✔					✔
Copper Sulfate; or Cupric Sulfate	✔	✔			✔	✔		✔
Diethylene Glycol n-Butyl Ether			✔					
Diethylene Glycol Ethyl Ether			✔					
Diethylene Glycol Methyl Ether			✔					
Dimethylaminoborane	✔							
Dimethylformamide	✔							
Ethanolamine; Monoethanolamine; 2-Aminoethanol	✔	✔			✔			✔
Ethylene Glycol	✔	✔						
Ethylenediaminetetraacetic Acid (EDTA)	✔							
Fluoroboric Acid; Sodium Bifluoride	✔							✔
Formaldehyde	✔							
Formic Acid	✔							

[8] Risk was not characterized for the conductive ink technology but human health and ecological hazards data are presented here.

Chemical List	Electroless Copper	Carbon	Conductive Ink	Conductive Polymer	Graphite	Non-Formaldehyde Electroless Copper	Organic-Palladium	Tin-Palladium
Graphite			✔		✔			
Hydrochloric Acid	✔					✔	✔	✔
Hydrogen Peroxide	✔					✔		✔
Hydroxyacetic Acid	✔							
Isophorone			✔					
Isopropyl Alcohol; 2-Propanol	✔					✔		✔
Lithium Hydroxide								✔
m-Nitrobenzene Sulfonic Acid; Sodium m-Nitrobenzenesulfonate	✔							
Magnesium Carbonate	✔							
Methanol	✔		✔					
p-Toluene Sulfonic Acid; Tosic Acid	✔							
Palladium	✔							✔
Palladium Chloride								✔
Peroxymonosulfuric Acid; Potassium Peroxymonosulfate	✔			✔	✔			
Phenol-Formaldehyde Copolymer			✔					
Phosphoric Acid				✔				✔
Potassium Bisulfate	✔							
Potassium Carbonate		✔			✔			✔
Potassium Cyanide	✔							
Potassium Hydroxide	✔	✔				✔		
Potassium Persulfate	✔					✔		
Potassium Sulfate	✔							
Potassium-Sodium Tartrate	✔							
Silver			✔					
Sodium Bisulfate	✔						✔	✔
Sodium Carbonate	✔			✔			✔	
Sodium Chloride								✔
Sodium Chlorite	✔					✔		
Sodium Cyanide	✔							
Sodium Hydroxide	✔			✔		✔		✔
Sodium Hypophosphite	✔						✔	
Sodium Persulfate		✔			✔		✔	✔
Sodium Sulfate	✔							
Stannous Chloride; Tin (II) Chloride	✔					✔		✔
Sulfuric Acid	✔	✔		✔	✔	✔		✔
Tartaric Acid	✔							
Triethanolamine; or 2,2',2" - Nitrilotris Ethanol	✔							✔

Chemical List	Electroless Copper	Carbon	Conductive Ink	Conductive Polymer	Graphite	Non-Formaldehyde Electroless Copper	Organic-Palladium	Tin-Palladium
Trisodium Citrate 5.5-Hydrate; Sodium Citrate							✔	
Vanillin								✔
Proprietary Chemicals (no. known for alternative)	12				5		1	5

3.3.1 Carcinogenicity

Table 3.24 summarizes the available information pertaining to carcinogenicity for the MHC chemicals, including classifications describing evidence of chemical carcinogenicity. Due to the large number of chemicals in commerce, including approximately 15,000 non-polymeric chemicals produced in significant amounts (i.e., > 10,000 lbs/year), many chemicals have not yet been tested or assigned carcinogenicity classifications. The classifications referenced in this risk assessment are defined below:

EPA Weight-of-Evidence Classification: In assessing the carcinogenic potential of a chemical, EPA classifies the chemical into one of the following groups, according to the weight-of-evidence from epidemiologic, animal and other supporting data, such as genotoxicity test results:

- 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).
- 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.[9]

International Agency for Research on Cancer (IARC) Classification: This is a similar weight-of-evidence method for evaluating potential human carcinogenicity based on human data, animal data, and other supporting data. A summary of the IARC carcinogenicity classification system includes:

[9] The "Proposed Guidelines for Carcinogen Risk Assessment" (EPA, 1996a) propose use of weight-of-evidence 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.

- 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 of these classification schemes represent judgements regarding the likelihood of human carcinogenicity. Table 3.24 lists all MHC chemicals which have been classified by EPA or IARC. The National Toxicology Program (NTP) is an additional source used to classify chemicals, but its classifications are based only on animal data from NTP studies.

Table 3.24 Available Carcinogenicity Information

Chemical Name[a]	Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Comments/Classifications
Formaldehyde	0.046[b]	EPA Group B1 (EPA, 1995b)[c]; IARC Group 2A (IARC, 1995)[c]
Carbon Black	ND	IARC Group 2B (IARC, 1996)[d]
Dimethylformamide	ND	IARC Group 2B (IARC, 1989)[d]
1,3-Benzenediol	ND	IARC Group 3 (IARC, 1987)[e]
Hydrochloric Acid	ND	IARC Group 3 (HSDB, 1995)[e]
Hydrogen Peroxide	ND	IARC Group 3 (IARC, 1987)[e]
Copper (I) Chloride	ND	EPA Group D (EPA, 1995c)[f]
Copper (II) Chloride	ND	EPA Group D (EPA, 1995c)[f]
Palladium; Palladium Chloride	ND	No classification; rats developed respiratory tumors and leukemia at 5 ppm in water (Schroeder & Mitchener, 1971)
Sodium Sulfate	ND	No classification; "equivocal evidence" of tumorigenicity in mice (RTECS, 1995)
Triethanolamine; or 2,2',2''-Nitrilotris Ethanol	ND	No classification; equivocal carcinogenic evidence in animals (NTP, 1994)
Cyclic Ether[g]	not reported[h]	Possible/probable human carcinogen[i]
Alkyl Oxide[g]	not reported[h]	Probable human carcinogen[i]
Trisodium Acetate Amine B[j]	ND	Possible human carcinogen[i]

[a] Only those chemicals with available data or classifications are listed.
[b] Unit risk units were converted from 1.3×10^{-5} $\mu g/m^{3\,-1}$ to slope factor units of $(mg/kg\text{-}day)^{-1}$ using 20 m^3/day inhalation (breathing) rate and 70 kg body weight.
[c] EPA Group B: Probable Human Carcinogen (B1 - limited evidence of carcinogenicity in humans); IARC Group 2A: Possibly carcinogenic to humans.
[d] IARC Group 2B: Possibly carcinogenic to humans.
[e] IARC Group 3: Not classifiable as to human carcinogenicity.
[f] EPA Group D: Not classifiable as to human carcinogenicity (inadequate or no evidence).
[g] In graphite and electroless copper technologies.
[h] Cancer slope factors are available but not reported in order to protect proprietary chemical identities.
[I] Specific EPA and/or IARC groups not reported in order to protect proprietary chemical identities.
[j] In electroless copper technology.
ND: No Data. A cancer slope factor has not been determined for this chemical.

For carcinogenic effects, there is presumably no level of exposure that does not pose a small, but finite, probability of causing a response. This type of mechanism is referred to as "non-threshold." When the available data are sufficient for quantification, EPA develops an estimate of the chemical's carcinogenic potency expressed as a "slope factor." The slope factor (q_1*) is a measure of an individual's excess risk or increased likelihood of developing cancer if exposed to a chemical (expressed in units of $[mg/kg\text{-}day]^{-1}$). 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 and is expressed as the upper bound excess lifetime cancer risk per $\mu g/m^3$ in air, or as risk per $\mu g/L$ in water, for continuous lifetime exposures. (Unit risk is simply a transformation of slope factor into the appropriate scale.) Slope factors and unit risks can be viewed as quantitatively derived judgements of the magnitude of carcinogenic effect. These estimates will continue to be used whether the current EPA weight-of-evidence guidelines are retained or the new proposals are adopted. Their derivation, however, may change for future evaluations.

EPA risk characterization methods require a slope factor or unit risk to quantify the upper bound excess cancer risk from exposure to a known or suspected carcinogen. Therefore, formaldehyde is the only non-proprietary chemical for which cancer risk was characterized (see Section 3.4, Risk Characterization).

3.3.2 Chronic Effects (Other than Carcinogenicity)

Adverse effects other than cancer and gene mutations are generally assumed to have a dose or exposure threshold. Therefore, a different approach is needed to evaluate toxic potency and risk for these "systemic effects." Systemic toxicity means an adverse effect on any organ system following absorption and distribution of a toxicant to a site in the body distant from the toxicant's entry point. A reference dose (RfD) is an estimate (with uncertainty spanning perhaps an order of magnitude) of the daily exposure through ingestion to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious non-cancer effects during a lifetime (in 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 (in mg/m^3) (Barnes and Dourson, 1988). RfDs and RfCs can also be derived from developmental toxicity studies. However, this was not the case for any of the MHC chemicals evaluated. RfDs and RfCs are derived from EPA peer-reviewed study results (for values appearing in EPA's Integrated Risk Information System [IRIS]), together with uncertainty factors regarding their applicability to human populations. Table 3.25 presents a summary of the available RfC and RfD information obtained from IRIS and EPA's Health Effects Assessment Summary Tables (HEAST). One proprietary chemical, in the tin-palladium alternative, has an RfD available; this is not reported to protect the identity of the proprietary chemical.

Table 3.25 Summary of RfC and RfD Information

Chemical Name [a]	Inhalation RfC (mg/m^3)	Comments[c] (Inhalation)	Oral/Dermal RfD (mg/kg-day)	Comments[b] (Oral/Dermal)
2-Butoxyethanol Acetate	0.02	Rat, 13 weeks, hematological and liver effects (EPA, 1995d)[c, d]	ND	
2-Ethoxyethanol	0.2	Rabbit, 13 weeks, reduced spleen, testicular weights, and white blood cell counts (EPA, 1996b)	0.4	Gavage, rat and mouse, 103 weeks, reduced body weight, testicular degeneration, and enlargement of adrenal gland (EPA, 1995d)
Ammonia	0.1	Occupational study, lack of irritation to workers exposed to 9.2 ppm concentration (EPA, 1997)	ND	
Diethylene Glycol Ethyl Ether and Acetate	ND		2	Oral, rat, 3-generation study (chronic reproductive), kidney and bladder damage (EPA, 1995d)
Diethylene Glycol n-Butyl Ether	0.02	Inhalation, rat, 7 hours (EPA, 1995c,d)[d]	ND	
Dimethylformamide	0.03	Inhalation, human, 5+ years, 54 workers for hepatoxicity effects (EPA, 1996b)	ND	
Ethylene Glycol	ND		2	Oral, rat, 2 years, decreased growth, renal calculi (EPA, 1995c)
Formaldehyde	ND		0.2	Oral, rat, 2 years, GI tract and histopathological changes (EPA, 1995b)
Hydrochloric Acid	0.007	Rat, respiratory tract hyperplasia, lifetime exposure (EPA, 1995c)	ND	
Isophorone	ND		0.2	Oral, dog, 90 days, no signs of cellular changes (EPA, 1995d)
Methanol	ND		0.5	Gavage, rat, 90 days, decreased brain weights (EPA, 1995c)
Potassium Cyanide	ND		0.05	Oral, rat, 2 years, no treatment effects on weight gain (EPA, 1995c)
Silver	ND		0.005	Oral, human, 2 - 9.75 years, argyria of skin, eyes, mouth, and throat (EPA, 1996b)
Sodium Cyanide	ND		0.04	Oral, rat, 2 years (EPA, 1995c)

Chemical Name [a]	Inhalation RfC (mg/m^3)	Comments[c] (Inhalation)	Oral/Dermal RfD (mg/kg-day)	Comments[b] (Oral/Dermal)
Stannous Chloride	ND		0.62	Rat, 105 weeks (EPA, 1994a)[e]

[a] Only those chemicals with available data are listed. Proprietary chemical data are not presented in order to protect proprietary chemical identities.
[b] Comments may include exposure route, test animal, duration of test, effects, and source of data.
[c] Based on data for 2-butoxyethanol.
[d] Provisional RfC or RfD.
[e] Based on data for tin.
ND: No data. An RfD or RfC has not been determined for this chemical.

When an RfD or RfC 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.) But unlike the majority of RfD/RfCs, NOAEL/LOAELs have not received EPA peer-review of the studies on which the values are based, and uncertainty factors have not been considered.

The LOAEL is the lowest 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/m^3 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/m^3 for inhalation). LOAEL values are presented only where NOAELs were not available. Table 3.26 presents a summary of the available NOAEL and LOAEL values.

Table 3.26 NOAEL/LOAEL Values

Chemical Name[a]	Inhalation NOAEL/ LOAEL[b] (mg/m^3)	Comments (Inhalation)	Oral/Dermal NOAEL/ LOAEL[b] (mg/kg-day)	Comments (Oral/Dermal)
1,3-Benzenediol	ND		100 (N)[c]	Gavage, rat/mouse, 2 years (NTP, 1992)
Ammonium Chloride	ND		1,691 (N)	Oral, mouse, developmental study in drinking water (Shepard, 1986)
Benzotriazole	ND		109 (L)	Oral, rat, 26 weeks, induced anemia, endocrine effects (RTECS, 1995)
Boric Acid	ND		62.5 (L)	Gavage, rabbit, developmental study showed cardiovascular defects (U.S. Borax Co., 1992)

Chemical Name[a]	Inhalation NOAEL/ LOAEL[b] (mg/m^3)	Comments (Inhalation)	Oral/Dermal NOAEL/ LOAEL[b] (mg/kg-day)	Comments (Oral/Dermal)
Carbon Black	7.2 (L)	Human, 14 years, decrease in lung function: vital capacity (IARC, 1984)	ND	
Copper (I) Chloride	0.6 (L)	Human, dust caused leukocytosis/anemia, respiratory irritant (U.S. Air Force, 1990)	0.07 (L)	Oral, human, 1.5 years, GI tract effects (ATSDR, 1990a)
Diethylene Glycol Methyl Ether	ND		1,000 (N)	Oral, rat, 13 weeks, kidney damage, (HSDB, 1995)
Diethylene Glycol n-Butyl Ether	NA		191	Dermal, rat, 90 days, hemolytic effects (RM1, 1992)
Dimethylformamide	NA		125 (L)	Oral, rat, 100 days, liver weight increases and body weight gains (Trochimowicz et al., 1994)
Ethanolamine	12.7 (L)	Rat, dog, guinea pig, 90 days, skin irritation/ weight loss (ACGIH, 1991)	320 (N)	Oral, rat, 90 days, altered liver/kidney weights at higher concentrations (ACGIH, 1991)
Ethylene Glycol	31	Human, headache, respiratory tract irritation, lymphocytosis (ATSDR, 1993)	NA	
Fluoroboric Acid	ND		0.77	Human, 2 years, bone disease, GI problems & osteoarticular pain in women (HSDB, 1995; based on 50-100 mg/d, for fluorides, adjusted for 65 kg body weight)
Formaldehyde	0.1 ppm (L)	Human, eye and upper respiratory tract irritation (EPA, 1991c)[d]	NA	
Formic Acid	59.2 (N)	Rat/mouse, 2 weeks, respiratory epithelial lesions (Katz and Guest, 1994)	ND	
Graphite	56 (L)	Human effect level for pneumoconiosis, nuisance from dust (Pendergrass, 1983)	ND	

Chemical Name[a]	Inhalation NOAEL/ LOAEL[b] (mg/m^3)	Comments (Inhalation)	Oral/Dermal NOAEL/ LOAEL[b] (mg/kg-day)	Comments (Oral/Dermal)
Hydrogen Peroxide	79	Mouse, 7/9 died from 79 mg/m^3 in 6 weeks (EPA, 1988)	630 (N)	Oral, developmental and reproductive studies for 5 weeks (rat) and 3 months (mouse), respectively (IARC, 1985)
Hydroxyacetic Acid	ND		250 (N)	Gavage, developmental rat study showed lung noise, reduced weight gain (DuPont, 1995)
Isopropyl Alcohol, 2-Propanol	980 (N)	Rat, 13 weeks (SIDS, 1995)	100 (N)	Oral, rat, 2-generation study (CMA, 1995; RM2, 1996)
Magnesium Carbonate	Generally regarded as safe (U.S. FDA as cited in HSDB, 1995).			
Methanol	1,596 - 10,640 (1,200 - 8,000 ppm)	Human, 4 year occupational study, vapor caused vision loss (ACGIH, 1991)	NA	
Palladium, Palladium Chloride	ND		0.95 (L)	Oral, rat, 180 days, decreased weight (Schroeder & Mitchener, 1971)
Potassium Hydroxide	7.1	Human, caused cough/bronchial effects, severe eye/skin irritant (Graham et al., 1984)	ND	
Potassium Sodium Tartrate	Generally regarded as safe (U.S. FDA as cited in HSDB, 1996).			
Potassium Sulfate	15 (TC_{LO})[e]	Rat, 4 hr/d for 17 weeks, metabolic effects (RTECS, 1995)	ND	
Sodium Carbonate	10 (N)	Rat, 4 hr/d, 5 d/w for 3.5 months, decreased weight gain, lung effects (Pierce, 1994)	ND	
Sodium Chlorite	ND		10 (N)	Gavage, rat, 13 weeks, hematological effects (Harrington et al., 1995)
Sodium Hydroxide	2 (L)	Human, dyspnea, irritant (ACGIH, 1991)	ND	
Sodium Sulfate	ND		420 (N)	Oral, rat, 16 weeks (Young, 1992)
Sulfuric Acid	0.066 (N)	Human (EPA, 1994a)	ND	

Chemical Name[a]	Inhalation NOAEL/ LOAEL[b] (mg/m^3)	Comments (Inhalation)	Oral/Dermal NOAEL/ LOAEL[b] (mg/kg-day)	Comments (Oral/Dermal)
Tartaric Acid	ND		8.7	Oral, dog study, 3/4 developed casts (color or tint) in urine, weight changes and advanced renal tubular degeneration, at 990 g/kg for 90-114 days (Informatics, Inc., 1974)
Triethanolamine; or 2,2',2"-Nitrilotris Ethanol	ND		32 (L)	Dermal, mouse, 105 weeks, irritation effects (NTP, 1994)
Vanillin	ND		64 (L)	Oral, rat, 10 weeks, growth depression and damage to kidney, myocardium, liver and spleen (Kirwin and Galvin, 1993)

[a] Only those chemicals with available data are listed. Proprietary chemical data are not presented in order to protect proprietary chemical identities.
[b] 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.
[c] (N) = NOAEL; (L) = LOAEL. If neither is indicated, the toxicity measure was not identified as a NOAEL or LOAEL in the available information.
[d] This value is highly uncertain; precise thresholds for these irritant effects of formaldehyde have not been established. Estimates based on a large number of clinical and non-clinical observations indicate that most people have irritant reaction thresholds over the range of 0.1 to 3.0 ppm formaldehyde (EPA, 1991c).
[e] TC_{LO} = total concentration resulting in a sublethal effect.
ND: No Data. A NOAEL or LOAEL was not available for this chemical.
NA: Not Applicable. A NOAEL or LOAEL is not required because an RfD or RfD was available for this chemical.

Neither RfDs/RfCs nor LOAELs/NOAELs were available for several chemicals in each MHC process alternative. For these chemicals, no quantitative estimate of risk could be calculated. EPA's Structure-Activity Team (SAT)[10] has reviewed the chemicals without relevant toxicity data to determine if these chemicals are expected to present a toxicity hazard. This review was based on available toxicity data on structural analogues of the chemicals, expert judgement, and known toxicity of certain chemical classes and/or moieties. Chemicals received a concern level rank of high, medium, or low. Results of the SAT evaluation are presented in Table 3.27. A summary of the SAT results for proprietary chemicals is presented in Table 3.28. An overview of chemicals and available toxicity data is presented in Table 3.29.

[10] The SAT is a group of expert scientists at EPA who evaluate the potential health and environmental hazards of new and existing chemicals.

Table 3.27 Summary of Health Effects Information (from Structure-Activity Team Reports)

Chemical	SAT Health Effects (pertaining to dermal or inhalation exposure)	Overall Concern Level
Dimethylaminoborane	Absorption is expected to be good via all routes of exposure. This compound is corrosive when handled in concentrated form. There is concern for developmental toxicity and reproductive effects for the boron.	High concern
EDTA, Sodium Salt	Expect no absorption by skin, but expect absorption by lungs and GI tract. Compound is a chelator and is expected to chelate Ca and Mg. Concerns for developmental toxicity and cardiac arrhythmia due to ability to chelate Ca. Arrhythmia expected to occur only at high doses.	Low moderate concern
Fluoroboric Acid	Expect absorption via the skin following irritation. Expect good absorption via the lungs and GI tract. This compound is a severe skin irritant and may be corrosive. There is uncertain concern for developmental toxicity based on information for fluoride.	High concern
Graphite	Expect absorption to be nil by all routes. There is concern for lung effects through lung overall (fibrosis) with repeated inhalation exposure of respirable particles.	Low moderate concern
Magnesium Carbonate	Absorption is expected to be nil through the skin and good through the lungs and GI tract. This compound is used as an antacid.	Low moderate concern
m-Nitrobenzene Sulfonic Acid, Sodium Salt	Absorption is expected to be nil through the skin and good through the lungs and GI tract. The nitro group can be reduced to anamine. There is concern for methemoglobinemia as an aromatic amine compound. As a nitrobenzene derivative, there is concern for neutrotoxicity and developmental toxicity. Serious brain damage was noted at 125 ppm in a 2-week inhalation study with nitrobenzene. It is expected to be irritating to mucous membranes and the upper respiratory tract.	Moderate concern
Monopotassium Peroxymonosulfate	Absorption is expected to be nil through the skin and good through the lungs and GI tract. The peroxymonosulfate moiety is reactive with moisture (oxidizing agent). This material will be an irritant as a concentrated solution.	Moderate concern
Palladium Chloride	Absorption is expected to be nil through the skin and good through the lungs and GI tract. It is an irritant and is reported to be a dermal sensitizer in humans (HSDB).	Moderate high concern
Phosphoric Acid	Expect absorption by all routes. Compound is corrosive.	Moderate concern for corrosive effects to all tissues

Chemical	SAT Health Effects (pertaining to dermal or inhalation exposure)	Overall Concern Level
Potassium Bisulfate	Absorption is expected to be nil through the skin as the neat material and good through the lungs and GI tract. Expect absorption via the skin in solution because of damage to the skin. This compound is expected to be a severe irritant and/or corrosive to the skin, eyes, and mucous membranes because of its acidity.	Moderate concern
Potassium Carbonate	Absorption is expected to be nil through the skin and good through the lungs and GI tract. This material is an alkaline solution and is irritating to the skin, mucous membranes, and upper respiratory tract.	Low moderate concern
Potassium Persulfate	Absorption may occur through the skin following irritation of the skin. Absorption is expected to be good via the lungs and GI tract with reaction of the persulfate (oxidizing agent). This compound is irritating and/or corrosive to the skin, eyes, and mucous membranes. It may also be a dermal and respiratory sensitizer.	Moderate concern
Potassium Sulfate	Absorption is expected to be nil through the skin and good through the lungs and GI tract. No significant adverse effects expected.	Low concern
p-Toluene Sulfonic Acid	Expect no absorption by skin, moderate absorption by GI tract, and good absorption by lungs. TSCA Section 8e-10286 report that this chemical is a severe skin irritation. No other health concern identified.	Low moderate concern
Sodium Bisulfate	Absorption is expected to be nil through the skin as the neat material and good through the lungs and GI tract. Expect absorption via the skin in solution because of damage to the skin. This compound is expected to be a severe irritant and/or corrosive to the skin, eyes, and mucous membranes because of its acidity.	Moderate concern
Sodium Hypophosphite	Absorption is expected to be nil through the skin and good through the lungs and GI tract. It is irritating to mucous membranes and may cause dermal sensitization (HSDB).	Low moderate concern
Sodium Persulfate	Absorption may occur through the skin following irritation of the skin. Absorption is expected to be good via the lungs and GI tract with reaction of the persulfate (oxidizing agent). This compound is irritating and/or corrosive to the skin, eyes, and mucous membranes. It may also be a dermal and respiratory sensitizer. In an inhalation sensory irritation study in mice, mortality occurred at 0.77 mg/l and greater (TSCA Section 8e-12867 Report). Sodium peroxysulfate is positive for dermal sensitization in a human patch test (TSCA Section 8e-2767 Report). Ocular opacity was also reported.	Moderate concern

Table 3.28 Summary of EPA Structure-Activity Team Results for Proprietary Chemicals

Technology	No. of Additional Trade Secret Chemicals[a]	No. of Additional Trade Secret Chemicals With No Human Health Toxicity Data[b]	SAT Human Health Concern Rank (no. of proprietary chemicals)		
			Low	Low-Moderate	Moderate
Electroless Copper	9	4	1	2	1
Graphite	5	3	0	2	1
Tin-Palladium	5	4	2	1	1
Organic-Palladium	1	0	0	0	0

[a] New chemical for this process alternative.
[b] The toxicity data required to calculate cancer risk, hazard quotient, and MOE were not available.

Table 3.29 Available Toxicity Data for Non-Proprietary Chemicals

Chemical	Cancer: Slope Factor (SF), Weight-of-Evidence (WOE) Classification	Inhalation: RfC, NOAEL, or LOAEL	Oral/Dermal: RfD, NOAEL, or LOAEL	SAT
2-Ethoxyethanol		**RfC**	**RfD**	
1,3-Benzenediol	WOE		NOAEL	
2-Butoxyethanol Acetate; Butylcellusolve Acetate		**RfC**		
Ammonia		**RfC**		
Ammonium Chloride			NOAEL	
Benzotriazole			LOAEL	
Boric Acid			LOAEL	
Carbon Black	WOE	LOAEL		
Copper (I) Chloride; Copper	WOE	LOAEL	LOAEL	
Copper Sulfate; or Cupric Sulfate[a]				
Diethylene Glycol n-Butyl Ether		**RfC**	Other[b]	
Diethylene Glycol Ethyl Ether			**RfD**	
Diethylene Glycol Methyl Ether			NOAEL	
Dimethylaminoborane				✔
Dimethylformamide	WOE	**RfC**	LOAEL	
Ethanolamine; Monoethanolamine; 2-Aminoethanol		LOAEL	NOAEL	
Ethylene Glycol		Other[b]	**RfD**	
Ethylenediaminetetraacetic Acid (EDTA)				✔
Fluoroboric Acid; Sodium Bifluoride			Other[b]	✔
Formaldehyde	**SF,** WOE	LOAEL	**RfD**	
Formic Acid		NOAEL		
Graphite		LOAEL		✔
Hydrochloric Acid	WOE	**RfC**		

Chemical	Cancer: Slope Factor (SF), Weight-of-Evidence (WOE) Classification	Inhalation: RfC, NOAEL, or LOAEL	Oral/Dermal: RfD, NOAEL, or LOAEL	SAT
Hydrogen Peroxide	WOE	Other[b]	NOAEL	
Hydroxyacetic Acid			NOAEL	
Isophorone			**RfD**	
Isopropyl Alcohol; 2-Propanol		NOAEL	NOAEL	
Lithium Hydroxide				✔
m-Nitrobenzene Sulfonic Acid; Sodium m-Nitrobenzenesulfonate				✔
Magnesium Carbonate				✔
Methanol		Other[b]	**RfD**	
p-Toluene Sulfonic Acid; Tosic Acid				✔
Palladium			LOAEL	
Palladium Chloride			LOAEL	✔
Peroxymonosulfuric Acid; Potassium Peroxymonosulfate				✔
Phenol-Formaldehyde Copolymer				
Phosphoric Acid				✔
Potassium Bisulfate				✔
Potassium Carbonate				✔
Potassium Cyanide			**RfD**	
Potassium Hydroxide		Other[b]		
Potassium Persulfate				✔
Potassium Sulfate		Other[b]		✔
Potassium-Sodium Tartrate[c]				
Silver			**RfD**	
Sodium Bisulfate				✔
Sodium Carbonate		NOAEL		
Sodium Chloride[d]				
Sodium Chlorite			NOAEL	
Sodium Cyanide			**RfD**	
Sodium Hydroxide		LOAEL		
Sodium Hypophosphite				✔
Sodium Persulfate				✔
Sodium Sulfate			NOAEL	
Stannous Chloride; Tin (II) Chloride			**RfD**	
Sulfuric Acid		NOAEL		
Tartaric Acid			Other[b]	

Chemical	Cancer: Slope Factor (SF), Weight-of-Evidence (WOE) Classification	Inhalation: RfC, NOAEL, or LOAEL	Oral/Dermal: RfD, NOAEL, or LOAEL	SAT
Triethanolamine; or 2,2',2''-Nitrilotris Ethanol			LOAEL	
Trisodium Citrate 5.5-Hydrate; Sodium Citrate				✔
Vanillin			LOAEL	

[a] The toxicity data for copper (I) chloride was used to evaluate copper sulfate and cupric sulfate.
[b] Toxicity data other than an RfC, RfD, NOAEL, or LOAEL was used. See Table 3.26 for description of the toxicity data.
[c] Potassium-sodium tartrate added directly to human food is affirmed as generally regarded as safe when meeting specified food manufacturing requirements (U.S. FDA as cited in HSDB, 1996).
[d] Sodium chloride (table salt) is a necessary mineral and electrolyte in humans and animals, and under normal conditions the body efficiently maintains a systemic concentration of 0.9 percent by retaining or excreting dietary sodium chloride. It is not generally considered poisonous to humans or animals, its main systemic effect being blood pressure elevation.

Chemicals having potential developmental toxicity were identified based on the data provided in the toxicity profiles. The data are summarized in Table 3.30. The values listed in the table included the no-observable-effect level (NOEL) or, in the absence of a NOEL, the lowest-observable-effect level (LOEL) concentrations. Chemicals which have inconclusive data concerning the developmental toxicity, as a result of multiple studies having conflicting conclusions, are identified as possible developmental toxicants. The chemical is listed as a possible toxicant given the uncertainty in the data.

Table 3.30 Developmental Hazards Summary

Chemical Name	Oral NOEL (mg/kg/day)[a]	Comments	Inhalation NOEL (mg/m^3)[a]	Comments
Ammonium Chloride	1,691	Drinking water, mice, after day 7 of gestation. No congenital effects (Shepard, 1986).	NA	
Boric Acid	125	Oral, rabbits, gestation days 6-19. Prenatal mortality, interventricular septal defect, unspecified malformations (U.S. Borax Co., 1992).	NA	
2-Butoxyethanol - **possible inhalation**	100	Oral, rats, gestation days 9-11 or 11-13. Reduced prenatal viability noted (Gingell et al., 1994).	50 ppm	Rats exposed 6 hours/day on gestation days 6-15 to 100 and 200 ppm. Maternal toxicity noted and increased resorbed litters, decreased pup viability, and delayed ossification (Rohm and Haas, 1992). In another study, rats exposed 7 hours/day to 150 and 200 ppm on gestation days 7-15 had maternal toxicity (transient hemoglobinuria), but no developmental toxicity (Gingell et al., 1994).
Copper	51.7	Food, mice, 30 days before mating through day 19 of gestation. Malformations (EPA, 1984a).	NA	
Diethylene Glycol Methyl Ether	150 (LOEL)	Oral, mice, gestation days 6-15. Malformation of neural tube, heart, renal and skeletal systems (Price et al., 1987).	NA	
2-Ethoxyethanol	93.1	Oral, rats, gestation days 1-21. Increase major skeletal malformations (EPA, 1984b).	369 (LOEL)	Mice, exposure of 6 hours/day, days 6-15 of gestation. Developmental neurotoxicity (EPA, 1996b; 1985a).
Ethanolamine	50 (LOEL)	Oral, rats, gestation days 6-15. Increases in intrauterine deaths, malformations, and increased fetal weight (Mankes, 1986 as reported in TOXLINE, 1995).	NA	

Chemical Name	Oral NOEL (mg/kg/day)[a]	Comments	Inhalation NOEL (mg/m^3)[a]	Comments
Ethylene Glycol	500	Oral, mice, gestation days 6-15. Lower body weights and craniofacial and skeletal malformations (Shell Oil, 1992a).	150	Rats and mice, exposure of 6 hours/day, days 6-15 of gestation. Fetal malformations in mice (exencephaly, cleft palate, and abnormal rib and facial bones) (Shell Oil, 1992b; Union Carbide, 1991).
Ethylenediaminetetraacetic Acid (EDTA)	954 - LOEL	Diet, rats, gestation days 7-14. Maternal-toxicity and reduced litters, reduced fetal weight and malformations (EPA, 1987).	NA	
Hydrazine	NA	Subcutaneous, rats, gestation days 11-21. Injection of 8 mg/kg/day resulted in reduced ratio of fetal survivors to implantation sites, reduced fetal weight, and 100% mortality of pups within 24 hrs of birth (Lee and Aleyassine, 1970).	NA	
Hydrochloric Acid	NA		450 (LOEL)	Rats, exposure of 1 hour/day for 12-16 days prior to mating or on gestation day 9. Adults exhibited mortality. Increased fetal mortality, decreased fetal weight and increased fetal lung weights (EPA, 1995c).
Hydroxylamine Sulfate	NA	Mice. No details given for type of exposure, duration, or dose. Resulted in early fetal deaths and pre-implantation losses (Gross, 1985).	NA	
Isopropanol	480	Oral, rabbits, gestation days 6-18. Reduced fetal body weights noted in oral exposure of rats, but at concentrations with maternal toxicity. No teratogenic effects noted (Tyl, et al., 1995, as cited in CMA, 1995).	3,000 ppm (LOEL)	Rats, exposure of 7 hours/day, gestation days 1-19. Reduced fetal weight (Nelson et al., 1943 as cited in ACGIH, 1991).

Chemical Name	Oral NOEL (mg/kg/day)[a]	Comments	Inhalation NOEL (mg/m^3)[a]	Comments
Isophorone	NA		50 ppm	Rats, exposure of 6 hours/day, gestation days 6-15. Reduction in mean crown-rump length, significant decrease in maternal body weight noted (Bio/Dynamics Inc., 1984).
Lithium Hydroxide	NA	Studies indicate that the risk of major congenital malformations in offspring from women receiving lithium during early pregnancy is slightly higher (4-12%) than that among control groups (2-4%) (Cohen et al., 1994 as cited in Opresko, 1995). Lithium chloride has been shown to cause cleft palate in rats and mice, but lithium carbonate was negative for developmental effects in monkeys, rabbits, and rats (Beliles, 1994). However other studies have shown an increase incidence of cleft palate in mice (Szabo, 1970 as cited in Opresko, 1995).	NA	
Methanol	NA	Drinking water, folate-deficient rats, gestation days 6-15. Maternal toxicity (decreased weight gain) and developmental toxicity (increased resorption) observed at drinking water concentrations of 1% and 2% (Lington and Bevan, 1994).	6,650 (LOEL)	Mice, exposure of 7 hours/day, gestation days 7-9. Increased exencephaly (Lington and Bevan, 1994).
N,N-Dimethylformamide	200	Dermal, rats, gestation days 8-16 (EPA, 1986). Hydrocephalus, growth retardation, post-implantation losses, and increase mortality in offspring (IARC, 1989).	0.05 (LOEL)	Rabbits, exposure of 4 hours/day, days 1-19 of gestation. Reduced fetal growth (IARC, 1989).
Phenol	60	Oral, rats, gestation days 6-15. Reduced fetal body weights (EPA, 1996c).	NA	

Chemical Name	Oral NOEL (mg/kg/day)[a]	Comments	Inhalation NOEL (mg/m^3)[a]	Comments
Potassium Carbonate	NA	Epidemiology study of 226 males employed at potash mine. After starting work underground, mean birth weights increased slightly and there was a decrease in male/female ratio (Wiese and Skipper, 1986).	NA	
Potassium and Sodium Cyanide	NA (276.6 mg CN/kg diet)	Oral, pigs, through gestation and lactation. Fetuses had reduced thyroid, spleen, and heart weights. Sows showed hyperplasia of kidney glomeruli and histological changes in thyroid (Tewe and Maner, 1981).	NA	
Silver - **Possible**	NA	Silver concentrations in 12 anencephalic human fetuses was higher than silver concentrations in livers of 12 therapeutically aborted fetuses and 14 fetuses aborted spontaneously. Could not be determined if high silver concentrations were associated with the anencephalic malformation or with fetal age (ATSDR, 1990b).	NA	
Sodium Chloride	56,400 (TD_{LO})[b]	Oral, rats, day 5 or 7 pre-conception and one or more days post-conception. Unspecified toxic effects noted (RTECS, 1996).	NA	
Sodium Chlorite	1.4 (LOEL)	Drinking water, rats, 2.5 months prior to mating through gestational day 20. Increase in variation of sternum and increase in crown-rump length. Same study, oral dose 200 mg/kg/day and 2,800 mg/kg/day via drinking water, gestational days 8-15, no developmental effects (Perry et al., 1994).	NA	

Chemical Name	Oral NOEL (mg/kg/day)[a]	Comments	Inhalation NOEL (mg/m^3)[a]	Comments
Sodium Sulfate	2,800	Oral, mice, gestation days 8-12. No effect on body weights or litter sizes (Young, 1992). Parentally administered dose of 60 mg/kg on day 8 of gestation produced developmental abnormalities of the musculosketal system (RTECS, 1995).	NA	
Stannous Chloride	50	Oral, mice, 10 consecutive days, no effect on gestation of fetal survival (Gitilitz and Moran, 1983). Method of exposure unknown, rats, gestation days 7-12. 500 mg/kg resulted in teratogenic effects (Wu, 1990, as reported in TOXLINE, 1995).	NA	

[a] Unless otherwise noted.
[b] TD_{Lo} = The lowest dose of a chemical that is expected to cause a defined toxic effect.
NA: Not applicable. Data for calculating a dose were not available.

3.3.3 Ecological Hazard Summary

Table 3.31 presents a summary of the available ecological hazard information. Concern concentrations (CCs) were determined only for aquatic species (e.g., *Daphnia*, algae, and/or fish) using standard EPA methodology. Methods for determining CCs are summarized below. (*Cleaner Technologies Substitutes Assessment: A Methodology and Resources Guide* [Kincaid et al., 1996] presents the methods in more detail.)

Table 3.31 Aquatic Toxicity Information

Chemical Name[a]	LC_{50} (mg/L)[b]	Test Information	Species	CC (mg/L)[c]	Source
1,3-Benzenediol	> 100 0.25 88.6 262 > 100	all 96 hr	rainbow trout water flea minnow zebra fish snail	AsF = 100[(2)] 0.0025	AQUIRE, 1995
2-Butoxyethanol Acetate	150 960 > 500	48 hr 17 hr 72 hr	water flea protozoa green algae	AsF = 100[(2)] 1.5	Verschueren, 1996
2-Ethoxyethanol	> 5,000 > 10,000 7,660	24 hr 96 hr 48 hr IC_{50}[d]	goldfish bluegill & silversides water flea	AsF = 1,000[(3)] 5.0	AQUIRE, 1996; EPA, 1985a
Ammonia	0.42-0.84 1.74 1.58	8 hr 24 hr 24 hr	rainbow trout water flea snail	AsF = 100[(2)] CC = 0.0042	AQUIRE, 1995
Ammonium Chloride	640 139 50	24 hr TLm[e] 24-96 hr TLm 96 hr TLm	carp bluegill water flea	AsF = 1,000[(3)] 0.05	Verscheuren, 1983
Boric Acid	46-75 22-155 79-100	7 day 9 day 28 day	goldfish catfish rainbow trout	AsF = 1,000[(3)] 0.022	AQUIRE, 1995
Carbon Black	No information found in literature				
Copper	0.8-1.9 0.0885-21 0.13-0.5 0.125 10-33	96 hr 96 hr 96 hr 96 hr 24 hr	carp minnow rainbow trout salmon shrimp	AsF = 100[(2)] 0.00088	AQUIRE, 1995
Copper Chloride (Cuprous)	0.40-2.3	96 hr	mummichog (fish)	AsF = 1,000[(3)] 0.0004	AQUIRE, 1995
Copper Sulfate	0.18-12 0.096-0.12 0.036-1.38 0.002-160 0.10-0.24 0.002-23.6 0.56-40	96 hr 96 hr 96 hr 96 hr 96 hr 96 hr 96 hr	bullhead zebrafish goldfish carp salmon minnow oyster	AsF = 100[(2)] 0.00002	AQUIRE, 1995
Diethylene Glycol Methyl Ether	> 5,000 7,500	24 hr 96 hr	goldfish minnow	AsF = 1,000[(3)] 5.0	AQUIRE, 1995

Chemical Name[a]	LC_{50} (mg/L)[b]	Test Information	Species	CC (mg/L)[c]	Source
Diethylene Glycol Ethyl Ether	9,650-26,500 12,900-13,400 15,200 6,010 1,982-4,670	96 hr 96 hr 96 hr 96 hr 48 hr	minnow rainbow trout mosquito fish catfish water flea	AsF = 100(2) CC = 20	AQUIRE, 1996
Diethylene Glycol n-Butyl Ether	1,300 3,200 1,000	96 hr EC_{50}[f] decreased cell multiplication	bluegill water flea blue-green algae	AsF = 100(2) 10	AQUIRE, 1995
Dimethylformamide	1.2-2.5 1,300 > 1,000 9,860 18,800	MATC[g], chronic 24 hr 48 hr 96 hr 48 hr EC_{50}	water flea guppy medaka rainbow trout water flea	AsF = 10(4) CC = 0.12	EPA, 1986
Ethanolamine	170 40 & 70 140 0.75	96 hr 24 hr LC_0[h] & LC_{100}[i] 24 hr 8 day, toxicity threshold	goldfish creek chub water flea green algae	AsF = 10(1) CC = 0.075	AQUIRE, 1995
Ethylene Glycol	41,000 49,000-57,000 41,000-57,600 > 5,000 330	96 hr 96 hr 48 hr 24 hr 48 hr	rainbow trout minnow water flea goldfish African frog	AsF = 100(2) CC = 3.3	AQUIRE, 1995
Ethylenediaminetetraacetic Acid (EDTA)	129 625 59.8 41-532 280	96 hr 24 hr 96 hr 96 hr, varying pH 24 hr	catfish water flea minnow bluegill shrimp	AsF = 100(2) CC = 0.41	AQUIRE, 1995
Fluoroboric Acid	125 (as fluoride)	48 hr	brown trout	AsF = 1,000(3) CC = 0.125	Woodiwiss & Fretwell, 1974
Formaldehyde	25.2-40 47.2 6.7 25.5-26.3	96 hr 96 hr 96 hr 96 hr	bluegill rainbow trout striped bass catfish	AsF = 1,000(3) CC = 0.0067	EPA, 1985b
Formic Acid	175 80-90 151	24 hr 48 hr 48 hr	bluegill green crab water flea	AsF = 1,000(3) CC = 0.08	AQUIRE, 1995
Hydrochloric Acid	282 100 180	24-96 hr 96 hr produced no stress effects 96 hr	mosquito fish green crab goldfish	AsF = 1,000(3) CC = 0.1	AQUIRE, 1995
Hydrogen Peroxide	89 12 155	24 hr 228 hr LT_{50}[j] 24 hr	mackerel zebra mussel gobi	AsF = 10(1) CC = 1.2	AQUIRE, 1995
Isophorone	12.9 79 228	96 hr NOEC[k] 96 hr	mysid shrimp green algae minnow	AsF = 100(2) CC = 0.13	AQUIRE, 1996

Chemical Name[a]	LC_{50} (mg/L)[b]	Test Information	Species	CC (mg/L)[c]	Source
Isopropanol	> 1,400 900-1,100 1,150 1,800	96 hr 24 hr 96 hr toxicity threshold	mosquito fish creek chub shrimp green algae	AsF = 100(2) CC = 9.0	AQUIRE, 1995
Lithium Hydroxide	No aquatic toxicity information available				
m-Nitrobenzene Sulfonic Acid	8,600 > 500	24 &48 hr 48 & 96 hr	water flea trout, guppy, bluegill, minnow	AsF = 100(2) CC = 5	AQUIRE, 1995; Greim et al., 1994
Methanol	28,200 20,100 1,700 2.6-3.1% > 10,000	96 hr 96 hr 48 hr 10-14 day EC_{50} 24 hr LC_{50}	minnow rainbow trout goldfish algae brine shrimp	AsF = 100(2) CC = 17	AQUIRE, 1995
Palladium, Palladium Chloride	0.237 0.142	24 hr EC_{50} 48 hr EC_{50}	tubificid worm	AsF = 1,000(3) CC = 0.00014	AQUIRE, 1995
Phenol-Formaldehyde Copolymer	No aquatic toxicity information available. Once cured, PF copolymer is highly insoluble and is not expected to be toxic to aquatic life.				
Phosphoric Acid	138	TLm	mosquito fish	AsF = 1,000(3) CC = 0.138	HSDB, 1995
Potassium Cyanide, Sodium Cyanide	0.052 0.057 0.0079	96 hr 96 hr chronic value	brook trout rainbow trout brook trout	AsF = 10(1) CC = 0.79	EPA, 1980
Potassium Hydroxide	85 80 80	24 hr 48 hr 96 hr	mosquito fish mosquito fish guppy	AsF = 1,000(3) CC = 0.08	AQUIRE, 1995
Potassium Persulfate	1,360 234 845 92-251	48 hr 48 hr 48 hr 48 hr	carp rainbow trout guppy water flea	AsF = 100(2) CC = 0.92	AQUIRE, 1995
Potassium-Sodium Tartrate	No aquatic toxicity information available.				
Potassium Sulfate	112 1,180 3,550 2,380	all 96 hr	mussel adult snail bluegill bleak	AsF = 1,000(3) CC = 0.11	AQUIRE, 1995
1H-Pyrrole	210 856	96 hr 72 hr EC_{50}	minnow protozoan	AsF = 1,000(3) CC = 0.21	AQUIRE, 1996
Silver	0.0514 0.064 0.036 58	96 hr 96 hr 96 hr 98 hr	rainbow trout bluegill minnow minnow	AsF = 1,000(3) CC = 0.000036	AQUIRE, 1996
Sodium Bisulfate	58-80 190	24 & 48 hr immobilized after 48 hrs	mosquito larvae water flea	AsF = 1,000(3) CC = 0.058	AQUIRE, 1995
Sodium Carbonate	300-320 297 242 524	96 hr 50 hr 5 day 96 hr	bluegill guppy diatom (algae) water flea	AsF = 100(2) CC = 2.4	AQUIRE, 1995

Chemical Name[a]	LC_{50} (mg/L)[b]	Test Information	Species	CC (mg/L)[c]	Source
Sodium Chloride	4,324-13,750 17,550-18,100 23,000-32,000 280-1,940 1,500-5,000	24 hr-10 day 25-96 hr 24-96 hr $\geq$ 24 hr 24-96 hr	goldfish mosquito fish damsel fly water flea striped bass	AsF = 100[(2)] CC = 2.8	AQUIRE, 1996
Sodium Chlorite	75 0.65 0.161	96 hr 96 hr 48 hr	minnow mysid shrimp water flea	AsF = 1,000[(3)] CC = 0.00016	TR-Metro, 1994; Albright & Wilson, 1992a,b
Sodium Citrate	3,330	24 hr	water flea	AsF = 1,000[(3)] CC = 3.3	AQUIRE, 1995
Sodium Hydroxide	125 30 33-100 $\geq$ 25	96 hr 24 hr LC_{40}[l] 48 hr chronic	mosquito fish pikeperch poacher guppy	AsF = 10[(1)] CC = 2.5	AQUIRE, 1995; HSDB, 1995
Sodium Persulfate	1,667 64.6 388 631	48 hr 48 hr 48 hr 48 hr	carp water flea rainbow trout guppy	AsF = 1,000[(3)] CC = 0.065	AQUIRE, 1995
Sodium Sulfate	200-290 81 204 4,380 3,360	96 hr 96 hr 96 hr 96 hr 32 day	amphipoda bass larvae water flea bluegill *Myriophyllum spicatum*	AsF = 100[(2)] CC = 0.81	AQUIRE, 1995
Stannous Chloride[m]	0.6 2.1 0.09 0.4	30 day lethal conc 7 day 7 day 28 day	green algae goldfish eggs toad eggs rainbow trout eggs	AsF = 100[(2)] CC = 0.0009	AQUIRE, 1995
Sulfuric Acid	80-90 42 42.5 20	48 hr 96 hr 48 hr 7 day, no mortality	poacher mosquito fish prawn water flea	AsF = 10[(1)] CC = 2.0	AQUIRE, 1995
Tartaric Acid	250-320	LD_0[n]	paramecium	AsF = 10[(1)] CC = 1.0	Verschueren, 1983
	200	LD_0 longtime hardwater exp.	goldfish		
	10	LD_0 longtime softwater exp.			
Tetrasodium EDTA	360 663 1,033 11 1,030-2,070	72 hr 48 hr EC_{50} 8 day, decreased cell multiplication 96 hr	protozoa cryptomonad water flea green algae bluegill	AsF = 10[(1)] CC = 1.1	AQUIRE, 1995

Chemical Name[a]	LC_{50} (mg/L)[b]	Test Information	Species	CC (mg/L)[c]	Source
Triethanolamine; or 2,2',2''-Nitrilotris Ethanol	> 5,000 11,800 176-213 mg/kg 1.8	24 hr 96 hr 48 hr, LD_0 8 day, decreased cell multiplication	goldfish minnow carp green algae	AsF = 10(1) CC = 0.18	AQUIRE, 1995
Vanillin	112-121 57-123	96 hr 96 hr	minnow minnow	AsF = 1,000(3) CC = 0.057	AQUIRE, 1996; Verschueren, 1996

[a] Only those chemicals with data are listed. Proprietary chemical data are not presented in order to protect proprietary chemical identities.

[b] Lethal concentration (LC_{50}) = the concentration of a chemical in water that causes death or complete immobilization in 50 percent of the test organisms at the end of the specified exposure period. LC_{50} values typically represent acute exposure periods, usually 48 or 96 hours but up to 14 days for fish. Units are mg/L unless otherwise noted.

[c] Concern concentration (CC) = most sensitive toxicity value (mg/L) ÷ AsF. AsF = Assessment (uncertainty) factor.

[d] Concentration that immobilizes 50 percent of the test population.

[e] TLm = Median threshold limit value, or tolerance limit median - equivalent to an LC_{50} value.

[f] EC_{50} = Effective concentration to 50 percent of a test population.

[g] MATC = Maximum acceptable toxicant concentration. It is generally defined as the geometric mean of the highest concentration tested at which no significant deleterious effect was observed and the lowest concentration tested at which some significant deleterious effect was observed.

[h] LC_0 = Estimated maximum concentration that would not result in death of the exposed organisms.

[i] LC_{100} = Lethal concentration to 100 percent of a test population.

[j] LT_{50} = Time for 50 percent of the test population to die at a preselected concentration.

[k] NOEC = No-observed effect concentration.

[l] LC_{40} = Lethal concentration to 40 percent of a test population.

[m] Stannous chloride is expected to rapidly dissociate in water under environmental conditions, followed by formation of tin complexes and precipitation out of the water column. This process would make stannous chloride much less available for toxic effects to aquatic organisms.

[n] LD_0 = Estimated maximum dose that would not result in death of the exposed organisms.

(1) Chronic data available and was most sensitive endpoint, AsF = 10.

(2) Acute data available for multiple species and trophic levels, AsF = 100.

(3) Limited acute data available, AsF = 1,000.

(4) AsF of 10 used for MATC data.

The CC for each chemical in water was calculated using the general equation:

CC = acute or chronic toxicity value ÷ AsF

where:

CC = aquatic toxicity concern concentration, the concentration of a chemical in the aquatic environment below which no significant risk to aquatic organisms is expected.

AsF = assessment factor (an uncertainty factor), the adjustment value used in the calculation of a CC that incorporates the uncertainties associated with: 1) toxicity data (e.g., laboratory test versus field test, measured versus estimated data); 2) acute exposures versus chronic exposures; and 3) species sensitivity. This factor is expressed as an order of magnitude or as a power of ten (EPA, 1984c).

If several acute or chronic toxicity values are available, the lowest one is used (most sensitive tested species), unless poor or uncertain data quality disqualifies one or more of the values. The AQUIRE database, an extensive source of aquatic toxicity data, includes a numerical rating of study quality.

AsFs are dependent on the amount and type of toxicity data contained in a toxicity profile and reflect the amount of uncertainty about the potential effects associated with a toxicity value. In general, the more complete the toxicity profile and the greater the quality of the toxicity data, the smaller the AsF used.

The following approach was used, depending on availability and type of data:

- If the toxicity profile only contained one or two acute toxicity values (no chronic values), AsF = 1,000 and the CC was calculated by using the lower acute value.
- If the toxicity profile contained three or more acute values (no chronic values), AsF = 100 and the CC was calculated by using the lowest acute value.
- If the toxicity profile contained at least one chronic value, and the value was for the most sensitive species, AsF = 10 and the CC was calculated by using the lowest chronic value. Otherwise, AsF = 100 and the CC was calculated with the acute value for the most sensitive species.
- If the toxicity profile contained field toxicity data, AsF = 1 and CC was calculated by using the lowest value.

Aquatic toxicity values were estimated using the ECOSAR program (EPA, 1994b) for chemicals without available measured acute or chronic aquatic toxicity data. These values are presented in Table 3.32. An AsF of 1,000 was used to calculate all CCs based on such estimates.

Table 3.33 presents chemicals with aquatic toxicity CCs. The chemicals are listed in ascending order (i.e., the chemical with the lowest CC to the chemical with the highest CC for each of the alternatives). The lowest CC is for copper sulfate, based on fish toxicity data. The table also presents aquatic hazard concern levels; chemicals were assigned to aquatic toxicity concern levels according to the following EPA criteria:

For chronic values:

≤ 0.1 mg/L.....High concern
> 0.1 to ≤ 10 mg/L.....Moderate concern
> 10 mg/L.....Low concern

For acute values:

≤ 1 mg/L.....High concern
> 1 to ≤ 100 mg/L.....Moderate concern
> 100 mg/L.....Low concern

Chronic toxicity ranking takes precedence over the acute ranking.

It should be noted that aquatic hazard concern levels are derived from the lowest toxicity value available. Therefore, these rankings are derived separately from the CCs which are derived based on the amount of toxicity data available for a given chemical. A summary of the aquatic toxicity results for the known proprietary chemicals is presented in Table 3.34.

These rankings are based only on chemical toxicity to aquatic organisms, and are not an expression of risk. The number of chemicals with a high aquatic hazard concern level include two in carbon, two in conductive ink, none in the conductive polymer process, nine in the electroless copper process, three in graphite, three in non-formaldehyde electroless copper, two in organic-palladium, and nine in tin-palladium.

Table 3.32 Estimated Ecological (Aquatic)Toxicity Information for Non-Proprietary Chemicals

Chemical	Acute Toxicity (mg/L)			Chronic Toxicity (mg/L)			AsF, CC (mg/L)
	Fish (FW) 96 hr LC_{50}	Daphnid 48 hr LC_{50}	Green Algae 96 hr EC_{50}	Fish 14 day LC_{50}	Daphnid 16 day EC_{50}	Green Algae >96 hr ChV	
Benzotriazole[1]	45.3	378.1	23.4	ND	ND	ND	1,000 0.023
Dimethylaminoborane[2]	10	0.7	3.0	1.0	0.070	0.3	10 0.007
Graphite[2]	*	*	*	*	*	*	
Hydroxyacetic Acid[1]	> 1,000 *	> 1,000 *	> 1,000 *	ND	ND	ND	1,000 1
Magnesium Carbonate[2]	> 100	140	> 100	> 10	82	> 10	10 > 1.0
Peroxymonosulfuric Acid[2]	$\leq$ 3.0	$\leq$ 3.0	$\leq$ 3.0	$\leq$ 0.30	$\leq$ 0.30	$\leq$ 1.0	10 0.030
Potassium Bisulfate[2]	> 1,000	> 100	> 100	> 100	> 10	> 10	10 > 1.0
Potassium Carbonate[2]	1,300	330	100	100	190	> 30	10 > 3.0
p-Toluene Sulfonic Acid[2]	Predicted toxicity values of environmental base set all > 100 mg/L, chronic values all > 10.0 mg/L based on SARs for anionic LAS surfactants.						10 1.0
Sodium Hypophosphite[2]	> 100	> 100	0.030	> 10	> 10	0.060	10 0.006

[1] ECOSAR Program.
[2] SAT Report.
* No adverse effects expected in a saturated solution.
ND: No Data. ECOSAR (EPA, 1994b) did not include an estimating component for this endpoint for the chemical class.

Table 3.33 Aquatic Hazard Concern Concentrations (CCs) and Hazard Concern Levels by MHC Technology for Non-Proprietary Chemicals

Chemicals in MHC Processes[a]	CCs (mg/L)	Aquatic Hazard Concern Level[b]
Electroless Copper		
Copper Sulfate	0.00002(2)	High(A)
Palladium; Palladium Chloride	0.00014(3)	High(A)
Sodium Chlorite	0.00016(3)	High(A)
Copper Chloride	0.0004(3)	High(A)
Stannous Chloride[c]	0.0009(2)	High(A)
Sodium Hypophosphite	0.006(5)	Low(A)
Formaldehyde	0.0067(3)	Moderate(A)
Dimethylaminoborane	0.007(5)	High(C)
Boric Acid	0.022(3)	Moderate(A)
Benzotriazole	0.023(5)	Moderate(A)
Peroxymonosulfuric Acid	0.030(5)	Moderate(C)
Ammonium Chloride	0.05(3)	Moderate(A)
Sodium Bisulfate	0.058(3)	Moderate(A)
Ethanolamine	0.075(1)	High(A)
Potassium Hydroxide	0.08(3)	Moderate(A)
Formic Acid	0.08(3)	Moderate(A)
Potassium Hydroxide	0.08(3)	Moderate(A)
Hydrochloric Acid	0.1(3)	Moderate(A)
Potassium Sulfate	0.11(3)	Low(A)
Dimethylformamide	0.12(4)	Moderate(C)
Fluoroboric Acid	0.125(3)	Low(A)
Triethanolamine; or 2,2',2"-Nitrilotris Ethanol	0.18(1)	Moderate(C)
Ethylenediaminetetraacetic Acid (EDTA)	0.41(2)	Moderate(A)
Sodium Cyanide	0.79(1)	High(C)
Potassium Cyanide	0.79(1)	High(C)
Sodium Sulfate	0.81(2)	Moderate(A)
Potassium Persulfate	0.92(2)	Moderate(A)
Hydroxyacetic Acid	1(5)	Low(A)
Magnesium Carbonate	1.0(5)	Low(C)
p-Toluene Sulfonic Acid	1.0(5)	Low(C)
Tartaric Acid	1.0(1)	Moderate(C)
Potassium Bisulfate	>1.0(5)	Low(C)
Hydrogen Peroxide	1.2(1)	Low(C)
Sulfuric Acid	2.0(1)	Low(C)

Chemicals in MHC Processes[a]	CCs (mg/L)	Aquatic Hazard Concern Level[b]
Sodium Carbonate	2.4(2)	Low(A)
Sodium Hydroxide	2.5(1)	Low(C)
Ethylene Glycol	3.3(2)	Low(A)
m-Nitrobenzene Sulfonic Acid	5(2)	Low(A)
2-Ethoxyethanol	5.0(3)	Low(A)
Isopropanol	9.0(2)	Low(A)
Methanol	17(2)	Low(A)
Potassium-Sodium Tartrate	no data available	
Carbon		
Copper Sulfate	0.00002(2)	High(A)
Sodium Persulfate	0.065(3)	Moderate(A)
Ethanolamine	0.075(1)	High(A)
Potassium Hydroxide	0.08(3)	Moderate(A)
Sulfuric Acid	2.0(1)	Low(C)
Potassium Carbonate	> 3.0(5)	Low(C)
Ethylene Glycol	3.3(2)	Low(A)
Carbon Black	no data available	
Conductive Ink		
Silver	0.000036(3)	High(A)
Copper	0.00088(2)	High(A)
Isophorone	0.13(2)	Moderate(A)
2-Butoxyethanol Acetate	1.5(2)	Low(A)
Diethylene Glycol Methyl Ether	5.0(3)	Low(A)
Diethylene Glycol n-Butyl Ether	10(2)	Low(A)
Methanol	17(2)	Low(A)
Diethylene Glycol Ethyl Ether	20(2)	Low(A)
Graphite	not expected to be toxic(5)	Low
Phenol-Formaldehyde Copolymer	not expected to be toxic(5)	Low
Carbon Black	no data available	
Conductive Polymer		
Peroxymonosulfuric Acid	0.030(5)	Moderate(C)
Phosphoric Acid	0.138(3)	Low(A)
1H-Pyrrole	0.21(3)	Low(A)
Sulfuric Acid	2.0(1)	Low(C)
Sodium Carbonate	2.4(2)	Low(A)
Sodium Hydroxide	2.5(1)	Low(C)

Chemicals in MHC Processes[a]	CCs (mg/L)	Aquatic Hazard Concern Level[b]
Graphite		
Copper Sulfate	0.00002[(2)]	High[(A)]
Ammonia	0.0042[(2)]	High[(A)]
Peroxymonosulfuric Acid	0.030[(5)]	Moderate[(C)]
Sodium Persulfate	0.065[(3)]	Moderate[(A)]
Ethanolamine	0.075[(1)]	High[(A)]
Sulfuric Acid	2.0[(1)]	Low[(C)]
Potassium Carbonate	> 3.0[(5)]	Low[(C)]
Graphite	not expected to be toxic[(5)]	Low
Non-Formaldehyde Electroless Copper		
Copper Sulfate	0.00002[(2)]	High[(A)]
Sodium Chlorite	0.00016[(3)]	High[(A)]
Stannous Chloride[c]	0.0009[(2)]	High[(A)]
Potassium Hydroxide	0.08[(3)]	Moderate[(A)]
Hydrochloric Acid	0.1[(3)]	Moderate[(A)]
Potassium Persulfate	0.92[(2)]	Moderate[(A)]
Hydrogen Peroxide	1.2[(1)]	Low[(C)]
Sulfuric Acid	2.0[(1)]	Low[(C)]
Sodium Hydroxide	2.5[(1)]	Low[(C)]
Isopropanol	9.0[(2)]	Low[(A)]
Organic-Palladium		
Sodium Hypophosphite	0.006[(5)]	High[(C)]
Sodium Bisulfate	0.058[(3)]	Moderate[(A)]
Sodium Persulfate	0.065[(3)]	Moderate[(A)]
Hydrochloric Acid	0.1[(3)]	Moderate[(A)]
Sodium Carbonate, Sodium Bicarbonate	2.4[(2)]	Low[(A)]
Sodium Citrate	3.3[(3)]	Low[(A)]
Tin-Palladium		
Copper Sulfate	0.00002[(2)]	High[(A)]
Palladium Chloride, Palladium	0.00014[(3)]	High[(A)]
Copper	0.00088[(2)]	High[(A)]
Stannous Chloride[c]	0.0009[(2)]	High[(A)]
1,3-Benzenediol	0.0025[(2)]	High[(A)]
Dimethylaminoborane	0.007[(5)]	High[(C)]
Vanillin	0.057[(3)]	Moderate[(A)]
Sodium Bisulfate	0.058[(3)]	Moderate[(A)]
Sodium Persulfate	0.065[(3)]	Moderate[(A)]

Chemicals in MHC Processes[a]	CCs (mg/L)	Aquatic Hazard Concern Level[b]
Ethanolamine	0.075(1)	High(A)
Hydrochloric Acid	0.1(3)	Moderate(A)
Fluoroboric Acid	0.125(3)	Low(A)
Phosphoric Acid	0.14(3)	Low(A)
Triethanolamine; or 2,2',2''-Nitrilotris Ethanol	0.18(1)	Moderate(C)
Hydrogen Peroxide	1.2(1)	Low(C)
Sulfuric Acid	2.0(1)	Low(C)
Sodium Hydroxide	2.5(1)	Low(C)
Sodium Chloride	2.8(2)	Low(A)
Potassium Carbonate	> 3.0(5)	Low(C)
Isopropanol	9.0(2)	Low(A)
Lithium Hydroxide	no data available	

[a] Different supplier's product lines do not necessarily include all of the chemicals listed for a process alternative.

[b] Based on lowest available toxicity data:

(A) indicates the lowest acute value was used for hazard ranking.

(C) indicates the hazard ranking is based on a chronic value, if available and lower than any acute value.

[c] Stannous chloride is expected to rapidly dissociate in water under environmental conditions, followed by tin forming complexes and precipitating out of the water column. This process would make stannous chloride much less available for toxic effects to aquatic organisms.

Basis of Concern Concentrations:

(1) Chronic data.

(2) Acute data for multiple species and taxonomic groups.

(3) Limited acute data.

(4) Chronic MATC.

(5) Structure-activity relationship estimate using the ECOSAR program or SAT report.

Table 3.34 Summary of Aquatic Toxicity for Proprietary Chemicals

Technology	No. of Additional Trade Secret Chemicals[a]	Aquatic Toxicity Concern Rank			CC (mg/l)			
		Low	Moderate	High	< 0.1	0.9 - 0.99	1 - 10	> 10
Electroless Copper	9	6	3	0	1	2	5	1
Graphite	5	4	1	0	0	2	2	1
Tin-Palladium	5	2	1	2	2	1	1	1
Organic-Palladium	1	0	0	1	1	0	0	0

[a] Includes chemicals not previously identified in the publicly-available bath chemistry data for a technology.

3.3.4 Summary

For human health hazards, toxicity data in the form of RfDs, RfCs, NOAELs, LOAELs, and cancer slope (cancer potency) factors were compiled for inhalation and dermal pathways. Formaldehyde was the only non-proprietary chemical with an established cancer slope (cancer potency) factor. Other non-proprietary chemicals in the MHC processes are suspected

carcinogens, but do not have established slope factors. Dimethylformamide and carbon black have been determined by IARC to possibly be carcinogenic to humans (IARC Group 2B). Dimethylformamide is used by at least one supplier in the electroless copper process. Carbon black is used in the carbon and conductive ink processes. Two proprietary chemicals used in the graphite and electroless copper processes, cyclic ether and alkyl oxide, have cancer slope factors. Another proprietary chemical used in the electroless copper process, trisodium acetate amine B, is possibly carcinogenic to humans but does not have an established slope factor.

An ecological hazards assessment was performed based on chemical toxicity to aquatic organisms. Concern concentrations (CCs) were estimated for MHC chemicals using an established EPA method. A CC is an acute or chronic toxicity value divided by an assessment factor (AsF). AsFs are dependent on the amount and type of toxicity data contained in a toxicity profile and reflect the amount of uncertainty about the potential effects associated with a toxicity value. Concern concentrations were determined for aquatic species (e.g., *Daphnia*, algae, and/or fish). The lowest CC is for copper sulfate, based on fish toxicity data.

Chemicals were also ranked for aquatic toxicity concern levels using established EPA criteria (high, moderate, and low concern) based on the available toxicity data. The number of chemicals with a high aquatic hazard concern level include nine in the electroless copper process, two in carbon, two in conductive ink, none in conductive polymer, three in graphite, three in non-formaldehyde electroless copper, and nine in the tin-palladium process, and two in the organic palladium process.