Local Hazardous Waste
Management Program
in King County, Washington

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Final Report

Waterborne vs. Solventborne Automotive Basecoats: An Alternatives Assessment

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This report was prepared by the Local Hazardous Waste Management Program in King County, Washington (LHWMP), a coalition of local governments. Our customers are residents, businesses and institutions with small quantities of hazardous wastes. Our mission is: to protect and enhance public health and environmental quality in King County by reducing the threat posed by the **production**, **use, storage** and **disposal** of hazardous materials.

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CONTENTS

Figures

Tables

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ACRONYMS AND ABBREVIATIONS

ACGIH	American Conference of Government Industrial Hygienists
ATSDR	Agency for Toxic Substances and Disease Registry
CAS	Chemical Abstract Service
CoC	Chemical of Concern
CoPC	Chemical of Potential Concern
CSC	Coconut shell charcoal
DfE	Design for the Environment
DOSH	Division of Occupational Safety & Health
DW	Dangerous Waste
EGBE	Ethylene glycol monobutyl ether
EH Lab	Environmental Health Laboratory
EHW	Extremely Hazardous Waste
EPA	United States Environmental Protection Agency
Ecology	Washington State Department of Ecology
GC-FID	Gas chromatography with flame ionization detection
g/mol	grams/mol
HVLP	High volume low pressure
IARC	International Agency for Research on Cancer
IC2	Interstate Chemicals Clearing House
lbs./gal	pounds per gallon
LHWMP	Local Hazardous Waste Management Program in King County
LT	List Translator
mg/m3	Milligrams per cubic meter
MLOQ	Method Limit of Quantitation
NIOSH	National Institutes for Occupational Safety and Health
O90	ORBO 90
OEM	Original equipment manufacturer
OSHA	Occupational Safety and Health Administration
PPE	Personal Protective Equipment
ppm	parts per million
SCAQMD	South Coast Air Quality Management District
SDS	Safety Data Sheet
SIC	Standard Industrial Classification
STEL	Short-term exposure limit
TLV	Threshold Limit Value
TWA	Time-weighted average
µg	micrograms
UW	University of Washington
VOC	Volatile Organic Compound

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EXECUTIVE SUMMARY

We used the Alternatives Assessment Guide (version 1.0) developed by the Interstate Chemicals Clearinghouse (IC2) as the framework for a comparison of two types of automotive basecoats: solventborne and waterborne. Solventborne products, which contain relatively high levels of volatile organic compounds (VOCs), have been used extensively by the auto body industry for many decades. However, a new generation of waterborne products have appeared in the marketplace in the last two decades to comply with air quality regulations in Europe, Canada, and some jurisdictions in the United States. Although there are no regulations requiring the use of waterborne products in Washington state and King County, over 50 percent of King County auto body shops have adopted these products voluntarily.

Despite their demonstrated benefits with regard to ambient air quality, the impacts of these relatively new waterborne products on other aspects of human health and the environment have not been critically evaluated. Therefore, the purpose of this document is to determine whether waterborne basecoats are safer alternatives to solventborne products from several perspectives, including hazard, exposure, performance, cost, availability, social impact, and waste management. This information will be used by the Local Hazardous Waste Management Program in King County (LHWMP) to determine whether resources should be devoted to helping shops transition from using solventborne to waterborne products.

From a hazard perspective, waterborne basecoats and the associated paint gun cleaners were shown to contain fewer hazardous ingredients and at lower concentrations than their solventborne counterparts. Exposure evaluations conducted while automotive painters spray-painted vehicles revealed significantly lower exposures to several harmful solvents when waterborne products were used, compared to solventborne products.

Interviews with individuals associated with the auto body industry revealed a variety of opinions about waterborne basecoats, occasionally depending on whether the interviewee was currently using waterborne products. On balance, we conclude that waterborne basecoats can offer advantages as far as performance and cost are concerned. However, we recognize that some shops do not currently have the infrastructure, equipment, or work practices necessary for a straightforward conversion from solventborne to waterborne products.

We learned that waterborne products are readily available in King County and that there are advantages with regard to social impacts from using waterborne paints. Some of these advantages include lower worker and community exposure to VOCs, reduced VOC release and smog formation, reduced potential for generation of and exposure to hazardous waste, and reduced chemical exposures in workers and nearby community residents.

Because the waste streams associated with waterborne painting operations have not been adequately characterized, it is not clear whether adoption of waterborne technology offers

significant advantages from this perspective. Although a portion of the shop's waste stream would no longer be comprised of hazardous solvents, managing a second, aqueous waste steam may prove challenging to some shops.

In conclusion, waterborne basecoats and associated products offer many advantages over their solventborne counterparts, and we consider them to be safer alternatives. Consequently, LHWMP will provide technical and financial assistance to our local auto body industry to help them transition from solventborne to waterborne products.

INTRODUCTION

Purpose of this assessment

Waterborne basecoats have been widely adopted for use in automotive refinishing. These products have replaced solventborne products in the European Union, Canada, and California because of regulatory requirements to reduce VOC emissions. Although there are no regulations requiring the use of waterborne products in Washington state and King County, many local auto body shops are adopting these products voluntarily.

The benefits of waterborne basecoats with regard to reduced VOC emissions from automotive refinishing have been well-documented.(1) However, the impacts of these relatively new products on other aspects of human health and the environment have not been critically evaluated. Therefore, the purpose of this document is to determine whether waterborne basecoats are preferred alternatives to solventborne products. This information will be used in LHWMP's decision-making process as we consider the possibility of providing technical and financial assistance to our local auto body industry to help shops transition from solventborne to waterborne products.

Note that the solventborne basecoats discussed primarily in this report are the "high-VOC" products used extensively in King County, Washington. We briefly address "low-VOC" solventborne products, which are used more extensively in California and elsewhere, in the Hazard Assessment section. However, the focus of this report is the high-VOC products used locally. Also included in this report is an assessment of the paint gun cleaning products currently used in conjunction with waterborne and solventborne coatings.

The framework for this report is based on version 1.0 of IC2's *Alternatives Assessment Guide*,(2) with some modifications. Waterborne and high-VOC solventborne products were evaluated according to the following modules (IC2 Guide assessment level provided in parentheses):

- Hazard (Initial Screen) – on-line toxicity screening method used to compare products
- Exposure (Level 3) – personal breathing zone evaluation
- Performance (Level 1) – interviews and literature review
- Cost (Level 2) – interviews and literature review
- Availability (Level 2) – interviews and literature review
- Social impacts (Level 1) – local emphasis, interviews and literature review
- Waste management (not applicable – custom module)

By necessity, this assessment will focus on the characteristics of these products at point-of-use (i.e., in auto body shops). Resource constraints prevented consideration of human health and environmental impacts during these products' life cycles.

Overview of automotive refinishing

Industry characteristics in King County, Washington

Our review of Salesgenie® business listings, restricted to Standard Industrial Classification Code (SIC code) 7532-01 (Automobile Body-Repairing & Painting) revealed that there are approximately 260 auto body shops in King County (database accessed March, 2015). Of these, approximately 20 percent are part of a multi-store business, consolidator, franchise, cooperative group, chain, or similar collection of businesses.

Identifying the shops in King County that have converted to waterborne basecoats proved challenging. Telephone interviews conducted with shop owners and managers in 2014 indicated that 10% of King County shops had adopted waterborne technology.[3] However, more recent conversations with sales representatives suggest that national chains/franchises typically use waterborne basecoats to ensure consistency across business locations. Although this information has proven difficult to corroborate (many of the national chains have not responded to requests for information from LHWMP), we estimate that over 50% of auto body shops are currently using waterborne products in King County (as of March 2019).

A survey of Washington state's collision repair industry conducted in 2005 revealed that the median number of painters per shop was one and the average was 1.8.[4,5] This finding is consistent with field investigations conducted in King County by LHWMP in 2014-2015, where most shops were observed to have one painter.[6]

Spray painting is typically conducted with high volume low pressure (HVLP) paint guns in ventilated spray booths (usually downdraft models). Painters most commonly wear the personal protective equipment (PPE) shown in Figure 1, including half-face air purifying respirators with organic vapor and particulate cartridges, coveralls, and disposable gloves.

Unless the painter wears a full-face respirator with a face shield, they generally do not use eye protection because of perceived issues with visual acuity.[6] LHWMP field personnel have observed spray painting in street clothes with no gloves. We have never observed spray painting without a respirator. Other variations in spray painting practices include application in ventilated "prep stations" (separated from the rest of the shop floor with heavy duty plastic curtains) and the occasional use of supplied-air respirator systems, which provide the greatest protection from inhalation exposures.[6]

Figure 1: Painter applying basecoat

Painter tasks

Regardless of the paint product line used by a shop, the basic tasks conducted by a painter are largely consistent between shops. As described in the LHWMP report, *Characterizing Waterborne Paints used in Automotive Collision Repair*,[(6)] painters typically perform the following tasks:

1. Review the work order provided by shop management.
2. Inspect the work conducted by collision technicians (aka "bodymen") and prepare the vehicle for painting. This may include sanding (outside of the spray booth), taping, and wiping the surfaces to remove loose particles of dust, dirt, and lint.
3. Mount new (replacement) components, such as bumpers and quarter panels, on stands inside the spray booth. These items typically require minimal preparation.
4. Spray a coat of solvent-based primer/sealer and bake/cure the vehicle in the paint booth.
5. Prepare the basecoat by mixing several pigmented toners by weight according to a prescribed formula to achieve color-matching. Then add a reducer/thinner to provide the required viscosity and flow, and drying characteristics. Solventborne basecoats are comprised of solventborne toners and a reducer that also contains high concentrations of organic solvents. Waterborne basecoats are comprised of waterborne toners and water-based reducers that contain low concentrations of VOCs. Note that most painters do not use respiratory protection while mixing the basecoats, and many do not wear gloves.

6. Spray the basecoat in the booth (see Figure 1). Multiple coats are occasionally needed, depending on the color and manufacturer of the coating.
7. Dry the basecoat in the paint booth. For waterborne products, the basecoats are dried by air flow using specialty air multipliers (Venturi nozzles). Solventborne basecoats are dried via baking.
8. Spray a coat of solvent-based clearcoat and bake in the booth.
9. Remove the vehicle from the booth.
10. Remove tape and other coverings from the vehicle.

The painter must clean the paint gun after applying each type of coating to prevent buildup of paint in the gun's mechanism. The painter must also periodically manage the waste streams generated from the painting operations, including excess coatings and rinsates generated from cleaning the paint guns.[6]

The use of PPE while cleaning paint guns and managing hazardous waste is extremely variable, especially with regard to respiratory protection.[6]

Solventborne basecoats

The solventborne products evaluated in this report are traditional "high-VOC" basecoats. Although "low-VOC" solventborne products are used in California and other markets, we have not observed their use in King County and they are not a focus of this report. (A brief description of low-VOC basecoats is presented in the *Hazard Module* and in Appendix C.) *Therefore, unless stated otherwise, all reference to solventborne products is to high-VOC basecoats.*

The primary carrier used in solventborne coatings is an organic solvent or a blend of solvents. Solventborne toners, which contain the required colored pigments, are then mixed with a solvent-based reducer prior to spraying. Common solvents used in solventborne products include methyl ethyl ketone, methyl isobutyl ketone, xylene, toluene, n-butyl acetate, ethyl benzene, 1-methoxy-2-propyl acetate, and 2-heptanone.[7]

Many of these solvents are regarded as VOCs, which contribute to the creation of ground-level ozone, a major component of "smog." VOCs also have health implications for the workers who use solvent-based coatings. Many VOCs are irritants to workers' eyes, skin, respiratory systems, and they can also affect the central nervous system.[8] Additionally, some frequently-used solvent-based coatings, like two-part clearcoats (i.e., polyurethane-based protective coatings), are mixed with isocyanate-containing hardeners. Isocyanates are powerful irritants to the mucous membranes of the eyes and the gastrointestinal- and respiratory- tracts.[9] Isocyanates can also sensitize workers' immune systems, subjecting them to severe hypersensitivity reactions when re-exposed. Workers may be sensitized to isocyanates through both dermal and respiratory exposures.[5,10,11]

Regulatory limits on VOC emissions

Because auto body refinish coatings contribute a significant amount of VOC emissions, in 1998 the United States Environmental Protection Agency (EPA) released the first federal regulation for emissions of VOCs for the automotive refinish coating industry, called the "National Volatile Organic Compound Emission Standards for Automotive Refinish Coatings".(12) The aim of this "National Rule" is to reduce VOC emissions during automotive painting and standardize VOC regulations across the United States by placing limits on the VOC content of products.(12)

These national VOC limits vary by type of automotive coating. These rules apply to the manufacturers and the importers of coating materials. The VOC content of basecoats is regulated at 5-6 pounds per gallon (lbs./gal).(13)

However, some areas in the US are either considering or have adopted stricter limits than those stipulated by the National Rule. For example, in 2008, the California South Coast Air Quality Management District (SCAQMD) limited the VOC content of clearcoat and basecoat to 2.1 lbs./gal and 3.5 lbs./gal, respectively.(14) Although clearcoats containing 2.1 lbs./gal VOCs have been available for several years, the available solventborne basecoats contained 5-7 lbs./gal. Consequently, auto body shops in the SCAQMD sought a basecoat that met the 3.5 lbs./gal rule.(15)

Waterborne basecoats

The first commercial waterborne coatings were introduced in the automotive industry in the 1990s.(16) These coatings were developed in anticipation of air quality rules related to VOC emissions in the United Kingdom, which were soon to also be adopted by the European Union.(1)

In waterborne products, water is used to replace a significant portion of the organic solvents as the carrier and the fraction of solids is relatively high. Typical solventborne basecoats may contain up to 85% organic solvents by weight and 15% solids. Conversely, waterborne coatings contain about 10% organic solvent by weight, 70% water, and 20% solids.(17) Waterborne basecoats also contain polar solvents that undergo negligible atmospheric photochemical reactions to create smog and are therefore regarded as exempt by regulatory agencies.(15)

Currently, only waterborne basecoats are widely available in the United States. Although waterborne primers are available, solvent-based primers contain mostly exempt organic solvents and therefore comply with VOC emission limits.(15)

Because the waterborne clearcoats must fully dehydrate for proper cross-linking and curing, paint manufacturers face greater challenges in formulating waterborne clearcoats for auto body shops than they do for automobile original equipment manufacturers (OEMs). The clearcoats currently used by automobile OEMs are 2-6 times thicker than the basecoats, which makes dehydration more difficult. These clearcoats require greater air movement to ensure adequate dehydration than can be achieved in most auto body shops.(15)

Although waterborne coatings contain relatively low concentrations of VOCs, they contain other ingredients that may be of concern, especially from a human health perspective. Most notably, many waterborne products contain ethylene glycol monobutyl ether (EGBE; also known as 2-butoxyethanol); Chemical Abstract Service (CAS) number 111-76-2. Dermal contact can be an important route of exposure to EGBE and other glycol ethers.(18) In animal studies, EGBE is not only an irritant of the eyes, mucous membranes and skin, but it can also cause hemolysis, kidney damage, reproductive effects, immunotoxicity, and embryotoxicity.(19) The International Agency for Research on Cancer (IARC) concluded that EGBE is not classifiable as to its carcinogenicity to humans, based on inadequate evidence in humans and limited evidence in experimental animals.(20) Waterborne products may also contain petroleum-based solvents, including, naphthas, Stoddard solvent, and mineral spirits, albeit at relatively low concentrations.

Paint gun cleaning

Paint guns must be cleaned after applying coatings to ensure that dried residue does not block nozzles and other components. When using solventborne coatings, painters clean their paint guns with organic solvents to remove these residues. When using waterborne coatings, guns can be cleaned effectively with low-VOC water-based products.

Although gun cleaning may be performed in enclosed, automatic gun washers, our field observations revealed that most painters clean their paint guns manually after every spray application (Figure 2). Painters typically wear their disposable gloves when manually cleaning their paint guns but rarely use respiratory protection.

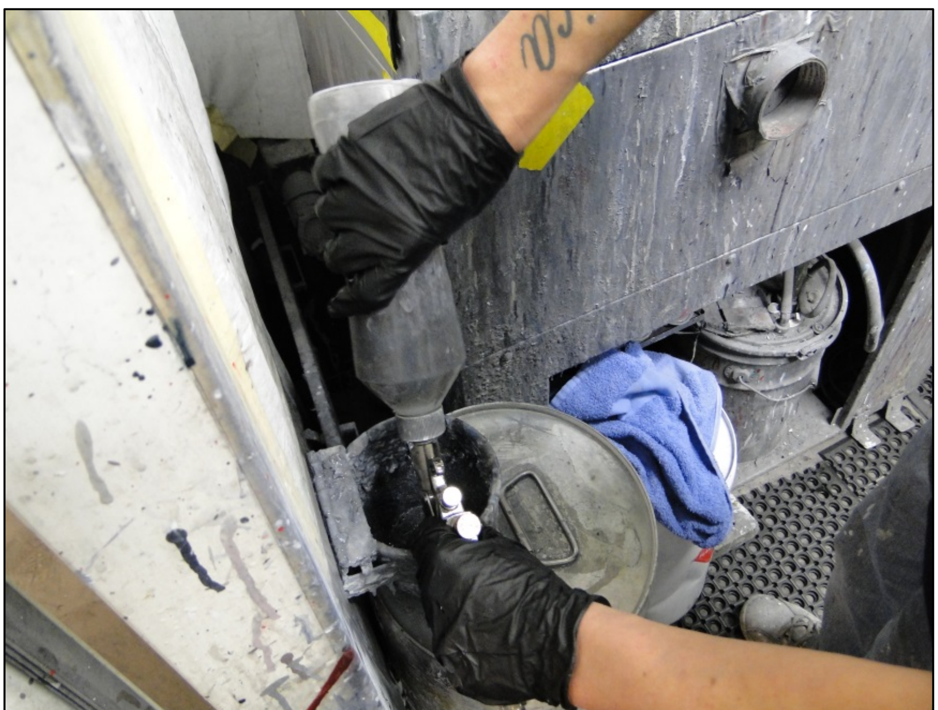

Figure 2: Painter cleaning a paint gun with lacquer thinner

When using solventborne coatings, painters typically clean their paint guns with lacquer thinner. Although the formulations of this product vary between manufacturers, lacquer thinner typically contains methanol, toluene, acetone, petroleum naphthas, and EGBE. Many shops recycle their used lacquer thinner on-site via distillation, which is an effective waste reduction strategy but generates a mixture of hazardous solvents of unknown composition. These distilled solvents may then be used to manually clean paint guns. It is noteworthy that the disposable nitrile gloves typically used for spray painting and gun cleaning are not resistant to lacquer thinner and therefore do not offer sufficient dermal protection.

Painters may also clean their paint guns with products contained in aerosol cans. These products may contain hazardous ingredients such as toluene, petroleum naphthas, phenol, methanol, methylene chloride, and Stoddard solvent.

Paint guns used with waterborne basecoats only require cleaning with water-based products. Some paint manufacturers also recommend a final rinse with acetone. Although these water-based products typically do not contain VOCs or other hazardous solvents, we have noted that many painters continue to use lacquer thinner and other organic solvents to clean their paint guns even when using waterborne basecoats.[(6)]

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HAZARD MODULE

The purpose of this module is to perform a hazard screening of ingredients present in: 1) waterborne and high-VOC solventborne basecoats and 2) paint gun-cleaning products. This information will be used to evaluate the relative chemical hazards associated with waterborne vs. solventborne painting operations. The overall strategy is depicted in Figure 3.

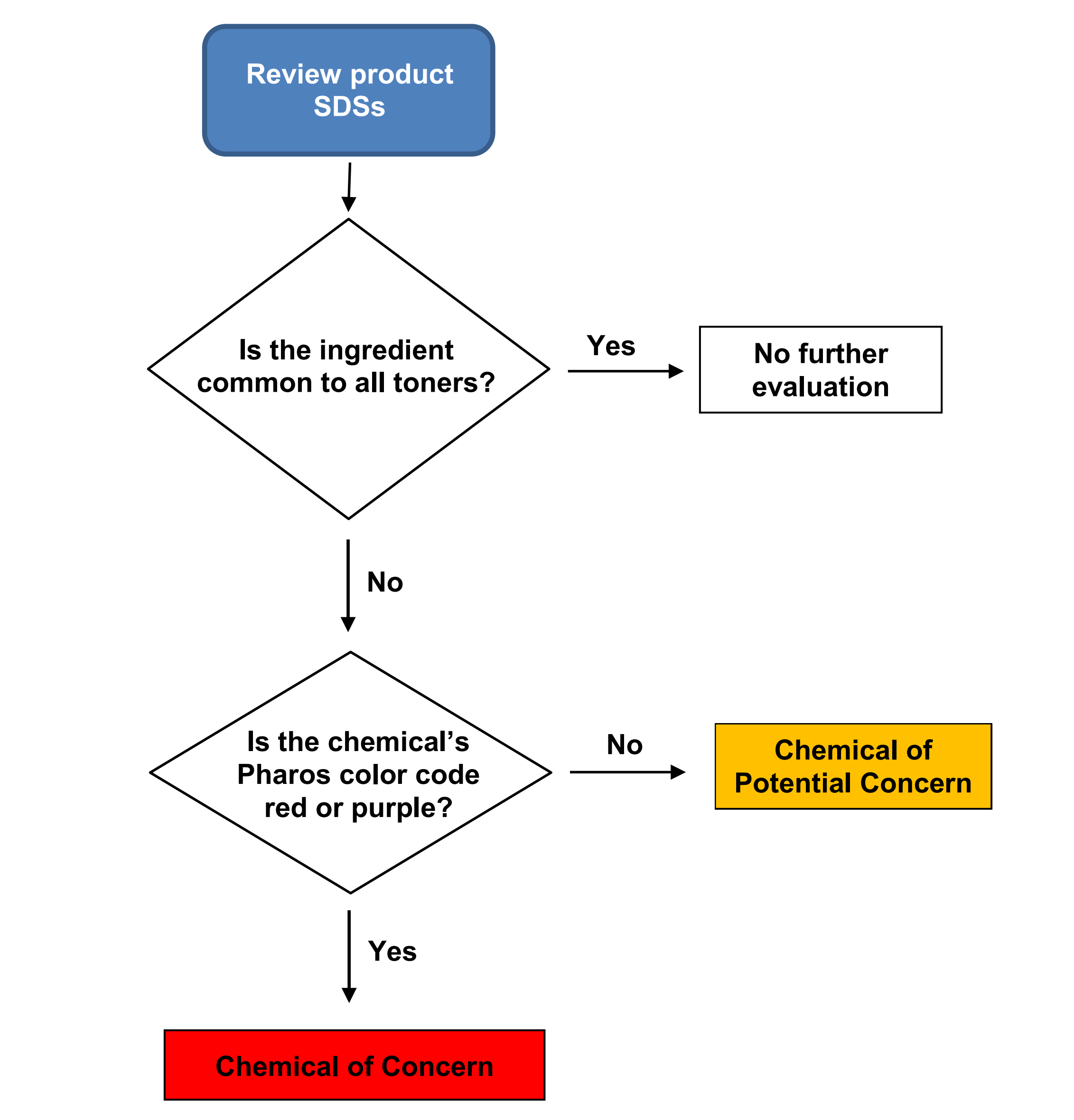


Figure 3: Hazard screening of product ingredients

Hazard assessment of basecoats

Safety Data Sheets (SDSs) retrieved from paint manufacturers' web sites were reviewed for waterborne and high-VOC solventborne basecoat products used in King County. In all product types, pigmented toners are mixed with a reducer/thinner before spraying. The reducer may comprise between 5% and 50% of the final basecoat mixture, depending on the manufacturer and application. An isocyanate-containing activator may also be added to solventborne basecoats for specialty coatings. However, because the activator is typically added at a relatively low concentration (i.e., 1 oz. per quart of basecoat), the hazards associated with activators were not evaluated.

Waterborne products were identified from interviews conducted with industry representatives in 2014 and LHWMP's field study conducted in 2014-2015.(6) SDSs were reviewed for the products presented in Table 1. Some waterborne product lines require a coating of a blend-in additive product (or "wet-bed") to ensure proper coverage of waterborne basecoat. This blender may be applied as a separate coating or mixed with the toner and reducer before spray application.

High-VOC solventborne products were selected for evaluation following field visits to several shops and interviews with representatives of major paint manufacturers (PPG Industries, Inc. and Axalta Coatings Systems, LLC) and auto body shop owners/managers. This information was gathered in January-March, 2016. SDSs were reviewed for the solventborne products presented in Table 2.

Ingredients listed on SDSs for the waterborne and solventborne basecoat products are presented in Table 1 and Table 2 (see Appendix A).

The ingredients presented in Appendix A were screened using The Healthy Building Network's Pharos scoring system, which is based largely on the GreenScreen® for Safer Chemicals methodology(21) (accessed May, 2018). Pharos assigns a color code that reflects the highest hazard associated directly with this substance as designated by an authoritative hazard list. The colors represent the relative level of hazard, ranging from **purple** (highest concern) through **red**, **orange**, and **yellow** to **green** (lowest concern). **Grey** indicates that the authoritative hazard listing is ambiguous and covers a wide range of possible hazard levels. **Blue** indicates that the substance is referenced on a restricted substance list rather than an authoritative hazard list.

Table 1: Waterborne basecoat products used for hazard screening				
Manufacturer	**Product line**	**Product name**	**Product number**	**Product type**
Akzo Nobel Coatings, Inc.	Wanda	Waterbase White	W100	Toner
		Waterbase Mixing Black	W160	Toner
		Waterbase Reducer	481232	Reducer
	Lesonal	White Transparent	WB MM 12	Toner
		Mixing Black	WB MM 22	Toner
		Activator WB	None	Reducer
	Sikkens Autowave	White	MM 00	Toner
		Mixing Black	MM744	Toner
		Activator WB	None	Reducer
PPG Industries, Inc.	Envirobase	Black Envirobase	T408	Toner
		Basecoat Thinner	T494	Reducer
	Nexa	Aquabase Plus Basecoat	P989-1	Toner
		Aquabase Plus Thinner	P980-5000	Reducer
Spies-Hecker	Permahyd Hi-TEC 480	Permahyd Hi-TEC Color Series 480	None[a]	Toner
		WT Additive	6050	Reducer
		WT Additive	6052	Reducer
		Blend-in Additive	1050	Blender
DuPont Refinish	Cromax Pro	Waterborne basecoat (mixed color)	None[a]	Toner
		Controller Standard	WB2040	Reducer
		Controller Low Humidity	WB2045	Reducer
		Blender	WB2091	Blender
BASF Corporation	Glasurit 90	90 Line Bases and Colors	None[a]	Toner
		Extended Dry Time Mixing Base	90-M4EDT	Reducer
		Slow Adjusting Base	93-E3S	Reducer
Sherwin-Williams Automotive Finishes	AWX Performance Plus	Waterborne Basecoats, All Colors	None[a]	Toner
		Higher Humidity and/or Lower Temp	4550020	Reducer
		Lower Humidity and/or Higher Temp	4550030	Reducer
		Transparent Basecoat Blender	4550500	Blender

[a] Single SDS provided for all toner colors

Table 2: Solventborne basecoat products used for hazard screening				
Manufacturer	**Product line**	**Product name**	**Product number**	**Product type**
Akzo Nobel Coatings, Inc.	Sikkens Autobase Plus	White	MM Q110	Toner
		Black	MM Q160	Toner
		HP Reducer Medium	391265	Reducer
		HP Reducer Fast	391264	Reducer
Axalta Coatings Systems, LLC	ChromaPremier	Super Jet Black BC	G9900S	Toner
		Basemaker Medium Temperature	7175S	Reducer
		Basemaker High Temperature	7185S	Reducer
BASF Corporation	Glasurit 55	55 Line Bases and Colors	None[a]	Toner
		Glasurit Reducer	352-91	Reducer
	R-M Diamont	Diamont Bases and Colors	None[a]	Toner
		Mid Temp Reducer	UR50	Reducer
DeBeer Refinish	BeroBase 500	White	MM500	Toner
		Super Jet Black	MM579	Toner
		Uni Thinner Medium	1-151	Reducer
		Uni Thinner Slow	1-161	Reducer
PPG Industries, Inc.	Deltron	Basecoat Black	DBC9700	Toner
		White Solid	DBC4318	Toner
		Reducer	DT870	Reducer
		Reducer	DT895	Reducer
Valspar Refinish	999 Series	White Solar System Tint Base	W51.G02	Toner
		Black Solar System Tint Base	K54.G02	Toner
		Uni-Solvent - Medium	172	Reducer

[a] Single SDS provided for all toner colors
Note: High-VOC solventborne products

The Pharos scoring system ranks chemicals on a four-point hazard scale.[22] Chemicals that have undergone a full GreenScreen assessment by Licensed GreenScreen Profilers are given a “Benchmark score”, which is the most reliable designation. Chemicals that have only been assessed using an automated comparison to hazard lists are given a List Translator (LT) score, which is less authoritative. Because full GreenScreen assessments are comprised of an extensive toxicological review, they supersede the results from LT scoring.

GreenScreen scores in order from highest concern to lowest concern are:

- Benchmark 1: Avoid - Chemical of high concern
- LT-1: List Translator Likely Benchmark 1
- LT-P1: List Translator Possible Benchmark 1
- LT-UNK: List Translator Benchmark Unknown
- Benchmark U: Unspecified due to insufficient data
- Benchmark 2: Use, but search for safer substitutes
- Benchmark 3: Use, but still opportunity for improvement
- Benchmark 4: Preferred - Safer chemical

Identifying the Chemicals of Concern in basecoats

Chemicals of Concern (CoCs) were identified by reviewing the Pharos color codes associated with the Chemicals of Potential Concern (CoPCs) listed in Appendix A. Ingredients were designated as CoCs if they were assigned a Pharos color code of red or purple; those assigned yellow or orange color codes were regarded as CoPCs. As shown in Table 3, the SDSs for the products that contained CoCs were further reviewed for their percentage composition by weight. (Note that the displayed percentages reflect the chemical composition of the individual products, rather than the ultimate concentration in the final basecoat mixture.)

Exclusion of acetone

The Pharos color code for acetone (red) is not consistent with its List Translator score of LT-P1 or its Benchmark score of BM2.[23] Therefore, acetone was excluded from the list of CoCs for this assessment.

Exclusion of ethylbenzene

The Pharos color code of red assigned to ethylbenzene is not consistent with its GreenScreen score of BM2. Therefore, ethylbenzene was not considered to be a CoC.

Consideration of pigments

Several pigments, especially titanium dioxide (CAS# 13463-67-7) and carbon black (CAS# 1333-86-4), are common to both product types. However, even within a single product line, their presence and concentrations vary considerably depending on the particular toner color being evaluated. Because of this variability, we did not include these substances in the overall hazard evaluation. However, both pigments are CoCs because they are Pharos color code red (High: Cancer) and LT-1.

Table 3: Chemicals of Concern in waterborne vs. solventborne basecoats					
Chemical	**CAS number**	**Presence in waterborne basecoats**	**Presence in solventborne basecoats**	**Pharos color code with hazard level / endpoint**	**GreenScreen score**
methyl isobutyl ketone (MIBK)	108-10-1	No	Toners: • BASF (55) 0-50% • BASF (RM) 0-50% • PPG 11.3-20.5% Reducers: • Axalta 5.5% • PPG 10-30%	High: Cancer	LT-1
toluene	108-88-3	Toners: • BASF (90) 0-0.3%	Toners: • AW 0-1% • Axalta 30% • BASF (55) 0-0.3% • BASF (RM) 0-0.3% • PPG 0.1-1% • Valspar 0.1-0.3% Reducers: • Axalta 2% • DeBeer 0.3-1% & 0.1-0.3% • PPG 10-30% & 0.1-1% • Valspar 10-25%	High: Developmental	BM1
xylene	1330-20-7	No	Toners: • AW 1-5% • Axalta 6% • BASF (55) 0-15% • BASF (RM) 0-20% • DeBeer 5-10% • Deltron 16-25% & 3-7% • Valspar 10-25 & 5-10% Reducers: • AW 25-30% • Axalta 10% • BASF (55) 12.5-15% • DeBeer 25-50% & 5-10% • Deltron 3-7%	High: Reproductive	BM1

Table 3: Chemicals of Concern in waterborne vs. solventborne basecoats

Chemical	CAS number	Presence in waterborne basecoats	Presence in solventborne basecoats	Pharos color code with hazard level / endpoint	GreenScreen score
2-methoxy propanol	1589-47-5	Toners: • BASF (90) 0-0.2%	Toners: • BASF (55) 0-0.2% • BASF (RM) 0-0.2%	High: Developmental	LT-1
formaldehyde	50-00-0	No	Toners: • DeBeer 100 ppm-<0.1%	High: Cancer	LT-1
naphtha, heavy alkylate	64741-65-7	Toners: • BASF (90) 0-5%	Toners: • BASF (55) 0-5% • BASF (RM) 0-5%	High: Cancer	LT-1
naphtha (petroleum), light hydrocracked	64741-69-1	No	Reducers: • BASF (55) 7-10%	High: Cancer	LT-1
petroleum naphtha, heavy	64742-48-9	Toners: • BASF (90) 0-15% • Nexa 1-13%	Toners: • BASF (55) 0-15% • BASF (RM) 0-15%	High: PBT	BM1
mineral spirits	64742-49-0	No	Toners: • BASF (55) 0-7%	High: Cancer	LT-1
solvent naphtha, light aliph., Low boiling P., <0,1% benzene	64742-89-8	No	Toners: • BASF (55) 0-20% • BASF (RM) 0-20% Reducers: • BASF (RM) 10-20% • Deltron 1-5%	High: Cancer	LT-1
solvent naphtha, petroleum, heavy aromatic	64742-94-5	No	Reducers: • Valspar 10-25%	High: Bioaccumulative	BM-1

Table 3: Chemicals of Concern in waterborne vs. solventborne basecoats

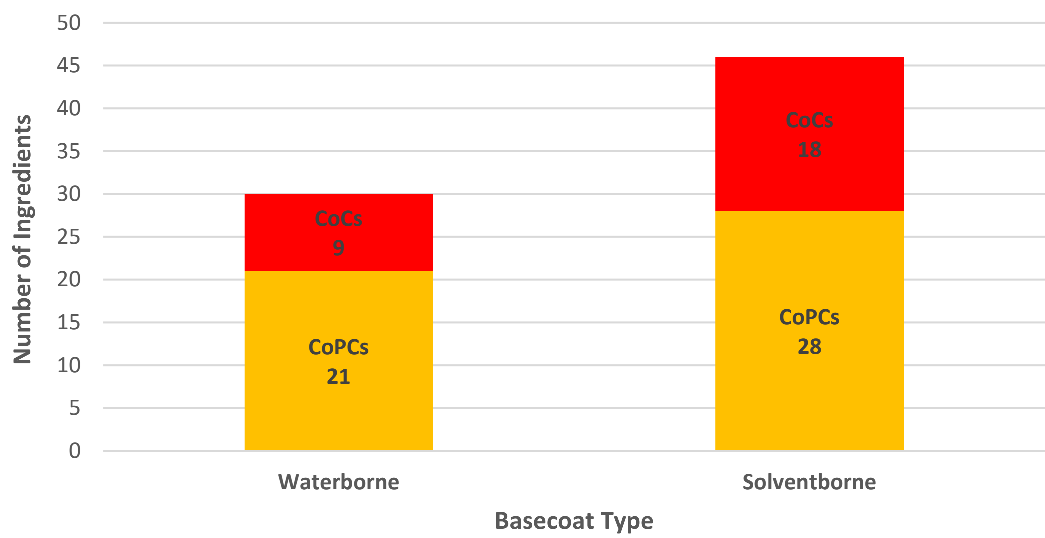
Chemical	CAS number	Presence in waterborne basecoats	Presence in solventborne basecoats	Pharos color code with hazard level / endpoint	GreenScreen score
aromatic hydrocarbon	64742-95-6	Toners: • BASF (90) 0-3%	Toners: • AW 1-5% • BASF (55) 0-5% • BASF (RM) 0-1% • Valspar 5-10% Reducers: • AW 5-10% • Axalta 1-4% • BASF (55) 5-7% • BASF (RM) 5-7% • Valspar 10-25%	High: Cancer	LT-1
vm&p naphtha (Ligroine)	8032-32-4	No	Toners: • PPG 1.1-8.1% Reducers: • Axalta 4-15% • Deltron 10-30%	High: Cancer	LT-1
stoddard solvent	8052-41-3	Toners: • BASF (90) 0-5%	Toners: • BASF (55) 0-3% • BASF (RM) 0-3%	High: Cancer	LT-1
benzyl butyl phthalate	85-68-7	No	Toners: • BASF (RM) 0-3% • Deltron 0.1-1%	High: Developmental	LT-1
1-methyl-2-pyrrolidone	872-50-4	Toners: • SW 0-1%	No	High: Developmental	LT-1
naphthalene	91-20-3	No	Reducers: • Valspar 1-3%	Very high: PBT	BM1
2-butanone oxime	96-29-7	Toners: • EnvB 0.1-1%	Toners: • Valspar 0.3-1%	High: Cancer	LT-1
cumene (isopropylbenzene)	98-82-8	Toners: BASF (90) 0-0.3%	Toners: • Valspar 0.1-0.3% Reducers: • Axalta 0.1% • Valspar 0.1-0.3%	High: Cancer	LT-1

Table 3: Chemicals of Concern in waterborne vs. solventborne basecoats					
Chemical	**CAS number**	**Presence in waterborne basecoats**	**Presence in solventborne basecoats**	**Pharos color code with hazard level / endpoint**	**GreenScreen score**
Key: AW: Akzo Nobel Sikkens Autowave Plus product line BASF (55): BASF Glasurit 55 product line BASF (90): BASF Glasurit 90 product line BASF (RM): BASF R-M Diamont product line Deltron: PPG Deltron product line EnvB: PPG Envirobase product line Nexa: PPG Nexa Aquabase Plus product line SW: Sherwin-Williams AWX Performance Plus product line PBT: Persistent, Bioaccumulative, and Toxic GreenScreen Scores: BM1: Benchmark 1; BM2: Benchmark 2; LT-1: List Translator Likely Benchmark 1; LT-P1: List Translator Possible Benchmark 1					

Hazard screening of waterborne vs. solventborne basecoat products

The number of CoPCs and CoCs in the two product types are presented in Figure 4. In waterborne basecoat products, of the 30 ingredients evaluated, 21 were CoPCs (i.e., yellow or orange Pharos color codes) and 9 were CoCs (i.e., red Pharos color code). In solventborne products, of the 46 ingredients evaluated, 28 were CoPCs, and 18 were CoCs (17 were Pharos color code red and one was purple). Therefore, solventborne products contained more hazardous ingredients (including twice the number of CoCs) than their waterborne counterparts.

Figure 4: Number of CoPCs and CoCs in basecoat products



CoPCs = Chemicals of Potential Concern (ingredients with Pharos color codes orange and yellow).
CoCs = Chemicals of Concern (ingredients with Pharos color codes red and purple).

Some waterborne basecoats contain the same CoCs that are present in solventborne products (i.e., toluene, 2-methoxy propanol, heavy petroleum naphtha, heavy alkylate naphtha, aromatic hydrocarbon, Stoddard solvent, 2-butanone oxime, and cumene). CoCs were identified only in waterborne toners from the following product lines: BASF Glasurit 90, PPG Envirobase, PPG Nexa Aquabase Plus, and Sherwin-Williams AWX Performance Plus. However, the concentrations of these CoCs were typically higher in the solventborne products.

None of the waterborne products contain the CoCs naphthalene; formaldehyde; methyl isobutyl ketone (MIBK); xylene; naphtha (light hydrocracked); solvent naphtha, petroleum, heavy aromatic; or vm&p naptha. In contrast, several of these chemicals are present at relatively high concentrations in the solventborne products.

Although the Pharos screening process did not indicate that glycol ethers are CoCs, it is noteworthy that waterborne products may contain EGBE in toners, reducers, and blenders (present at up to 75% by weight in the BASF 55-line toner) – see Appendix A. EGBE was also listed as an ingredient of a BASF 55-line solventborne toner (up to 5%) and butylglycol acetate (EGBEA) was present in BASF solventborne toners and reducers.

Also of note is the presence of several relatively low-hazard alcohols in waterborne products, which are absent in the solventborne products (see Appendix A).

Chemical footprinting of waterborne vs. solventborne basecoat products

The term "chemical footprinting", as defined by Clean Production Action, is:

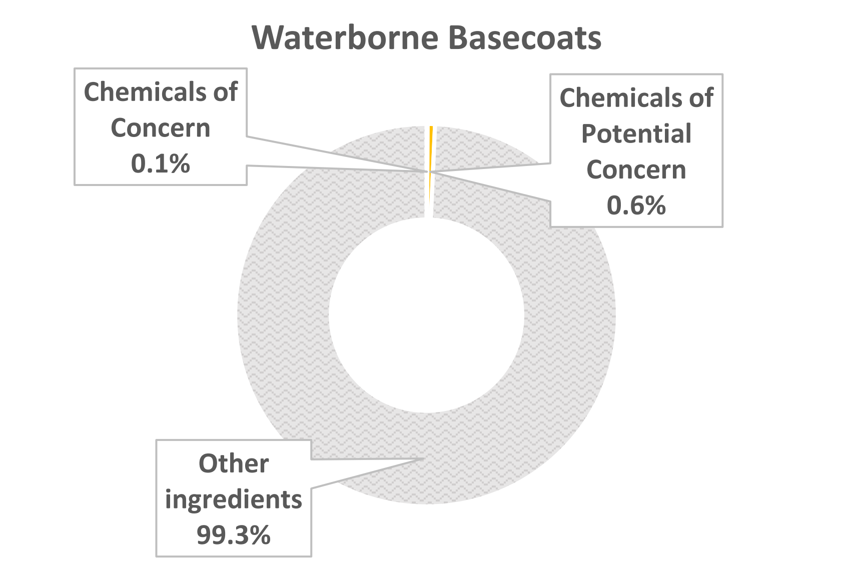
> "*…the process of evaluating the presence of hazardous chemicals in products, manufacturing processes, supply chains, and/or packaging. Chemical footprints provide baseline data, be they the number of chemicals of high concern in products and/or their mass, for evaluating performance and benchmarking progress away from hazardous chemicals to safer alternatives.*"[24]

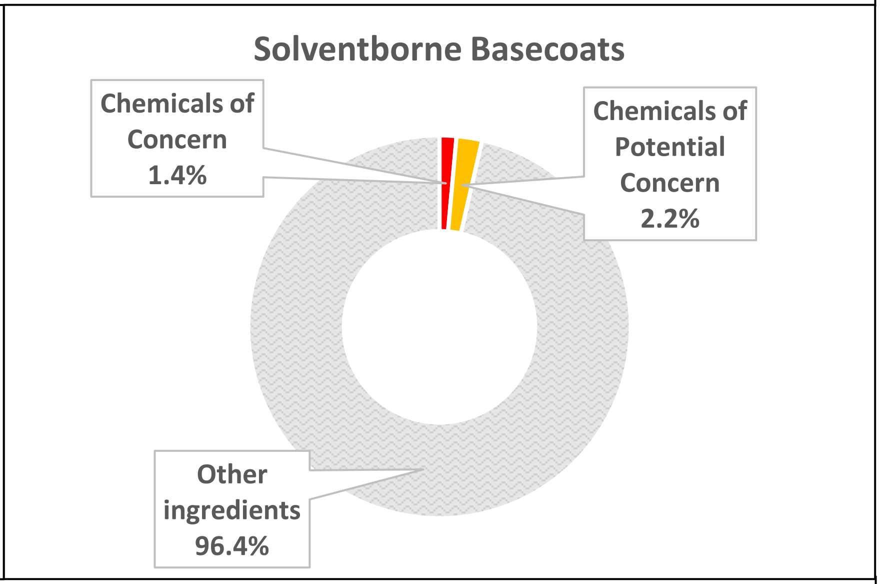
Chemical footprints for basecoat products were derived by calculating the percentage of CoCs, CoPCs, and other ingredients in waterborne vs. high-VOC solventborne products (see Figure 5). As stated previously, ingredients with red or purple Pharos color codes were characterized as CoCs, whereas those with orange or yellow codes were CoPCs.

The average percent concentrations of individual ingredients in toners and reducers were calculated in all waterborne and solventborne products. Where concentration ranges were provided on an SDS, the mid-point was selected for use in the calculation. For the footprinting comparison, the average percent concentrations of CoCs and CoPCs were calculated separately for each a product type. The average percent concentrations of CoCs plus CoPCs was subtracted from 100 to yield the average percent concentration of "Other ingredients," which were not reported on SDSs or were pigments common to all products.

This chemical footprinting revealed that the average percent concentration of CoCs in waterborne and solventborne products was 0.1% and 1.4%, respectively. Therefore, on the average, the concentration of CoCs in solventborne basecoats was 14-times higher than in waterborne products.

Figure 5: Chemical footprints for basecoat products





Percentages are average percent concentrations of Chemicals of Concern and Chemicals of Potential Concern.
"Other ingredients" are those not disclosed on SDSs or common to all products.

Hazard assessment of paint gun cleaners

Product ingredients were identified from SDSs for paint gun cleaners found via an on-line search or from field visits where we documented their use in King County.[6]

- Gun cleaner products used with waterborne basecoats:
    - Acetone (bulk liquid)
    - BASF R-M 915 Waterborne Gun Cleaner (bulk liquid)
    - OneChoice SWX100 Waterborne Gun Cleaner (bulk liquid)
    - BECCA Water Wave Waterborne Cleaning Solution (bulk liquid)
    - DuPont Final Klean V-3921S Surface Cleaner (bulk liquid)
- Gun cleaner products used with solventborne basecoats:
    - Klean-Strip Naked Gun Spray Gun Paint Remover (aerosol can)
    - Sherwin Williams Clean Shot CS105 (aerosol can)
    - Klean-Strip Aircraft Paint Remover (aerosol can)
    - Klean-Strip Lacquer Thinner (bulk liquid)

Hazard screening was conducted using the ingredients listed on SDSs for the products described above (see Appendix B). This chemical list was screened using the Pharos scoring system, as described above.

Identifying the Chemicals of Concern in paint gun cleaners

CoCs were identified by reviewing the Pharos color codes associated with the chemicals listed in Appendix B. Ingredients were considered CoCs if they were assigned a Pharos color code of red or purple. As shown in Table 4, the SDSs for the products that contained these chemicals were further reviewed for their percentage composition by weight. (Note that the displayed percentages reflect the chemical composition of the actual products, rather than the ultimate concentration in the final mixture if dilution was required.) As described previously, acetone was excluded from the list of CoCs because of an overly conservative Pharos rating.

Hazard screening of paint gun cleaners used for waterborne vs. solventborne basecoats

The number of CoPCs and CoCs in the two product types are presented graphically in Figure 6. In waterborne paint gun cleaning products, all six of the ingredients evaluated were CoPCs; no CoCs were identified. In solventborne products, of the 16 ingredients evaluated, six were CoPCs and eight were CoCs. Therefore, solventborne products contained a greater number of hazardous ingredients than their waterborne counterparts.

In conclusion, none of the paint gun cleaners used to clean waterborne material contained CoCs (see Table 4 and Figure 6). Conversely, all the products used in conjunction with solventborne basecoats contained at least one CoC, occasionally at very high concentrations.

Table 4: Chemicals of Concern in paint gun cleaners

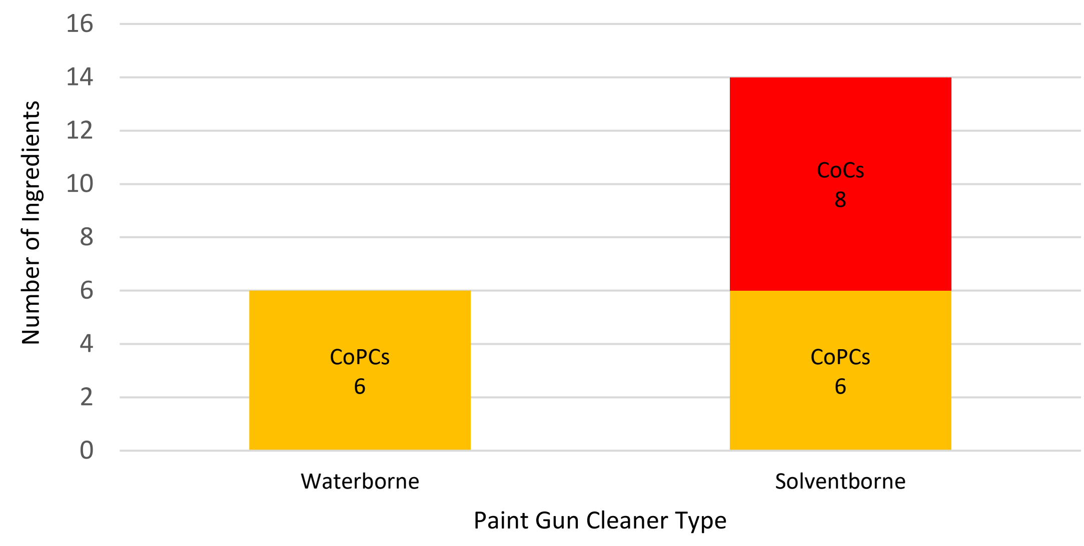
Chemical	CAS number	Presence in waterborne gun cleaners	Presence in solventborne gun cleaners	Pharos color code with hazard level / endpoint	GreenScreen score
toluene	108-88-3	No	LT: 5-10%	High: Developmental	BM1
phenol	108-95-2	No	NG: 1-5%	High: Reproductive	LT-P1
hexane, light aliphatic naphtha	64742-89-8	No	LT: 30-50%	High: Cancer	LT-1
methanol	67-56-1	No	AP: 1-5% CS: 9% LT: 20-25%	High: Developmental	BM1
liquefied petroleum gas, sweetened	68476-86-8	No	AP: 15%	High: Cancer	LT-1
dichloromethane (methylene chloride)	75-09-2	No	AP: 60-100% NG: 30-60%	High: Cancer	BM1
stoddard solvent	8052-41-3	No	NG: 10-30%	High: Cancer	LT-1
nonylphenol ethoxylate	9016-45-9	No	AP: 1-5%	Very high: PBT	BM1

Key:

AP: Klean-Strip Aircraft Paint Remover
CS: Sherwin Williams Clean Shot CS105
LT: Klean-Strip Lacquer Thinner
NG: Klean-Strip Naked Gun Spray Gun Paint Remover

GreenScreen Scores: BM1: Benchmark 1; LT-1: List Translator Likely Benchmark 1; LT-P1: List Translator Possible Benchmark 1

Figure 6: Number of CoPCs and CoCs in paint gun cleaners



CoPCs = Chemicals of Potential Concern (ingredients with Pharos color codes orange and yellow).
CoCs = Chemicals of Concern (ingredients with Pharos color codes red and purple).

Chemical footprinting of waterborne vs. solventborne paint gun cleaners

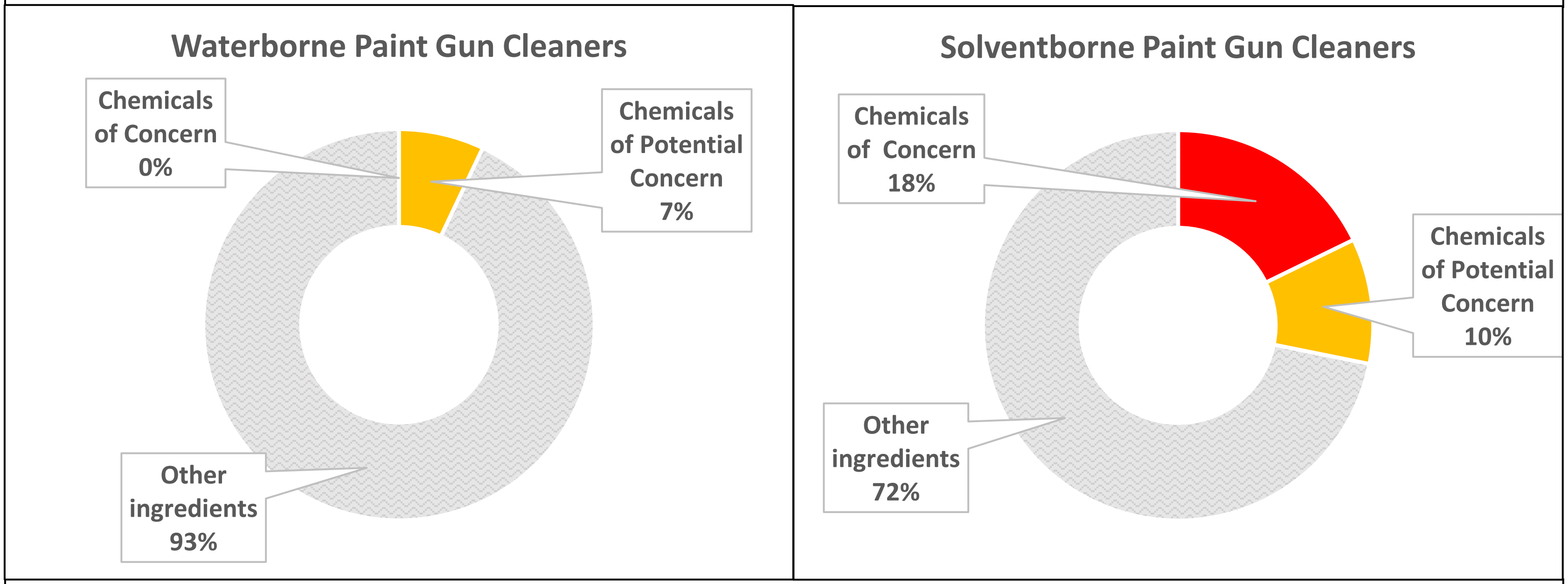
Chemical footprints were derived as described previously. As shown in Figure 7, the average concentration of CoCs in solventborne products was 18%. As stated above, 100% of the ingredients in waterborne products were CoPCs (i.e., no CoCs were identified).

Low-VOC solventborne basecoats

While conducting this study, we learned that another class of basecoats – low-VOC solventborne basecoats – is used in California and elsewhere to conform with local air quality regulations. However, we are not aware of any shops that are using these products in King County and therefore did not perform a formal hazard evaluation or chemical footprinting comparison.

Nevertheless, a review of SDSs of several low VOC solventborne products revealed that they contain numerous CoCs, occasionally at very high concentrations (see Appendix C). Some of these CoCs are unique to low-VOC products, including styrene and tert-butyl acetate.

Figure 7: Chemical footprints for paint gun cleaners



Percentages are average percent concentrations of Chemicals of Concern and Chemicals of Potential Concern.
"Other ingredients" are those not disclosed on SDSs or common to all products.

Strengths and limitations of the hazard assessment

This assessment is the first comprehensive evaluation of the hazards associated with basecoats and paint gun cleaners used in waterborne and solventborne basecoat painting operations. The assessment was informed by observations made during field investigations conducted in King County and interviews with local shop owners, managers, painters, vendors, and paint manufacturer representatives. The comprehensive review of SDSs for products unique to waterborne basecoat operations offers valuable insights into the chemical hazards associated with this relatively new technology compared to traditional solventborne coatings.

However, we recognize the following limitations of this assessment:

- The products evaluated in this assessment may not entirely represent their respective product classes. Resource constraints prevented us from reviewing all basecoat products available in the United States.
- The assignment of CoCs by relying on Pharos color coding of red or purple does not account for all possible hazard considerations, such as the potential additive or synergistic health effects of the multiple chemicals in these complex mixtures.
- Many of the substances regarded as CoPCs can potentially have several human and environmental effects, especially when present at high concentrations in complex mixtures.
- The chemical footprinting likely overstates the hazards associated with waterborne products relative to solventborne products. The undisclosed ingredients in waterborne products likely include water, which is the only GreenScreen Benchmark 4 substance. In contrast, solventborne products likely contain undisclosed solvents that are more hazardous than water.
- Hazardous ingredients present at relatively low concentrations in products may not be listed on SDSs and therefore would be excluded from this evaluation. The Occupational Safety and Health Administration (OSHA) only requires that manufacturers list the hazardous chemicals that are found in a product in quantities of 1% or greater, or 0.1% or greater if the chemical is a carcinogen. Without full disclosure of product composition, it is not possible to determine whether the SDSs accurately represented the chemical composition of the products.
- Because paints are periodically reformulated, some formulations presented on SDSs may not reflect the composition of products seen in the shops.
- The ranges of ingredient concentrations provided on SDSs varied widely, particularly for BASF products, where the reported concentrations sometimes included 0%. In contrast, some manufacturers provided a single SDS for their

entire toner product line, which may not accurately represent the composition of frequent combinations of toners.

- We did not include all the potential additives to the toner-reducer mixture in this evaluation, some of which may be hazardous. For example, painters occasionally include isocyanate-containing activators in the basecoats. However, the final concentrations of the activator ingredients are typically very low because activators are usually included at 1 oz. per quart of basecoat.
- The ingredient concentrations presented in this assessment are those presented on SDSs in unmixed or undiluted products and may not reflect the final concentrations in the in-use basecoats or paint gun cleaners. This simplification was necessary because the ratio of toner to reducer (for example) varies by manufacturer and painters frequently modify these ratios for specific applications.
- Pigments such as titanium dioxide and carbon black are CoCs but were not included in the hazard evaluation. Different colored toners may also vary in their composition with regard to VOCs and other hazardous ingredients. However, resource constraints prevented review of multiple toners within a product line. Consequently, the hazards associated with some basecoat formulations may be underestimated in this evaluation.
- The Pharos color codes occasionally conflicted with more extensive toxicological evaluations from the literature and Benchmark scores. Examples include acetone and ethylbenzene. Therefore, the Pharos color codes must be evaluated against credible sources of toxicity information before designating substances as CoCs.

Conclusions

Despite the limitations described above, this hazard assessment demonstrated that solventborne products contain more hazardous chemicals and at higher concentrations than are present in waterborne products. Therefore, waterborne products exhibit a smaller chemical footprint and are less hazardous than solventborne products. Based on our limited review, low-VOC solventborne basecoats do not appear to be significantly safer than traditional high-VOC products.

EXPOSURE MODULE

Introduction

The exposure assessment methodology for waterborne coatings and human subjects protection considerations are presented in the LHWMP report, *Characterizing Waterborne Paints Used In Automotive Collision Repair*.[6] The goal of this exposure assessment was to collect personal breathing zone samples from painters while they sprayed either waterborne or high-VOC solventborne basecoats.

Methods

Recruitment

Four sources of data were used to recruit auto body shops: 1) LHWMP's Business Field Services' database, 2) LHWMP's EnviroStars Program database, 3) Internet searches for reference to coating type in business advertising, and 4) referrals from auto body shop owners and managers.

Shops using waterborne basecoats were recruited between September and December 2014. Shops using solventborne basecoats were recruited between October 2015 and May 2016.

Personal air sampling

Selection of target analytes

Target analytes for solventborne and waterborne basecoats were selected by reviewing SDSs for selected toners and reducers in the product lines presented in Table 5.

The target analytes were chosen based on the following criteria:

1) Widely used among different manufacturers; or
2) Present at relatively high concentrations; or
3) Low occupational exposure limits.

Note that benzene was included as a target analyte, even though it was not identified on SDSs, because of this compound's high toxicity and its potential presence as a contaminant in naphthenic hydrocarbons.

The selected target analytes for waterborne products included both non-polar compounds and polar compounds, as shown in Table 6.

For high-VOC solventborne basecoats, we included all the target analytes identified in the waterborne products and four additional compounds that were unique to solventborne products: 1,3,5-trimethylbenzene, MIBK, n-butyl acetate, and EGBEA (see Table 6).

Table 5: SDSs reviewed to identify target analytes	
Manufacturer	**Product Line**
Waterborne basecoats	
Akzo Nobel Coatings, Inc.	Sikkens
	Lesonal
	Wanda
Axalta	Standox
BASF Corporation	Glasurit 90
	Onyx HD
PPG Industries, Inc.	Envirobase
	Aquabase
Sherwin-Williams Automotive Finishes	AWX Performance Plus
Spies-Hecker	Permahyd Hi-TEC 480
Solventborne basecoats	
Akzo Nobel Coatings, Inc.	Sikkens Autobase Plus
BASF Corporation	Glasurit 55
	R-M Diamont
DeBeer products	Berobase 500
Valspar Refinish	999 Series

Air sampling procedures

National Institutes for Occupational Safety and Health (NIOSH) sampling methods were used as guidelines for personal sampling procedures. Personal sampling devices included SKC personal sampling pumps (AirChek XR5000) and sorbent tubes. Sampling pumps were calibrated prior to field visits using a DryCal Defender 530. Coconut shell charcoal (CSC) sorbent tubes (SKC Anasorb CSC, 226-01A, 100/50 mg) were used to sample the non-polar compounds and ORBO 90 (O90) sorbent tubes (Sigma-Aldrich ORBO 90 Carboxen 564, 160/80 mg) were used for the polar compounds.

Pumps were calibrated to draw air through each of the sorbent tubes at a rate of 0.4 liters per minute during spraying of waterborne basecoats to account for low analyte concentrations, and at 0.2 liters per minute for solventborne basecoats. During sampling, a manifold was used to hold a single CSC tube and a single O90 sorbent tube; the sampling train is shown in Figure 8.

Table 6: Descriptive statistics and estimated median airborne concentrations (ppm)

Analyte	% <MLOQ	Range, values >MLOQ		Range, All values*		Median**
		Min	Max	Min	Max	
Petroleum distillates* **						
Solventborne	0%	2.04	27.13	2.04	27.13	8.77
Waterborne	45%	0.20	7.81	0.10	7.81	0.39
p-value						**<0.001**** **
Benzene						
Solventborne	100%	NE	NE	0.040	0.200	NE
Waterborne	100%	NE	NE	0.020	0.200	NE
p-value						1.0
Toluene						
Solventborne	29%	0.65	3.20	0.20	3.20	0.70
Waterborne	34%	0.06	17.00	0.02	17.00	0.16
p-value						**0.02**** **
Ethylbenzene						
Solventborne	29%	0.20	2.00	0.20	2.00	0.30
Waterborne	86%	0.06	0.16	0.03	0.30	NE
p-value						**<0.001**** **
Total xylenes						
Solventborne	0%	0.30	10.10	0.30	10.10	3.90
Waterborne	86%	0.18	0.28	0.01	0.30	NE
p-value						**<0.001**** **

Table 6: Descriptive statistics and estimated median airborne concentrations (ppm)

Analyte	% <MLOQ	Range, values >MLOQ		Range, All values*		Median**
		Min	Max	Min	Max	
1,2,4-Trimethylbenzene						
Solventborne	57%	0.10	0.50	0.10	0.50	**0.10**
Waterborne	97%	0.03	0.03	0.03	0.60	**0.03**
p-value						**<0.001*******
Acetone						
Solventborne	0%	0.50	2.30	0.50	2.30	1.00
Waterborne	45%	0.12	9.03	0.10	9.03	0.52
p-value						0.10
2-Butanol						
Solventborne	100%	NE	NE	0.10	0.50	NE
Waterborne	86%	0.16	2.29	0.02	2.29	NE
p-value						0.4
1-Methoxy-2-propanol						
Solventborne	71%	2.51	2.60	0.10	2.60	NE
Waterborne	69%	0.03	0.83	0.01	0.83	NE
*p-value***						0.4
Ethyl 3-ethoxypropionate						
Solventborne	100%	NE	NE	0.07	0.30	NE
Waterborne	90%	0.03	0.61	0.01	0.61	NE
p-value						0.6

Table 6: Descriptive statistics and estimated median airborne concentrations (ppm)						
		Range, values >MLOQ		**Range, All values***		
Analyte	**% <MLOQ**	**Min**	**Max**	**Min**	**Max**	**Median****
4-Hydroxy-4-methyl-2-pentanone						
Solventborne	100%	NE	NE	0.09	0.30	NE
Waterborne	100%	NE	NE	0.02	0.20	NE
p-value						1.0
Ethylene glycol monobutyl ether						
Solventborne	100%	NE	NE	0.07	0.30	NE
Waterborne	62%	0.08	2.00	0.04	2.00	NE
p-value						0.10
n-Propanol						
Solventborne	100%	NE	NE	0.10	0.60	NE
Waterborne	69%	0.11	0.90	0.02	0.90	NE
p-value						0.2
1,3,5-Trimethylbenzene						
Solventborne	71%	0.19	0.20	0.10	0.20	NE
Waterborne	--	--	--	--	--	--
p-value						--
Methyl isobutyl ketone						
Solventborne	71%	0.50	6.44	0.10	6.40	NE
Waterborne	--	--	--	--	--	--
p-value						--

Table 6: Descriptive statistics and estimated median airborne concentrations (ppm)

Analyte	% <MLOQ	Range, values >MLOQ		Range, All values*		Median**
		Min	Max	Min	Max	
n-Butyl acetate						
Solventborne	0%	2.5	30.1	2.5	30.1	8.6
Waterborne	--	--	--	--	--	--
p-value						--
Ethylene glycol monobutyl ether acetate						
Solventborne	71%	0.30	0.38	0.10	0.38	NE
Waterborne	--	--	--	--	--	--
p-value						--

*Concentrations at MLOQ represented by the nominal MLOQ value
**Median estimated from the Kaplan-Meier curve
***Petroleum distillates include all peaks minus those for non-polar target analytes.
****$p<0.05$ for the logrank test for comparison of medians

Notes:
p-value = logrank test for the non-parametric comparison of the distributions for the comparison of the medians
NE = not estimable
-- = not analyzed

Figure 8:
Sampling train

Red arrow: O90 sorbent tube
Green arrow: CSC sorbent tube

Sampling was limited to basecoat spraying tasks; painters' pumps were turned on immediately prior to entering the booth and turned off immediately upon exiting after basecoat application. To prevent breakthrough, total sampling duration per sorbent tube was limited to 40 minutes, with an average duration of 15 minutes.

Some jobs required multiple layers of basecoat, depending on the paint brand. In this case, the painter first sprayed one coat of basecoat, exited the paint booth, allowed the coating to dry, and re-entered the booth to spray the next coat. This process was repeated until the painter successfully matched the vehicle's color. In this situation, we switched off the pumps when the painter exited the booth but left the sampling unit attached to the painter. We then switched the pump on before the painter re-entered the booth to spray additional basecoat. If the pumps were switched off for more than 10 minutes, we removed the sorbent tubes from the manifold, applied a cap, and stored them on ice in a cooler until the painter notified us that he was about to re-enter the booth.

The original sampling plan was to use one pair of sorbent tubes (i.e., one CSC tube and one O90 tube) per complete basecoat application. However, because some applications lasted less than 10 minutes, we used the same pair of sorbent tubes to sample subsequent applications that were also of limited duration. This helped to ensure samples were of sufficient volume for meaningful interpretation of analytical results in comparison to occupational exposure limits.

Samples were stored on ice in a cooler during the sampling visit and transferred to the University of Washington's (UW's) Field Research and Consultation Group's freezer at –20 °C until they were submitted to the UW Environmental Health Laboratory (EH Lab) for analysis.

Analysis of air samples

Analyte concentrations

The EH Lab performed sample analysis according to their EHLSOP-06 method. Samples analyzed for polar analytes (O90 tubes) were desorbed according to NIOSH Method 2554 (85:15 $MeCl_2$:MeOH). n-Butanol was used as the internal standard. Samples analyzed for non-polar analytes (CSC tubes) were desorbed using NIOSH method 1501. Propyl benzene was used as the internal standard.

Gas chromatography with flame ionization detection (GC-FID) (Agilent Technologies 7890A GC with Autosampler) was used to analyze all the samples. The GC column used was an Agilent Technologies DB-Was (60 m x 0.25 mm, 0.5 µm film thickness).

The GC FID method detected the analyte's mass in micrograms (µg) per sample. The procedure for calculating analyte concentrations and Method Limits of Quantitation (MLOQs) (expressed as parts per million (ppm)) is presented in *Characterizing Waterborne Paints Used In Automotive Collision Repair*.[6] The petroleum distillates (PDs) on CSC tubes were quantified as heptane and included all non-target analyte peaks (i.e., the peaks for the non-polar target analytes were not included). PDs were converted from mg/m^3 to ppm, assuming an average molecular weight of 120 grams/mol (g/mol).

Results

Comparison of air concentrations from solventborne vs. waterborne products

A total of 29 air samples were collected from 10 auto body shops using waterborne basecoats. Seven air samples were collected from three shops using solventborne basecoats.

In order to determine whether the airborne concentrations of chemicals in waterborne basecoats were significantly different from those in solventborne products, statistical analyses were conducted for the 13 chemicals that were analyzed in both the waterborne and solventborne basecoat air samples. Statistical analyses were conducted by The Mountain-Whisper-Light Statistics (Seattle, WA) using R (The R Foundation for Statistical Computing, Vienna, Austria), version 3.3.0.

Plots of the raw data for these 13 analytes and the four additional chemicals that were analyzed only in the solventborne samples are presented in Figure 9. The x-axis labels "S" and "W" represent the Solventborne and Waterborne data, respectively. Plots include data from all sampled shops. The green triangles and orange dots represent data >MLOQs and <MLOQs, respectively.

We initially considered calculating mean air concentrations, by substituting the nominal MLOQ values by dividing them by a factor of 2 or $\sqrt{2}$, and testing their equality using a t-test. However, this approach was not considered further because the choice of replacement values is arbitrary and the means (and their comparisons by the t-tests) may be unduly influenced by differences in MLOQ values, rather than the measured concentrations.

Therefore, medians were estimated from Kaplan-Meier survival curves (see Appendix D). This nonparametric method is designed to incorporate data with multiple censoring levels and to estimate the percentiles, or cumulative distribution function.(25,26) Medians can be estimated only if at least 50% of the values are >MLOQ.

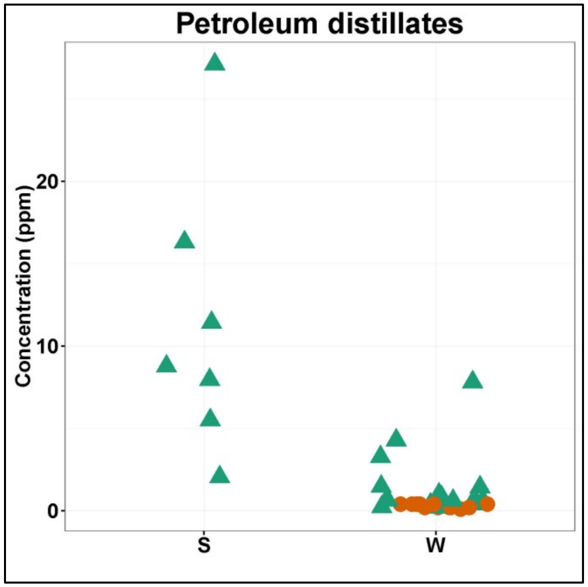
The non-parametric logrank test was applied to the comparison of the medians. This method is applicable for the comparison of the distribution even when the median(s) cannot be estimated and appropriately accounts for concentrations <MLOQ.(25,26) Table 6 provides the descriptive statistics and medians for the airborne concentrations.

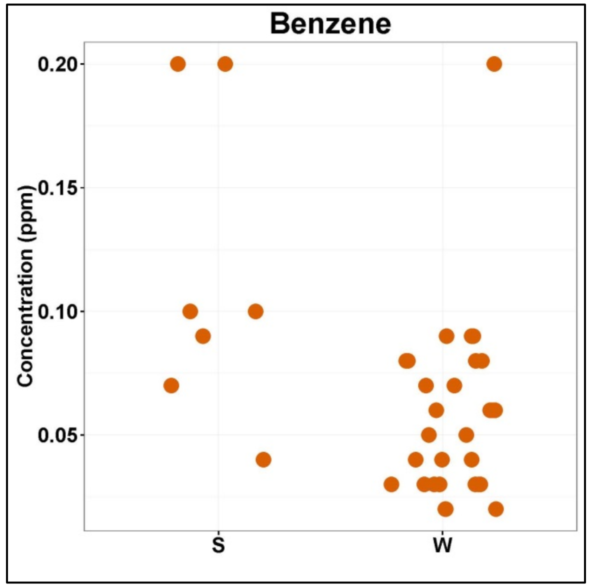
This analysis revealed that the median concentrations were statistically significantly higher in solventborne basecoats compared to waterborne products ($p<0.05$) for the following analytes: petroleum distillates, toluene, ethylbenzene, total xylenes, and 1,2,4-trimethylbenzene. Note that the only non-polar-analyte that was not present at significantly higher concentrations in the solventborne basecoats was benzene (<MLOQ in all samples).

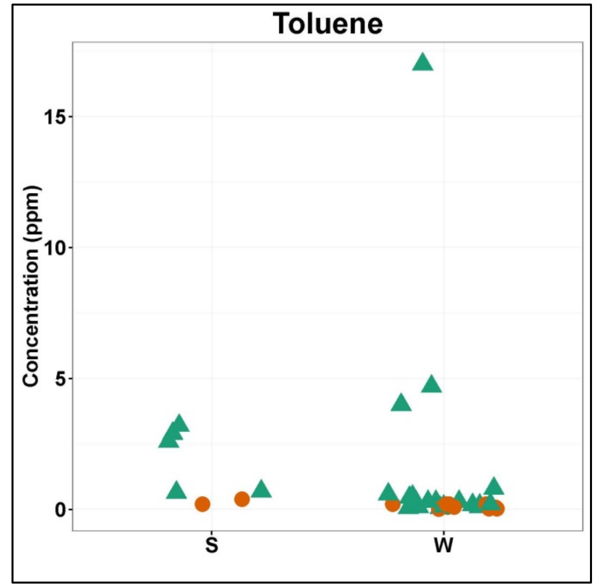
Note that one sample collected during the spraying of waterborne basecoats had much higher concentrations of several analytes compared to other waterborne basecoat samples: petroleum distillates (7.81 ppm), toluene (17 ppm), total xylenes (0.28 ppm), acetone (9.03 ppm), and ethyl 3-ethoxypropionate (0.61 ppm). The toluene concentration in this sample (17 ppm) also exceeded the highest concentration detected in the solventborne basecoat samples (3.2 ppm). However, toluene is not listed as an ingredient in the waterborne basecoat products used in this shop (i.e., PPG Envirobase). We noted, however, that the painter sprayed a product of unknown composition on to a door panel while the sampling pump was running. Consequently, the high concentrations of toluene and other non-polar analytes may have originated from the unknown product, which likely contained VOCs.

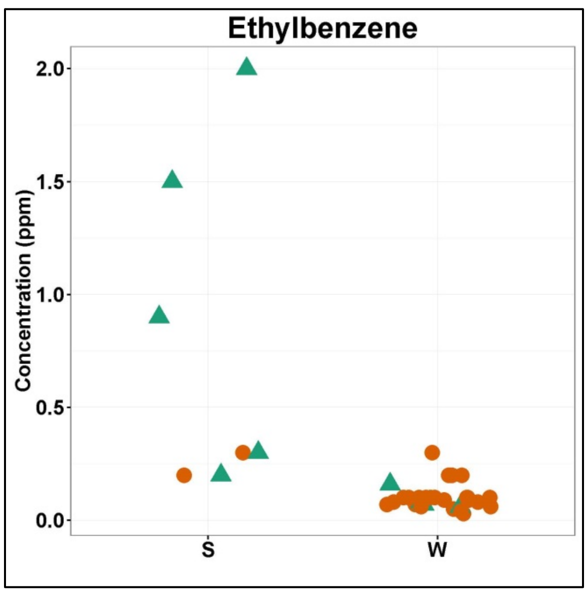
There were no significant differences in the concentrations of polar analytes between waterborne and solventborne products. It is noteworthy that although the concentrations of EGBE in several waterborne basecoat samples were higher than those in the solventborne product samples (where all samples were <MLOQ), the statistical analysis was confounded by the fact that 62% of the waterborne samples were also <MLOQ. This finding likely reflects the heterogeneity in the chemical composition of waterborne basecoats, as discussed previously.

One limitation of the logrank test is that it does not account for the potential correlation of multiple samples within the same shop. Consequently, the p-values may be anti-conservative (i.e., the p-values indicate that differences appear to be more statistically significant than they would be if the analysis accounted for statistical dependence).


Petroleum distillates
Concentration (ppm)
0
10
20
S
W


Benzene
Concentration (ppm)
0.05
0.10
0.15
0.20
S
W


Toluene
Concentration (ppm)
0
5
10
15
S
W


Ethylbenzene
Concentration (ppm)
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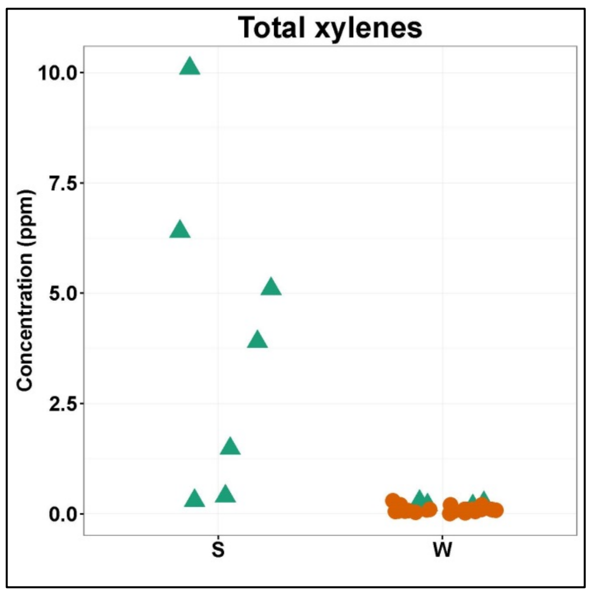
0.5
1.0
1.5
2.0
S
W


Total xylenes
Concentration (ppm)
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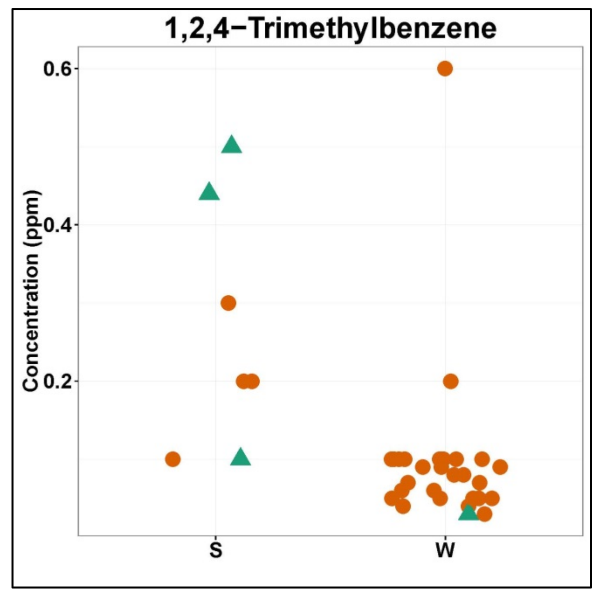
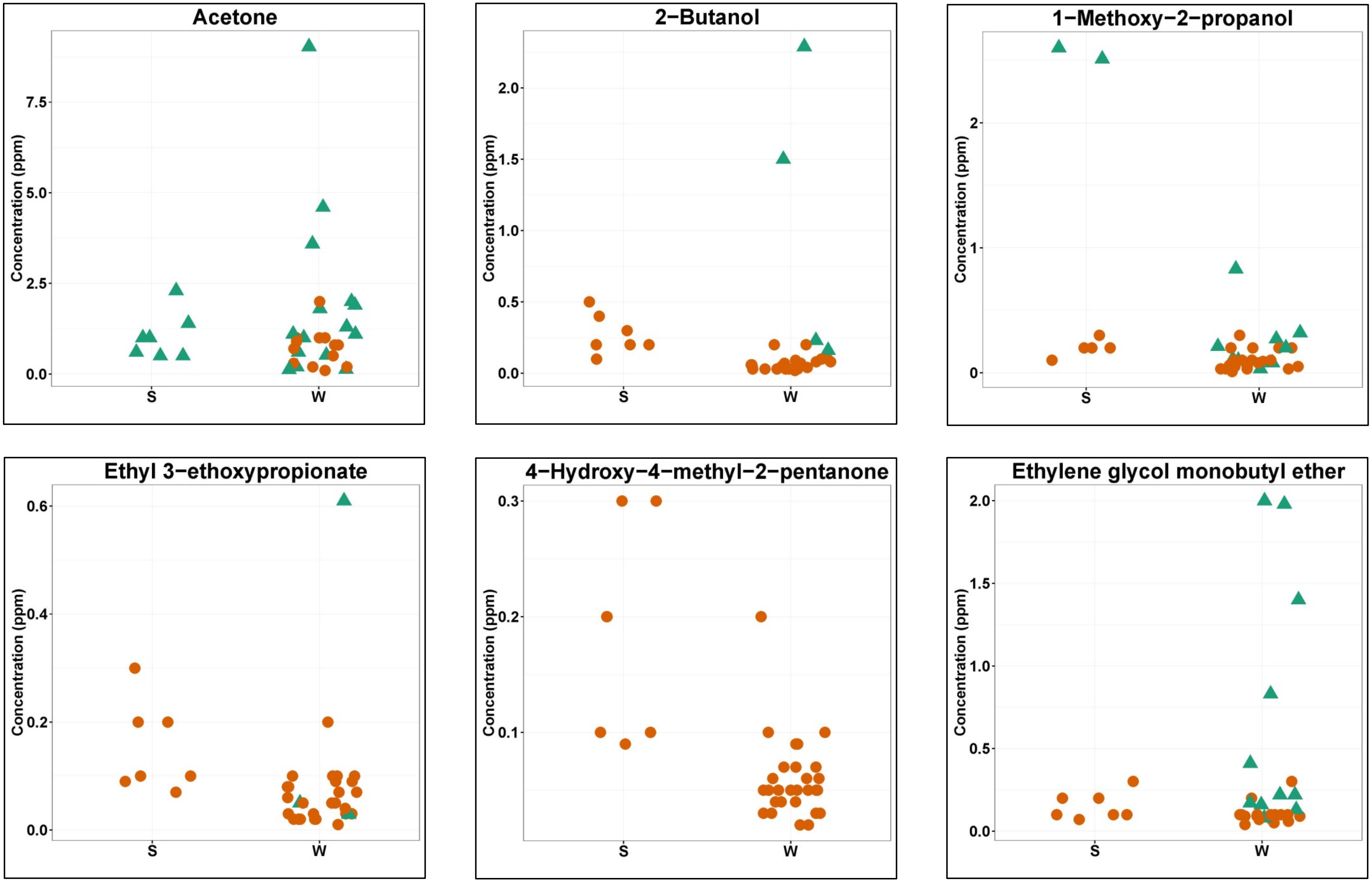
2.5
5.0
7.5
10.0
S
W


1,2,4−Trimethylbenzene
Concentration (ppm)
0.2
0.4
0.6
S
W


Acetone
Concentration (ppm)
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2.5
5.0
7.5
S
W
2−Butanol
Concentration (ppm)
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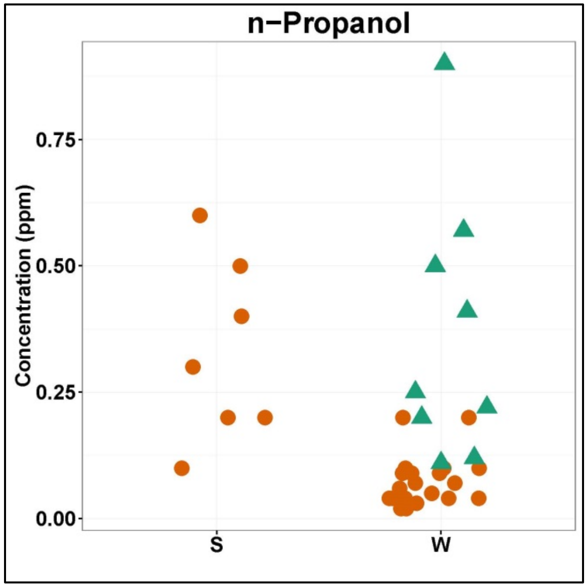
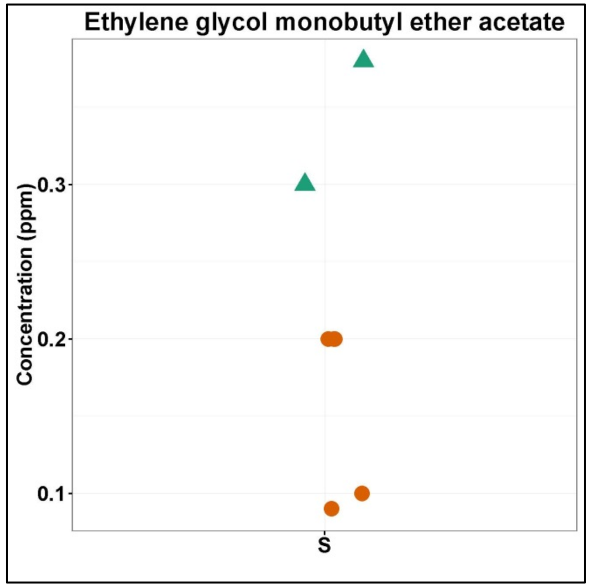
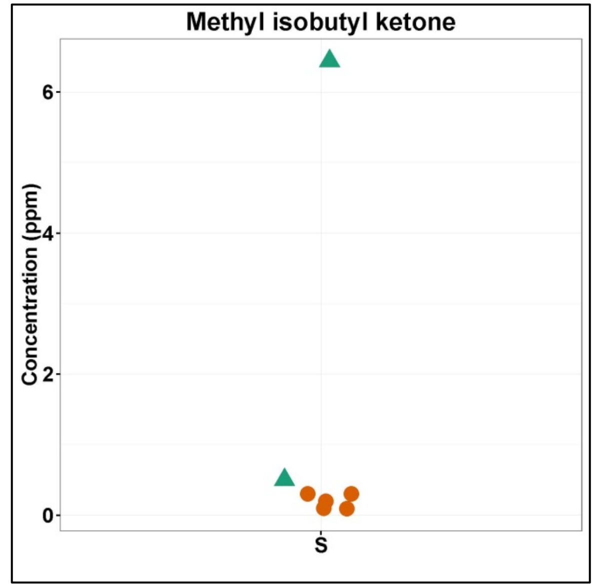
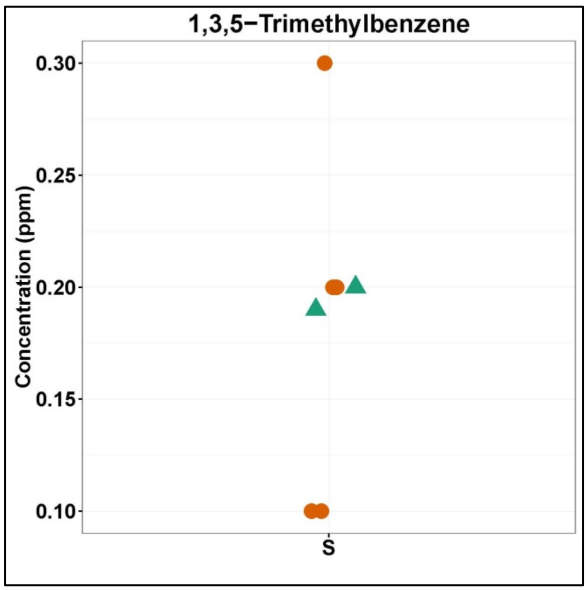
0.5
1.0
1.5
2.0
S
W
1−Methoxy−2−propanol
Concentration (ppm)
0
1
2
S
W
Ethyl 3−ethoxypropionate
Concentration (ppm)
0.0
0.2
0.4
0.6
S
W
4−Hydroxy−4−methyl−2−pentanone
Concentration (ppm)
0.1
0.2
0.3
S
W
Ethylene glycol monobutyl ether
Concentration (ppm)
0.0
0.5
1.0
1.5
2.0
S
W









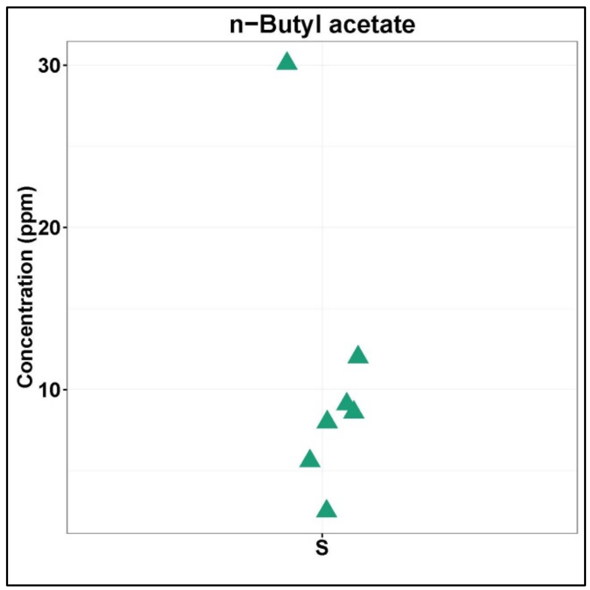


Figure 9: Dot plots of air concentrations

Key:

Green triangles = measured concentrations (i.e., >MLOQ)

Orange dots = Concentration <MLOQ

S = Solventborne basecoats

W = Waterborne basecoats

Where:

29 samples collected from 10 waterborne shops

7 samples collected from 3 solventborne shops

TLV fractions for basecoat analytes

The American Conference of Governmental Industrial Hygienists (ACGIH) has established professional best practice guidelines for occupational exposures called Threshold Limit Values (TLVs).[27,28] ACGIH TLVs are non-regulatory guidelines based on current research. ACGIH has developed time-weighted average TLVs (TLV-TWA) reflecting concentrations that nearly all workers may be repeatedly exposed to for 8-hour workdays and 40-hour workweeks without adverse health effects. In addition, 15-minute Short-Term Exposure Limit TLVs (TLV-STEL) have been established for substances with the potential to exert acute effects, such as irritation or narcosis.

TLV-TWAs are available for all the analytes included in this study, with the exception of petroleum distillates and ethyl-3-ethoxypropionate. TLV-STELs have been established for benzene, xylene, acetone, methyl isobutyl ketone, n-butyl acetate, and 1-methoxy-2-propanol. For petroleum distillates, Washington state's Division of Occupational Safety and Health's (DOSH's) permissible exposure limits were used.[29]

TLV fractions were calculated by dividing the analytes' median air concentrations by their respective TLVs. This was done for both 8-hour TLV-TWAs and 15-minute TLV-STELs. A TLV fraction greater than or equal to one indicates exceedance of the TLV.

TLV-TWA fraction

Direct comparison between exposure results and 8-hour TLV-TWAs was not appropriate because samples were of short duration (i.e., the sampling periods were not representative of the painters' tasks for their entire 8-hour shift, which may include considerable time not painting, and use of other products of varying chemical composition). However, the 8-hour TLV-TWA fraction may be used to compare exposures during spraying of different basecoats and to provide some context for health relevance.

Table 7 presents the TLV fractions for analytes with TLV-TWAs for which median air concentrations could be calculated. The TLV-TWA fractions for basecoat spraying tasks were below 0.1 for all analytes. The highest TLV-TWA fraction was 0.088, for petroleum distillates in solventborne samples. Where analytes were detected in both solventborne and waterborne air samples, the TLV-TWA fractions were consistently higher in solventborne air samples.

TLV-STEL fraction

The average sample duration in this study was 15 minutes; consequently, the median air concentrations are more suited to comparison with TLV-STELs. Table 8 presents the TLV fractions for analytes with TLV-STELs for which median air concentrations could be calculated. The TLV-STEL fractions for basecoat spraying tasks were below 0.1 for all analytes. The highest TLV-STEL fraction was 0.058, for petroleum distillates in solventborne samples. Where analytes were detected in both solventborne and waterborne air samples (i.e., petroleum distillates and acetone), the TLV-STEL fractions were higher in solventborne air samples.

Table 7: TLV-TWA fractions for basecoat analytes

Analyte	TWA-TLV (ppm)	Basecoat Type	Median Air Concentration (ppm)*	TWA-TLV Fraction
Petroleum distillates**	100***	Solventborne	8.77	**0.088**
		Waterborne	0.39	0.0039
Toluene	20	Solventborne	0.70	**0.035**
		Waterborne	0.16	0.008
Ethylbenzene	20	Solventborne	0.30	0.015
		Waterborne	NE	NE
Total xylenes	100	Solventborne	3.90	0.039
		Waterborne	NE	NE
1,2,4-Trimethylbenzene	25	Solventborne	0.10	**0.004**
		Waterborne	0.03	0.0012
Acetone	250	Solventborne	1.00	**0.004**
		Waterborne	0.52	0.0021
n-Butyl acetate	150	Solventborne	8.60	0.057
		Not analyzed	--	--

*Median estimated from the Kaplan-Meier curve
**Petroleum distillates include all peaks minus those for non-polar target analytes
***DOSH Permissible Exposure Limit
NE = not estimable
Bold underlined values are the highest TWA-TLV fractions in the solventborne vs. waterborne comparison

Table 8: TLV-STEL fractions for basecoat analytes

Analyte	STEL-TLV (ppm)	Basecoat Type	Median Air Concentration (ppm)*	TWA-STEL Fraction
Petroleum distillates**	150***	Solventborne	8.77	**0.058**
		Waterborne	0.39	0.0026
Total xylenes	150	Solventborne	3.90	0.026
		Waterborne	NE	NE
Acetone	500	Solventborne	1.00	**0.002**
		Waterborne	0.52	0.0010
n-Butyl acetate	200	Solventborne	8.6	0.043
		Not analyzed	--	--

*Median estimated from the Kaplan-Meier curve
**Petroleum distillates include all peaks minus those for non-polar target analytes
***DOSH Permissible Exposure Limit
NE = not estimable
Bold underlined values are the highest TWA-STEL fractions in the solventborne vs. waterborne comparison

Hazards associated with mixtures

ACGIH also provides guidance for assessing potential health hazards when workers are exposed to mixtures of substances. The ACGIH formula uses an additive model, which sums the health effects of individual analytes with similar toxicological endpoints. If the total is greater than or equal to one, then the threshold limit of the mixture has been exceeded. This additive mixture formula can be used for full-shift exposures to substances with TLV-TWAs or for short-term exposures to substances with TLV-STELs.

Health endpoints were identified using ACGIH's "Documentation of the TLVs and BEIs," and the mixture formula was used to evaluate the most common health endpoints: irritation and central nervous system (CNS) effects. For irritation effects, separate calculations were completed for analytes with TLV-TWAs and those with TLV-STELs. Analytes in the CNS effects calculations had only TLV-TWAs. Table 9 presents the analytes used in the mixture calculations.

Table 9: Analytes included in TLV mixture calculations

Health endpoint	Analytes
Irritation – short term	xylene, acetone, methyl isobutyl ketone, n-butyl acetate, 1-methoxy-2-propanol
Irritation – full shift	ethylbenzene, 1,2,4- and 1,3,5- trimethylbenzene, xylenes, acetone, methyl isobutyl ketone, 2-butanol, n-butyl acetate, 1-methoxy-2-propanol, 4-hydroxy-4-methyl-2-pentanone, ethylene glycol monobutyl ether, n-propanol
CNS effects	toluene, ethylbenzene, 1,2,4- and 1,3,5- trimethylbenzene, methyl isobutyl ketone, xylene, 1-methoxy-2-propanol

Table 10 presents the TLV mixture fractions. The mixture fractions for all health endpoints were less than one for all samples, indicating no exceedances of mixture threshold limits. The median mixture fractions were consistently higher in solventborne air samples than waterborne air samples.

Table 10: TLV mixture fractions

Health endpoint	Time period	Basecoat type	Median TLV mixture fraction
Irritation	Short term	Solventborne	**0.09**
		Waterborne	0.001
Irritation	Full shift	Solventborne	**0.19**
		Waterborne	0.01
CNS effects	Full shift	Solventborne	**0.23**
		Waterborne	0.01

Bold underlined values are the highest Median TLV mixture fractions in the solventborne vs. waterborne comparison

Strengths and limitations of the exposure assessment

To our knowledge, this is the first study to compare exposures to solventborne and waterborne basecoats using the same sampling methods. This assessment was informed by reviewing SDSs of waterborne and solventborne products that are currently being used in King County, Washington, so that the most important analytes were included in the study.

However, we recognize the following limitations of this assessment:

- This study focused solely on painters' personal breathing zone exposures while they sprayed basecoats. However, painters may also be exposed to solvents and other hazardous chemicals when they prepare vehicles for painting, mix paints, clean paint guns, handle wastes, etc. Painters who use waterborne basecoats also routinely apply solvent-based primers, clearcoats, and other products. Consequently, the full-shift exposures experienced by painters are likely significantly greater than indicated in this study. Our assessment also did not consider dermal exposures, although we observed considerable potential for skin contact when painters did not wear gloves and coveralls throughout the painting process.

- None of the shops evaluated in this study used both waterborne and solventborne basecoats, as is typical in the industry. Consequently, it was not possible to compare exposures for these two product types in the same painter and shop.

- The selection of analytes relied upon information provided on SDSs of representative products. Consequently, the completeness of the exposure assessment was dependent upon the accuracy of information provided by the products' manufacturers.

- Although painters were instructed to inform us before they applied products other than basecoats or cleaned their paint guns, some air samples may have been contaminated with other products. This was illustrated in the shop that used waterborne basecoats but had the highest detected concentration of toluene. In this case, we noted that the painter sprayed a product of unknown composition on a door panel while the sampling pump was running. However, we may not have been aware of other instances of cross-contamination during the painting process.

Conclusions

Airborne exposures to all non-polar analytes were statistically significantly higher in the personal breathing zones of painters using solventborne basecoats compared to waterborne basecoats (except for benzene, which was not detected in any air samples). It is notable that the median airborne concentration of petroleum distillates in solventborne samples was 22-times higher than the median concentration in waterborne samples.

Although these task-based personal breathing zone concentrations were much lower than the TLVs for all analytes, we conclude that solventborne products still pose a greater risk to workers because there are opportunities for exposure via additional exposure routes (especially dermal). In addition, many of these non-polar solvents are known to be carcinogenic and cause other adverse human health effects, like irritation and CNS effects.

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PERFORMANCE MODULE

Introduction

This module reviews the performance characteristics of solventborne vs. waterborne basecoats. The critical performance factors for automobile coatings are (a) aesthetic characteristics; (b) corrosion protection; (c) market availability; (d) cost and environmental requirements; and (e) appearance and durability.[(30)] Cost and mass production (i.e., auto body shop productivity) are addressed in the Cost Evaluation module.

No research studies were found comparing the performance of waterborne versus solventborne basecoats. Therefore, the cited references for this module are articles written by body shop professionals located across the United Sates in addition to the experiences of King County auto body shop staff, which we gathered via interviews.

Waterborne basecoats appear to have various advantages compared to solventborne products. One advantage is that less waterborne paint is needed to provide the required coverage.[(31)] Customers have also reported that waterborne coatings are more chip-resistant and less brittle than solventborne coatings.[(32)] At least one shop owner considers waterborne paints to be more durable than solventborne paints,[(33)] although another suggested that "as a general rule, waterborne automotive paints will typically not be quite as durable as a solventborne alternative."[(34)]

Metallic paints can be challenging to spray because the suspended particles are difficult to control and may lay on the surface unevenly, giving an undesirable appearance. Painters using waterborne basecoats report that the metallic particles lay on the surface flatter and dry at a more even pace than solventborne products.[(35)]

A BASF representative suggested that waterborne basecoat technology is the better choice for approximately 80 percent of shops, because of its of high quality and superior color-matching. However, he suggested that low-VOC solvent-based technologies remain ideal for mobile repair businesses and custom or restoration shops.[(36)] Because mobile painters often work in relatively uncontrolled areas with exposure to weather and airborne particulates, solventborne products are reportedly easier to use under these conditions. For custom and restoration shops, solvent basecoats are reportedly easier to use when graphics and stripes are involved.

Interviews with industry experts concerning performance

From May through October 2016, LHWMP staff interviewed King County auto body paint distributors, manufacturers, and auto body shop personnel - either in-person or via telephone.[(37)]

We learned that approximately 50 percent of the auto body shops in King County are using waterborne basecoats.[(37)] The fact that about half the shops are using these products helps support the conclusion that many in the industry believe that waterborne products are at least comparable in performance to solventborne basecoats.

Interviews with distributors and manufacturers

Table E-1 (see Appendix E) summarizes the answers from a question asked about auto body paint performance from interviews with eight distributors and manufacturers. At least one representative from all known King County distributors/manufacturers was interviewed. Of these distributors/manufacturers, all sold waterborne and solventborne basecoats except for Distributor #5.

Except for Distributor #5, the distributors/manufacturers believed that the performance of waterborne paint products is superior. Distributor #5 did not sell waterborne basecoats because he believed that waterborne coatings were less productive than solventborne coatings. This individual believed that low-VOC solventborne products were the best option because they meet VOC emission standards and shops would not be required to expend resources to convert to waterborne products.

Distributor #6, a PPG "Platinum" distributor, stated that PPG's waterborne products outperform their solventborne products. It was also suggested by the same distributor that AkzoNobel and Valspar (DeBeer) waterborne products outperform their solventborne counterparts.

Interviews with body shop staff who use waterborne basecoats

Table E-2 summarizes interviews with auto body shop personnel who were using waterborne basecoats at 11 different shops. Seven of the shops responded to a specific performance interview question and four mentioned performance as part of an answer to another question.

Reviewing the answers in Table E-2 to the question, *Regarding cost, availability, and performance, how do waterborne paint systems compare to solvent systems?*, the respondents generally regarded waterborne paint system performance to be superior to solventborne. Better color matching (at least for 2005 or newer cars), ease of fixing mistakes, less hazardous waste generated, and less environmental and health impacts were mentioned in support of better waterborne basecoat performance. The better color matching comments are not surprising since most automotive manufacturers currently use waterborne basecoats in their production process (with the notable exception of Ford Motor Company).[38,39] One shop expressed concerns about the 10-15-year performance of waterborne products, since they have seen two clearcoats peel. The interviewee believes this may be due to the application of a solventborne clearcoat over a waterborne basecoat. Another interviewee suggested that waterborne products highlight imperfections in older vehicles.

Interviews with body shop staff who use solventborne basecoats

Table E-3 summarizes opinions about waterborne basecoat performance, cost, and availability from auto body shop personnel from 12 shops that had not switched to waterborne basecoats.

These shops expressed concerns about waterborne basecoat performance, although the basis for many of these concerns is unclear and may simply reflect a resistance to change or lack of familiarity with the products. Only one shop had tried using waterborne paint. Four shops mentioned concerns that the waterborne basecoat layer, which is applied between coatings of solventborne primer and clearcoat, may not form a permanent bond with the other coatings. There was also skepticism as to whether waterborne basecoats significantly reduced overall VOC emissions, given that the primer and clearcoat are still solventborne. Four shops mentioned that solventborne basecoats provide superior color matching when painting older cars. Three shops were concerned that waterborne basecoats take longer to dry.

Conclusions

Although the Performance Evaluation module was informed by interviews with a limited number of industry contacts, we conclude that waterborne basecoats have some performance advantages over solventborne basecoats. They offer the advantage of meeting VOC regulations and providing superior color matching, particularly for newer vehicles. Waterborne basecoat performance advantages for factors such as aesthetics, corrosion protection, appearance and durability appear less compelling.

It is important to recognize that several variables can affect waterborne coating performance. Some of the variables that may influence the opinions of shop owners or painters, include:

- Shop cleanliness;
- Availability of sufficient clean, oil-free, dry air;
- Quality of the basecoat product;
- Quality of the painting equipment, including the paint booth;
- Sufficient investment in drying equipment;
- Age of the vehicles being painted;
- Performing complete vehicle or partial vehicle paint jobs, and
- Level of employee commitment and training.

Shop cleanliness and having sufficient clean dry air are two variables mentioned during our shop staff and distributor interviews as being particularly important for waterborne basecoat success.[(37)]

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COST MODULE

Introduction

For most auto body shops, cost is an important factor in any decision-making. The cost associated with an automotive paint system includes the cost of paint, equipment, materials, energy, painter training, and waste management. There may also be infrastructure costs associated with switching from one paint technology to another. This module provides a cost comparison between using solventborne and waterborne basecoats. Although Version 1.0 of IC2's *Alternatives Assessment Guide* combines cost and availability,[(2)] these modules were considered separately in this document to simplify discussion.

The most recent detailed cost analysis comparing waterborne and solventborne basecoats we identified was a 2008 report published by the Institute for Research and Technical Assistance (IRTA). IRTA evaluated the conversion to waterborne basecoats for two auto body shops within California's SCAQMD.[(40)] In one shop, the cost of using waterborne coatings was somewhat higher than that for solventborne basecoats. The cost analysis of the second shop indicated comparable costs.

The EPA's Design for the Environment (DfE) Auto Refinishing Project also published a case study in 2008, which highlighted the experience of Visser's Collision Center in Chicago. This shop switched to waterborne basecoats in 2005. While waterborne basecoats were reportedly more expensive than traditional solvent basecoats, this shop reported that the cost was offset by a decrease in the volume of paint they were required to purchase because fewer coats were needed per job. The application of fewer coats resulted in increased worker productivity and more jobs completed per week.[(32)] A shop in Anchorage, Alaska that switched in 2007 saw a 20 percent increase in throughput, which made them more profitable, even after accounting for the additional expense of waterborne paints.[(41)] Reduced energy consumption after switching to waterborne paints has also been observed.[(42)]

There is some evidence that using waterborne basecoats can reduce insurance premiums for the body shop. One shop's premiums were reduced after switching to waterborne basecoats, likely because waterborne products are less flammable and thus less of a fire hazard.[(32)] However, interviews conducted in 2013 at four King County, WA shops using waterborne coatings revealed that none had seen a reduction in their insurance rates.[(43)]

Due to variables like the current state of the shop and the variety of products available on the market, it is difficult to generalize about the cost to transition shops from solventborne to waterborne basecoat systems.

Internet searches suggest that the cost to switch to waterborne products depends largely on the condition of the shop. Those that are already equipped with corrosion-resistant stainless steel HVLP paint guns, functional paint booths, and other modern equipment will experience a fairly inexpensive transition — approximately a few thousand dollars or less.[(44)] However, most shops need to invest in paint booth air driers and associated equipment because of the importance of having sufficient clean, dry air. Shops may also need to purchase a more powerful air compressor, new paint guns, waterborne paint gun washers, and air filtration systems. One owner noted that because his shop is housed in an older building, he needed to replace air compressors, air lines, the paint booth, etc. He stated that mediocre equipment cannot be used with waterborne products.(44)

IRTA published a case study that reported the cost incurred by one small shop (75 cars per month) when it switched to waterborne basecoats. Comparing the costs three months before and after conversion, they found that the total cost of using a waterborne basecoat was three percent lower than using a solventborne basecoat.(40)

An interview with a modern shop in Oregon revealed that the only purchases required to switch to waterborne basecoats, were two hand-held air dryers (~$80/each), a paint gun dedicated to waterborne products (~$700-900), waterborne-compatible consumables (~$100-500), and a waterborne gun washer ($1500+).(45)

In a 2015 LHWMP study of King County, WA auto body shops, we found that most shops used corner-mounted as well as hand held multipliers for drying waterborne basecoats.(46)

Although various supplies used for car painting, such as tack cloths, painter strainers, and masking tapes and papers differ depending on whether solvent or waterborne basecoats are being sprayed, the cost for these supplies is equivalent.(35)

Interviews with industry experts concerning costs

During May through October 2016, we interviewed auto body paint distributors, manufacturers, and auto body shop personnel either in-person or via telephone.(37)

We learned that approximately 50 percent of the auto body shops in King County are using waterborne basecoats.(37) Since cost is an important consideration for businesses, the finding that approximately 50 percent of shops are using waterborne basecoat systems helps support the conclusion that many in the industry believe that waterborne systems are at least comparable in cost to solvent systems.

We also learned from many interviewees the importance of clean, dry air for painting with waterborne basecoats.(37) As stated previously, depending on the shop's current equipment, the shop may have to upgrade its compressor, which could impact cost.

Interviews with distributors and manufacturers

Table E-1 (see Appendix E) summarizes the answers from a question asked about auto body paint cost (cost column) from eight interviews with distributors and manufacturers. At least one representative from all known King County distributors/manufacturers was interviewed.

Reviewing the answers from the eight distributors/manufacturers in Table E-1 (cost column), five interviewees said that waterborne basecoats are “a little” more expensive to up to 25 percent more expensive to buy than solvent basecoats; one said they are about the same; one stated that waterborne basecoats are the same or slightly less; and one stated they are the same or at the most 10 percent more. Two interviewees added that although waterborne basecoats tend to be more expensive per ounce than solvent basecoats, they are cheaper to use since fewer coats are required.

Interviews with body shop staff who use waterborne basecoats

Table E-2 (see Appendix E) summarizes interviews with auto body shop personnel working at 11 different shops that currently use waterborne basecoats. Six of the shops mentioned cost in their response.

Reviewing the answers in Table E-2 (i.e., auto body shops that have already switched to waterborne basecoat products) most shops mentioned that waterborne basecoats cost more to purchase, but some shops added that less paint is needed, so the cost of painting a vehicle is not greater overall.

Interviews with body shop staff who use solventborne basecoats

Table E-3 (see Appendix E) summarizes opinions and concerns about waterborne basecoat performance/cost/availability from auto body shop personnel who have not switched to waterborne basecoats. Answers from 12 shops are included in Table E-3.

The shops that have not switched to waterborne basecoats (Table E-3), did not generally mention concerns about product costs. Two shops mentioned product cost and that waterborne products appear to be more expensive than solvent basecoats. Some shops mentioned the conversion cost and the need to replace or upgrade their spray booth.

Conclusions

Although the Cost Evaluation module was informed by interviews with a limited number of industry contacts, we conclude from these interviews and the literature the following about the costs associated with solventborne vs. waterborne basecoats:

- For most if not all shops, there will be an initial cost associated with switching from solventborne to waterborne basecoats, ranging from $2000 to as high as $100,000 if a new paint booth is required.[37]
- Waterborne basecoat products typically cost more per ounce than solventborne products of comparable quality. Pricing may vary based on painter and distributor agreements
- Once conversion to waterborne basecoat paint system has occurred, the overall cost of using waterborne basecoats does not appear to be substantially different than using solventborne basecoats because less paint (fewer coats) is needed for painting.

- Conversion to waterborne basecoat products from solvent products can result in increased shop productivity.

AVAILABILITY MODULE

Introduction

This module compares the availability of waterborne and solventborne automotive basecoats in King County, WA.

Interviews with industry experts concerning availability

From May through October 2016, we interviewed auto body paint distributors, manufacturers, and auto body shop personnel either in-person or via telephone.[37]

We learned that approximately 50 percent of the auto body shops in King County are using waterborne basecoats.[37] The fact that about half the shops are using waterborne basecoats indicates that waterborne basecoat products are available in King County.

Interviews with distributors and manufacturers

Table E-1 (see Appendix E) summarizes the answers from a question asked about auto body paint availability. Eight distributor interviews were conducted. At least one representative from all known King County distributors/manufacturers were interviewed.

Reviewing the answers from the eight distributors/manufacturers in Table E-1 (availability column), six of the distributors said that solvent and waterborne basecoats were equally available. One distributor who did not sell waterborne basecoat products did not answer the question. Shortly after the interview, this distributor told us that he added a waterborne basecoat product to his inventory.

The PPG manufacturer training center representative answered the question by pointing out that not all shops are large enough to have a stirring mixing bank. These automatic stirring systems are required for all solvent paints and some waterborne paints. For this reason, smaller shops will not be able to use waterborne paint brands that require a stirring mixing bank. In addition, most distributors will not mix waterborne basecoats for over the counter clients (typically for smaller shops and mobile painters). One distributor said they would mix small quantities of PPG waterborne paint for shops.

Interviews with body shop staff who use waterborne basecoats

Table E-2 (see Appendix E) summarizes interviews with auto body shop personnel working at 11 different shops that currently use waterborne basecoats. Only one of the 11 shops interviewed answered the availability question. This one shop that uses PPG Envirobase said that they believe waterborne basecoats are more available than solvent basecoats because of the investments that have been made by the paint manufacturers into waterborne paint systems.

Interviews with body shop staff who use solventborne basecoats

Table E-3 (see Appendix E) summarizes opinions and concerns from personnel from 12 auto body shops about waterborne basecoat performance/cost/availability. None of the shops specifically mentioned availability in their answer.

Conclusions

Although the Availability module was informed by interviews with a limited number of industry contacts, we conclude that a variety of waterborne basecoat products are available at about the same ease of availability as solventborne basecoat products in King County, WA. However, exceptions include shops that are not equipped with stirring mixing systems or depend on having their basecoats mixed by a distributor.

SOCIAL IMPACT MODULE

Introduction

Social impact is defined as *the effect an organization's actions have on the well-being of the community*.[47] Because all of LHWMP's work is conducted using an equity and social justice lens, we considered it important to include this optional module in the alternatives assessment. This module compares the worker, community, and global impact of waterborne and solventborne basecoat systems.

Social impact findings

Information was gathered via interviews conducted with King County industry experts in 2016 and 2017,[37] data collected by previous LHWMP auto body projects[3,6,43,46,48], and the combined knowledge of the authors of this alternatives assessment. Using templates provided in IC2's Alternatives Assessment Guide version 1.0,[2] the findings for this module are found in Appendix F.

Worker perspective

From a worker's standpoint, waterborne basecoats appear to be safer than solventborne basecoats because of the lower concentrations of harmful organic solvents in the worker's breathing zones and the resulting waste streams. This conclusion is based on the information in Table F-1 (see Appendix F) and the Hazard and Exposure modules in this alternatives assessment. Despite lower concentrations of odoriferous volatile organic solvents in waterborne basecoats, it is still important for workers to use the appropriate personal protective equipment. However, it is important to consider that applying basecoats is only one step in the painting process. Because waterborne versions of these products have not yet been perfected, body shops still use solventborne primers and clearcoats. Nonetheless, the use of waterborne basecoats is likely to improve the safety of the auto body painting process since waterborne basecoats represent a significant fraction of the total sprayed product. In addition, shops that have switched to waterborne basecoats will also likely find it easier to use waterborne primers and clear coats when they become more readily available.

Limited data was found in the literature that demonstrates health impacts experienced by auto body shop workers from VOCs and other hazardous chemicals used in auto body basecoats products. A 2016 study concluded that occupation exposure as a car spray painter was associated with DNA damage and development of cancer.[49] Another study published in 2018 demonstrated that the use of appropriate PPE and good workplace hygiene were associated with reduced risk of symptoms of neurotoxicity in solvent-exposed vehicle spray painters.[50] A Taiwanese study concluded that waterborne paints reduce the exposure potential to lead and other toxic metals (except copper).[51] Information is available showing health impacts from VOC exposures to workers in other occupations.[52,53]

Despite limited data, from a precautionary perspective, Table F-1 clearly demonstrates that waterborne products have several social impact advantages over solventborne basecoats. One advantage that solventborne basecoats may have from a worker perspective is avoidance of emotional stress that sometimes accompanies changing to a new technology. This stress may be greatest for older workers who have spent their entire career spraying solventborne basecoats.

Another possible social impact may be financial stress to workers in shops that would like to switch to waterborne basecoats, but would need to borrow money to do so. As more shops switch to waterborne basecoat products, there may be a time when solventborne basecoat products become less available and consequently costlier, due to lower demand. Shops that do not switch with the rest of the industry may feel financial stress and eventually go out of business, resulting in job loss.

Community and Global.

Appendix F Tables F-2 and F-3 outline community and global social impacts. One of the primary social impacts from auto body paints can be ground level ozone formation (i.e., photochemical smog). Ozone forms when atmospheric nitrogen oxides react with VOCs in the presence of sunlight.(54) High-VOC solventborne auto body basecoat products contain photoreactive solvents.

The impact from photochemical smog varies by geographic location and climatic conditions. As of June 30, 2018, no counties in Washington state were regarded as ozone nonattainment areas.(55) However, two areas are regarded by Ecology as "problem areas" for ozone: the western foothills of the Cascade Mountains and the Tri-Cities area (Kennewick, Pasco, and Richland).(56) Some areas in the United States have passed regulations requiring auto body shops to use low VOC basecoats to reduce photochemical smog formation. To date, no jurisdictions in Washington state have passed such regulations.

On a community level, odors from auto body shops using solventborne basecoats could impact local neighborhoods. A 2016 study of San Diego County air compliance records indicated that more than 10 percent (224 out of 2,100) of air complaints from January 2013 – April 2016 cited auto and truck painting.(57) Significantly fewer complaints were recorded in King County. In late January 2017, complaint data was received from the Puget Sound Clean Air Agency (PSCAA). Reviewing the last three years of data, about 12 odor complaints were reported to PSCAA each year. The specifics of the complaints were difficult to determine, but it appeared that many concerned unlicensed auto body operations. We conclude that community impacts from solvent odor from auto body shops do not appear to be a significant problem in King County.

Based on information in the Hazard Module, solventborne basecoats contain more hazardous chemicals than do waterborne products. The health and environmental impacts from these chemicals have not be clearly described in the literature, but we surmise that solventborne basecoats would have greater community and global health and environmental impacts than waterborne products.

Community financial impacts could possibly occur if shops, particularly those in economically disadvantaged areas, switch to waterborne basecoats, and increase their prices to cover the costs involved to switch.

Conclusions

The two potential impacts of switching from solventborne to waterborne basecoats are worker emotional stress and supply-and-demand financial impacts to shops that do not switch. Despite these potential impacts, the worker, community, and global social impacts from waterborne basecoats appear to be less than those associated with solventborne basecoats. Some expected impacts from using waterborne basecoats include: include lower worker and community exposure to VOCs, reduced VOC release and smog formation, reduced potential for generation of and exposure to hazardous waste, and reduced exposures to workers and nearby community residents.

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WASTE MANAGEMENT MODULE

Introduction

Waste Management is not a required module in the IC2's Alternatives Assessment Guide version 1.0.[(2)]. For this module the term "waste management" includes both waste generation and disposal. An important aspect of waste management is whether the waste is regarded as a dangerous waste. In Washington state, the term "dangerous waste" is used in lieu of "hazardous wastes":

- "Hazardous waste" refers to solid waste designated by the federal government under 40 Code of Federal Regulations Part 261.
- "Dangerous waste" refers to solid waste designated as dangerous by Washington state under Washington Administrative Code 173-303-070 through 173-303-100.

Washington state further divides all federal and "state-only" dangerous wastes into two categories: Dangerous Waste (DW) and Extremely Hazardous Waste (EHW).

The process of determining whether a waste is regulated under the dangerous waste regulations is called designation. If waste is designated as dangerous, waste codes are applied to indicate the type of waste. Federal waste codes begin with F, K, P, U, or D codes and those specific to Washington state (i.e., Washington state-only) begin with W. Wastes can have more than one code. Washington state only waste codes are:

- WP01—Persistent dangerous wastes, halogenated organic compounds (EHW).
- WP02—Persistent dangerous wastes, halogenated organic compounds (DW).
- WP03—Persistent dangerous wastes, polycyclic aromatic hydrocarbons (EHW).
- WPCB—Wastes that designate as state-specific PCB sources (DW).
- WT01—Toxic dangerous waste, extremely hazardous (EHW).
- WT02—Toxic dangerous waste (DW).
- WSC2—Solid or semi-solid corrosive waste (DW).

If a waste is designated as dangerous, it can have an impact on a facilities management requirements and costs. More information can be found in the *Dangerous Waste Regulations*, Washington Administrative Code Chapter 173-303.[(58)]

Whether a waste is a dangerous waste impacts management costs and health and environmental impacts from mismanagement. Regarding auto body spray painting waste generation, waste is generated during vehicle preparation as well as the painting process. Paint-related waste includes:

- Paint gun cleaning waste
- Leftover paint
- Used paint booth filters and masking tape/paper contaminated with overspray during spray painting.

A more comprehensive list of common wastes generated in auto body shops is described by the Washington State Department of Ecology.[59]

The types of waste generated by solventborne and waterborne basecoat shops are similar, although the quantities may differ. The paint manufacturer, PPG, asserts that waterborne products generate up to 75% less hazardous waste than is typical for solventborne basecoats.[60]

Waste management findings

Waste management was occasionally mentioned during our interviews with industry experts. One shop representative stated that they have "better" waste management now they are using waterborne products. A solventborne shop mentioned that using waterborne basecoats would require them to manage two different waste streams (solventborne and waterborne), as well as two different paint gun cleaner waste streams. This individual indicated that it would not be worth the trouble switching to waterborne basecoats because of the challenges associated with managing two waste streams.

Data regarding waste was also collected during an LHWMP field project in 2014-2015.[6] Two conclusions from the project report are pertinent to this module:

1. Although none of the waste samples collected from waterborne shops exceeded the state-only criteria for persistence, the results from two samples were close to the regulatory benchmark of 100 ppm. Wastes from the sampled shops could fail the state-only persistence criteria if a higher proportion of basecoats that contain chlorinated pigments were used in the future. Based on our assessment of basecoat chemicals (see Hazard Module and Appendix A), chlorinated pigments appear to be the only source of persistence.

2. Procedures for disposing of waterborne coating wastes varied between shops. Some shops were disposing of their waterborne paint wastes in violation of Washington state's dangerous waste regulations.

These conclusions were used as the basis for a waterborne painting waste management flyer (see Appendix G). Of importance to this discussion is the fact that although waste from waterborne basecoat products has a lower organic solvent content than solventborne basecoats, they still may be regarded as dangerous waste in Washington state because of the presence of halogenated organic compounds (from chlorinated pigments associated with certain paint colors).

Conclusions

Detailed data documenting waste amounts and types for waterborne versus solventborne automotive painting is not currently available. Although there are indications that the waste associated with waterborne products may not be regarded as hazardous waste, halogenated organic pigments may cause some waterborne wastes to exceed the state-only criteria for persistence.

ALTERNATIVES ASSESSMENT SUMMARY

Hazard

Waterborne basecoats and the paint gun cleaners used with this product class contain many fewer hazardous ingredients and at lower concentrations than their high-VOC solventborne counterparts. A brief review of the hazards associated with low-VOC solventborne basecoats revealed that they offered no advantages over the high-VOC solventborne basecoats that were the focus of this study.

Exposure

Although no painter exposures exceeded occupational exposure limits, the breathing zone concentrations of non-polar analytes were significantly lower when painters sprayed waterborne products. Of particular note was the finding that the median airborne concentration of petroleum distillates in solventborne samples was 22-times higher than the median concentration in waterborne samples.

Performance

Waterborne basecoats can offer some performance advantages over solventborne products, especially in terms of color matching in newer vehicles.

Cost

The cost question is complicated by the condition of the body shop prior to conversion. Some shops do not currently have the infrastructure, equipment, or work practices necessary for a straightforward conversion. Therefore, costs can vary greatly, depending on the amount of additional equipment, supplies, and training needed to successfully adopt waterborne technology. Once converted, however, the cost of using waterborne basecoats appear to be similar.

Availability

Waterborne products are readily available in King County, as evidenced by the finding that 50 percent or more of local shops are currently using waterborne basecoats and they are available from all distributors.

Social Impact

Advantages with regard to social impacts from using waterborne paints include lower worker and community exposure to VOCs, reduced health and environmental impacts, reduced VOC release and smog formation, reduced potential for generation of and exposure to hazardous waste.

Waste management

Because the waste streams associated with waterborne painting operations have not been adequately characterized, it is not clear whether adoption of waterborne technology offers significant waste management advantages. Although a portion of the shop's waste stream would no longer be comprised of hazardous solvents, some shops may find appropriately managing a second, aqueous waste steam to be challenging.

Overall conclusions

In conclusion, the IC2's Alternatives Assessment Guide version 1.0,[2] was a valuable tool to help guide this alternatives assessment. Considering the information gathered in the modules described above, we also conclude that waterborne basecoats and associated products (i.e., waterborne gun cleaners) offer many advantages, and we consider them to be safer alternatives to solventborne products. Consequently, LHWMP will provide technical and financial assistance to our local auto body industry to help them transition from solventborne to waterborne products.

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APPENDIX A

HAZARD SCREENING OF BASECOATS

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Table A-1. Hazard Screening of waterborne and high-VOC basecoats

Chemical	CAS number	Presence in waterborne basecoats	Presence in high-VOC solventborne basecoats	Pharos color code with hazard level / endpoint	GreenScreen score
ethylbenzene[a]	100-41-4		T,R	High: Cancer	BM2
n-propylbenzene	103-65-1		R	Med: Respiratory	LT-P1
1-methoxy-2-propanol (PGME)	107-98-2	T	T,R	Med: Developmental	LT-P1
dimethylethanol amine	108-01-0	T	T	High: Respiratory	LT-UNK
methyl isobutyl ketone (MIBK)	108-10-1		T,R	High: Cancer	LT-1
methyl isobutyl carbinol	108-11-2		R	Med: Respiratory	LT-UNK
2-methoxy-methylethyl acetate	108-65-6		T,R	Med: Developmental	LT-UNK
mesitylene (1,3,5-trimethylbenzene)	108-67-8		R	Med: Developmental	BM2
methylcyclohexane	108-87-2		R	High: Flammable	LT-P1
toluene	108-88-3	T	T,R	High: Developmental	BM1
methyl isoamyl ketone	110-12-3		R	Med: Mammalian	LT-UNK
methyl amyl ketone	110-43-0		R	Med: Mammalian	LT-UNK
2-butoxyethanol (EGBE)	111-76-2	T,R,B	T	Med: Cancer	BM2
2-(2-methoxyethoxy)-ethanol	111-77-3	T		Med: Developmental	LT-P1
2-(2-ethoxyethoxy)-ethanol	111-90-0	R		Med: Developmental	LT-UNK
butylglycol acetate (EGBEA)	112-07-2		T,R	Med: Cancer	LT-UNK
2-(2-butoxyethoxy)-ethanol	112-34-5	T,R		Med: Developmental	LT-UNK
sulphanilic acid	121-57-3	T		High: Eye irritation	LT-P1
diacetone alcohol	123-42-2	T		Med: Reproductive	LT-UNK
n-butyl acetate	123-86-4		T,R	Med: Developmental	LT-UNK
triisobutyl phosphate	126-71-6	T		High: Skin sensitize	LT-UNK
2,4,7,9-tetramethyl-5 decyne-4,7,diol	126-86-3	T	T	Med: Eye irritation	LT-UNK
xylene	1330-20-7		T,R	High: Reproductive	BM1

Table A-1. Hazard Screening of waterborne and high-VOC basecoats					
Chemical	**CAS number**	**Presence in waterborne basecoats**	**Presence in high-VOC solventborne basecoats**	**Pharos color code with hazard level / endpoint**	**GreenScreen score**
2-methylbutan-1-ol	137-32-6	T		Med: Developmental	LT-UNK
dipentene (DL limonene)	138-86-3		R	High: Respiratory	BM2
heptane	142-82-5		R	Very high: Acute aquatic	LT-P1
trimethyl orthoacetate	1445-45-0		T	High: Flammable	LT-UNK
1-propoxy-2-propanol	1569-01-3	T		High: Eye irritation	LT-UNK
2-methoxy propanol	1589-47-5	T	T	High: Developmental	LT-1
polypropylene glycol	25322-69-4	R		Med: Mammalian	LT-UNK
formaldehyde	50-00-0		T	High: Cancer	LT-1
3-butoxypropan-2-ol	5131-66-8	T		Med: Mammalian	LT-UNK
n-pentyl propionate	624-54-4		T	Med: Acute aquatic	LT-UNK
naphtha, heavy alkylate	64741-65-7	T	T	High: Cancer	LT-1
naphtha (petroleum), light hydrocracked	64741-69-1		R	High: Cancer	LT-1
petroleum naphtha, heavy	64742-48-9	T	T	High: PBT	BM1
mineral spirits	64742-49-0		T	High: Cancer	LT-1
solvent naphtha, medium aliphatic	64742-88-7	T		High: Mammalian	LT-P1
solvent naphtha, light aliph., Low boiling P., <0,1% benzene	64742-89-8		T,R	High: Cancer	LT-1
solvent naphtha, petroleum, heavy aromatic	64742-94-5		R	High: Bioaccumulative	BM1
aromatic hydrocarbon	64742-95-6	T	T,R	High: Cancer	LT-1
isopropyl alcohol	67-63-0	T	T	Med: Developmental	BM2
acetone[b]	67-64-1	T	R	High: Developmental	LT-P1
n-propanol	71-23-8	T		Med: Cancer	BM2
n-butanol	71-36-3		T	Med: Developmental	BM2

Table A-1. Hazard Screening of waterborne and high-VOC basecoats					
Chemical	**CAS number**	**Presence in waterborne basecoats**	**Presence in high-VOC solventborne basecoats**	**Pharos color code with hazard level / endpoint**	**GreenScreen score**
n-pentanol (amyl alcohol)	71-41-0	T,R,B		Med: Developmental	LT-UNK
ethyl-3-ethoxyproprionate	763-69-9		R	Med: Developmental	LT-UNK
isobutyl alcohol	78-83-1		T,R	Med: Developmental	BM2
sec-butyl alcohol	78-92-2	T		Med: Reproductive	LT-UNK
butanone (MEK)	78-93-3		T,R	Med: Developmental	BM2
vm&p naphtha (Ligroine)	8032-32-4		T,R	High: Cancer	LT-1
stoddard solvent	8052-41-3	T	T	High: Cancer	LT-1
methyl methacrylate	80-62-6		T	Med: Developmental	LT-UNK
benzyl butyl phthalate	85-68-7		T	High: Developmental	LT-1
1-methyl-2-pyrrolidone	872-50-4	T		High: Developmental	LT-1
naphthalene	91-20-3		R	Very High: PBT	BM1
1,2,4-trimethylbenzene	95-63-6		T,R	Med: Developmental	BM2
2-butanone oxime	96-29-7	T	T	High: Cancer	LT-1
n-butyl methacrylate	97-88-1		T	High: Skin sensitize	LT-UNK
cumene (isopropylbenzene)	98-82-8	T	T,R	High: Cancer	LT-1

Key:

[a] Pharos hazard level for ethylbenzene likely overestimated based on GreenScreen score of BM2. See text for explanation.
[b] Pharos hazard level & level of concern for acetone likely overestimated. See text for explanation.

Chemical listed in at least one SDS:
- T – Toner
- R – Reducer (Thinner)
- B – Blender

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APPENDIX B

HAZARD SCREENING OF PAINT GUN CLEANERS

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Table B-1. Hazard screening of waterborne and solventborne paint gun cleaners					
Chemical	**CAS number**	**Presence in waterborne gun cleaners**	**Presence in solventborne gun cleaners**	**Pharos color code with hazard level / endpoint**	**GreenScreen score**
1-methoxy-2-propanol	107-98-2	BASF		Med: Developmental	LT-P1
cyclohexanone	108-94-1	OC		Med: Cancer	LT-P1
toluene	108-88-3		LT	High: Developmental	BM1
phenol	108-95-2		NG	High: Reproductive	LT-P1
2-butoxyethanol (EGBE)	111-76-2	FK	LT	Med: Cancer	BM2
n-butyl acetate	123-86-4		CS	Med: Developmental	LT-UNK
potassium hydroxide	1310-58-3	WW	NG	High: Eye irritation	LT-UNK
acetic acid, ethyl ester	141-78-6		LT	Med: Developmental	LT-UNK
hexahydro-1,3,5-tris(2-hydroxyethyl)-s-triazine	4719-04-4	WW		High: Eye irritation	LT-UNK
hexane, light aliphatic naphtha	64742-89-8		LT	High: Cancer	LT-1
methanol	67-56-1		AP, CS, LT	High: Developmental	BM1
acetone[a]	67-64-1	Ac, BASF, FK	CS, LT	High: Developmental	LT-P1
liquefied petroleum gas, sweetened	68476-86-8		AP,	High: Cancer	LT-1
dichloromethane (methylene chloride)	75-09-2		AP, NG	High: Cancer	BM1
butanone (MEK)	78-93-3		LT	Med: Developmental	BM2
stoddard solvent	8052-41-3		NG	High: Cancer	LT-1
nonylphenol ethoxylate	9016-45-9		AP	Very high: PBT	BM1
1,2,4-trimethylbenzene	95-63-6		NG	Med: Developmental	BM2

Key:
[a] Pharos hazard level & level of concern for acetone likely overestimated and not included as a CoC. See text for explanation.
Ac: Acetone;
AP: Klean-Strip Aircraft Paint Remover
BASF: BASF R-M 915 Waterborne Gun Cleaner
CS: Sherwin Williams Clean Shot CS105
FK: DuPont Final Klean V-3921S Surface Cleaner
LT: Klean-Strip Lacquer Thinner
NG: Klean-Strip Naked Gun Spray Gun Paint Remover
OC: OneChoice SWX100 Waterborne Gun Cleaner
WW: BECCA Water Wave Waterborne Cleaning Solution

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APPENDIX C

LOW-VOC SOLVENTBORNE BASECOATS

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Table C-1. Low-VOC solventborne basecoats evaluated for Chemicals of Concern				
Manufacturer	**Product line**	**Product name**	**Product number**	**Product type**
Axalta	Cromax	Mosaic Jet Black	SBL9900B	Toner
		Application Adjustment Binder	SBL6665S	Reducer
BASF	Onyx	LVOC Productive System Bases and Colors[a]		Toner
		HD LV Slw Redr	RMR09	Reducer
		Ultra LVOC Redu	VR0	Reducer
PPG	Deltron	Basecoat Black	DBU9700	Toner
		Reactive Reducer mid-temp	DRR1170	Reducer
Sherwin-Williams	Dimension	HS Basecoat, All Colors[a]	3B	Toner
		Low VOC Reducer Medium	DLV713	Reducer
Valspar	Matrix	Premium Low VOC Basecoat	MPB-LV	Toner
		Low VOC Basecoat Reducer –EXT	MBR-400-QT	Reducer
		Low VOC Basecoat Reducer – Med	MBR-200-QT	Reducer
	Pro-Spray	3.5 Low VOC Basecoat Series Mixed Color	Prospraybase coat-LV	Toner
		3.5 VOC Basecoat Act/Reducer	BCA-200-2	Reducer
		Compliant Thinner	PCR-1463-1	Reducer
[a] Single SDS/MSDS provided for all toner colors				

Table C-2. Chemicals of Concern in Low-VOC basecoats				
Chemical	**CAS number**	**Presence in low-VOC solventborne basecoats**	**Pharos color code with hazard level / endpoint**	**GreenScreen score**
styrene[a]	100-42-5	Toners: • Pro-spray 0-0.2%	High: Cancer	BM1
toluene	108-88-3	Toners: • Pro-Spray 0-0.3% • Deltron ≥1.0-≤5.0% • SW 2% Reducers: • Deltron ≥10-≤18%	High: Developmental	BM1
xylene	1330-20-7	Toners: • Matrix 0-<5% • Pro-Spray 0.3-20% • Deltron ≥1.0-≤4.3% • SW 4% Reducers: • Deltron ≥5.0-≤9.3%	High: Reproductive	BM1
liquid HALS[a]	41556-26-7	Toners: • Matrix 0.1-<1%	High: PBT	LT-P1
t-butyl acetate (exempt)[a]	540-88-5	Toners: • Cromax 37-48%	High: Persistent	LT-UNK
petroleum naphtha, heavy	64742-48-9	Toners: • Pro-Spray 0-5% • Onyx 0-5%	High: PBT	BM1
petroleum naphtha, hydrodesulfurized heavy[a]	64742-82-1	Toners: • Onyx 0-5%	High: PBT	LT-1
solvent naphtha, light aliph., Low boiling P., <0,1% benzene	64742-89-8	Reducers: • Deltron ≥1.0-≤5.0%	High: Cancer	LT-1
aromatic hydrocarbon	64742-95-6	Toners: • Pro-Spray 0-10% • Onyx 0-5% Reducers: • SW 1.5%	High: Cancer	LT-1
2-methoxypropyl-1-acetate[a]	70657-70-4	Toners: • Pro-spray 0-0.3%	High: Developmental	LT-1
Tertiary butyl alcohol[a]	75-65-0	Toners: • Cromax 0.2%	High: Persistent	LT-P1
magnesium fluoride[a]	7783-40-6	Toners: • Pro-spray 0-10%	High: Persistent	LT-UNK
vm&p naphtha (Ligroine)	8032-32-4	Toners: • Matrix 0-<1% • Deltron ≥1.0-≤5.0%	High: Cancer	LT-1
stoddard solvent	8052-41-3	Toners: • Matrix 0.1-<1%	High: Cancer	LT-1
benzyl butyl phthalate	85-68-7	Toners: • Matrix 0-<1% • Deltron ≥1.0-≤5.0%	High: Developmental	LT-1

Table C-2. Chemicals of Concern in Low-VOC basecoats				
Chemical	**CAS number**	**Presence in low-VOC solventborne basecoats**	**Pharos color code with hazard level / endpoint**	**GreenScreen score**
cumene	98-82-8	Toners: • Pro-Spray 0-1% Reducers: • SW 0.3%	High: Cancer	LT-1

Key:

[a] Not found in high-VOC or waterborne basecoats
[b] Exempt solvent per South Coast Air Quality Management District exempt chemicals for motor vehicle coatings

Matrix:
- Toner: Valspar Matrix Premium Low VOC Basecoat (MPB-LV Premium Low VOC Basecoat)
- Reducer: Valspar Matrix Low VOC Basecoat Reducer –EXT (MBR-400-QT)
- Reducer: Valspar Matrix Low VOC Basecoat Reducer – Med (MBR-200-QT)

Pro-Spray:
- Toner: Valspar Pro-Spray 3.5 Low VOC Basecoat Series Mixed Color (Prospraybasecoat-LV)
- Activator/Reducer: Valspar Pro-Spray 3.5 VOC Basecoat Act/Reducer (BCA-200-2)
- Reducer: Valspar Pro-SprayCompliant Thinner (PCR-1463-1)

Deltron:
- Toner: PPG Deltron Basecoat Black (DBU9700)
- Reducer: PPG Deltron Reactive Reducer mid-temp (DRR1170)

Onyx
- Toner: BASF Onyx LVOC Productive System Bases and Colors
- Reducer: BASF Onyx HD LV Slw Redr (RMR09)
- Reducer: BASF Ultra LVOC Redu (VR0)

Cromax:
- Toner: Axalta Cromax Mosaic Jet Black (SBL9900B)
- Binder: Axalta Cromax Application Adjustment Binder (SBL6665S) [needed for spraying; similar to a reducer]

SW:
- Toner: Sherwin-Williams Dimension HS Basecoat, All Colors (3B)
- Reducer: Sherwin-Williams Dimension Low VOC Reducer Medium (DLV713)

PBT: Persistent, Bioaccumulative, and Toxic

GreenScreen Scores: BM1: Benchmark 1; BM2: Benchmark 2; LT-1: List Translator Likely Benchmark 1; LT-P1: List Translator Possible Benchmark 1

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APPENDIX D

REVERSE CUMULATIVE DISTRIBUTION OF THE CONCENTRATIONS ESTIMATED BY THE KAPLAN-MEIER CURVES

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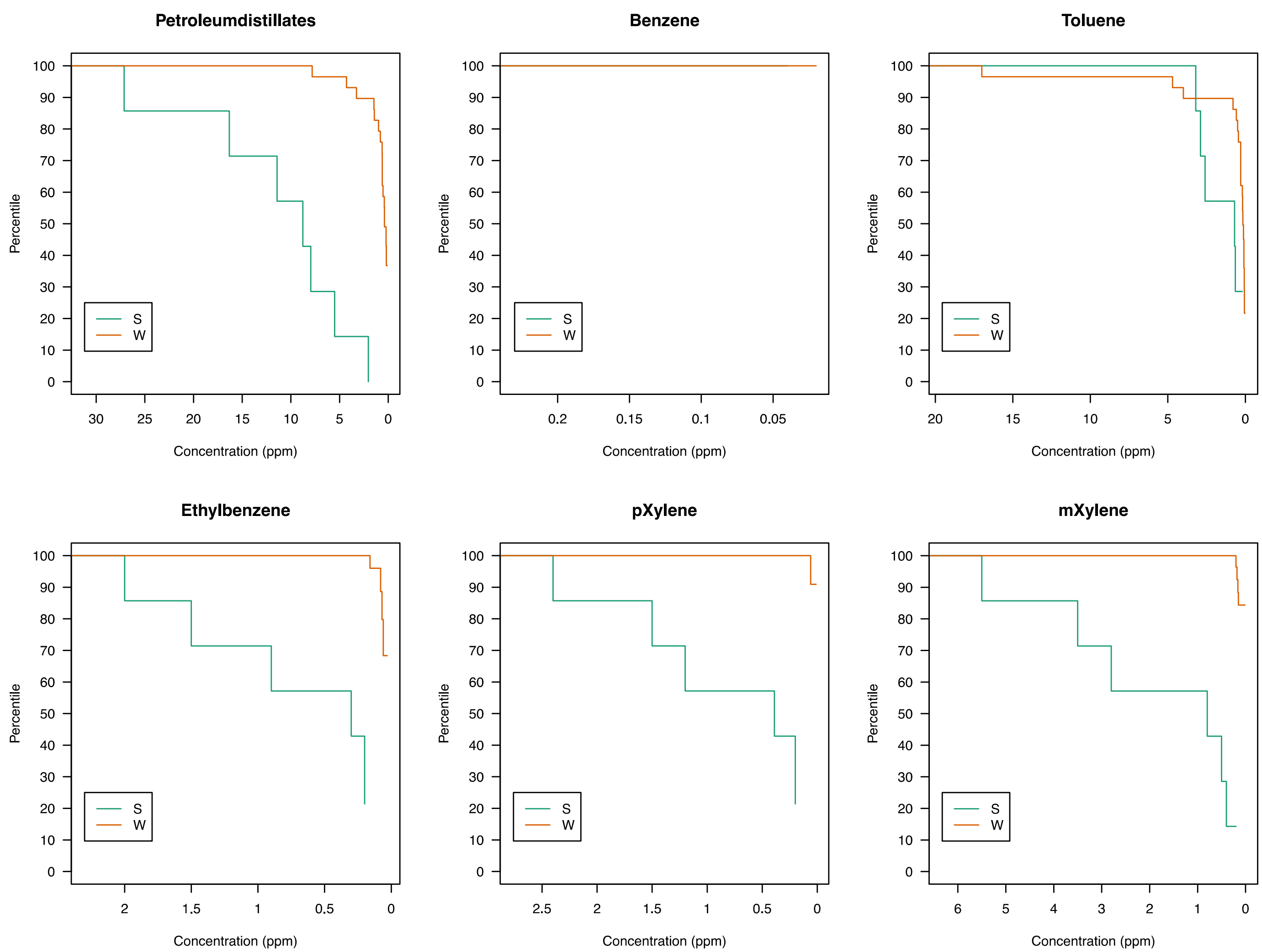
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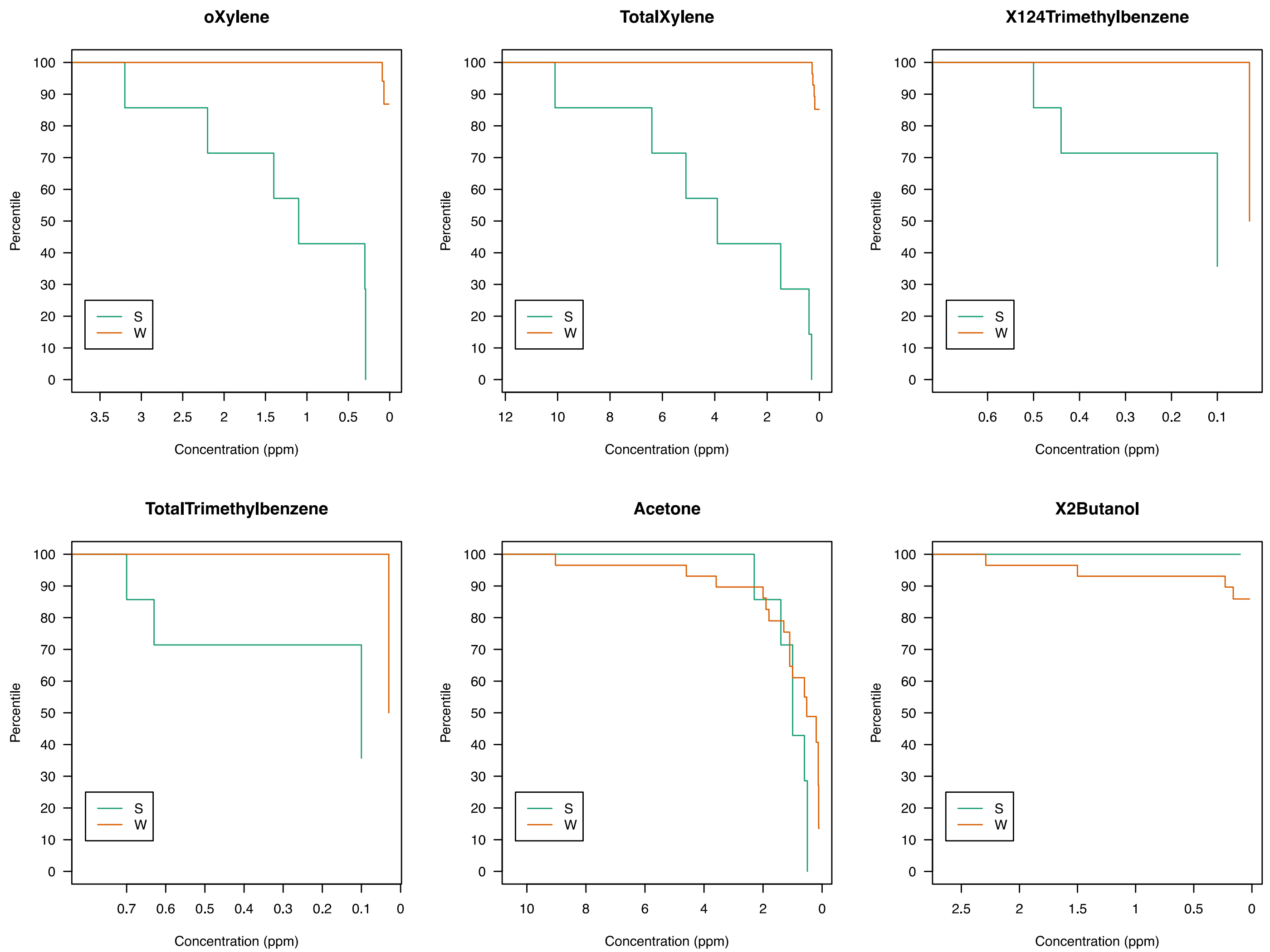
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X2Butanol
Percentile
Concentration (ppm)
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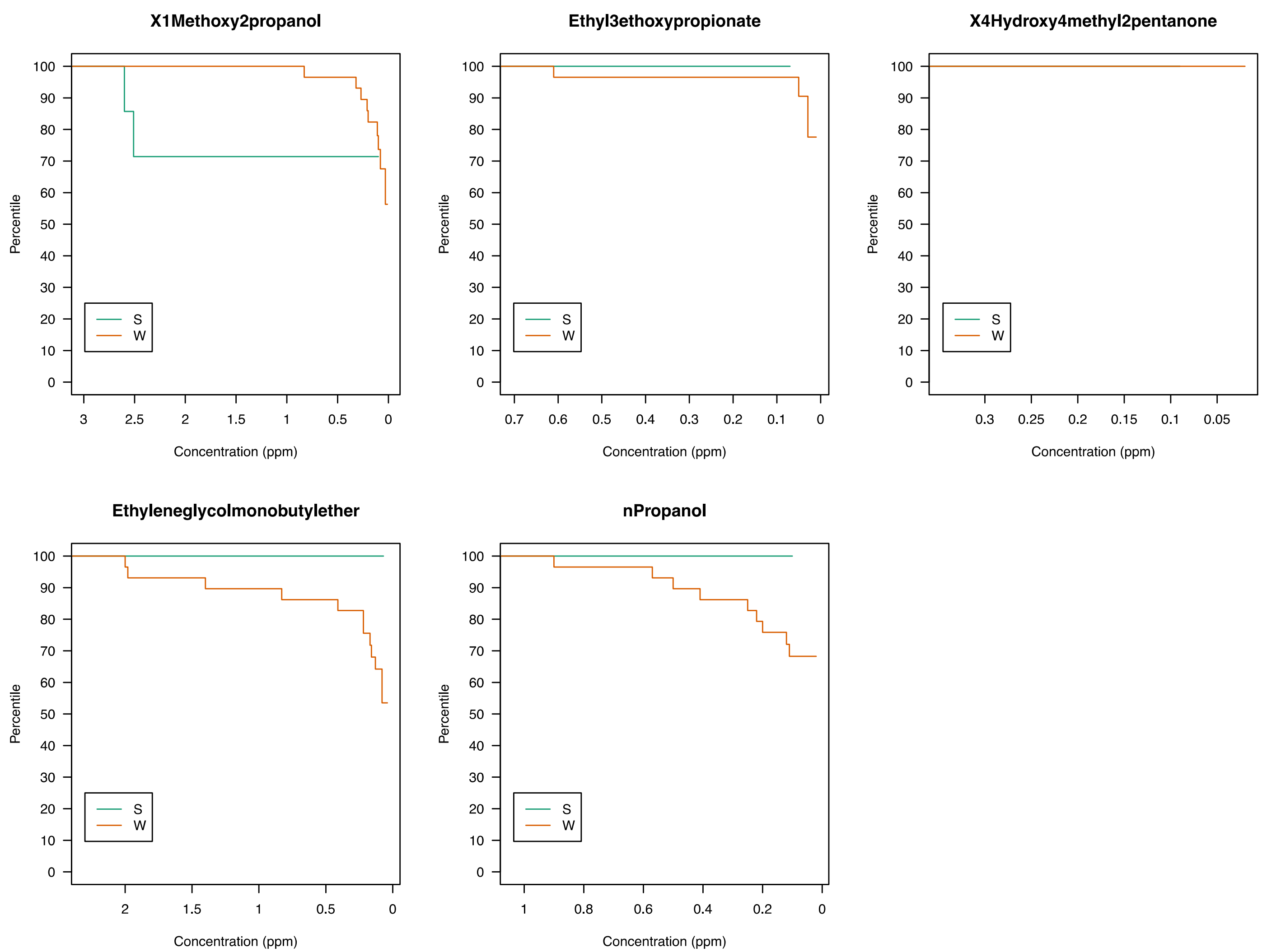
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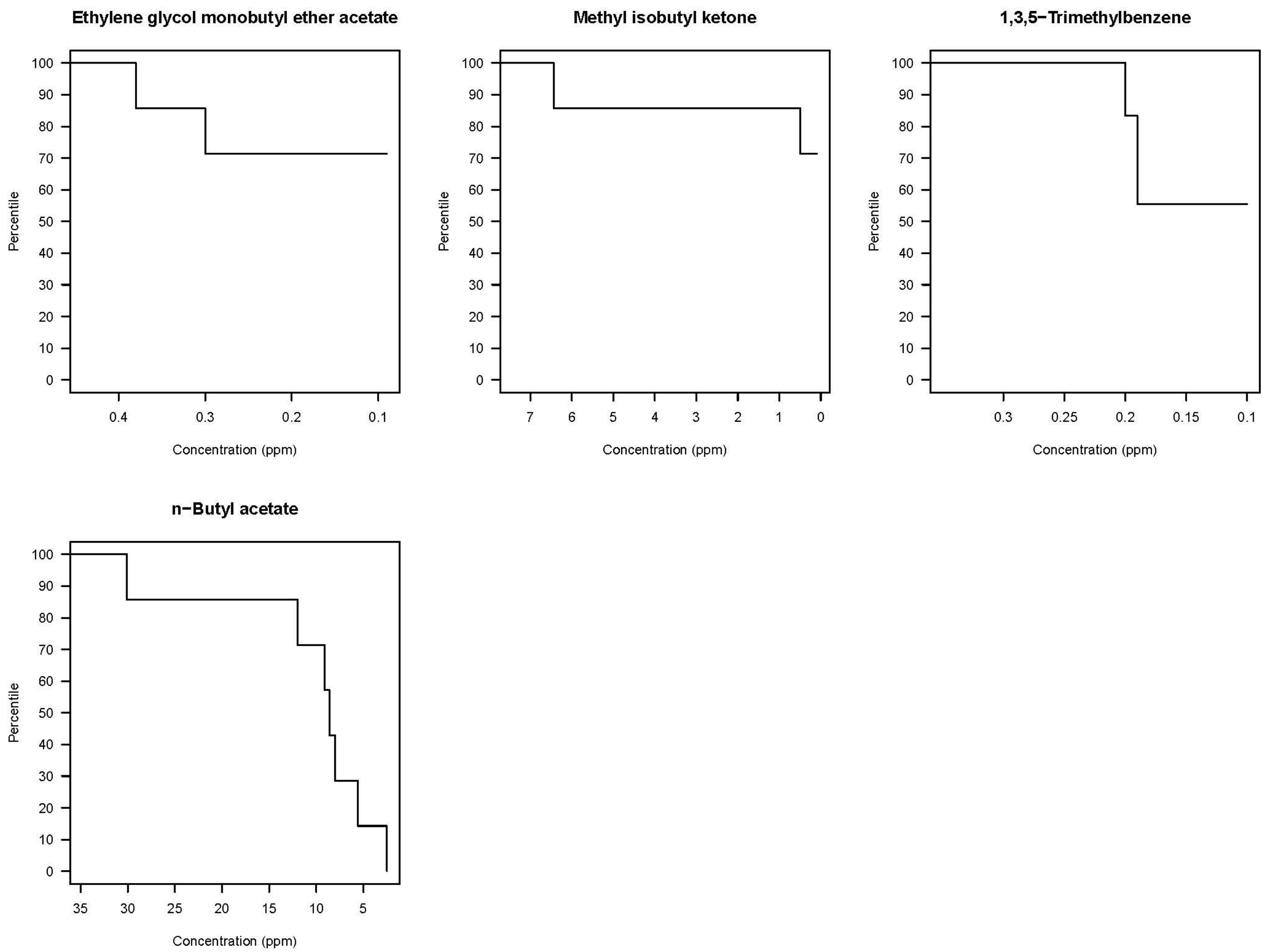
Ethyl3ethoxypropionate
X4Hydroxy4methyl2pentanone
Ethyleneglycolmonobutylether
nPropanol
Percentile
Concentration (ppm)
S
W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Methyl isobutyl ketone
1,3,5−Trimethylbenzene
n−Butyl acetate
Percentile
Concentration (ppm)
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70
60
50
40
30
20
10
0
0.4
0.3
0.2
0.1
7
6
5
4
3
2
1
0
0.25
0.15
35
30
25
20
15
10
5

APPENDIX E

INTERVIEW RESULTS FROM DISTRIBUTORS AND AUTO BODY SHOPS

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Table E-1. Responses to the Question: How do waterborne paint systems compare to solvent systems?			
Shop	**Performance**	**Cost**	**Availability**
Distributor 1 5/19/16 interview with manager and sales rep [manufacturer distributor, 1 store in King County]	Waterborne is better (same # of cars painted with either system).	Sherwin Williams waterborne system is a more compact line (i.e., fewer products) than solvent system. Same or at the most 10% more than solvent (They think this is true for all manufacturers. Could have exception if have expensive solvent line and cheap waterborne line).	Same
Distributor 2 Did not interview. Emailed questions 5/4/16 to equipment service manager/lead technician with follow-up email 5/11/16, completed form returned 5/19/16 [distributor, several stores in King County]	Better in many respects.	A little more.	Same
Distributor 3 Did not interview. Emailed questions 5/4/16 to paint technician with follow-up email 5/11/16, completed form returned 5/19/16 [distributor, several stores in King County]	Better	More expensive.	Same
Distributor 4 5/25/16 interview with technical training instructor [manufacturer training center, 1center in King County]	Performance is more than just paint. Certain air movement needed to make paint perform properly. "Dirty air" i.e., contamination, from compressors and distribution lines can be a problem regarding performance.	Waterborne (PPG Envirobase) system can be 25% more. Make up higher paint cost since through put is higher (# of cars painted since fewer coats are required). (In an 8-10 hr. day, the most cars capable of being painted [not full paint jobs], is 10-12 per booth. Interviewer is uncertain if this is for solvent or waterborne)	Not all shops are large enough to have a stirring mixing bank system (automatic stirring). A stirring mixing bank system is required for all solvent paints from all manufacturers and some waterborne from some manufacturers (e.g., BASF 90 Line, Axalta Cromax Pro). Waterborne Mfg. lines not requiring mixing banks are PPG, Sikkens, Spring Pro (?), and DeBeers. Smaller shops require paint to be mixed by distributor for various brands of solvent paint. For waterborne, distributors don't mix it. Interviewer conclusion: For small shops without stirring mixing banks, they will need to use a certain type of waterborne paint and can't use solvent paint (unless they have the distributor mix the solvent paint for them. Distributors do not mix waterborne paint).
Distributor 5 6/16/16 interview with store owner and manufacturer territory manager		Believes waterborne is more expensive and less productive re performance.	

Table E-1. Responses to the Question: How do waterborne paint systems compare to solvent systems?			
Shop	**Performance**	**Cost**	**Availability**
Does not sell waterborne basecoats [distributor, 1 store in King County]			
Distributor 6 7/13/16 interview with sales manager (18 years, time in auto body industry), store owner (50 years), sales rep (43 years), sales rep (40 years), sales rep (36 years), sales rep [PPG platinum distributor, 1 store in King County]	For PPG, waterborne is better than PPG solvent. Other manufacturer paints in which their waterborne outperforms their solvent is AkzoNobel and Valspar (DeBeer). None of these waterborne products require toner stirring.	Waterborne will be less or the same as solvent.	Same, except that waterborne is not available over the counter from distributors (not mixed by distributors, solvent is).
Distributor 7 6/14/16 interview at Chinook with area sales manager, also instructor for I-CAR (the Inter-Industry Conference on Auto Collision Repair, international collision repair non-profit) [distributor, 2 stores in King County]	Waterborne is much faster to use.	Waterborne is more expensive per ounce, but generally cheaper to use.	Same
Interviewer Interview Analysis and Comments	Waterborne performance is generally better. Performance might vary by manufacturer and also in comparison to solvent products of different qualities.	Waterborne is the same or slightly more costly than solvent. Due to increased productivity with waterborne, it is generally cheaper to use.	Similar to solvent, except that distributors will generally not mix waterborne for shops. Some waterborne brands require stirring systems (similar to solvent).

Table E-2. Waterborne Auto Body Shop Interview Results	
Waterborne shop 1 6/9/16 (RV)[a] Seattle, WA General Manager Axalta Chromax Pro	• Touch up harder with waterborne • Waterborne more cost effective; about 49/51 compared to solvent • After training, profitability in speed of processing cars • Can wash off waterborne basecoats with a redo; not with solvent.
Waterborne shop 2 5/19/16 (LB) Bellevue, WA Owner Sherwin Williams AWX Performance Plus	Waterborne is a little more expensive, but depends on paint.
Waterborne shop 3 6/30/16 (RJ) Seattle, WA Owner PPG Envirobase	Not sure. Wasn't around when solvent paint was used. A bit more efficient, probably.
Waterborne shop 4 7/1/16 (RJ) Burien, WA Staff Axalta Standoblue	Waterborne basecoats costs more money for the product.
Waterborne shop 5 7/1/16 (RJ) Kent, WA Owner Axalta Chromax Pro	• 6 years ago, materials went down by 10% • Production savings are very large. • But cost per sprayable product has gotten a bit more expensive. For the cost of a quart of solvent, you can get a pint of water.
Waterborne shop 6 7/6/16 (RJ) Seattle, WA Owner PPG Envirobase	• Lower cost – use less material with waterborne than we did with solvent. • Better performance – color matching is better. • More available. Paint companies are investing (as mentioned earlier).
Waterborne shop 7 7/15/16 (RJ) Auburn, WA Owner PPG (product line data not collected)	• Overall, material costs have gone up tremendously – but she's not sure how much of that has to do with waterborne. It might also vary among shops. With large businesses, material costs are going to be more. • But it is generally more expensive in price of paint. For most insurance companies they get $2 increase in materials. • Does not necessarily take longer to dry. Booth is a downdraft heated booth, and it cures waterborne paint the same as solvenborne. (People who say it takes too long to dry don't know how to use it. They haven't mastered it.) • They haven't really felt production increase because their work varies in terms of how much of the car they're working on.
Waterborne shop 8 8/16 (RV) Seattle, WA Staff PPG Envirobase	Need open attitude towards changing. By 2020 90% shops will be waterborne (per seminar taken 5 yrs. ago). Fantastic. Less waste to dispose. Painters love it. Easier to fix mistakes. Not as much tinting. Color match second to none. One of the best moves in industry.

Table E-2. Waterborne Auto Body Shop Interview Results	
Waterborne shop 9 8/4/16 (LB) Seattle, WA Owner/manager? PPG Envirobase (waterborne), Shop-Line (solvent), Delfleet ESSS (solvent)	Uses waterborne for newer cars. Waterborne accents imperfections (i.e., best for premium grade finishes), and thus uses solvent paint for older cars and restorations.
Waterborne shop 10 8/18/16 (LB) SeaTac, WA Owner PPG Envirobase	12,000 sq. ft. shop. Has some concern about waterborne. Two cars have had the clearcoat peel. Both painted white. He mentioned about solvent clearcoat over waterborne basecoat and his concern about 10-15 year performance. He said perhaps it works well in Europe since Europeans turn cars over quicker than in USA. He did say he believes it has less environmental and health impacts, better color match, and better hazardous waste management.
Waterborne shop 11 8/16 (RV) Kirkland, WA Staff BASF Glasurit 90 Line	Waterborne is great product. 30 yr. painter received training and it helped. Quality of paint matters. Have heard bad stories, but believes quality of paint is issue.
[a]Date interviewed, interviewer initials, shop location, interviewee title, paint product.	

Table E-3. Solvent Auto Body Shop Interview Results	
Solvent Shop 1 9/16/16 (LB) Seattle, WA Manager	1) Performance concerns. Since other coats are solvent, believes that solvent and waterborne coats will not bite into each other. Paint will peel. 2) Waterborne paint and process used for new cars by manufacturers is different than used by shops. Mfg. use different kind of paint and positive/negative charges. 3) Waterborne is only about 10% better than solvent regarding reduced air emissions. 4) Waterborne still has solvents in it, still hazardous.
Solvent Shop 2 9/16/16 (LB) Tukwila, WA Manager	If doing complete paint jobs, he understands switching to waterborne, but since they do repair work and partial paint jobs, he believes that solvent is better since it is easier to match color on older cars.
Solvent Shop 3 8/4/16 (LB) Seattle, WA Manager	Won't switch to waterborne unless have to. Solvent is the proven system. They paint 20% new cars and 80% older. Solvent is easier to match color for older cars. Waterborne is more temperature dependent to dry. No one has come up with 100% sure method of drying waterborne.
Solvent Shop 4 8/12/16 (LB) SeaTac, WA Owner	Waterborne doesn't fit well with their business. They paint mainly rental cars. Owner believes waterborne requires more prep work and takes longer to paint car.
Solvent Shop 5 8/12/16 (LB) Seattle, WA Owner	Waterborne is only basecoat, clearcoats and primers are still solvent. Why just change basecoat? We are not a high volume shop. Concerned about changing. They strive for perfection, concerned that waterborne will not be high enough quality for them. Current painter is "old school." Easier to shoot solvent.
Solvent Shop 6 8/18/16 (LB) Kirkland, WA Owner	They tried Sherwin Williams waterborne (still has a mixing system). They decided not to switch. Mentioned that waterborne has good color matching for newer cars. He believes PPG waterborne works well. He mentioned that Sikkens is working on a Low VOC solvent. They will likely switch to that when available. Distributors/Mfg. provide incentives not only to switch to waterborne, but also to switch to their solvent from another manufacturer. Incentives for waterborne are not pushed as much as they use to be a few years ago when the industry was trying to establish the waterborne market. Barriers: 1) Waterborne comes out dirtier. In other words, dirt specks do not sink down like they do with solvent. They are more obvious. Thus more work to fix. A solvent paint shop may show 3 specks that need fixing, waterborne might show 6. 2) Waterborne basecoat is only one step, the primer and clearcoat are still solvent. The basecoat portion is about 22% of total amount sprayed to paint a typical auto repair. Thus, have two different waste streams, water and solvent, need different guns, cleaners, etc. Not worth the trouble. 3) They also do older vehicles. Waterborne color matching is best for cars less than 10-12 years old. Cars older than that, waterborne color matching not so well. 4) Painter has been their 30 years which makes it more difficult to switch. 5) Short shelf life. Once mixed, waterborne only is good for 1-2 days. 6) Waterborne is more expensive. 7) It will cost about $60,000 for them to upgrade their shop to use waterborne. 8) Solvent can be "pushed." Difficult to touch up waterborne.
Solvent Shop 7 8/16 (RV) Seattle, WA Owner	Solvent proven technology. Has seen waterborne demos and looks like more work.
Solvent Shop 8 8/16 (RV) Kirkland, WA Owner's spouse	Doesn't spray as nice; poor coverage. Would need to switch out all equipment.
Solvent Shop 9 8/3/16 (RJ) Snoqualmie, WA Owner	He understands that waterborne would be helping a bit on pollution – but he points out that other layers also has VOCs. He thinks that someday he'll have to make that switch. Would have to purchase new spray booth. Not sure on cost but beyond the start-up costs, waterborne also seems more expensive than solvent basecoats. Small business.
Solvent Shop 10 8/16 (RJ) Kirkland, WA Estimator	Color matching. Less time to apply waterborne.

Table E-3. Solvent Auto Body Shop Interview Results	
Solvent Shop 11 8/16 (RJ) Federal Way, WA Owner	He thinks that switching to waterborne is perhaps like switching to HVLP guns; once businesses make the switch, they can't imagine what it was like before. Coverage is better, less solvent. Better for environment. Heard it's easier to spray. In WA state, it might be harder to dry paint because of moisture in the air, but equipment to help dry paint has come a long way.
Solvent Shop 12 8/23/16 (RJ) Seattle, WA Manager	Interviewee formerly worked on military vehicles, and they used waterborne paints. Drying time was terrible. Considering the expense of new booths, he is not interested at all.
[a]Date interviewed, interviewer initials, shop location, interviewee title	

APPENDIX F

WORKER, COMMUNITY, AND GLOBAL SOCIAL IMPACT COMPARISON OF WATERBORNE AND SOLVENTBORNE BASECOATS

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Table F-1: Selected worker considerations across the product life cycle		
Consideration	Waterborne Basecoat	Solventborne Basecoat
Demographics		
Sex	Same (see pregnant women under sensitive populations below)	
Age		Older workers may favor solvent since that is what they learned and it can be hard to change.
Culture	Workers who are environmentalist may favor waterborne.	
Language or cultural issues	Same	
Literacy	Same	
Gender equality	Same	
Human rights	Same	
Disability issues	Workers with asthma and chemical sensitivities may be less impacted by waterborne.	
Health		
Physical or social impacts such as ergonomics, noise, culture, etc.	Less odor, more pleasant work environment. Better worker retention. Less chance for solvent high and its potential short and long term effects resulting from exposure to volatile organic solvents. Potential health impacts could result from 2-butoxyethano, a common waterborne basecoat ingredient.[46] If an ergonomic spray gun is used for waterborne and solvent, ergonomics impact should be similar.	
Health care	Potential for less need for worker health care due to reduced health impacts to workers and community. A Massachusetts Office of Technical Assistance and Technology publication suggests using waterborne paints may result in reduced sick days.[61]	
Sensitive populations such as pregnant women, children, the elderly, etc.	Less volatile organic solvents to impact workers and the surrounding community.	
Treatment with dignity and respect	Same	
Body burden of chemicals with unknown individual, synergistic or other impacts	Less body burden due to reduced chemical exposure to volatile organic solvents.	
Life Expectancy	Less potential to shorten life due to hazardous ingredients.	
Sanitary facilities including toilet, potable water, food storage, etc.	Less potential for wastewater contamination due to less hazardous ingredients.	
Non-abusive work conditions and hours	Same	
Environment		
Generation of toxic wastes	Generally less hazardous/toxic waste	
Product recycling, extraction of valuable resources and final disposition of wastes generated	Hazardous waste disposal less costly.	
Use of hazardous chemicals	Generally fewer hazardous ingredients and less exposure (see hazard and exposure modules) using	

Table F-1: Selected worker considerations across the product life cycle		
Consideration	Waterborne Basecoat	Solventborne Basecoat
	waterborne compared to solvent basecoats.	
Adequate training and hazard communication training	Same, training and use of personal protective equipment required for each	
Financial		
Compensation: overtime, lost time, and wages	Waterborne may results in less sick time taken by workers as well as increased worker productivity while working.	
Number and quality of jobs	Based on LHWMP 2016 estimates, about half of the auto body shops in King County use waterborne basecoats, the other half use solvent basecoats.(37) Since the numbers of shops are about the same, the assumption is that the numbers of workers (jobs) using each product category is also about the same. It could be argued, that the quality of waterborne jobs are better, since there is less exposure to volatile organic solvents in the work place.	
Pay equality	Same	
Part-time workers	Same	
Educational level of workers	Same	

Table F-2: Selected community considerations across the product life cycle		
Consideration	**Waterborne Basecoat**	**Solvent Basecoat**
Demographics		
Quality of life including historical, cultural or religious priorities, etc.	Potential for better quality of life for surrounding community as a result of less volatile organic solvents being released to the community air.	
Use of forced or child labor	Same	
Health		
Quality of life including recreational activities	Less volatile organic solvent odor could result in greater outdoor enjoyment by nearby community residents.	
Sale of products banned in other, regulated areas in unregulated markets		Some jurisdictions in the US have banned the use of high VOC auto body paint systems. These products currently can still be purchased in King County which is unregulated.
Communities over-burdened by pollution	Less volatile organic solvents in waterborne basecoats, thus reduced chance for air pollution to surrounding community. Some evidence is available from San Diego that solvent odor from auto body shops may impact the surrounding community.[57] Locally, some community odor complaints about auto body shops do occur. King County complaint data received January 27, 2017 from the Puget Sound Clean Air Agency for the last 3 years indicates that on average about 12 odor complaints about auto body shops are reported to PSCAA each year. It is very difficult from the data to determine the specifics. Many of the complaints appear to be about illegal auto body operations. The number of complaints against licensed auto body shops with functioning paint booths and using solvent versus waterborne basecoats is unknown from the data. Since many of the complaints mention a solvent odor, the assumption is that these are likely shops using solvent basecoats.	
Environment		
Disproportionate impacts on 'fenceline' communities	Likely, less impacts to 'fenceline' communities.	
Impacts upon local water, air, land, etc.	Automotive coatings can contain volatile organic compounds (VOCs), toxic air contaminants, stratospheric ozone-depleting	

Table F-2: Selected community considerations across the product life cycle		
Consideration	**Waterborne Basecoat**	**Solvent Basecoat**
	compounds, and globally warming compounds. Waterborne has less chance for impacts due to reduced volume of toxic chemicals released to the environment. Volatile organic compounds (VOCs are at higher concentrations in high VOC solvent basecoats compared to waterborne or low VOC solvent basecoats) react with oxides of nitrogen, carbon monoxide, sulfur dioxide, etc. in the presence of sunlight to form ground-level ozone (smog). In 1992, most of King County was a nonattainment area for ozone. It was re-designated to attainment (i.e., maintenance area) in 2005. Waterborne basecoats and low VOC solvent basecoats will have reduced impacts to potential smog formation.	
Potential generation of toxic wastes or use of hazardous chemicals	Generally waste from waterborne paint systems will be less toxic than solvent systems, but still might be a hazardous waste in Washington state.	
Product recycling, extraction of valuable resources and final disposition of remains	Generally, disposal of waterborne hazardous waste will be less toxic and disposal less costly.	
Financial		
Quality and types of jobs	Based on LHWMP 2016 estimates, currently about half the auto body shops in King County use waterborne basecoats and the other half use solvent basecoats.[37] Since the numbers of shops are about the same, the assumption is that the numbers of workers (jobs) using each product category is also about the same. It could be argued, that the quality of waterborne jobs are better since there is less exposure to volatile organic solvents in the work place.	
Crime	Shift to waterborne may reduce crimes associated with chop shops, since illegal auto body chop shops may not convert.	Illegal chop shops are more likely using solvent paints.

Table F-2: Selected community considerations across the product life cycle		
Consideration	**Waterborne Basecoat**	**Solvent Basecoat**
Corruption	Shift to waterborne may reduce crime since illegal auto body chop shops may not convert.	Illegal chop shops are more likely using solvent paints.
Customer financial impact (added to template)	If the cost to paint a car is more expensive with waterborne and this cost is passed onto customers in the community, this increased cost could have a greater impact on economic disadvantaged communities.	
Community		
Establishment of partnerships with local, state, tribal and federal organizations to achieve health and sustainable communities	Local agencies may be interested in collaboration to switch to waterborne. Potential agencies include PSCAA, Ecology, EPA, and fire departments.	
Product availability	Both waterborne and solvent products available, although all solvent and some waterborne products require stirring mixing bank systems. Not all shops may be large enough to have these mixing systems. Small shops without stirring mixing bank systems will need to use a certain type of waterborne paint or continue to use solvent. Distributors will mix solvent paint for shops, but most will not mix waterborne paint.	
Empowerment of communities to take action to improve their health and environment	Potential for community empowerment if shops in neighborhoods switch to waterborne and solvent smells are reduced.	
Discrimination, harassment, intimidation or retaliation	Shops that can't afford to convert to waterborne may be forced out of business if solvent paint becomes unavailable or much more expensive due to lack of demand.	

Table F-3: Selected global societal considerations across the product life cycle

Consideration	Waterborne Basecoat	Solventborne Basecoat
Demographics		
Use of forced or child labor	Same	
Health		
Sale of products banned in other, regulated areas in unregulated markets		Some jurisdictions in the US have banned the use of solvent auto body paint systems. These products can be purchased in King County which currently is unregulated.
Changes to quality of life	Europe, Canada, and some parts of the US have banned solvent paint use by auto body shops. In addition to VOCs which contribute to smog production, the collision repair industry in the US generates 45,456 tons of cancer causing chemicals into the atmosphere per year (1999 data).[62] Switching to waterborne from solvent worldwide will likely improve quality of life globally.	
Environment		
Product recycling, extraction of valuable resources and final disposition of remains	Generally, disposal of waterborne hazardous waste will be less toxic and disposal will be less costly.	
Body burden of chemicals with unknown individual, synergistic or other impacts	Less body burden due to reduced chemical exposure to volatile solvents.	
Financial		
Wealth of society	Since the cost of using waterborne is equal to or only slightly greater than solvent, switching to waterborne will likely not impact the wealth of society significantly.	
Global		
Discrimination, harassment, intimidation or retaliation	Shops that can't afford to convert to waterborne may be forced out of business if solvent paint becomes unavailable or very expensive due to low demand.	
Product availability	Both waterborne and solvent products available, although all solvent and some waterborne products require stirring mixing bank systems. Not all shops may be large enough to have these mixing systems. Small shops without stirring mixing bank systems may need to use a certain type of waterborne paint or continue to use solvent. Distributors will mix solvent paint for shops, but not waterborne paint.	
Contributes to unhealthy societies such as support of military actions, genocide, etc.	Waterborne will likely have less impact on human health. Worldwide, shops using solvent products are likely contributing considerable toxic VOCs and other volatile organic solvents to the environment, which could increase smog and other human health impacts. As human health worsens, other actions could result.	

APPENDIX G

LHWMP FLYER - HOW TO MANAGE WATERBORNE AUTOMOTIVE PAINT WASTE

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How to Manage Waterborne Automotive Paint Waste

You must manage waste from waterborne automotive paint as dangerous waste, unless you have proved that it does not contain chlorinated pigments or other hazardous chemicals.

Lab testing and safety data sheets are the most reliable ways to find out if your paint waste contains hazardous chemicals. It is the business owner's responsibility to manage waste correctly.

Follow these steps to manage waterborne paint waste according to dangerous waste rules:

- Use separate containers for waterborne paint waste and solvent-based paint waste.
- Clearly label waste drums with the following information.
    1. Contents of the drum (e.g. waterborne paint waste)
    2. The words "dangerous waste" or "hazardous waste"
    3. Major risk(s) of the waste (e.g. toxic, flammable)
    4. Accumulation start date
- Have a hazardous waste vendor pick up your wastes.

You can avoid additional paperwork and legal requirements by creating less than 220 lbs. of waste each month and by having a vendor pick it up before you collect 2,200 lbs.

Here are ways to dispose of your waterborne paint waste, if you have verified that it is not dangerous waste:

- Allow the paint to dry and throw it in the trash.
- Add an absorbent material to solidify the paint. Throw the solidified waste in the trash.
- Spray leftover paint onto cardboard, allow it to dry, and throw it in the trash.

Paint booth filters can go in the trash if they have been verified as non-dangerous waste.

Here are reminders for managing and disposing of any type of paint waste:

- Keep liquid waste out of the trash. Store liquid waste in an appropriate container.
- Avoid spraying excess paint into your paint booth filter.

Here are tips for cleaning your waterborne paint gun:

- Use a water-based gun-cleaning product that does not contain solvents.
- If you must use an organic solvent for detailed cleaning of dried waterborne paint, use acetone for the final rinse. Used acetone should go in the solvent-based waste drum. Avoid lacquer thinner and aerosol gun cleaners.
- Use an enclosed gun-cleaning system.

Contact the Business Waste Line for free, confidential assistance.

206-263-8899   business.waste@kingcounty.gov

Local Hazardous Waste Management Program in King County, Washington

Alternate Formats Available
206-263-1672   TTY Relay: 711

HazWasteHelp.org
Printed on recycled paper. Please recycle.
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