BizNGO
FOR SAFER CHEMICALS AND SUSTAINABLE MATERIALS

Alternatives to Methylene Chloride in Paint and Varnish Strippers


Availability of Safer Alternatives & Requirements for Meeting Stage 1 of the California Safer Consumer Products Regulations

OCTOBER 27, 2015

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Acknowledgments

This report benefitted from numerous discussions and comments from participants in the BizNGO Alternatives Assessment Work Group. We are especially thankful for their feedback, which clarified both the hazard assessment process in the context of an alternatives assessment as well as the potential requirements of a Stage 1 analysis that complies with the California Safer Consumer Products regulations. In producing the final report we thank Mariel Wolfson of Clean Production Action for her detailed copy editing and David Gerratt of DG Communications for his creativity in design. We take full responsibility for the contents herein and understand that providing comments on the report does not in any way construe support and agreement with the final product.

We are especially grateful to ToxServices LLC for sharing its GreenScreen® hazard assessments that were used in this model report. While ToxServices' GreenScreen® summaries are included in the report appendix and GreenScreen® summary classifications are included in the body of the report, full GreenScreen reports are the property of ToxServices and are not included. Those interested in obtaining copies of the full reports should contact ToxServices (*info@toxservices.com*).

On behalf of all of us working to advance safer alternatives to chemicals of concern for human health or the environment (including the avoidance of regrettable substitutes), we hope that this report contributes to the growth and development of the emerging field of alternatives assessment.

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October 27, 2015

BizNGO — FOR SAFER CHEMICALS AND SUSTAINABLE MATERIALS

BizNGO is a collaboration of leaders from businesses, environmental organizations, government agencies and universities. Our mission is to promote the creation and adoption of safer chemicals and sustainable materials, thereby creating market transitions to a healthy economy, healthy environment, and healthy people.

CLEAN PRODUCTION ACTION

Clean Production Action's mission is to design and deliver strategic solutions for green chemicals, sustainable materials and environmentally preferable products. Critical to our success is working closely with existing networks across the globe, developing new partnerships, learning about emerging technological trends and associated environmental health problems, and developing and communicating essential solutions. For further information go to *www.CleanProduction.org*.

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About this Report

In 2013, California finalized its Safer Consumer Products (SCP) regulations, which establish a process for evaluating chemicals of concern and their potential alternatives in consumer products. This landmark legislation addresses the critical need to reduce toxic chemicals in consumer products—chemicals that are responsible for known human health and environmental harms. The regulations require "responsible entities" (which include manufacturers, importers, assemblers, and/or retailers) of a "priority product" (a consumer product containing a chemical of concern) to complete an alternatives analysis to determine whether feasible alternatives are available to minimize the public health and environmental impacts of their products. "Alternatives analysis" is synonymous with the term "alternatives assessment," defined as a process for identifying, comparing, and selecting safer alternatives to chemicals of concern (including those in materials, processes, or technologies) on the basis of their hazards, performance, and economic viability. The process is intended to provide guidance for assuring that chemicals of concern are replaced with safer alternatives that are not likely to prove regrettable at a later date—known as "regrettable substitutions."

The California SCP regulations divide alternatives analysis into two stages. Stage 1 includes the following primary components: an examination of the product's and chemical of concern's function and performance requirements; identification of candidate alternatives; identification of relevant comparison factors (for example, environmental, human health, and physicochemical properties); assessment of human and environmental health hazards of concern; and a work plan and associated timeline relevant to completion and submission of the Stage 2 assessment. Stage 2 involves a broader assessment, including life cycle impacts as well as an assessment of economic and technical feasibility for both the product and its chemicals of concern.

BizNGO—a collaboration of leaders from businesses, environmental groups, universities, and governments—initiated a demonstration project to draft a report on a priority product under the California SCP regulations: paint and varnish strippers with methylene chloride (also known as dichloromethane). The purpose of the process was to identify less hazardous alternatives to methylene chloride in paint/varnish strippers and to model and explore compliance with Stage 1 of the alternatives analysis requirements under the California SCP regulations. The goals of this demonstration project were three-fold: (1) to identify less hazardous alternatives to methylene chloride in formulated paint stripper products; (2) to identify candidate alternatives for methylene chloride in paint stripping formulations that will likely be considered in actual/future Stage 1 submissions for this "priority product" in California; and (3) to identify challenges and needs confronting compliance with the alternatives analysis process under the California SCP regulations.

The following report provides an example of the flow of a California SCP-type alternatives analysis, specifically the scoping and hazard assessment step as specified for Stage 1. The report follows the required format, including the executive summary. This report does not, however, substitute for specific compliance guidance to be issued by the California Department of Toxic Substances Control (DTSC) as additional details may be required.

This demonstration project was conducted from the perspective of a chemical formulator that manufactures a methylene chloride-based paint stripper consumer product—one of the entities that may be required to comply with the California regulations. However, the analysis summarized in the report *is not tied to any real or specific company or product.*

Highlights from the report, including summary of results and lessons learned in relation to the SCP regulations, are described in the last section of this report.

California Safer Consumer Products Regulations: Stage 1 Executive Summary

Paint stripping products are used to remove old, blistered, or cracked paint to ready the substrate for an application of coatings such as fresh paint. They are intended to remove surface coatings such as paint, lacquers, varnishes, or graffiti from a broad range of substrates (e.g., metal, wood, and concrete). There are generally three categories of paint stripper use: consumer, professional, and industrial.

This analysis models the perspective of a manufacturer of a methylene chloride-based paint stripper for consumers that seeks compliance with the California Safer Consumer Products (SCP) regulations. The category of paint strippers that is the subject of this alternatives analysis includes both consumer and professional uses. These uses include products readily purchased at consumer retail outlets, such as paint and hardware supply stores. Industrial uses of paint strippers are considered beyond the scope of this analysis given that these are not sold in the consumer marketplace.

Methylene chloride (CAS number 75-09-2)— the chemical of concern in paint strippers—is the primary stripping solvent. Methylene chloride in paint strippers functions through a combination of processes that involve penetrating the paint layers and breaking the bond between the paint and the substrate. As methylene chloride volatizes, it pushes up on the resulting painted film, tenting it away from the substrate, and making the paint easy to subsequently remove with a blunt metal surface such as a putty knife. The most important function of a solvent in a paint stripper is its diffusivity. Other primary functions include causing the target paints to swell and delivering activators to the interfaces of paints and substrates.

Paint strippers have two general performance requirements: (1) effective removal of surface coatings and (2) maintenance of the quality and integrity of the substrate surface. The American Society for Testing and Materials (ASTM) D6189-97 outlines testing procedures relevant to paint stripping. The two metrics examined in this standard include:

- amount (percentage ranking) of each layer of coating removed based on specified stripping times; and
- condition (qualitative ranking) of substrate after coating removal.

Performance factors considered in this standard include:

- compatibility with the substrate;
- effectiveness in removing a variety of paint/coating types (e.g., latex enamel, polyurethane, varnish, shellac, nitrocellulose lacquer, etc.); and
- stripping time.

Green Seal's GS52 standard for household cleaning products also includes a standard for graffiti removal.

There are three generally recognized categories of paint stripping methods:

- Physical/mechanical stripping, which involves the use of abrasion methods. Examples include: use of metal tools for scraping, sand paper, media blasting (e.g., plastic media blasting, wheat media blasting, liquid nitrogen blasting, etc.).
- Pyrolytic/thermal stripping, which involves the use of heat. Examples include: heat guns, steam, and laser stripping.
- Chemical stripping, which uses solvents or alkaline or acidic chemicals to strip paint.

Chemical alternatives prioritized in this Stage 1 analysis include those with a solvent function to replace the function of methylene chloride in the existing paint stripping product. In order to expand the range of alternatives relevant to chemical formulation manufacturers, this analysis will also examine chemical formulations that can strip paint via other functions, including acidic and alkaline chemicals that can strip paint via an acidic or caustic function.

While there are additional alternative paint strippers available in consumer retail outlets, including pyrolytic techniques and physical/mechanical techniques as noted above, these alternatives are not economically feasible for a chemical formulator to consider. For the purpose of this model Stage 1 analysis, the costs required of this hypothetical chemical formulator to change its business model to the manufacturing of metal products (e.g., metal scrappers) or paper products (e.g., sand paper), or the manufacturing of other articles (e.g., heat guns) would rank lowest among the alternatives, given the tremendously high capital and employee costs required. Required investments were assumed to include new plant infrastructure (capital expenditures associated with building new plants, purchasing new manufacturing equipment, etc.) as well as personnel costs (e.g., unemployment/severances for downsized chemical staff). These costs render such a change financially infeasible.

Additional alternatives not considered for further screening in this report, because they are intended for uses in industrial facilities rather than consumer or professional settings, include media blasting and alkaline and acid chemical stripping that require use in immersion tanks.

The 11 alternatives prioritized for hazard screening are identified in Table A. These potential alternatives were identified through a review of publicly available reports from industry research, government, and/or government research sponsored institutions. The 11 alternatives were prioritized based on: (a) a review of existing MSDSs demonstrating that these alternatives are being used in paint strippers on the market today; (b) case study experience (including those listed on product specifications); and (c) those also likely to be prioritized by DTSC as they are referenced in its *Priority Product Profile: Paint Strippers Containing Methylene Chloride* report.

An alternative excluded from the hazard assessment was 1-Methyl-2-pyrrolidone (NMP). While this alternative was identified as a candidate given the same sources used for those identified in Table A, and is often found as a co-solvent with alternatives identified in Table A in products available on the market today, DTSC states in its *Priority Product Profile: Paint Strippers Containing Methylene Chloride*, that NMP alternatives for methylene chloride are not to be considered because "DTSC does not recognize NMP as a 'safer alternative' to methylene chloride." NMP is considered a reproductive and developmental toxicant under California's Proposition 65 and is included on DTSC's list of candidate chemicals. For these reasons, NMP was screened out of the assessment.

This hazard assessment uses GreenScreen® for Safer Chemicals version 1.2 hazard assessment method, which is based on the Globally Harmonized System (GHS) for Classification and Labeling. It uses national and international precedents from authoritative agencies regarding evidence classifications for specific hazard endpoints wherever feasible. It includes 12 human health endpoints (carcinogenicity, genotoxicity/mutagenicity, reproductive toxicity, developmental toxicity and endocrine activity, acute toxicity, systemic toxicity and organ effects, neurotoxicity, skin sensitization, respiratory sensitization, skin irritation, and eye irritation), two ecotoxicity endpoints (acute and chronic aquatic toxicity), and four physicochemical characteristics (persistence, bioaccumulation, reactivity, and flammability), two of which also reflect environmental fate (persistence and bioaccumulation).

TABLE A

Methylene Chloride Alternatives included in BizNGO Comparative Hazard Assessment

Chemical (or mixture)	CASRN	Molecular Formula
Benzyl alcohol	100-51-6	C_7H_8O
2-(2-Butoxyethoxy) Ethanol	112-34-5	$C_8H_{28}O_2$
Dimethyl-sulfoxide (DMSO)	67-68-5	C_2H_6OS
1,3-Dioxolane	646-06-0	$C_3H_6O_2$
Estasol (Mixture of 3 dibasic esters) **(a) Dimethyl succinate (15-25%)** **(b) Dimethyl glutarate (55-65%)** **(c) Dimethyl adipate (10-25%)**	95481-62-2	(a) $C_6H_{10}O_4$ (b) $C_7H_{12}O_4$ (c) $C_8H_4O_4$
d-Limonene	138-36-3	$C_{10}H_{16}$
Hydrocarbon solvents (likely used as a mixture, but assessed individually) **(a) methanol** **(b) acetone** **(c) toluene**	(a) 67-56-1 (b) 67-64-1 (c) 108-88-3	(a) CH_4O (a) C_3H_6O (a) C_7H_8
Formic acid	64-18-6	CH_2O_2
Caustic soda	1310-73-2	HNaO

Comparison factors including additional environmental impacts (e.g., ozone depletion and global warming potential), adverse waste and end-of-life impacts, and materials and resource consumption impacts will be addressed in the Stage 2 life cycle analysis of the California SCP regulations. Additional hazards not considered in the GreenScreen® assessment, such as environmental fate and additional environmental impacts, will be addressed in the Stage 2 assessment.

Results from the GreenScreen® hazard assessment are included in Table B.

TABLE B

GreenScreen® Hazard Assessment Results

Chemical Name	CASRN	Group I Human					Group II & II Human									Ecotox		Fate		Physical	
								ST		N											
		C	M	R	D	E	AT	Single	repeated	Single	repeated	SnS	SnR	IrS	IrE	AA	CA	P	B	RX	F
Methylene chloride	75-09-2	H	NE	DG	DG	M	*M*	vH	H	*vH*	*vH*	L	DG	H	H	M	*L*	*vH*	vL	L	L
Benzyl alcohol	100-51-6	L	L	*L*	M	DG	M	L	L	*M*	*H*	H	*L*	L	H	L	L	vL	vL	*L*	L
2-(2-butoxyethoxy) ethanol	112-34-5	*L*	L	L	L	DG	L	L	H	DG	L	L	DG	*M*	H	L	L	vL	vL	*L*	M
Dimethyl sulfoxide	67-68-5	*L*	L	L	L	DG	L	L	L	L	L	L	L	*M*	*M*	L	*L*	*L*	vL	*L*	M
1,3-dioxolane	646-06-0	L	*M*	*M*	M	DG	L	M	M	M	L	L	DG	*M*	*H*	L	L	*M*	vL	*L*	H
Estasol (dibasic esters mixture)	95481-62-2	*L*	L	L	*M*	*M*	L	M	*M*	M	DG	L	DG	L	*M*	M	L	vL	vL	*M*	L
d-Limonene	5989-27-5	L	L	DG	L	DG	L	L	L	DG	DG	H	DG	H	*H*	vH	H	vL	M	*L*	M
Acetone	67-64-1	*L*	L	*M*	M	DG	L	*M*	M	M	*M*	L	DG	L	H	L	L	vL	vL	L	H
Methanol	67-56-1	NA	NA	NA	H	NA	H	vH	NA	NA	NA	NA	NA	NA	NA	L	*L*	vL	*vL*	NA	H
Toluene	108-88-3	DG	L	H	H	M	L	M	H	M	H	L	DG	H	L	H	*H*	*H*	vL	L	H
Formic acid	64-18-6	L	L	L	*L*	DG	H	vH	*H*	vH	DG	L	DG	vH	vH	M	M	vL	vL	L	M
Caustic soda	1310-73-2	*L*	L	*L*	*L*	*L*	H	vH	*L*	*L*	*L*	L	DG	vH	vH	M	DG	*L*	*vL*	*M*	L

Abbreviations

C = Carcinogenicity
M = Mutagenicity
R = Reproductive Toxicity
D = Developmental Toxicity
E = Endocrine Activity
AT = Acute Toxicity
ST = Systemic Organ Toxicity
N = Neurotoxicity
SnS = Skin Sensitization
SnR = Respiratory Sensitization
IrS = Skin Irritation
IrE = Eye Irritation
AA = Aquatic Toxicity
CA = Chronic Aquatic Toxicity
P = Persistence
B = Bioaccumulation
RX = Reactivity
F = Flammability

Note

Hazard levels (Very High (vH), High (H), Moderate (M), Low (L), Very Low (VL) in italics reflect estimated (modeled values, authoritative B lists, screening lists, weak analogues, and lower confidence. Hazard levels in BOLD are used with good quality data, authoritative A lists, or strong analogues. Group II Human Health endpoints differ from Group II Human Health endpoints in that they have four hazard scores (i.e., vH, H, M and L) instead of three (i.e., H, M and L), and are based on single exposures instead of repeated exposures. DG indicates insufficient data for assigning hazard level. NE indicates no determination was made (conflicting data).

The GreenScreen® Benchmark™ scores for methylene chloride and each of the candidate alternatives are described in Table C. Dimethyl sulfoxide (DMSO) was the only candidate alternative that received a Benchmark 3 score: "Use but Still Opportunity for Improvement." While the hazard severity of DMSO associated with the range of endpoints examined was deemed lower than other candidate alternatives, DMSO has the capacity to potentiate the toxicity of other chemicals that are included in the final product formulation or other chemicals that users are in contact with while using a DMSO-containing product. Should DMSO be further considered as a potential alternative given Stage 2 analysis of the Safer Consumer Products regulations, a deeper examination of the hazards of other formulation chemicals is essential since DMSO will increase the toxicity potency of chemicals contained in the formulation.

TABLE C
GreenScreen® Hazard Assessment Benchmarks

Chemical	CASRN	Benchmark	Benchmark Explanation	Benchmark Reason (Primary Hazard Endpoints of Concern)
Methylene chloride	75-09-2	1	Avoid Chemical of High Concern	"High" carcinogenicity
Benzyl alcohol	100-51-6	2	Use but Search for Safer Substitutes	"Moderate" developmental toxicity; "High" neurotoxicity (repeated dose) and skin sensitization
2-(2-butoxyethoxy) ethanol	112-34-5	2	Use but Search for Safer Substitutes	"High" systemic toxicity (repeated dose)
Dimethyl sulfoxide (DMSO)	67-68-5	3	Use but Still Opportunity for Improvement	"Moderate" toxicity associated with skin irritation & eye irritation; "Moderate" flammability
1,3-dioxolane	646-06-0	2	Use but Search for Safer Substitutes	"Moderate" mutagenicity, reproductive toxicity and developmental toxicity; "High" flammability
Estasol (dibasic esters mixture)	95481-62-2	2	Use but Search for Safer Substitutes	"Moderate" developmental toxicity and endocrine activity
d-Limonene	5989-27-5	2	Use but Search for Safer Substitutes	"Very high" acute ecotoxicity and "high" toxicity associated with skin sensitization
Acetone	67-64-1	2	Use but Search for Safer Substitutes	"Moderate" developmental toxicity & reproductive toxicity and "high" flammability
Methanol	67-56-1	1	Avoid Chemical of High Concern	"High" reproductive and developmental toxicity
Toluene	108-88-3	1	Avoid Chemical of High Concern	"High" developmental toxicity
Formic acid	64-18-6	2	Use but Search for Safer Substitutes	"Very High" toxicity associated with skin irritation, eye irritation & systemic toxicity (single dose) & neurotoxicity (single dose); "High" systemic toxicity (repeated dose)
Caustic soda	1310-73-2	2	Use but Search for Safer Substitutes	"Very High" toxicity associated with skin irritation, eye irritation & systemic toxicity (single dose)

CASRN = Chemical Abstracts Service Registration Number

- GreenScreen Benchmark 1: Chemical of High Concern—Avoid.
- GreenScreen Benchmark 2: Use but search for something safer.
- Use but Still Opportunity for Improvement.

Table D lists chemicals that have been de-selected for further consideration. Methanol was classified as having "high" developmental toxicity, while toluene similarly demonstrated "high" developmental toxicity as well as "high" reproductive toxicity. As in the case of NMP described in Section 2.1, both methanol and toluene are considered reproductive/developmental toxicants under California's Proposition 65 and are included on DTSC's list of candidate chemicals. Given that these decision rules guided the de-selection of NMP, they should also guide the de-selection of methanol and toluene.

TABLE D
Chemicals De-Selected for Further Assessment in California SCP Stage 2 Alternatives Analysis

De-selected alternative	CASRN	Reason for De-selection
Methanol	67-56-1	Developmental toxicant – Listed on CA Prop 65 and DTSC's Candidate List of Chemicals
Toluene	108-88-3	Developmental & reproductive toxicant – Listed on CA Prop 65 and DTSC's Candidate List of Chemicals

Table E includes the nine chemicals that BizNGO will advance to the Stage 2 analysis of the SCP regulations. Stage 2 will focus, depending on the availability of data, on the evaluation of additional hazards not considered in the GreenScreen® assessment and additional environmental impacts. Stage 2 will also focus on preventing the shifting of negative impacts from one environmental or human heath endpoint to another by reviewing available multi-media life cycle information. Product performance and economic impacts will be assessed in Stage 2 as well.

The proposed final alternatives assessment work plan and associated schedule is described in Table F.

TABLE E
Chemicals Selected for Further Assessment in California SCP Stage 2 Alternatives Analysis

Chemical	CASRN
Benzyl alcohol	100-51-6
2-(2-butoxyethoxy) ethanol	112-34-5
Dimethyl sulfoxide (DMSO)	67-68-5
1,3-dioxolane	646-06-0
Estasol (dibasic esters mixture)	95481-62-2
d-Limonene	5989-27-5
Acetone	67-64-1
Formic acid	64-18-6
Caustic soda	1310-73-2

TABLE F
BizNGO Proposed Final Alternatives Analysis Work Plan and Schedule for Complying with California Safer Consumer Products Regulations

Action Item	Description	Completion Date*
Re-evaluation of relevant factors from preliminary alternatives assessment	Relevant factors identified in the Preliminary Alternatives Assessment will be reviewed and changes will be documented.	6 weeks
Review of product function and performance factors	The Performance Evaluation Module (Level 3) of the Interstate Chemicals Clearinghouse Alternatives Assessment Guide (version 1.0) will be followed for performance evaluation guidance. Performance standards identified in Section 1.3 will be used to evaluate key performance parameters and for determining the range of acceptable values for those parameters. The focus of the product function and performance evaluation will be on preventing burden shifting in the form of decreased safety. Given that methylene chloride is a non-flammable solvent, additional fire safety standards will be assessed. Those alternatives demonstrating high concern regarding fire safety will be screened out of the analysis.	10 weeks
Consideration of materials and resource consumption impacts	Existing life cycle inventories or life cycle assessments will be reviewed for relevant data. Where life cycle assessment data are lacking, data for proxy chemicals will be explored as a substitute. Results will be summarized and alternatives that demonstrate significant life cycle burden risk shifting will be screened-out.	14 weeks
Reassessment of hazards for other co-chemicals in the best performing formulations. Conduct literature review to ensure no new hazard information substantively changes the hazard classifications from Stage 1.	In order to minimize hazards in the total formulation, rather than only the chemical of concern, a screening hazard assessment will be performed on all co-chemicals in the formulation above 0.01% concentration (100 parts per million) in the formulation. The 4-5 best performing formulations will be screened for using more "quick screening" methods given the number of chemicals to be examined. These methods employ the use of authoritative lists. A literature review will be performed to ensure that new hazard information is considered that may substantively change the hazard classifications in Stage 1.	17 weeks
Review of economic factors	Cost and Availability Evaluation Module (Level 4) of the Interstate Chemicals Clearinghouse Alternatives Assessment Guide (version 1.0) will be followed to assess economic feasibility. It is anticipated that one or more of the alternatives will be selected for substitution of the chemical of concern; therefore, the economic impacts are expected to be positive from a burden shifting perspective. Economic factors, as specified in the regulations, will be researched and evaluated.	21 weeks
Review of priority product and alternatives/alternative selection decision	The Priority Product and the alternatives will be compared based on the relevant factors and one or more alternatives will be selected as the recommended option. Relevant factors will include factors identified, but not analyzed, in the preliminary alternatives assessment, plus relevant function, performance, and economic factors.	30 weeks
Submittal of final report	The scheduled submission date of final report.	40 weeks**

* Completion date: number of weeks after BizNGO receives Notice of Compliance for Preliminary Alternatives Assessment from DTSC.

** Note that BizNGO plans to submit its work plan 12 weeks before the required DTSC deadline of 52 weeks.

Standard Template for California Safer Consumer Products Regulations, Stage 1 Submission: Preparer Information

Preparer

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Entities involved in Funding, Directing Overseeing, Preparing, and/or Reviewing the Report

Name	***
Organization	***
Address	***
Telephone	***
Email	***

"I certify that this document and all attachments were prepared or compiled under my direction or supervision to assure that qualified personnel properly gathered and evaluated the information submitted. Based on my inquiry of the person(s) directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that submitting false information or statements is a violation of law.

Responsible Entity Signature	***	Date	***
Preparer Signature	***	Date	***

*** This is a model assessment and not tied to any real or specific company or product.
This information is not provided in this model assessment.

Standard Template for California Safer Consumer Products Regulations, Stage 1 Submission: Responsible Entity and Supply Chain Information

Preparer

Name	***
Organization	***
Address	***
Telephone	***
Email	***

Importer

Name	***
Organization	***
Address	***
Telephone	***
Email	***

Distributor (as identified on product label)

Name	***
Organization	***
Address	***
Telephone	***
Email	***

California Customer Identification
(to whom product was directly sold within the prior twelve months)

Customer A	***
Organization	***
Address	***
Telephone	***
Email	***
Customer B	***
Organization	***
Address	***
Telephone	***
Email	***

Direct Retail Sales Outlet Identification

Name	***
Organization	***
Address	***
Telephone	***
Email	***

*** This is a model assessment and not tied to any real or specific company or product.
This information is not provided in this model assessment.

1. Priority Product Information

1. Brand Names and/or Product Names	***
2. Products in Which Priority Product is Used	Paint strippers and paint removal products
3. Chemical of Concern	Methylene chloride / dichloromethane (CASRN 75-09-2)
4. Material Safety Data Sheet Reference	****

*** This is a model assessment and not tied to any real or specific company or product.
This information is not provided in this model assessment.

1.1 Product Functional Requirements

Paint stripping products on the market today are used to clean surfaces by removing surface coatings, including paint, lacquers, varnishes, or graffiti from various substrates. These substrates are most often metal and wood, and in the case of graffiti, also concrete. These products, referred to hereafter as "paint strippers," are often used to remove old, blistered, or cracked paint to "clean" and ready the substrate for an application of coatings such as fresh paint. There are generally three categories of paint stripper use: consumer, professional, and industrial.[1]

Consumer: Paint strippers are used for a variety of "do-it-yourself" (DIY) home-improvement or household purposes or hobbies. Uses include stripping painted or varnished wood or metal furniture, kitchen cabinets, door and window jambs, and metal bathtubs (among other items). Paint strippers are also used on recreational boats or water craft. Use occurs both indoors and outdoors. Paint strippers are most often purchased in small quantities at paint or hardware supply stores.

Professional: Hired contractors and trades workers use paint strippers to remove paint from exterior and interior walls; to remove graffiti from wood, brick, or concrete structures; to remove paint from wooden doors, window frames, and other wooden building features such as banisters, hand rails, stairs, and floors; and to remove paint from metal bathtubs. Contractors also use paint strippers in marine settings to remove paint on boats and boating equipment. Paint strippers used by professionals are often purchased at paint or hardware supply stores or professional supply outlets.

Industrial: Industrial facilities using paint strippers at their onsite facilities often require the use of specialized and/or industrial scale equipment, such as immersion tanks. Paint strippers used in industrial applications include use in metal stripping, furniture stripping, automotive stripping (including part stripping), ship stripping, and aircraft stripping. Paint strippers used by industrial facilities are typically used in large volumes and purchased through industrial distributors.

The category of paint strippers that is the subject of this alternatives analysis includes both consumer and professional uses. These uses include products readily purchased at consumer retail outlets, including paint and hardware supply stores. Industrial uses of paint strippers are considered beyond the scope of this analysis given that these are not consumer products. While it is possible for consumers to obtain industrial paint strippers, these products are not directly marketed to consumers, nor are these industrial products available in consumer retail outlets.

1.2 Chemical of Concern Functional Requirements

The chemical of concern in paint strippers is methylene chloride (CASRN 75-09-2). Paint provides a protective coating and is designed to be environmentally robust and difficult to remove. Methylene chloride is the primary stripping solvent.

During professional and consumer use of methylene chloride-based paint strippers, the product is typically brushed onto the substrate; the stripper then softens or dissolves the paint or varnish coating, and the resulting substrate-stripper mixture is then scraped off. The substrate may need to be washed off after stripping to eliminate any residue left on the surface.

Methylene chloride in paint strippers functions through a combination of processes that involve penetrating the paint layers and breaking the bond between the paint and the substrate.[2] As methylene chloride volatizes it pushes up on the resulting painted film, tenting it away from the substrate, and making the paint easy to remove with a blunt metal surface such as a putty knife. The most important function of a solvent in a paint stripper is its diffusivity.[3]

Other primary functions include causing the target paint to swell and delivering activators to the interfaces of paints and substrates.[4]

To enhance the solvency function and performance of methylene chloride in paint strippers, product formulations routinely contain additional chemicals that perform the following functions: [5]

- co-solvents to improve the efficiency of stripping or to diminish the cost of the product without compromising the product's performance,
- activators that are involved in breaking the bond between paints and substrates,
- evaporation inhibitors to reduce evaporation of the solvent and increase time in contact with the substrate,
- thickeners to increase the viscosity of the product which is important for use on vertical surfaces,
- corrosion inhibitors used to ensure the stability of the stripper in its packaging or to protect the substrate,
- surfactants added so products and brushes used during applications can be rinsed with water,
- colorants, and/or
- water.

1.3 Performance Requirements

Paint strippers have two general performance requirements: (1) effective removal of surface coatings and (2) maintenance of the quality and integrity of the substrate surface. For example, the removal of paint from wooden substrates using chemical paint strippers can increase surface roughness while the removal from metal substrates can cause pitting and rusting.

The American Society for Testing and Materials (ASTM) published a standard (D6189-97) relevant to testing the effectiveness of chemical paint removers for organic coatings on wood and metal.[6] Performance factors considered include:

- compatibility with the substrate;
- effectiveness in removing a variety of paint or coating types (e.g., latex enamel, polyurethane, varnish, shellac, nitrocellulose lacquer, etc.); and
- stripping time.

The performance requirements based on the above three factors are application-specific and will vary. The two performance metrics included in the ASTM D6189-97 testing standard include:

- amount (percentage ranking) of each layer of coating removed based on specified stripping times; and
- condition (qualitative ranking) of substrate after coating removal.

Green Seal's GS52 standard for household cleaning products includes a standard for graffiti removal that is based on testing the performance of alternative products. The primary performance metric is that "the product shall demonstrate that it performs equivalent to or better than a national market-leading product in its category, compared at the most dilute/least concentrated manufacturer recommended dilution level for routine cleaning, using an objective, scientifically-validated method, conducted under controlled and reproducible laboratory conditions."[7]

1.4 Legal Requirements

There are no legal requirements for the performance of paint strippers for consumer or professional use.

1.5 Role of Chemical of Concern in Meeting Product Requirements

The role of methylene chloride, the chemical of concern, is to provide the primary function of paint or coating removal as reviewed above in Section 1.2. Either the chemical of concern or an alternative is necessary to meet the product's functional requirements. Therefore, it is required that alternatives be identified and evaluated according to the relevant comparison factors.

2. Scope and Comparison of Alternatives

2.1 Identification of Alternatives

An array of resource documents are available (see Appendix 1) that review in detail the broad range of paint removal options available.[8] These documents reveal three generally recognized categories of paint stripping methods:

- Physical/mechanical stripping, which involves the use of abrasion methods. Examples include: use of metal tools for scraping, sand paper, and media blasting (e.g., plastic media blasting, wheat media blasting, liquid nitrogen blasting, etc.).
- Pyrolytic/thermal stripping, which involves the use of heat. Examples include: heat guns, steam, and laser stripping.
- Chemical stripping, which uses solvents or alkaline or acidic chemicals to strip paint.

The performance and safety of the paint stripping methods described above will vary depending on the environmental conditions in which they are applied. For example, not all methods are appropriate for use indoors in residential settings.

This BizNGO analysis models the perspective of a chemical formulation manufacturer of methylene chloride-based paint stripper consumer products. While the three categories of paint stripping methods above offer a range of alternatives to consider, not all methods are compatible with the category of consumer or professional product paint strippers as justified in Section 1.1. Nor are all the alternatives relevant to a chemical stripping product manufacturer seeking to identify and adopt a safer alternative consumer product that can achieve the same product functional requirements as reviewed in Section 1.1 and preferably, the same functional use as reviewed in Section 1.2, as methylene chloride in the current product.

For Stage 1 analysis BizNGO prioritized alternative chemical stripping agents. Primary alternatives to be further screened and analyzed include those with a solvent function to replace the function of methylene chloride in the existing paint stripping product (see Section 1.2). In order to expand the options of potential chemical alternatives, chemical formulations that can strip paint via other functions will also be considered. In this chemical screening assessment, acidic and alkaline strippers will also be considered.

Alternatives not prioritized and considered in this Stage 1 assessment include: (1) non-chemical alternatives, as the expected economic costs for a chemical formulator associated with such a transition are expected to be infeasible and (2) alternatives not intended for consumer or professional uses, including: media blasting and alkaline and acid chemical stripping that require use in immersion tanks.

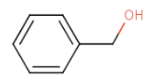
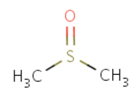
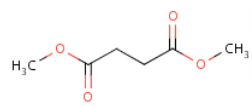
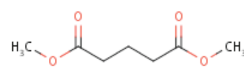
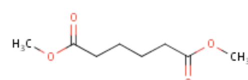
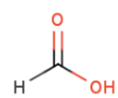
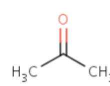
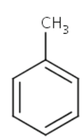
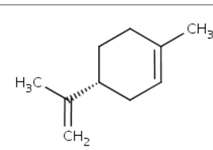
While there are a number of alternative paint strippers available in consumer retail outlets, including pyrolytic techniques and physical/mechanical techniques, these alternatives are not economically feasible options for a chemical formulator whose existing plant infrastructure is designed for chemical product manufacturing. While economic feasibility is considered in Stage 2 of the assessment, for the purpose of this model assessment, the costs required of a chemical formulator to change its business model to the manufacturing of metal products (e.g., metal scrappers), or to paper product manufacturing (e.g., sand paper), or article manufacturing (e.g., heat guns) would rank lowest among the alternatives due to financial infeasibility. Required investments were assumed to include new plant infrastructure (capital expenditures associated with building new plants, purchasing new manufacturing equipment, etc.) as well as personnel costs (e.g., unemployment/severances for downsized chemical staff).

Additional alternative paint stripping methods not considered are primarily for industrial uses as the nature of the stripping process requires use in industrial facilities. For example, media blasting involves propelling specific media types (e.g., polymers, wheat, or carbon dioxide) at high speeds at the substrate being stripped. While these methods have been shown to be quite effective,[9] media blasting technology is not readily available for purchase in consumer retail outlets. While in theory media blasting could be performed in residential settings (e.g., among automotive hobbyists to strip paint from cars), industrial equipment is required. Several alkaline and acid stripper products require use in immersion tanks that are often heated to high temperatures. Again, these products are designed for industrial uses, not consumer or professional uses in residential or institutional settings.

Eleven chemical alternatives were prioritized for the hazard assessment step (Table 1). These alternatives

TABLE 1

Chemical Properties of Methylene Chloride and Potential Alternatives

Chemical (or mixture)	CASRN	Water Solubility	Molecular Formula	Molecular Structure	Vapor Pressure
Methylene chloride	75-09-2	$1.3X10^4$ mg/L @ 25°C	CH_2Cl_2		435 mmHg @ 25°C
Benzyl alcohol	100-51-6	42,900 mg/L @ 25°C	C_7H_8O		0.94 mmHg @ 25°C
2-(2-butoxyethoxy) ethanol	112-34-5	$1X10^6$ mg/L @ 25°C	$C_8H_{28}O_2$		0.0219 mmHg @ 25°C
Caustic soda	1310-73-2	Soluble in water—1g/0.9ml (no temperature noted)	HNaO	Na—OH	$1.82X10^{-21}$ mmHg @ 25°C (extrapolated)
Dimethyl sulfoxide (DMSO)	67-68-5	$1X10^6$ mg/L @ 25°C	C_2H_6OS		0.61 mmHg @ 25°C
1,3-dioxolane	646-06-0	$1X10^6$ mg/L @ 25°C	$C_3H_6O_2$		79 mmHg @ 20°C
Estasol (mixture of 3 dibasic esters) **(a) Dimethyl succinate (15–25%)** **(b) Dimethyl glutarate (55–65%)** **(c) Dimethyl adipate (10–25%)**	95481-62-2	$5.3x10^4$g/L @20°C	(a) $C_6H_{10}O_4$ (b) $C_7H_{12}O_4$ (c) $C_8H_4O_4$	(a)  (b)  (c) 	(a) 0.41 mmHg @ 20°C*
Formic acid	64-18-6	$1X10^6$ mg/L @ 25°C	CH_2O_2		42.6 mmHg @ 25°C
Hydrocarbon solvents (likely used as a mixture, but assessed individually) **(a) methanol** **(b) acetone &** **(c) toluene**	(a) 67-56-1 (b) 67-64-1 (c) 108-88-3	(a) $1X10^6$ mg/L @ 25°C (b) $1X10^6$ mg/L @ 25°C (c) 526 mg/L@ 25°C	(a) CH_4O (b) C_3H_6O (c) C_7H_8	(a) H_3C—OH (b)  (c) 	(a) 127 mmHg @ 25°C (b) 232 mmHg @ 25°C (c) 28.4 mmHg @ 25°C
d-Limonene	138-36-3	13.8. mg/L @ 25°C	$C_{10}H_{16}$		1.98 mm Hg @ 25°C

Sources: ChemIDplus: *http://chem.sis.nlm.nih.gov/chemidplus* & Hazardous Substance Databank *http://toxnet.nlm.nih.gov/newtoxnet/hsdb.htm*.
* EPA 2008: *http://www.epa.gov/hpvis/rbp/Dibasic%20esters.Web.SupportDocs.031808.pdf*.

were identified through a review of publicly available reports from industry, government, and/or government research sponsored institutions.[10] This list of eleven candidate alternatives represents those alternatives with the greatest potential of being viable. These eleven alternatives were prioritized based on: (a) a review of existing material safety data sheets (MSDSs) demonstrating that these alternatives are being used in paint strippers on the market today;[11] (b) case study experience (including those listed on product specifications);[12] and (c) those also considered a priority by the California Department of Toxic Substances Control (DTSC) as they are referenced in its *Priority Product Profile: Paint Strippers Containing Methylene Chloride* report.[13] See Appendix 1 for further information specific to the demonstration project context of this assessment. One research article was also particularly useful as it uses the Hansen's solubility parameter, vapor pressure, and flashpoint among other physicochemical properties to identify "the sweet spot" of solvents with similar properties to methylene chloride to guide the selection of alternatives that function similarly.[14] While there is growing interest in bio-based solvents, including methyl soyate and lactate esters, additional research and development are needed and these options were excluded at this point in time in the Stage 1 assessment.

While a desirable aim is for the chosen alternative to achieve the same functional use as methylene chloride in paint stripping products, the candidate alternatives should not be considered drop-in substitutes. Product formulations will likely change, requiring new chemicals to be added to achieve the necessary performance. Thus an assessment of technical feasibility during Stage 2 of this analysis is essential. As necessary during Stage 2, additional assessments will be performed on formulation chemicals identified as necessary for the product function and performance in order to minimize the risk of regrettable substitutions.

Some physicochemical characteristics of the chemical of concern—methylene chloride—and the eleven candidate alternatives are listed in Table 1. The dibasic esters included in this hazard screening assessment are a mixture of 3 dibasic esters, known as estasol. The U.S. Environmental Protection Agency (EPA) has concluded that the three dibasic esters included in the mixture produce similar levels of toxicological effects, such that information on one type of dibasic ester in the mixture is expected to represent the toxicity of the category as a whole.[15] While resource documents suggest that a mixture of hydrocarbon solvents, including acetone, methanol, and toluene, may be suitable alternatives to methylene chloride, these chemicals are screened separately because their hazards are not expected to be similar (in contrast to dibasic esters).

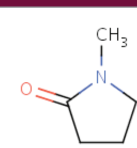
Table 2 lists an alternative that was excluded from further screening and analysis: 1-Methyl-2-pyrrolidone (NMP). While this alternative was identified as a candidate using the sources identified in Appendix 1, and is often found as a co-solvent with alternatives identified in Table 1 in products available on the market today, DTSC states in its *Priority Product Profile: Paint Strippers Containing Methylene Chloride*,[16] that NMP alternatives for methylene chloride are not to be considered because "DTSC does not recognize NMP as a 'safer alternative' to methylene chloride." NMP is considered a reproductive and developmental toxicant under California's Proposition 65 and is included on DTSC's list of candidate chemicals. For these reasons, NMP was screened out of the assessment.

2.1 Identification of Relevant Comparison Factors

According to the California Safer Consumer Products (SCP) regulations, comparison factors are relevant if they:

- "Make a material contribution to one or more adverse public health impacts, adverse environmental impacts, adverse waste and end-of-life effects, and/or materials and resource consumption impacts associated with the priority product and/or one or more alternatives under consideration; and
- There is a material difference in the factor's contribution to such impact(s) between the priority product and one or more alternatives under consideration and/or between two or more alternatives."

TABLE 2
Alternative Screened-out of the Assessment

Chemical (or chemical mixture)	CASRN	Description (including flammability)	Molecular Formula	Molecular Structure	Vapor Pressure
1-methyl-2-pyrrolidone (NMP)	872-50-4	A clear colorless liquid with a "fishlike" odor. Water soluble (water solubility = $1X10^6$ mg/L @ 25°C)	C_5H_9NO		0.345 mmHg @ 25°C

Factors to be considered for relevance and compliance with the SCP regulations, along with their associated exposure pathways and life cycle segments, include the following:

- adverse environmental impacts;
- adverse public health impacts;
- adverse waste and end-of-life impacts;
- environmental fate;
- materials and resource consumption impacts;
- physical chemical hazards; and
- physiochemical properties.

None of these factors required quantitative analysis to determine relevance; qualitative evaluation was sufficient as reviewed below.

2.1.1 Adverse Environmental Impact

Adverse environmental impact is a relevant impact factor. Given that some consumer use applications of paint strippers will likely result in residual paint stripper being subsequently flushed down the drain—for example, use in bathtub refinishing—impact on water quality, including interference with the microbial activity of waste water treatment processes as well as aquatic toxicity, should be considered. Aquatic toxicity (acute and chronic) will be addressed in Section 3 using the GreenScreen® version 1.2. Water, waste water/sewage treatment microorganisms will be addressed in the life cycle assessment in Stage 2 of the analysis as a preliminary review of the hazard literature for the eleven alternatives reveals a lack of study data. Because methylene chloride is very volatile and quickly evaporates to air, adverse air quality impacts associated with the alternatives should also be considered. Specific air quality impacts such as ozone depletion and greenhouse gases will be assessed in the life cycle considerations in Stage 2 of this analysis.

2.1.2 Adverse Public Health Impact

Adverse public health impact is a relevant comparison factor, as community and occupational health are of concern. Adverse public health impact factors to be compared in Section 3 include five hazard endpoints as evaluated using the GreenScreen® version 1.2 hazard assessment tool. These hazard endpoints are "critical" endpoints, or those categorized by GreenScreen® as Group I hazard endpoints: carcinogenicity, genotoxicity/mutagenicity, reproductive toxicity, developmental toxicity, and endocrine activity. Health endpoints of additional concern are categorized as Group II endpoints and include: acute toxicity, systemic toxicity and organ effects, neurotoxicity, skin sensitization, respiratory sensitization, skin irritation, and eye irritation.[17] The hazard assessment method in GreenScreen® version 1.2 is based on the Globally Harmonized System for Classification and Labeling (GHS) and uses national and international precedents from authoritative agencies regarding evidence classifications for specific hazard endpoints wherever feasible. The hazard assessment method was developed in conjunction with a technical advisory committee comprised of experts from non-governmental organizations (NGOs), government, academia, and industry.

2.1.3 Adverse Waste and End-of-Life Impacts

Adverse waste and end-of-life impacts—such as flushing residual stripper down the drain—are relevant comparison factors. These factors will be addressed in the life cycle analysis section in Stage 2 of the analysis.

2.1.4 Environmental Fate

Environmental fate is a relevant comparison factor. Both bioaccumulation and persistence will be addressed in Section 3 of this report. Additional environmental fate factors related to atmospheric deposition, such as global warming, acid rain, and ozone depletion will be addressed in Stage 2 of the analysis.

2.1.5 Material and Resource Consumption Impact

Material and resource consumption impact are relevant comparison factors. These factors, in addition to chemical and product manufacturing, transportation, and associated resource consumption (primarily energy) will be examined using life cycle assessment tools in Stage 2 of the analysis.

2.1.7 Physical Chemical Hazards

Physical hazards such as flammability and reactivity are important comparison factors and could significantly influence the inherent hazard of a given alternative and the associated risk to populations exposed. In particular, methylene chloride is a non-flammable solvent and flammability may be an important safety consideration in some applications. These two physical chemical safety hazards will be addressed in Section 3 of this report using GreenScreen®.

2.1.8 Physicochemical Properties

Physicochemical properties are relevant factors if they contribute to specific public health or environmental impacts (including environmental fate). Considering that the chemical of concern and its potential alternatives are solvents, a key physicochemical property is vapor pressure and water solubility as outlined in Table 1. Other physicochemical properties that are indicators of environmental persistence and bioaccumulation will be addressed in Section 3 of this report using GreenScreen®.

2.2 Quantities of the Chemical of Concern or Alternative Replacement Chemicals

Methylene chloride in consumer paint stripping products typically comprises 20%-90% of the formulation weight.[18] The formulation weights of alternatives similarly reflect this broad range of 20%-95% by weight based on paint stripping product formulations on the market that contain the candidate alternatives.[19] It is quite likely that a replacement formulation will have several active ingredients whose combined action replaces the function of methylene chloride. Until a product is definitively reformulated and tested it is not possible to estimate the volume or mass of the chemical of concern or alternative replacement chemical(s) that is/are or would be placed into the stream of commerce in California.[20] To the extent possible, this issue will be further addressed in Stage 2 of the analysis within the assessment of technical feasibility.

3. Initial Evaluation and Screening of Alternative Replacement Chemicals

3.1 GreenScreen® Evaluation

The initial evaluation and screening of alternative replacement chemicals used GreenScreen® version 1.2 hazard assessment tool. GreenScreen® includes threshold values or criteria to determine a hazard classification for each hazard endpoint. These classifications include a 3-point, 4-point, or 5-point ranking scheme—e.g., "very high," "high," "moderate," "low" or "very low" (a 5-point ranking scheme). Criteria used for the hazard classifications are derived from authoritative lists of chemicals of concern as well as criteria from the Globally Harmonized System for the Classification and Labeling of Chemicals (GHS) and the U.S. EPA Design for the Environment (DfE) Program Alternatives Assessment Criteria for Hazard Evaluation.

Hazard classifications include notations reflecting the level of confidence in the evidence used. Where no evidence was available, data gaps are also noted. Once the hazards are classified, GreenScreen® includes a decision framework that weights hazard endpoints and classifications to establish Benchmark scores.[21] The Benchmark scoring process applies greater weight to human health endpoints versus ecotoxicity and physicochemical characteristics, and among the human health endpoints, applies greater weight to carcinogenicity, mutagenicity, reproductive toxicity, developmental toxicity, and endocrine activity. A chemical with a score of Benchmark 1 is considered a chemical of high concern and should be avoided. More preferable alternatives are given Benchmark scores of 2-4. Benchmark 2 chemicals are categorized as usable, but efforts should

TABLE 3
GreenScreen® Hazard Assessment Results

Chemical Name	CASRN	Group I Human					Group II & II Human									Ecotox		Fate		Physical	
								ST		N											
		C	M	R	D	E	AT	Single	repeated	Single	repeated	SnS	SnR	IrS	IrE	AA	CA	P	B	RX	F
Methylene chloride	75-09-2	H	NE	DG	DG	M	*M*	vH	H	*vH*	*vH*	L	DG	H	H	M	*L*	*vH*	vL	L	L
Benzyl alcohol	100-51-6	L	L	*L*	M	DG	M	L	L	*M*	*H*	H	*L*	L	H	L	L	vL	vL	*L*	L
2-(2-butoxyethoxy) ethanol	112-34-5	*L*	L	L	L	DG	L	L	H	DG	L	L	DG	*M*	H	L	L	vL	vL	*L*	M
Dimethyl sulfoxide	67-68-5	*L*	L	L	L	DG	L	L	L	L	L	L	L	*M*	*M*	L	*L*	*L*	vL	*L*	M
1,3-dioxolane	646-06-0	L	*M*	*M*	M	DG	L	M	M	M	L	L	DG	*M*	*H*	L	L	*M*	vL	*L*	H
Estasol (dibasic esters mixture)	95481-62-2	*L*	L	L	*M*	*M*	L	M	*M*	M	DG	L	DG	L	*M*	M	L	vL	vL	*M*	L
d-Limonene	5989-27-5	L	L	DG	L	DG	L	L	L	DG	DG	H	DG	H	*H*	vH	H	vL	M	*L*	M
Acetone	67-64-1	*L*	L	*M*	M	DG	L	*M*	M	M	*M*	L	DG	L	H	L	L	vL	vL	L	H
Methanol	67-56-1	NA	NA	NA	H	NA	H	vH	NA	NA	NA	NA	NA	NA	NA	L	*L*	vL	*vL*	NA	H
Toluene	108-88-3	DG	L	H	H	M	L	M	H	M	H	L	DG	H	L	H	*H*	*H*	vL	L	H
Formic acid	64-18-6	L	L	L	*L*	DG	H	vH	*H*	vH	DG	L	DG	vH	vH	M	M	vL	vL	L	M
Caustic soda	1310-73-2	*L*	L	*L*	*L*	*L*	H	vH	*L*	*L*	*L*	L	DG	vH	vH	M	DG	*L*	*vL*	*M*	L

Abbreviations

C = Carcinogenicity
M = Mutagenicity
R = Reproductive Toxicity
D = Developmental Toxicity
E = Endocrine Activity
AT = Acute Toxicity
ST = Systemic Organ Toxicity
N = Neurotoxicity
SnS = Skin Sensitization
SnR = Respiratory Sensitization
IrS = Skin Irritation
IrE = Eye Irritation
AA = Aquatic Toxicity
CA = Chronic Aquatic Toxicity
P = Persistence
B = Bioaccumulation
RX = Reactivity
F = Flammability

Note

Hazard levels (Very High (vH), High (H), Moderate (M), Low (L), Very Low (VL) in italics reflect estimated (modeled values, authoritative B lists, screening lists, weak analogues, and lower confidence. Hazard levels in BOLD are used with good quality data, authoritative A lists, or strong analogues. Group II Human Health endpoints differ from Group II Human Health endpoints in that they have four hazard scores (i.e., vH, H, M and L) instead of three (i.e., H, M and L), and are based on single exposures instead of repeated exposures. DG indicates insufficient data for assigning hazard level. NE indicates no determination was made (conflicting data).

be taken to find safer alternatives. Benchmark 3 chemicals are those with an improved environmental health and safety profile but could still be improved. Chemicals that reach Benchmark 4 are considered safer chemicals and are therefore the most preferred. For a full description of GreenScreen® version 1.2 method see the GreenScreen® website.[22]

GreenScreen® evaluations for all but one of the candidate alternatives, toluene, were conducted by ToxServices. The hazard assessment for toluene—also using GreenScreen® —was publicly available through the Interstate Chemicals Clearinghouse (IC2) hazard assessment database.[23] The GreenScreen® for methylene chloride was also retrieved from IC2 hazard assessment database. Both sources included quality control evaluations. Appendix 2 provides the results from the GreenScreen® hazard assessments. The GreenScreen® evaluations conducted by ToxServices are proprietary. The public version of this report only contains executive summaries (although full reports would be provided to DTSC for review). Table 3 lists the summary results from the GreenScreen® hazard assessments.

The GreenScreen® Benchmarks™ for methylene chloride and each of the candidate alternatives are described in Table 4 along with the hazard endpoints that are the primary drivers of the Benchmark scores.

Methanol and toluene received a Benchmark 1 score: "Avoid—Chemical of High Concern."[24] Methanol was classified as having "high" developmental toxicity while toluene similarly demonstrated "high" developmental toxicity as well as "high" reproductive toxicity based on authoritative lists. Methanol is the most frequently used co-solvent in current methylene chloride paint stripping formulations, highlighting the need for a broader "formulation perspective" with regards to hazard. As stated earlier, feasible formulations identified in Stage 2 will be subsequently

TABLE 4
GreenScreen® Hazard Assessment Benchmarks

Chemical	CASRN	Benchmark	Benchmark Explanation	Benchmark Reason (Primary Hazard Endpoints of Concern)
Methylene chloride	75-09-2	1	Avoid Chemical of High Concern	"High" carcinogenicity
Benzyl alcohol	100-51-6	2	Use but Search for Safer Substitutes	"Moderate" developmental toxicity; "High" neurotoxicity (repeated dose) and skin sensitization
2-(2-butoxyethoxy) ethanol	112-34-5	2	Use but Search for Safer Substitutes	"High" systemic toxicity (repeated dose)
Dimethyl sulfoxide (DMSO)	67-68-5	3	Use but Still Opportunity for Improvement	"Moderate" toxicity associated with skin irritation & eye irritation; "Moderate" flammability
1,3-dioxolane	646-06-0	2	Use but Search for Safer Substitutes	"Moderate" mutagenicity, reproductive toxicity and developmental toxicity; "High" flammability
Estasol (dibasic esters mixture)	95481-62-2	2	Use but Search for Safer Substitutes	"Moderate" developmental toxicity and endocrine activity
d-Limonene	5989-27-5	2	Use but Search for Safer Substitutes	"Very high" acute ecotoxicity and "high" toxicity associated with skin sensitization
Acetone	67-64-1	2	Use but Search for Safer Substitutes	"Moderate" developmental toxicity & reproductive toxicity and "high" flammability
Methanol	67-56-1	1	Avoid Chemical of High Concern	"High" reproductive and developmental toxicity
Toluene	108-88-3	1	Avoid Chemical of High Concern	"High" developmental toxicity
Formic acid	64-18-6	2	Use but Search for Safer Substitutes	"Very High" toxicity associated with skin irritation, eye irritation & systemic toxicity (single dose) & neurotoxicity (single dose); "High" systemic toxicity (repeated dose)
Caustic soda	1310-73-2	2	Use but Search for Safer Substitutes	"Very High" toxicity associated with skin irritation, eye irritation & systemic toxicity (single dose)

CASRN = Chemical Abstracts Service Registration Number

- GreenScreen Benchmark 1: Chemical of High Concern—Avoid.
- GreenScreen Benchmark 2: Use but search for something safer.
- Use but Still Opportunity for Improvement.

screened using authoritative lists (rather than a complete GreenScreen® evaluation on all chemicals given the sheer number of chemicals and associated costs).

With the exception of dimethyl sulfoxide (DMSO), all other candidate alternatives received a Benchmark 2 score: "Use but Search for Safer Substitutes." The majority of these Benchmark 2 chemicals are associated with eye irritation and nearly half are associated with skin irritation, with two of the chemicals associated with skin sensitization. Other concerns for Benchmark 2 chemicals included: developmental and reproductive toxicity associated with acetone, systemic toxicity (kidney and respiratory toxicity) associated with formic acid and caustic soda, neurotoxicity associated with acetone, benzyl alcohol and formic acid, aquatic toxicity associated with d-limonene, and high flammability concerns related to acetone and 1,3-dioxolane.

While the hazard severity of DMSO associated with the range of endpoints examined was deemed lower than other candidate alternatives, DMSO has the capacity to potentiate the toxicity of other chemicals that are included in the final product formulation or other chemicals that users are in contact with while using a DMSO-containing product. It is well established that DMSO is a penetration enhancer of dermally applied/exposed substances.[25] Should DMSO be further considered as a potential alternative given Stage 2 analysis results, a deeper examination of the hazards of other formulation chemicals is *essential* since DMSO will increase the toxicity potency of chemicals contained in the formulation.

3.2 Chemicals De-Selected for Stage 2

Table 5 lists chemicals that have been de-selected for further consideration. Methanol was classified as having "high" developmental toxicity while toluene similarly demonstrated "high" developmental toxicity as well as "high" reproductive toxicity. As in the case of NMP (described in Section 2.1), both methanol and toluene are considered reproductive/developmental toxicants under California's Proposition 65 and are included on DTSC's list of candidate chemicals. Given that these decision rules guided the de-selection of NMP, they should also guide the de-selection of methanol and toluene.

TABLE 5

Chemicals De-Selected for Further Assessment in California SCP Stage 2 Alternatives Analysis

De-selected alternative	CASRN	Reason for De-selection
Methanol	67-56-1	Developmental toxicant—Listed on CA Prop 65 and DTSC's Candidate List of Chemicals
Toluene	108-88-3	Developmental & reproductive toxicant—Listed on CA Prop 65 and DTSC's Candidate List of Chemicals

TABLE 6

Chemicals Selected for Further Assessment in California SCP Stage 2 Alternatives Analysis

Chemical	CASRN
Benzyl alcohol	100-51-6
2-(2-butoxyethoxy) ethanol	112-34-5
Dimethyl sulfoxide (DMSO)	67-68-5
1,3-dioxolane	646-06-0
Estasol (dibasic esters mixture)	95481-62-2
d-Limonene	5989-27-5
Acetone	67-64-1
Formic acid	64-18-6
Caustic soda	1310-73-2

All chemicals in Table 3 were cross-referenced with DTSC's Candidate Chemical List. In addition to those identified in Table 5, caustic soda is also included on DTSC's Candidate Chemical List due to ocular, respiratory and dermal toxicity as identified by reference exposure levels (RELs) established by the California Office of Environmental Health Hazard Assessment under Health and Safety Code section 44360(b)(2).

Table 6 includes the nine chemicals that BizNGO will advance to the Stage 2 analysis of the SCP regulations. Stage 2 will focus, depending on the availability of data, on the evaluation of additional hazards not considered in the GreenScreen® assessment and additional environmental impacts. Stage 2 will also focus on preventing the shifting of negative impacts from one environmental or human heath endpoint to another by reviewing available multi-media life cycle information. Product performance and economic impacts will be assessed in Stage 2 as well.

4. Consideration of Additional Information

The U.S. EPA is currently examining alternatives for methylene chloride paint strippers. This screening analysis should be reexamined in light of new or different information that emerges in the U.S. EPA report, which is expected to be released as a draft in spring 2016. In addition, the literature will be monitored as outlined in Section 5 for substantive changes in the evidence (e.g., updated review by authoritative sources that increases the severity classification of a chemical on an authoritative list) used for classifying candidate alternatives. If substantive changes are identified that alter the hazard assessment, the assessment will be updated to aid in decision making during the Stage 2 analysis.

5. Work Plan and Proposed Implementation Schedule for Stage 2 of the Alternatives Analysis

The proposed final alternatives assessment work plan and associated schedule is described in Table 7.

TABLE 7

BizNGO Proposed Final Alternatives Analysis Work Plan and Schedule for Complying with California Safer Consumer Products Regulations

Action Item	Description	Completion Date*
Re-evaluation of relevant factors from preliminary alternatives assessment	Relevant factors identified in the Preliminary Alternatives Assessment will be reviewed and changes will be documented.	6 weeks
Review of product function and performance factors	The Performance Evaluation Module (Level 3) of the Interstate Chemicals Clearinghouse Alternatives Assessment Guide (version 1.0) will be followed for performance evaluation guidance. Performance standards identified in Section 1.3 will be used to evaluate key performance parameters and for determining the range of acceptable values for those parameters. The focus of the product function and performance evaluation will be on preventing burden shifting in the form of decreased safety. Given that methylene chloride is a non-flammable solvent, additional fire safety standards will be assessed. Those alternatives demonstrating high concern regarding fire safety will be screened out of the analysis.	10 weeks
Consideration of materials and resource consumption impacts	Existing life cycle inventories or life cycle assessments will be reviewed for relevant data. Where life cycle assessment data are lacking, data for proxy chemicals will be explored as a substitute. Results will be summarized and alternatives that demonstrate significant life cycle burden risk shifting will be screened-out.	14 weeks
Reassessment of hazards for other co-chemicals in the best performing formulations. Conduct literature review to ensure no new hazard information substantively changes the hazard classifications from Stage 1.	In order to minimize hazards in the total formulation, rather than only the chemical of concern, a screening hazard assessment will be performed on all co-chemicals in the formulation above 0.01% concentration (100 parts per million) in the formulation. The 4-5 best performing formulations will be screened for using more "quick screening" methods given the number of chemicals to be examined. These methods employ the use of authoritative lists. A literature review will be performed to ensure that new hazard information is considered that may substantively change the hazard classifications in Stage 1.	17 weeks
Review of economic factors	Cost and Availability Evaluation Module (Level 4) of the Interstate Chemicals Clearinghouse Alternatives Assessment Guide (version 1.0) will be followed to assess economic feasibility. It is anticipated that one or more of the alternatives will be selected for substitution of the chemical of concern; therefore, the economic impacts are expected to be positive from a burden shifting perspective. Economic factors, as specified in the regulations, will be researched and evaluated.	21 weeks
Review of priority product and alternatives/alternative selection decision	The Priority Product and the alternatives will be compared based on the relevant factors and one or more alternatives will be selected as the recommended option. Relevant factors will include factors identified, but not analyzed, in the preliminary alternatives assessment, plus relevant function, performance, and economic factors.	30 weeks
Submittal of final report	The scheduled submission date of final report.	40 weeks**

* Completion date: number of weeks after BizNGO receives Notice of Compliance for Preliminary Alternatives Assessment from DTSC.

** Note that BizNGO plans to submit its work plan 12 weeks before the required DTSC deadline of 52 weeks.

Summary of Results & Lessons Learned from Demonstration Project

Summary of Results

This analysis found safer chemical alternatives to methylene chloride. Using GreenScreen® comparative hazard assessment method, only two of the eleven alternatives were screened-out—methanol and toluene—due to "high" hazard levels for developmental toxicity and/or reproductive toxicity. The remainder of alternatives (N=9) were safer, yet not free of hazards, as reflected in GreenScreen® Benchmarks.

For example, compared to methylene chloride, all of the alternatives ranked "low" regarding carcinogenicity. However of the nine safer alternatives, a majority (N=7) demonstrated high or very high hazard rankings for eye irritation. All but one alternative (dimethyl sulfoxide or DMSO), demonstrated at least one "high" hazard ranking for one human health endpoint, ecotoxicity endpoint, and/or physicochemical characteristic.

GreenScreen Benchmarks™ were developed to assist in decision-making about alternatives. The benchmark scoring process applies greater weight to human health endpoints versus ecotoxicity—with the exception of the prioritization of persistent, bioaccumulative, and toxic (PBT), very persistent and toxic (vPT), and very bioaccumulative and toxic (vBT) chemicals, where "toxicity" is a factor of either ecotoxicity or human health toxicity—and physicochemical characteristics. Among the human health endpoints, the scoring process applies greater weight to carcinogenicity, mutagenicity, reproductive toxicity, developmental toxicity, and endocrine activity versus other endpoints. Using these decision rules, nine alternatives were rated as a GreenScreen Benchmark™ 2 chemicals, "Use but search for safer substitutes." One alternative, DMSO was rated as a GreenScreen Benchmark™ 3 chemical, "Use but still opportunity for improvement."

While DMSO demonstrated the lowest hazard rating overall (highest benchmark score), DMSO can potentiate the hazards of other substances. It is well established that DMSO is a penetration enhancer of dermally applied/exposed substances. Given that the function of this chemical is to dissolve paints and varnishes, DMSO could potentiate the hazards of those substances (e.g., the hazards associated with lead in lead paint), and other substances in the paint stripper formulation. These results demonstrate that hazard ratings need to be considered with additional information about a substance—such as conditions of use—that help to inform the inherent hazards of that substance.

Lessons Learned

Lesson Learned #1

Information is readily available about functional requirements, performance requirements, and potential alternatives to methylene chloride based paint strippers—all Stage 1 analysis requirements under the California SCP regulations.

The Stage 1 analysis requires applicants to define a product's and chemical of concern's functional requirements, performance requirements, and to identify potential alternatives to methylene chloride in paint stripping products. Information relevant to all of these requirements was readily and publicly available.

With regards to functional requirements, the U.S. Department of Defense has sponsored a number of research projects examining alternatives to methylene chloride that have also served to enhance understanding about how methylene chloride functions in paint-stripping products. Research reports resulting from these grant-sponsored research programs are publicly available. While only a few of these reports are cited in this document, interested parties can search the Defense Technical Information Center (see: *http://www.dtic.mil/dtic*) for a number of related articles and papers on methylene chloride-based strippers and associated alternatives.

Performance standards are available for paint strippers through the American Society for Testing and Materials (ASTM). As paint strippers govern a wide range of applications, which include graffiti removal, other standards may be relevant, including those by Green Seal.

Recent regulatory actions significantly restricting the use of methylene chloride paint strippers in the European Union—including a consumer product ban—were supported by a number of research and market evaluation reports that examined the question of alternatives.[26] These papers contain lists and descriptions of potential alternatives. Seminal technical white papers published by research organizations and government agencies in the U.S. have also examined potential alternatives.[27] Many of the alternatives cited in the above documents can be found on home improvement store shelves today, based on a cursory review of available MSDSs.[28] Organizations such as the Massachusetts Toxics Use Reduction Institute are actively researching alternatives, including newer generation chemical alternatives in paint strippers.

Lesson Learned #2

Based on our assessment of the hazards of eleven chemical alternatives, safer alternatives to methylene chloride for use in chemical paint strippers are widely available.

As highlighted above, safer chemical alternatives to methylene chloride paint/varnish strippers are available. SCP regulations raise the question of how many alternatives must be assessed in order to be meet legal requirements. It is our viewpoint that it is sufficient to meet Stage 1 of the Safer Consumer Products regulations by identifying alternatives for the hazard under review and prioritizing those that appear from a market perspective to be economically viable and technically feasible. Of the alternatives assessed, many are known to be effective in paint and/or graffiti removal given that: (1) they are primary ingredients in paint stripping products on the market today based on a cursory review of MSDSs and/or (2) they have been shown in prior case studies to be safer and feasible —both technically and financially. While technical (performance) and economic feasibility assessments during Stage 2 are largely based on the question of feasibility from the perspective of the "responsible entity," the results of this assessment suggest that at least from a market perspective, feasible alternatives are available.

Lesson Learned #3

The action-orientation of alternatives analysis/alternatives assessment should guide the process from the beginning: the type and range of alternatives to consider should be informed by the capacity of business entities to adopt those alternatives.

Flexibility and an action orientation should guide the practice of alternatives assessments. For alternatives assessments to effectively guide the adoption of safer substitutes, the scope of the alternatives considered needs to reflect the capacity of firms to implement them. As one moves down the supply chain of participants required to comply with the SCP regulations, the capacity to adopt a broader range of alternatives increases. For a manufacturer of formulated chemical products, alternatives that are most feasible to adopt are limited (in most, but not all cases) to either process changes that eliminate the chemical of concern or chemical substitutes. For a retailer further down the supply chain, feasible alternatives are much broader, including chemical formulated products as well as a range of material substitutes, such as sand paper or metal scrapers (physical/mechanical alternatives) or heat guns (thermal alternative). Alternatives analyses need to allow for flexibility given differences in the types of alternatives that can be adopted by different participants in a supply chain.

This demonstration project was undertaken from the perspective of a company that manufactures chemical formulations. While the regulations require consideration of all types of viable alternative products (formulated chemicals, physical, mechanical), from the perspective of a formulated products manufacturer the only viable alternative is another formulated product, given pre-existing investments and knowledge. While this report acknowledges a broader range of paint stripping alternatives and cites sources of additional information about those alternatives, only chemical alternatives are examined in the hazard assessment step.

It is important to recognize that a consideration of exclusively chemical alternatives could limit the SCP regulations' goal of creating safer substitutes to toxic chemicals in consumer products. It is plausible that for a given application, and from a consumer perspective, the safest and best performing substitute for the money is a non-chemical paint stripper. However, for DTSC to identify safer consumer products, the Department needs entities across the supply chain to provide information about the hazards, life cycle impacts, technical and economic feasibility of all potential options—chemical and non-chemical alternatives. It remains to be seen if regulatory compliance alone will be enough to showcase the full range of alternatives. It is essential that research institutions, public health and environmental advocacy organizations, and others be prepared to provide additional information and support to DTSC during public comment periods to ensure that the SCP regulations can reach their potential of identifying safer consumer products.

Lesson Learned #4

Whether or not GreenScreen® is sufficient to meet the requirements of the California SCP regulations concerning hazard assessment criteria remains to be determined.

For the hazard screening step, this demonstration project used GreenScreen®, which assesses chemicals on the basis of 18 hazard endpoints. This project demonstrated the utility of using GreenScreen® for the hazard assessment of a chemical and its alternatives. It remains to be determined whether GreenScreen® alone is sufficient for the hazard assessment stage of the SCP regulations. Additional analysis beyond GreenScreen® assessments may be warranted for a hazard assessment depending on the priority product and its alternatives. Note that performing GreenScreen assessments is an intensive process that requires technical expertise that only the largest of corporations typically have in-house. If GreenScreen assessments prove to be insufficient to meet the requirements of the SCP regulations, the costs to companies could be significant. In general the data requirements of the SCP regulations on the surface seem to be quite burdensome. For this project, BizNGO had access to experts in the field of alternatives assessment, and even under what could be considered best circumstances, we confronted questions about the sufficiency of our hazard assessments to meet the SCP regulations.

Lesson Learned #5

When conducting an alternatives assessment on formulated chemical products, the hazards of other chemicals in the formulation should also be considered.

The majority of chemical alternatives assessed in this demonstration project are those that function as a solvent—the same function as methylene chloride in a paint stripper. However, it is unlikely the alternative solvents can replace methylene chloride without any other reformulation to the product. Replacing the solvent will require reformulating the product to meet performance metrics. For the regulations to advance the goal of safer consumer products and to protect against regrettable substitutions, an additional assessment of hazards (or at minimum, a screen against authoritative hazard lists) should be performed on other chemicals above a threshold percent concentration in the formulation. For example, the U.S. EPA's Safer Choice program uses a cut-off of 0.01% (i.e., if a chemical is less than 100 ppm in a product, a hazard assessment does not need to be conducted in order for the product to qualify for the Safer Choice label).[29] This particular cut-off threshold is useful for many endpoints, but not for all. For example, for impacts such as endocrine disruption, a lower threshold is more appropriate given the extremely low concentrations that can activate/disrupt hormonal pathways. In addition, if products contain nanomaterials, lower thresholds may also be warranted given that the hazards of nanomaterials are better informed by particle counts contained in the product, rather than mass-based concentration measures.[30]

Additional Recommended Actions Not Undertaken in this Demonstration Project

Resource limitations, of the kind that most responsibility entities will also confront, constrained the scope of this demonstration project. For those using this report as a guide to compliance with California SCP regulations' Stage 1 requirements for methylene chloride-based paint strippers, we recommend:

- Considering a broader range of chemical alternatives. New bio-based solvents such as methyl soyate or ethyl lactate should be explored and tools such as the Hansen Solubility Parameters (HSP)31 may help identify a range of additional chemical solvents worth considering.
- Data permitting, considering a broader range of eco-toxicity endpoints. Hazard assessment tools such as the GreenScreen® assess chronic and acute ecotoxicity, which are the most widely available ecotoxicity data. However, additional eco-toxicity endpoints such as effects on organisms necessary for waste water treatment or terrestrial toxicity may be relevant for specific use scenarios of paint strippers. Information on these additional hazard endpoints should be considered wherever possible. The challenge, of course, is finding this data; which is typically not available for most chemical substances.
- Evaluating the hazards associated with all chemical ingredients in a formulated chemical product above 0.01%. As described in Lesson 4, it is important to consider the hazards of all chemicals in a formulated chemical product as the goal of an alternatives assessment is to ensure the final product is safer overall.

The use of alternatives analysis as being advanced by the California SCP regulations is one of the most important developments in recent years to advance the supply of safer chemicals and products. The regulations provide a framework for firms to identify that safer alternatives are available and are viable from a business perspective. The BizNGO Alternatives Assessment Work Group looks forward to working with multiple sectors as they begin the process of assessing their options for safer, feasible substitutes.

Appendix 1: Sources for Alternatives Identified

The table below outlines the sources used to identify alternatives assessed for hazard traits in this report and the specific lists of alternatives outlined in those publications.

While this demonstration project focused on assessing the hazards of 11 potential alternatives to methylene chloride in paint stripping consumer products, there are roughly a dozen additional alternatives that could have been included as well. Resource limitations constrained the selection of alternatives for consideration in this demonstration project to those chemicals where GreenScreen® evaluations already existed from ToxServices or the Interstate Chemicals Clearinghouse (IC2) website—this project did not have the resources necessary to conduct new GreenScreen® assessments.

Actual applicants developing their Stage 1 report to comply with the California SCP regulations will need to explicitly describe where information about potential alternatives was obtained and reasons for including/excluding these alternatives in the assessment. In practice, lists of potential alternatives can be quickly screened for exclusion/inclusion based on high-level hazards (e.g., cancer or developmental/reproductive toxicity) using authoritative lists (for example, using the GreenScreen® List Translator *http://www.greenscreenchemicals.org/method/greenscreen-list-translator*). Those alternatives not excluded can be further assessed using the suite of hazard endpoints in GreenScreen®.

TABLE 8
Sources & Lists of Chemical Alternatives to Methylene Chloride-Based Paint Strippers

Source	Primary Chemical Alternatives* Outlined *(Italicized = not included in this demonstration project)*
1. Policy Analysts Limited. Impact Assessment of Potential Restrictions on the Marketing and of Dichloromethane in Paint Strippers. Prepared for the European Commission Directorate-General Enterprise and Industry. 2007.	The report primarily reviews the following alternatives • Benzyl alcohol (CAS # 100-51-6) • Dibasic esters (CAS #'s 106-65-0, 1119-40-0, 627-93-0, and 95481-62-2) • Dimethyl sulfoxide (CAS # 67-68-5) • 1,3-Dioxolane (CAS # 646-06-0) • Caustic soda (CAS # 1310-73-2) • N-methyl-2-pyrrolidone (CAS # 872-50-4) Other alternatives noted for consumer/professional paint stripping applications (Table 5.12 of report) include: • Formic Acid (CAS # 64-18-6) • Acetone (CAS # 67-64-1) • Methanol (CAS # 67-56-1) • D-Limonene (CAS # 5989-27-5) • *Xylene (CAS # 1330-20-7)* • *Phosphoric Acid (CAS # 7664-38-2)* • *2-methoxymethylethoxypropanol (CAS # 7664-38-2)* • *Dipropyleneglycol monoethyl ether CAS # 15764-24-6)* • 2-(2-butoxyethoxy) ethanol (CAS # 112-34-5) • *methyl ethyl ketone (CAS # 78-93-3)*
2. Morris M and Wolf K. Methylene Chloride Consumer Product Paint Strippers: Low-VOC, Low Toxicity Alternatives. May 2006.	• Benzyl alcohol (CAS # 100-51-6) • N-methyl-2-pyrrolidone (CAS # 872-50-4)
3. US CPSC. What You Should Know about Using Paint Strippers. 2007.	• Benzyl alcohol (CAS # 100-51-6) • Dibasic esters (CAS #'s 106-65-0, 1119-40-0, 627-93-0, and 95481-62-2) • Acetone (CAS # 67-64-1) • Methanol (CAS # 67-56-1) • Toluene (CAS # 108-88-3) • Caustic soda (CAS # 1310-73-2) • N-methyl-2-pyrrolidone (CAS # 872-50-4)

TABLE 8

Sources & Lists of Chemical Alternatives to Methylene Chloride-Based Paint Strippers (continued)

Source	Primary Chemical Alternatives* Outlined *(Italicized = not included in this demonstration project)*
4. Massachusetts Toxics Use Reduction Institute. Massachusetts Chemical Fact Sheet: Methylene Chloride. November 2014.	• Benzyl alcohol (CAS # 100-51-6) • Dibasic esters (CAS #'s 106-65-0, 1119-40-0, 627-93-0, and 95481-62-2) • Acetone (CAS # 67-64-1) • Methanol (CAS # 67-56-1) • Toluene (CAS # 108-88-3) • Caustic soda (CAS # 1310-73-2) • N-methyl-2-pyrrolidone (CAS # 872-50-4)
5. Washington State Dept. of Labor & Industries, SHARP. Successful Bathtub Stripping with Benzyl Alcohol as an Alternative to Methylene Chloride. 2012.	Formulation 1: • Benzyl alcohol (CAS # 100-51-6) • Formic acid (CAS # 64-18-6) Formulation 2: • Dibasic ester (Dimethyl glutarate, CAS# 1119-40-0) • N-methyl-2-pyrrolidone (CAS# 872-50-4) • *Propylene carbonate (CAS # 108-32-7)* • *Potassium hydroxide (CAS # 1310-58-3)*
6. Tukker A and Simmons L. Methylene Chloride: Advantages and Drawbacks of Possible Market Restrictions in the EU. TNO-Report prepared for the European Commission Directorate General of Enterprise and Industry. 1999.	• Benzyl alcohol (CAS # 100-51-6) • Dibasic esters (CAS #'s 106-65-0, 1119-40-0, 627-93-0, and 95481-62-2) • Acetone (CAS # 67-64-1) • Methanol (CAS # 67-56-1) • Toluene (CAS # 108-88-3) • Dimethyl sulfoxide (CAS # 67-68-5) • N-methyl-2-pyrrolidone (CAS # 872-50-4)
7. Organization for Economic Cooperation and Development. Risk Reduction Monograph No. 2: Methylene Chloride Background and National Experience with Reducing Risk. 1993.	• Caustic soda • N-methyl-2-pyrrolidone (CAS # 872-50-4) • Dibasic esters (CAS #'s 106-65-0, 1119-40-0, 627-93-0, and 95481-62-2) • Toluene CAS # 108-88-3) • Acetone (CAS # 67-64-1) • *Xylene (CA S# 1330-20-7)* • *Ketone mixtures* • *Furfuryl alcohol (CAS # 98-00-0)*
8. Kelley J and Considine T. Performance Evaluation of Hap-Free Paint Strippers vs. Methylene-Chloride-Based Strippers for Removing Army Chemical Agent Resistant Coatings (CARC). Army Research Laboratory. ARL-TR-3823. June 2006.	• Benzyl alcohol (CAS # 100-51-6) • N-methyl-2-pyrrolidone (CAS # 872-50-4)
9. Luey KT, Coleman DJ, Ternet GK. Replacement of methylene chloride in NVR and paint removal applications. AeroSpace Corp (El Segundo, CA). December 30, 2000.	• Toluene CAS # 108-88-3) • Acetone (CAS # 67-64-1) • N-methyl-2-pyrrolidone (CAS # 872-50-4) • *Methyl ethyl ketone (CAS # 78-93-3)* • *Tetrahydrofuran (CAS # 109-99-9)* • *2-pyrrolidone (CAS 616-45-5)* [Note these alternatives identified based on Hansen Solubility parameters]

Appendix 2: GreenScreen® Summaries

The following pages include the GreenScreen® summaries for chemicals identified in Table 3.

Green Screen Assessment Prepared By:
Name: Brian Penttila, Ph. D.
Title: Chemical Engineer
Organization: PNW Pollution Prevention Resource Center
Date: 27 June 2012

Quality Control Performed By:
Name: Alex Stone, Sc. D.
Title: Safer Chemical Alternative Chemist
Organization: WA Department of Ecology
Date: 16 May 2013

GreenScreen™ Assessment for Dichloromethane (DCM) (CAS #75-09-2)

GreenScreen™ Version 1.2 Draft Assessment

Note: Validation Has Not Been Performed on this Green Screen Assessment

Chemical Name: Dichloromethane (DCM)

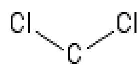
Confirm application of the de minimus rule[1]: (if no, what *de minimus* did you use?) Yes.

Chemical Name (CAS #): Dichloromethane (DCM) (CAS#78-93-3)

Also Called: "Bichloride, Methylene", "Chloride, Methylene", "Dichloride, Methylene", "Dichloromethane", "Methane, dichloro-", "Methylene chloride", "Methylene dichloride", "1,2-dichloromethane", "Freon 30", "R-30" (US EPA, ACToR database, actor.epa.gov/)

Chemical Surrogates, analogs or moieties used in this assessment (CASs #):

Chemical Structure(s):



Identify Applications/Functional Uses: (e.g. Cleaning product, TV casing)

1. Solvent in the pharmaceutical and chemical industry for reactions, and isolation of products.
2. Used as a feedstock for the production of HCFC 32 (R32), as a blowing agent in foam blowing, for plastics processing (e.g., polycarbonate resins), a
3. Used in aerosol products for applying or removing surface finishes or coatings, e.g., paints, varnishes, adhesives.
4. Used for cleaning and degreasing products, e.g., metal cleaning (e.g., cold or vapor degreasing).

See Substance Background section below for references.

GreenScreen Rating[2]: DCM was assigned a **Benchmark Score of 1** based on:

- Failure of Benchmark Rule 1e, due to High carcinogenicity.

GreenScreen Hazard Ratings: Dichloromethane																			
Group I Human					Group II and II* Human									Ecotox		Fate		Physical	
C	M	R	D	E	AT	ST		N		SnS*	SnR*	IrS	IrE	AA	CA	P	B	Rx	F
						single	repeat*	single	repeat*										
H	**NE**	**DG**	**DG**	**M**	*M*	*vH*	**H**	*vH*	*vH*	**L**	**DG**	**H**	**H**	**M**	*L*	*vH*	**vL**	**L**	**L**

Note: Hazard levels [Very High (vH), High (H), Moderate (M), Low (L), Very Low (vL)] in *italics* reflect estimated values and lower confidence. Hazard levels in **BOLD** font reflect values based on test data (See Guidance). NE indicates no determination was made (conflicting data) and DG indicates insufficient data for assigning hazard level.

[1] Every chemical in a material or formulation should be assessed if it is:
1. intentionally added and/or
2. present at greater than or equal to 100 ppm.

[2] For inorganic chemicals with low human and ecotoxicity across all hazard endpoints and low bioaccumulation potential, persistence alone will not be deemed problematic. Inorganic chemicals that are only persistent will be evaluated under the criteria for Benchmark 4.

GreenScreen® Executive Summary for Benzyl Alcohol (CAS #100-51-6)

Benzyl alcohol is a chemical that functions as a solvent, plasticizer, fragrance and flavoring component, preservative, viscosity-controlling agent, and degreasing agent.

Benzyl alcohol was assigned a **GreenScreen Benchmark™ Score of 2** ("Use but Search for Safer Substitutes"). This score is based on the following hazard score combinations:

- Benchmark 2e ("Moderate T (Group I Human)")
  - Moderate developmental toxicity (D)
- Benchmark 2f ("Very High T (Ecotoxicity or Group II Human) or High T (Group II* Human)")
  - High Group II* Human (repeated dose neurotoxicity (Nr*) and skin sensitization (SnS*)

A data gap (DG) exists for endocrine activity (E). As outlined in CPA (2013) Section 12.2 (Step 8 – Conduct a Data Gap Analysis to assign a final Benchmark score), benzyl alcohol meets requirements for a GreenScreen® Benchmark Score of 2 despite the hazard data gaps. In a worst-case scenario, if benzyl alcohol were assigned a High score for the data gap endocrine activity (E), it would be categorized as a Benchmark 1 Chemical.

GreenScreen® Benchmark Score for Relevant Route of Exposure:
As a standard approach for GreenScreen® evaluations, all exposure routes (oral, dermal and inhalation) were evaluated together, so the GreenScreen® Benchmark Score of **2** ("Use but Search for Safer Substitutes")is applicable for all routes of exposure.

GreenScreen® Hazard Ratings for Benzyl Alcohol

Group I Human					Group II and II* Human									Ecotox		Fate		Physical	
C	M	R	D	E	AT	ST		N		SnS*	SnR*	IrS	IrE	AA	CA	P	B	Rx	F
						single	repeated*	single	repeated*										
L	**L**	*L*	*M*	DG	**M**	**L**	**L**	*M*	*H*	**H**	*L*	**L**	**H**	**L**	**L**	**vL**	**vL**	*L*	**L**

Note: Hazard levels (Very High (vH), High (H), Moderate (M), Low (L), Very Low (vL)) in *italics* reflect estimated (modeled) values, authoritative B lists, screening lists, weak analogues, and lower confidence. Hazard levels in **BOLD** font are used with good quality data, authoritative A lists, or strong analogues. Group II Human Health endpoints differ from Group II* Human Health endpoints in that they have four hazard scores (i.e., vH, H, M, and L) instead of three (i.e., H, M, and L), and are based on single exposures instead of repeated exposures. Please see Appendix A for a glossary of hazard acronyms.

GreenScreen® Executive Summary for 2-(2-Butoxyethoxy) Ethanol (CAS 112-34-5)

2-(2-Butoxyethoxy) ethanol is used primarily as a solvent in coatings, inks, cleaners and specialty fluids, and to produce diethylene glycol butyl acetate.

2-(2-Butoxyethoxy) ethanol was assigned a **GreenScreen Benchmark™ Score of 2** ("Use but Search for Safer Substitutes"). This score is based on the following hazard score:

- Benchmark 2f
  - High Group II*Human Toxicity (System Toxicity (STr*) (repeated dose))

Data gaps (DG) exist for endocrine activity (E) and respiratory sensitization (SnR*). As outlined in CPA (2013) Section 12.2 (Step 8 – Conduct a Data Gap Analysis to assign a final Benchmark score), 2-(2-butoxyethoxy) ethanol meets requirements for a GreenScreen® Benchmark Score of 2 despite the hazard data gaps. In a worst-case scenario, if 2-(2-butoxyethoxy) ethanol were assigned a High score for the data gap E, it would be categorized as a Benchmark 1 Chemical.

GreenScreen® Benchmark Score for Relevant Route of Exposure:
As a standard approach for GreenScreen® evaluations, all exposure routes (oral, dermal, and inhalation) were evaluated together, so the GreenScreen® Benchmark Score of 2 ("Use but Search for Safer Substitutes") is applicable for all routes of exposure.

GreenScreen® Hazard Ratings for 2-(2-Butoxyethoxy) Ethanol (CAS 112-34-5)

Group I Human					Group II and II* Human									Ecotox		Fate		Physical	
C	M	R	D	E	AT	ST		N		SnS*	SnR*	IrS	IrE	AA	CA	P	B	Rx	F
						single	repeated*	single	repeated*										
L	**L**	**L**	**L**	DG	**L**	**L**	**H**	DG	**L**	**L**	DG	*M*	**H**	**L**	**L**	**vL**	**vL**	*L*	**M**

Note: Hazard levels (Very High (vH), High (H), Moderate (M), Low (L), Very Low (vL)) in *italics* reflect estimated values, authoritative B lists, screening lists, weak analogues, and lower confidence. Hazard levels in **BOLD** font are used with good quality data, authoritative A lists, or strong analogues. Group II Human Health endpoints differ from Group II* Human Health endpoints in that they have four hazard scores (i.e., vH, H, M, and L) instead of three (i.e., H, M, and L), and are based on single exposures instead of repeated exposures. Please see Appendix A for a glossary of hazard acronyms. DG: Data Gap

GreenScreen® Executive Summary for Dimethyl Sulfoxide (CAS #67-68-5)

Dimethyl sulfoxide is a polar solvent that is commonly used as a solvent for polar compounds, acids, alkalis and mineral salts. It is used as a solvent for chemical synthesis, pharmaceuticals, and paint and varnish removers. Dimethyl sulfoxide is also used as an analytical reagent, in the manufacture of synthetic fibers, industrial cleaners, pesticides, and electronics, as a preservative for organ transplantation, and in the treatment of interstitial cystitis.

Dimethyl sulfoxide was assigned a **GreenScreen Benchmark Score™ of 3** ("Use but Still Opportunity for Improvement"). This score is based on the following hazard score combinations:

- Benchmark 3c
  - Moderate Group II Human Toxicity (skin irritation (IrS) and eye irritation (IrE))
- Benchmark 3d
  - Moderate Flammability

Data gaps (DG) exist for endocrine activity (E) and respiratory sensitization (SnR*). As outlined in CPA (2013) Section 12.2 (Step 8 – Conduct a Data Gap Analysis to assign a final Benchmark score), dimethyl sulfoxide meets requirements for a GreenScreen® Benchmark Score of 3 despite the hazard data gaps. In a worst-case scenario, if dimethyl sulfoxide were assigned a High score for the data gap E, it would be categorized as a Benchmark 1 Chemical.

GreenScreen® Benchmark Score for Relevant Route of Exposure:
As a standard approach for GreenScreen® evaluations, all exposure routes (oral, dermal and inhalation) were evaluated together, so the GreenScreen® Benchmark Score of 3 ("Use but Still Opportunity for Improvement") is applicable for all routes of exposure.

GreenScreen® Hazard Ratings for Dimethyl Sulfoxide

Group I Human					Group II and II* Human									Ecotox		Fate		Physical	
C	M	R	D	E	AT	ST		N		SnS*	SnR*	IrS	IrE	AA	CA	P	B	Rx	F
						single	repeated*	single	repeated*										
L	**L**	**L**	**L**	DG	**L**	**L**	**L**	**L**	**L**	**L**	DG	*M*	*M*	**L**	*L*	*L*	**vL**	*L*	**M**

Note: Hazard levels (Very High (vH), High (H), Moderate (M), Low (L), Very Low (vL)) in *italics* reflect estimated (modeled) values, authoritative B lists, screening lists, weak analogues, and lower confidence. Hazard levels in **BOLD** font are used with good quality data, authoritative A lists, or strong analogues. Group II Human Health endpoints differ from Group II* Human Health endpoints in that they have four hazard scores (i.e., vH, H, M, and L) instead of three (i.e., H, M, and L), and are based on single exposures instead of repeated exposures. Please see Appendix A for a glossary of hazard acronyms.

GreenScreen® Executive Summary for 1,3-Dioxolane (CAS #646-06-0)

1,3-Dioxolane is used as a monomer for the production of high-molecular weight polyacetals. It is also a chemical intermediate, process solvent, and stabilizer for halogenated solvents.

1,3-Dioxolane was assigned a **GreenScreen Benchmark Score™ of 2** ("Use but Search for Safer Substitutes"). This score is based on the following hazard score combinations:

- Benchmark 2e
  - Moderate Group I Human Toxicity (mutagenicity (M), reproductive toxicity (R) and developmental toxicity (D))
- Benchmark 2g
  - High Flammability (F)

Data gaps (DG) exist for endocrine activity (E) and respiratory sensitization (SnR*). As outlined in CPA (2013) Section 12.2 (Step 8 – Conduct a Data Gap Analysis to assign a final Benchmark score), 1,3-dioxolane meets requirements for a GreenScreen® Benchmark Score of 2 despite the hazard data gaps. In a worst-case scenario, if 1,3-dioxolane were assigned a High score for the data gap E, it would be categorized as a Benchmark 1 Chemical.

GreenScreen® Benchmark Score for Relevant Route of Exposure:
As a standard approach for GreenScreen® evaluations, all exposure routes (oral, dermal and inhalation) were evaluated together, so the GreenScreen® Benchmark Score of 2 ("Use but Search for Safer Substitutes") is applicable for all routes of exposure.

GreenScreen® Hazard Ratings for 1,3-Dioxolane

Group I Human					Group II and II* Human									Ecotox		Fate		Physical	
C	M	R	D	E	AT	ST		N		SnS*	SnR*	IrS	IrE	AA	CA	P	B	Rx	F
						single	repeated*	single	repeated*										
L	*M*	*M*	**M**	DG	**L**	**M**	**M**	**M**	**L**	**L**	DG	*M*	*H*	**L**	**L**	*M*	**vL**	*L*	**H**

Note: Hazard levels (Very High (vH), High (H), Moderate (M), Low (L), Very Low (vL)) in *italics* reflect estimated (modeled) values, authoritative B lists, screening lists, weak analogues, and lower confidence. Hazard levels in **BOLD** font are used with good quality data, authoritative A lists, or strong analogues. Group II Human Health endpoints differ from Group II* Human Health endpoints in that they have four hazard scores (i.e., vH, H, M, and L) instead of three (i.e., H, M, and L), and are based on single exposures instead of repeated exposures. Please see Appendix A for a glossary of hazard acronyms.

GreenScreen® Executive Summary for Estasol (CAS #95481-62-2)

Estasol is a chemical that functions as a solvent, a plasticizer, a polymer intermediate, and a component in consumer paint strippers, polishes and lacquer thinners.

Estasol was assigned a **GreenScreen Benchmark Score™ of 2** ("Use but Search for Safer Substitutes"). This score is based on the following hazard score combination:

- Benchmark 2e
    - Moderate Group I Human Toxicity (developmental toxicity (D) and endocrine activity (E))

Data gaps (DG) exist for repeated dose neurotoxicity (Nr*) and respiratory sensitization (SnR*). As outlined in CPA (2013) Section 12.2 (Step 8 – Conduct a Data Gap Analysis to assign a final Benchmark score), Estasol meets requirements for a GreenScreen® Benchmark Score of 2 despite the hazard data gaps. In a worst-case scenario, if Estasol were assigned a High score for the data gaps Nr* or SnR*, it would still be categorized as a Benchmark 2 Chemical.

GreenScreen® Benchmark Score for Relevant Route of Exposure:
As a standard approach for GreenScreen® evaluations, all exposure routes (oral, dermal and inhalation) were evaluated together, so the GreenScreen® Benchmark Score of 2 Use but Search for Safer Substitutes") is applicable for all routes of exposure.

GreenScreen® Hazard Ratings for Estasol

Group I Human					Group II and II* Human									Ecotox		Fate		Physical	
C	M	R	D	E	AT	ST		N		SnS*	SnR*	IrS	IrE	AA	CA	P	B	Rx	F
						single	repeated*	single	repeated*										
L	**L**	*L*	*M*	*M*	**L**	**M**	*M*	**M**	DG	**L**	DG	**L**	*M*	**M**	*L*	**vL**	**vL**	*M*	**L**

Note: Hazard levels (Very High (vH), High (H), Moderate (M), Low (L), Very Low (vL)) in *italics* reflect estimated (modeled) values, authoritative B lists, screening lists, weak analogues, and lower confidence. Hazard levels in **BOLD** font are used with good quality data, authoritative A lists, or strong analogues. Group II Human Health endpoints differ from Group II* Human Health endpoints in that they have four hazard scores (i.e., vH, H, M, and L) instead of three (i.e., H, M, and L), and are based on single exposures instead of repeated exposures. Please see Appendix A for a glossary of hazard acronyms.

GreenScreen® Executive Summary for d-Limonene (CAS #5989-27-5)

d-Limonene is a chemical that functions as a solvent, fragrance ingredient, and flavoring agent.

d-Limonene was assigned a **GreenScreen Benchmark™ Score of 2** ("Use but Search for Safer Substitutes"). This score is based on the following hazard score combinations:

- Benchmark 2f ("Very High T (Ecotoxicity or Group II Human) or High T (Group II* Human)")
    - Very High Ecotoxicity (acute aquatic hazard (AA))
    - High Group II* Human hazard (skin sensitization (SnS*))

Data gaps (DG) exist for reproductive toxicity (R), endocrine activity (E), single and repeated dose neurotoxicity (Ns and Nr*), and respiratory sensitization (SnR*). As outlined in CPA (2013) Section 12.2 (Step 8 – Conduct a Data Gap Analysis to assign a final Benchmark score), d-limonene meets requirements for a GreenScreen® Benchmark Score of 2 despite the hazard data gaps. In a worst-case scenario, if d-limonene were assigned a High score for the data gaps reproductive toxicity (R) or endocrine activity (E), it would be categorized as a Benchmark 1 Chemical.

GreenScreen® Benchmark Score for Relevant Route of Exposure:
As a standard approach for GreenScreen® evaluations, all exposure routes (oral, dermal and inhalation) were evaluated together, so the GreenScreen® Benchmark Score of 2 ("Use but Search for Safer Substitutes") is applicable for all routes of exposure.

GreenScreen® Hazard Ratings for d-Limonene

Group I Human					Group II and II* Human									Ecotox		Fate		Physical	
C	M	R	D	E	AT	ST		N		SnS*	SnR*	IrS	IrE	AA	CA	P	B	Rx	F
						single	repeated*	single	repeated*										
L	**L**	DG	**L**	DG	**L**	**L**	**L**	DG	DG	**H**	DG	**H**	*H*	**vH**	**H**	**vL**	**M**	*L*	**M**

Note: Hazard levels (Very High (vH), High (H), Moderate (M), Low (L), Very Low (vL)) in *italics* reflect estimated (modeled) values, authoritative B lists, screening lists, weak analogues, and lower confidence. Hazard levels in **BOLD** font are used with good quality data, authoritative A lists, or strong analogues. Group II Human Health endpoints differ from Group II* Human Health endpoints in that they have four hazard scores (i.e., vH, H, M, and L) instead of three (i.e., H, M, and L), and are based on single exposures instead of repeated exposures. Please see Appendix A for a glossary of hazard acronyms.

Green Screen Assessment Prepared By:
Name: Brian Penttila, Ph. D.
Title: Chemical Engineer
Organization: PNW Pollution Prevention Resource Center
Date: 30 June 2012

Quality Control Performed By:
Name: Alex Stone, Sc. D.
Title: Safer Chemical Alternative Chemist
Organization: WA Department of Ecology
Date: April 22, 2013

GreenScreen™ Assessment for Acetone (CAS # 67-64-1)

GreenScreen™ Version 1.2 Draft Assessment
Note: Validation Has Not Been Performed on this Green Screen Assessment

Chemical Name: Acetone

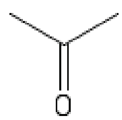
Confirm application of the de minimus rule[1]: (if no, what *de minimus* did you use?) Yes.

Chemical Name (CAS #): Acetone (CAS# 67-64-1)

Also called: 2-propanone, methyl ketone, beta-ketopropane, propan-2-one, pyroacetic acid.

Chemical Surrogates, analogs or moieties used in this assessment (CAS #s): Isopropanol (propan-2-ol) CAS # 67-63-0

Chemical Structure(s):



Identify Applications/Functional Uses: (e.g. Cleaning product, TV casing)

1. Chemical intermediate for methyl methacrylate, methacrylic acid and higher methacrylates, methyl isobutyl ketone, bisphenol a, acetic acid (ketene process), diacetone alcohol, chloroform, iodoform, bromoform, explosives, etc.
2. Solvent for fats, oils, waxes, resins, rubber, plastics, lacquers, varnishes (including nail polish), adhesives, printing inks and cements; cleaning and drying parts of all kinds. Extraction solvent for various plant and animal products.
3. Processing aid for manufacture of cellulose acetate.

See Background section below for references.

GreenScreen Rating[2]: Acetone was assigned a **Benchmark Score of 2** based on:

- Did not fail any Benchmark 1 criteria.
- Failed Benchmark 2c (very high persistence and moderate neurotoxicity) and 2g (high flammability).

GreenScreen Hazard Ratings: Acetone																			
Group I Human					Group II and II* Human									Ecotox		Fate		Physical	
C	M	R	D	E	AT	ST		N		SnS*	SnR*	IrS	IrE	AA	CA	P	B	Rx	F
						single	repeat*	single	repeat*										
L	**L**	*L*	*L*	DG	**L**	**L**	**L**	**M**	*M*	**L**	DG	**L**	**H**	**L**	**L**	*vH*	**vL**	**L**	**H**

Note: Hazard levels [Very High (vH), High (H), Moderate (M), Low (L), Very Low (vL)] in *italics* reflect estimated values and lower confidence. Hazard levels in **BOLD** font reflect values based on test data (See Guidance). NE indicates no determination was made (conflicting data); DG indicates insufficient data for assigning a hazard level.

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[1] Every chemical in a material or formulation should be assessed if it is:
1. Intentionally added.
2. Present at greater than or equal to 100 ppm.

[2] For inorganic chemicals with low human and ecotoxicity across all hazard endpoints and low bioaccumulation potential, persistence alone will not be deemed problematic. Inorganic chemicals that are only persistent will be evaluated under the criteria for Benchmark 4.

GreenScreen® Executive Summary for Methanol (CAS #67-56-1)

Methanol is a chemical that is used as an industrial solvent for inks, resins, adhesives, and dyes, and is also used as antifreeze for automotive radiators, antifreezing agent and octane booster in gasoline, and fuel for picnic stoves.

Methanol was assigned a GreenScreen® Benchmark Score of LT-1, which may be considered equivalent to a Benchmark 1 ("Avoid-Chemical of High Concern") chemical using the full GreenScreen® method as it has High developmental toxicity (D) based on classifications on Authoritative A lists in a GreenScreen® list translator search. This corresponds to GreenScreen® benchmark classification 1e in CPA 2011. Additional authoritative A listings were sufficient to assign hazard scores for acute toxicity (AT), systemic toxicity-single dose (STs), and flammability (F).

Under the scope of this project, ToxServices screened all paint components against Clean Production Action's GreenScreen® List Translator (LT). Those identified as List Translator Benchmark 1 chemicals ("LT-1") do not undergo a full GreenScreen® evaluation to save time and resources. Per the scope of work, only those hazard scores driven by authoritative listings in the List translator search were to be assigned. Upon inspection of the dataset, ToxServices expanded the assessments for all LT-1 chemicals in order to evaluate aquatic toxicity and environmental fate, as these endpoints are highly relevant to the alternatives assessment of nonbiocide boat paints. The expanded environmental fate and toxicity literature search or modeling for methanol did not identify any additional Benchmark 1 score combinations.

GreenScreen® Benchmark Score for Relevant Route of Exposure:
As a standard approach for GreenScreen® evaluations, all exposure routes (oral, dermal and inhalation) were evaluated together, so the GreenScreen® Benchmark Score of 1 ("Avoid-Chemical of High Concern") is applicable for all routes of exposure.

GreenScreen® Hazard Ratings for Methanol

Group I Human					Group II and II* Human									Ecotox		Fate		Physical	
C	M	R	D	E	AT	ST		N		SnS*	SnR*	IrS	IrE	AA	CA	P	B	Rx	F
						single	repeated*	single	repeated*										
NA	NA	NA	**H**	NA	**H**	**vH**	NA	NA	NA	NA	NA	NA	NA	**L**	*L*	**vL**	*vL*	NA	**H**

Note: Hazard levels (Very High (vH), High (H), Moderate (M), Low (L), Very Low (vL)) in *italics* reflect estimated values, authoritative B lists, screening lists, weak analogues, and lower confidence. Hazard levels in **BOLD** font are used with good quality data, authoritative A lists, or strong analogues. Group II Human Health endpoints differ from Group II* Human Health endpoints in that they have four hazard scores (i.e., vH, H, M, and L) instead of three (i.e., H, M, and L), and are based on single exposures instead of repeated exposures. Please see Appendix A for a glossary of hazard acronyms. NA: Not assessed.

Green Screen Assessment Prepared By:
Name: Brian Penttila, Ph. D.
Title: Chemical Engineer
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Date: 30 June 2012

Quality Control Performed By:
Name: Alex Stone, Sc. D.
Title: Safer Chemical Alternative Chemist
Organization: WA Department of Ecology
Date: 17 April 2013

GreenScreen™ Assessment for Toluene (CAS #108-88-3)

GreenScreen™ Version 1.2 Draft Assessment

Note: Validation Has Not Been Performed on this Green Screen Assessment

Chemical Name: Toluene

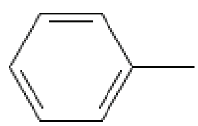
Confirm application of the de minimus rule[1]: (if no, what *de minimus* did you use?) Yes.

Chemical Name (CAS #): Toluene (CAS#108-88-3)

Also Called: "Benzene, methyl-", "Methacide", "Methylbenzene", "Phenylmethane", "TOLU", "Toluene", "Toluol" (US EPA, ACToR database, actor.epa.gov/)

Chemical Surrogates, analogs or moieties used in this assessment (CASs #):

Chemical Structure(s):



Identify Applications/Functional Uses: (e.g. Cleaning product, TV casing)

1. Toluene is used commercially in the production of benzene and many other chemicals, e.g. benzoic acid, nitrotoluenes, dyes, pharmaceuticals, food additives, plastics, etc.
2. Toluene is also widely used as a solvent in coatings, adhesives, inks, pharmaceuticals and chemical processing.

Reference: European Union 2003, Risk Assessment Report (see references to Substance Background below).

GreenScreen Rating[2]: Toluene was assigned a **Benchmark Score of 1** based on:

- Failure of Benchmark Rule 1e, due to High reproductive and developmental toxicity.

GreenScreen Hazard Ratings: Toluene																			
Group I Human					Group II and II* Human									Ecotox		Fate		Physical	
C	M	R	D	E	AT	ST		N		SnS*	SnR*	IrS	IrE	AA	CA	P	B	Rx	F
						single	repeat*	single	repeat*										
DG	**L**	**H**	**H**	**M**	**L**	**M**	**H**	**M**	**H**	**L**	**DG**	**H**	**L**	**H**	**H**	*H*	**vL**	**L**	**H**

Note: Hazard levels [Very High (vH), High (H), Moderate (M), Low (L), Very Low (vL)] in *italics* reflect estimated values and lower confidence. Hazard levels in **BOLD** font reflect values based on test data (See Guidance). NE indicates no determination was made (conflicting data) and DG indicates insufficient data for assigning hazard level.

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[1] Every chemical in a material or formulation should be assessed if it is:
1. intentionally added and/or
2. present at greater than or equal to 100 ppm.

[2] For inorganic chemicals with low human and ecotoxicity across all hazard endpoints and low bioaccumulation potential, persistence alone will not be deemed problematic. Inorganic chemicals that are only persistent will be evaluated under the criteria for Benchmark 4.

GreenScreen® Executive Summary for Formic Acid (CAS #64-18-6)

Formic acid is a chemical that is used in textile dyeing and finishing, rubber manufacture, and as a chemical intermediate, catalyst in resins, plasticizer in resins, antiseptic and preservative, component of cleaning solutions, and oil well acidifying agent. It is also used as a direct food additive and in food packaging. In hydraulic fracturing, it is used as a corrosion inhibitor to protect pipes and related fracking components.

Formic acid was assigned a **GreenScreen Benchmark™ Score of 2** ("Use but Search for Safer Substitutes"). This score is based on the following hazard combinations:

- Benchmark 2f
    - Very High Group II Human Toxicity (systemic toxicity single dose (STs), neurotoxicity single dose (Ns), skin irritation (IrS) and eye irritation (IrE))
    - High Group II* Human Toxicity (systemic toxicity-repeated dose (STr*))

Data gaps (DG) exist for endocrine activity (E), neurotoxicity-repeated dose (Nr*), and respiratory sensitization (SnR*). As outlined in CPA (2013) Section 12.2 (Step 8 – Conduct a Data Gap Analysis to assign a final Benchmark score), formic acid meets requirements for a GreenScreen® Benchmark Score of 2 despite the hazard data gaps. In a worst-case scenario, if formic acid were assigned a High score for the data gap endocrine activity, it would be categorized as a Benchmark 1 Chemical.

GreenScreen® Benchmark Score for Relevant Route of Exposure:
As a standard approach for GreenScreen® evaluations, all exposure routes (oral, dermal and inhalation) were evaluated together, so the GreenScreen® Benchmark Score of 2 ("Use but Search for Safer Substitutes") is applicable for all routes of exposure.

GreenScreen® Hazard Ratings for Formic Acid

Group I Human					Group II and II* Human									Ecotox		Fate		Physical	
C	M	R	D	E	AT	ST		N		SnS*	SnR*	IrS	IrE	AA	CA	P	B	Rx	F
						single	repeated*	single	repeated*										
L	**L**	**L**	*L*	DG	**H**	**vH**	*H*	**vH**	DG	**L**	DG	**vH**	**vH**	**M**	**M**	**vL**	**vL**	**L**	**M**

Note: Hazard levels (Very High (vH), High (H), Moderate (M), Low (L), Very Low (vL)) in *italics* reflect estimated (modeled) values, authoritative B lists, screening lists, weak analogues, and lower confidence. Hazard levels in **BOLD** font are used with good quality data, authoritative A lists, or strong analogues. Group II Human Health endpoints differ from Group II* Human Health endpoints in that they have four hazard scores (i.e., vH, H, M, and L) instead of three (i.e., H, M, and L), and are based on single exposures instead of repeated exposures. Please see Appendix A for a glossary of hazard acronyms.

GreenScreen® Executive Summary for Caustic Soda (CAS 1310-73-2)

Caustic soda is a chemical that is used for pH regulation, alkaline ore digestion, basic catalysis, removal of lignin in the paper industry, production of sodium phosphate in the detergent industry, manufacture of soaps via saponification of fats and oils, degreasing and cleaning in the food industry, and refining of vegetable oil.

Caustic soda was assigned a **GreenScreen Benchmark™ Score of 2** ("Use but Search for Safer Substitutes"). This score is based on the following hazard combination:

- Benchmark 2f
    - Very High Group II Human Toxicity (Skin Irritation (IrS), Eye Irritation (IrE), and Systemic Toxicity (STs) (single dose))

Data gaps (DG) exist for respiratory sensitization (SnR*) and chronic aquatic toxicity (CA). As outlined in CPA (2013) Section 12.2 (Step 8 – Conduct a Data Gap Analysis to assign a final Benchmark score), caustic soda meets requirements for a GreenScreen® Benchmark Score of 2 despite the hazard data gaps. In a worst-case scenario, if caustic soda were assigned a High score for the data gap SnR* or a Very High score for CA, it would still be categorized as a Benchmark 2 Chemical.

GreenScreen® Benchmark Score for Relevant Route of Exposure:
As a standard approach for GreenScreen® evaluations, all exposure routes (oral, dermal, and inhalation) were evaluated together, so the GreenScreen® Benchmark Score of 2 ("Use but Search for Safer Substitutes") is applicable for all routes of exposure.

GreenScreen® Hazard Ratings for Caustic Soda

Group I Human					Group II and II* Human									Ecotox		Fate		Physical	
C	M	R	D	E	AT	ST		N		SnS*	SnR*	IrS	IrE	AA	CA	P	B	Rx	F
						single	repeated*	single	repeated*										
L	**L**	*L*	*L*	*L*	**H**	**vH**	*L*	*L*	*L*	**L**	DG	**vH**	**vH**	**M**	DG	*L*	*vL*	*M*	*L*

Note: Hazard levels (Very High (vH), High (H), Moderate (M), Low (L), Very Low (vL)) in *italics* reflect estimated values, authoritative B lists, screening lists, weak analogues, and lower confidence. Hazard levels in **BOLD** font are used with good quality data, authoritative A lists, or strong analogues. Group II Human Health endpoints differ from Group II* Human Health endpoints in that they have four hazard scores (i.e., vH, H, M, and L) instead of three (i.e., H, M, and L), and are based on single exposures instead of repeated exposures. Please see Appendix A for a glossary of hazard acronyms. DG: Data Gap

Endnotes

1. Risk Policy Analysts Limited. Impact Assessment of Potential Restrictions on the Marketing and of Dichloromethane in Paint Strippers. Prepared for the European Commission Directorate-General Enterprise and Industry. 2007. Available at: *http://ec.europa.eu/enterprise/sectors/chemicals/files/markrestr/j549_dcm_final_report_en.pdf*.

2. Graham JL et al. Final Report: Understanding the Science Behind How Methylene Chloride/Phenolic Chemical Paint Strippers Remove Coatings, SERDP Project WP-1680. October 2011.

3. Han Y. Scientific Basis for Paint Stripping Mechanism of Methylene Chloride/Phenol-Based Paint Removers, SERDP Project WP-1682. September 2011.

4. Wynne JH et al. Memorandum Report for SERDP Project WP-224: Scientific Basis for Paint Stripping: Elucidated Combinatorial Mechanism of Methylene Chloride and Phenol Based Paint Removers. October 10, 2013.

5. See:
   (a) Risk Policy Analysts Limited. Impact Assessment of Potential Restrictions on the Marketing and of Dichloromethane in Paint Strippers. Prepared for the European Commission Directorate-General Enterprise and Industry. 2007. Available at: *http://ec.europa.eu/enterprise/sectors/chemicals/files/markrestr/j549_dcm_final_report_en.pdf*.

   (b) Wollbrink T. The composition of proprietary paint strippers. Journal of the American Institute for Conservation. 1993;32(1): 43-57. Available at: *http://cool.conservation-us.org/jaic/articles/jaic32-01-005.html*.

6. American Society for Testing and Materials (ASTM). Standard Practice for Evaluating the Efficiency of Chemical Removers for Organic Coatings (D6189-97). 2014.

7. Green Seal. Specialty cleaning products for household use, GS52. April 2014. Available at: *http://www.greenseal.org/GreenBusiness/Standards.aspx?vid=ViewStandardDetail&cid=2&sid=38.*

8. See:
   (a) Risk Policy Analysts Limited. Impact Assessment of Potential Restrictions on the Marketing and of Dichloromethane in Paint Strippers. Prepared for the European Commission Directorate-General Enterprise and Industry. 2007. Available at: *http://ec.europa.eu/enterprise/sectors/chemicals/files/markrestr/j549_dcm_final_report_en.pdf*.

   (b) Massachusetts Toxics Use Reduction Institute. Massachusetts Chemical Fact Sheet: Methylene Chloride. November 2014. Available at: *http://www.turi.org/TURI_Publications/TURI_Chemical_Fact_Sheets/Methylene_Chloride_Fact_Sheet/Fact_Sheet_Methylene_Chloride.2014*.

   (c) U.S. Consumer Product Safety Commission. What You Should Know about Using Paint Strippers. 2007. Available at: *http://www.cpsc.gov/Global/Safety%20Education/Home-Appliances-Maintenance-Structure/423%20Paint%20Stripper%20Publication.pdf*.

9. National Aeronautics and Space Administration, Acquisition Pollution Prevention Office. Joint Test Report: For Validation of Alternative Low-Emission Surface Preparation/Depainting Technologies for Structural Steel. NAP2.PROJ.JTR.DEP.PL.02.16.07, 2007.

10. See:
   (a) Risk Policy Analysts Limited. Impact Assessment of Potential Restrictions on the Marketing and of Dichloromethane in Paint Strippers. 2007. Available at: *http://ec.europa.eu/enterprise/sectors/chemicals/files/markrestr/j549_dcm_final_report_en.pdf*.

   (b) Morris M and Wolf K. Methylene Chloride Consumer Product Paint Strippers: Low-VOC, Low Toxicity Alternatives. May 2006. Available at: *http://www.irta.us/Methylene%20Chloride%20Consumer%20Product%20Paint%20Strippers%20REPORT%20ONLY.pdf*.

   (c) Tukker A and Simmons L. Methylene Chloride: Advantages and Drawbacks of Possible Market Restrictions in the EU. TNO-Report prepared for the European Commission Directorate General of Enterprise and Industry. 1999. Available at: *http://ec.europa.eu/enterprise/sectors/chemicals/files/studies/tno-methylene_chloride_en.pdf.*

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   (i) Kelley J and Considine T. Performance Evaluation of Hap-Free Paint Strippers vs. Methylene-Chloride-Based Strippers for Removing Army Chemical Agent Resistant Coatings (CARC). Army Research Laboratory. ARL-TR-3823. June 2006. Available at: *http://www.dtic.mil/dtic/tr/fulltext/u2/a451375.pdf*.

11. See: example MSDSs

   Liftoff: *http://liftoffinc.com/wp-content/uploads/2015/02/msdspvr-20121.pdf.*

   Smart Strip: *http://www.dumondchemicals.com/pdf/MSDS/Smart_Strip.pdf.*

   CRC's Graffiti & Paint Removal towels: *http://www.crcindustries.com/faxdocs/msds/4104.pdf.*

   KleanStrip: *http://www.kleanstrip.com/uploads/documents/GKAR35336_SDS-2554.1.pdf.*

12. See:
   (a) Morris M and Wolf K. Methylene Chloride Consumer Product Paint Strippers: Low-VOC, Low Toxicity Alternatives. May 2006. Available at: *http://www.irta.us/Methylene%20Chloride%20Consumer%20Product%20Paint%20Strippers%20REPORT%20ONLY.pdf*.

   (b) Washington State Department of Labor and Industries, Safety and Health Assessment and Research on Prevention (SHARP) Program. Successful bathtub stripping with benzyl alcohol as alternatives to methylene chloride. 2012. Available at: *http://www.lni.wa.gov/Safety/Research/Files/MCHazAlertBenzylAlcoholAlternative.pdf*.

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13. California Environmental Protection Agency, Department of Toxic Substances Control. Priority Product Profile: Paint Strippers Containing Methylene Chloride. March 2014 (p12-13).

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15. U.S. EPA. Supporting Documents for Initial Risk-Based Prioritization of High Volume Chemicals. March 18, 2008 (p9). Available at: *http://www.epa.gov/hpvis/rbp/Dibasic%20esters.Web.SupportDocs.031808.pdf*.

16. California Environmental Protection Agency, Department of Toxic Substances Control. Priority Product Profile: Paint Strippers Containing Methylene Chloride. March 2014 (p14).

17. See GreenScreen® hazard assessment tool information. Available at: *http://www.greenscreenchemicals.org.*

18. See several MSDS's: *http://www.savogran.com/pdfs/Strypeeze_Orginal_MS.pdf; http://www.savogran.com/pdfs/Kutzit_MS.pdf; http://www.savogran.com/pdfs/SuperStrip_MS.pdf.*

19. Risk Policy Analysts Limited. Impact Assessment of Potential Restrictions on the Marketing and of Dichloromethane in Paint Strippers. Prepared for the European Commission Directorate-General Enterprise and Industry. 2007. Available at: *http://ec.europa.eu/enterprise/sectors/chemicals/files/markrestr/j549_dcm_final_report_en.pdf*.

20. This is a model assessment and not tied to any real or specific company or product. This information could only be provided if a manufacturing company could estimate production volumes needed for the alternatives in reformulated products.

21. GreenScreen® for Safer Chemicals version 1.2. GreenScreen Benchmarks. November 2014. Available at: *http://www.greenscreenchemicals.org/static/ee_images/uploads/resources/cpa-benchmark_1104.pdf*.

22. GreenScreen® for Safer Chemicals version 1.2. Guidance and Methods Downloads. Available at: *http://www.greenscreenchemicals.org/info/guidance-and-method-documents-downloads*.

23. Interstate Chemicals Clearinghouse (IC2). Chemical Hazard Assessment Database. Available: *http://theic2.org/hazard-assessment*.

24. Only an abbreviated GreenScreen® assessment was performed on methanol given its authoritative listings that lead to a Benchmark Score of 1 without assessing additional endpoints.

25. Hazard Substance Data Bank. Dimethyl Sulfoxide. Toxicity Summary. *http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB* [accessed March 15, 2015].

26. A notable example includes: Risk Policy Analysts Limited. Impact Assessment of Potential Restrictions on the Marketing and of Dichloromethane in Paint Strippers. Prepared for the European Commission Directorate-General Enterprise and Industry. 2007. Available at: *http://ec.europa.eu/enterprise/sectors/chemicals/files/markrestr/j549_dcm_final_report_en.pdf.*

27. Notable examples include:

    Morris M and Wolf K. Methylene Chloride Consumer Product Paint Strippers: Low-VOC, Low Toxicity Alternatives. May 2006. Available at: *http://www.irta.us/Methylene%20Chloride%20Consumer%20Product%20Paint%20Strippers%20REPORT%20ONLY.pdf*.

    US EPA. Proceedings of an International Conference on Reducing Risk in Paint Stripping. Washington DC: February 12–13, 1991.

    US CPSC. What You Should Know about Using Paint Strippers. 2007. Available at: *http://www.cpsc.gov/Global/Safety%20Education/Home-Appliances-Maintenance-Structure/423%20Paint%20Stripper%20Publication.pdf*.

    Washington State Dept. of Labor & Industries, SHARP. Successful Bathtub Stripping with Benzyl Alcohol as an Alternative to Methylene Chloride. 2012. Available at: *http://www.lni.wa.gov/Safety/Research/Files/MCHazAlertBenzylAlcoholAlternative.pdf.*

28. See: example MSDSs

    Liftoff: *http://liftoffinc.com/wp-content/uploads/2015/02/msdspvr-20121.pdf.*

    Smart Strip: *http://www.dumondchemicals.com/pdf/MSDS/Smart_Strip.pdf.*

    CRC's Graffiti & Paint Removal towels: *http://www.crcindustries.com/faxdocs/msds/4104.pdf.*

    KleanStrip: *http://www.kleanstrip.com/uploads/documents/GKAR35336_SDS-2554.1.pdf.*

29. US EPA. EPA's Safer Choice Standard (formerly, the 'DfE Standard for Safer Products') June 2009. See: *http://www2.epa.gov/sites/production/files/2013-12/documents/standard-for-safer-products.pdf.*

30. See for example: Linde NJ et al. Utility of GreenScreen® for Safer Chemicals for nanoscale hazard assessment: nanosilver case study. Submitted to International Journal of Occupational and Environmental Health (May 2015).

31. For more information, see: *http://hansen-solubility.com/index.html.*

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