Waterborne Paint Exposure in the Auto Body Collision Repair Industry

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Contents

Figures

Tables

Acronyms and Abbreviations

ACGIH	American Conference of Governmental Industrial Hygienists
AM	Arithmetic Mean
APR	Air Purifying Respirator
CAS	Chemical Abstract Service
CNS	Central Nervous System
CSC	Coconut Shell Charcoal
eff	effect
EGBE	Ethylene Glycol Monobutyl Ether
EH Lab	Environmental Health Laboratory
EPA	Environmental Protection Agency
EU	European Union
FID	Flame Ionization Detector
GC	Gas Chromatography
GM	Geometric Mean
GSD	Geometric Standard Deviation
HHE	Health Hazard Evaluation
HVLP	High Volume Low Pressure
irr	irritation
L	Liter
L/m^3	Liter per cubic meter
L/mole	Liter per mole
lb./gal	Pound per gallon
LHWMP	Local Hazardous Waste Management Program
$MeCl_2$	Dichloromethane
MEOH	Methanol
mg/m^3	Milligram per cubic meter
mg/µg	Milligram per microgram
ml/L	Milligram per liter
ml/min	Milligram per minute
MLOQ	Method Limit of Quantitation
MSDS	Material Safety Data Sheet
NIOSH	National Institute of Occupational Safety and Health
NO_x	Mono-nitrogen oxides
O90	ORBO 90
OEM	Original Equipment Manufacture
OSHA	Occupational Safety and Health Administration
OTC	Ozone Transport Commission
PAPR	Pressured Air Purifying Respirator

PEL	Permissible Exposure Limit
PPE	Personal Protective Equipment
ppm	Parts per million
PNS	Parasympathetic Nervous System
REL	Recommended Exposure Limit
SCAQMD	South Coast Air Quality Management District
ASD	Arithmetic Standard Deviation
TLV	Threshold Limit Value
TWA	Time Weighted Average
µg	microgram
µG/AIR	microgram per sampled air volume
µG/L	microgram per liter
UK	United Kingdom
UW	University of Washington
VOC	Volatile Organic Compound

Abstract

Objectives: The purpose of this study was to characterize workers' exposures to emerging waterborne coatings used in automotive refinishing systems and observe other work practices associated with using these products.

Methods: Ten auto body shops in King County, Washington that use waterborne coatings were recruited to participate in this study. Based on reviews of Material Safety Data Sheets (MSDSs) from commonly used waterborne basecoats, 14 target compounds were selected to characterize exposures to components of these products. Task-based personal air sampling was conducted on 11 painters when applying basecoats. Sampling results were summarized and compared to MSDSs and historical exposure studies of solvent-based paints. Painters' work practices were also recorded to determine other possible routes of exposure. Work practices recorded included the use of Personal Protective Equipment (PPE), gun-cleaning procedures, waste disposal, and paint booth maintenance.

Results: Breathing zone concentrations of aromatic hydrocarbons and polar volatile organic compounds were typically below their respective method limits of quantitation (MLOQ). On average, 11% (SD= 16%) of the aromatic hydrocarbon samples and 23% (SD=19%) of the polar compound samples exceeded their respective MLOQs. All analyte concentrations had threshold limit value (TLV) parametric exceedance fractions below 0.03, and National Institute of Occupational Safety and Health (NIOSH) odor parametric exceedance fractions below 0.05. VOC exposures when spraying waterborne paints were up to 56 times lower than historical studies on VOC exposures to solvent-based paints. Procedures for cleaning paint guns and disposing of waterborne paint wastes varied between shops. Several shops disposed of waste in the municipal solid waste stream without chemical characterization, in violation of state regulations. Painters were observed using lacquer thinner to clean their waterborne paint guns, which is not recommended by manufacturers. Painters were also observed handling

waterborne waste with inadequate exposure controls. We observed that the air flow rates in spray booths typically failed to meet OSHA requirements.

Conclusions: Workers' exposures to target compounds when applying waterborne basecoats were typically below their respective MLOQs and regulatory limits. The typical PPE worn by painters should be adequate to protect painters from possible exposures. This study also shows that the waterborne paint exposures during spraying are lower than the historical exposures due to spraying solvent-based paints. However, without maintaining adequate airflow in the paint booths and adequate guidelines for all aspects of handling the paints, workers can still be at risk of exposures to waterborne paints and other chemicals used during non-spraying operations. Therefore, more information is needed on the chemical composition of the waste generated from waterborne paint systems to establish best practices for spray gun cleaning and waste disposal.

1. Introduction

In the auto body refinishing industry, the most commonly used paints are solvent-based, which contain high concentrations of volatile organic compounds (VOCs) that have potential health implications for the environment and workers. In the early 1990s, the first commercial waterborne paints were introduced in the automotive industry.[1] These paints were developed in anticipation of air quality rules related to VOC emissions in the United Kingdom (U.K.), which were soon to be also adopted by the European Union (EU).[2] In the United States, VOCs are regulated under the Clean Air Act. In particular, VOC emissions in the auto body industry are regulated under the "National Volatile Organic Compound Emission Standards for Automotive Refinish Coating", also known as the "National Rule".[3] Currently, the U.S. Environmental Protection Agency (EPA) is anticipating revision of the National Rule, which will further restrict the allowable VOC emissions of the auto body industry in the U.S.[4] In addition, many commercially-available waterborne paints provide higher quality and faster finishing than solvent-based paints.[5] Therefore, it is likely more auto body refinishing shops will convert to waterborne paints.

Based on field observations and interviews conducted by the Local Hazardous Waste Management Program in King County (LHWMP), approximately 10-20% of auto body shops in King County, WA are currently using waterborne coatings (unpublished data). However, the number of auto body shops that use waterborne paints will likely increase in future years. Therefore, it is important to characterize auto body workers' exposures to waterborne paint components and determine whether current information known by the painters regarding working with waterborne paints is sufficient for them to use these products safely and dispose of the wastes according to best management practices and local regulations.

1.1 Specific aims and scope

The aim of this study was to recruit auto body collision repair shops in King County to characterize workers' experience and exposure when handling and spraying waterborne paints. The study will provide information to LHWMP to help them determine whether the program should contribute resources to promote the use of waterborne paints and help develop best management practices for these products. The specific aims are:

- Deliver technical LHWMP services to traditionally underserved auto body painters.
- Conduct field sampling at auto body collision repair shops, including collecting personal air sampling in workers' breathing zones, collecting bulk samples of paint product and wastes, and measuring paint booth performance.
- Characterize painters' exposures to target analytes in their personal breathing zones, and compare exposures to those in other studies.
- Identify current waterborne paint work-practices and possible routes of exposure, including the use of PPE, gun cleaning, and waste management.

1.2 Overview of the study

We conducted personal air sampling during the spray application of waterborne paints to evaluate workers' chemical exposures in their breathing zones. Bulk paint product samples and waste samples were also collected for analysis to determine the composition of waterborne paint and waste (data not reported in this dissertation). Information regarding the paint booths and paint products were also recorded. Subjects' work practices, such as PPE worn, gun cleaning process, and waste disposal methods were also documented to provide LHWMP with insights into how to develop best practices for using waterborne paints.

2. Background

2.1 Solvent-based Paints

The most commonly used paints in the auto body refinishing industry in the United States are solvent-based. The paints consist of several ingredients, including binders/resins/or polymers, pigments, and liquid carriers.[6] These paints are classified as solvent-based because the primary carriers are an organic solvent or a blend of solvents. The solvents provide the required viscosity and flow, as well as desirable drying characteristics. Common solvents include methyl ethyl ketone, methyl isobutyl ketone, xylene, toluene, n-butyl acetate, ethyl benzene, 1-methoxy-2-propyl acetate, and 2-heptanone.[7] The release of these VOCs has environmental health implications and is regulated by the EPA. These regulations are undergoing revision to limit VOC emissions. [4]

VOCs contribute to the creation of ground-level ozone, which is a major component of “smog”. Ground-level ozone is formed in the atmosphere by reactions of VOCs and oxides of nitrogen (NOx) in the presence of sunlight. Exposure to ozone is associated with a wide variety of human health effects, agricultural crop loss, and damage to forests and ecosystems.[8] Auto body refinish coatings contribute a significant amount of VOC emissions. As a result, in 1998, 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”.[8] The aim of this National Rule is to reduce VOC emissions during collision repair processes and standardize VOC regulation across the U.S. by placing limits on VOC content in the products.[8]

From an occupational health standpoint, VOCs have health implications for the employees working with solvent-based paints. Many of the VOCs can be irritants to workers’ eyes, skin, respiratory systems, and affect the central nervous system.[9] Additionally, some frequently-used solvent-based paints, such as specialty products and clear coats, are mixed with hardeners. These two-component products usually contain isocyanates, which are powerful irritants to the mucous membranes of the eyes and gastrointestinal and respiratory tract.[10] Isocyanates can also sensitize workers’ immune systems, subjecting them to severe asthma attacks when exposed again. There is evidence that workers can be sensitized to isocyanates through both dermal and respiratory exposures.(11)

2.1.1 VOC emission regulatory limits

VOC content and thus emissions in the auto body refinishing industry is regulated by coating type. Current EPA National Rule limits for the different coatings are shown in Table 1 VOC content for basecoats (or topcoats) is regulated at 5-6 pounds per gallon (lb./gal); clear coats are not regulated.(12)

Table 1 EPA VOC Content Standards for Automobile Refinish Coatings

Coating Category	**EPA VOC content limit g/L (lb./gal)**
Pretreatment Wash Primer	780 (6.5)
Primer/Primer Surfacer	580 (4.8)
Primer Sealer	550 (4.6)
Single/2-Stage Topcoats	600 (5.0)
Topcoats of 3 or more stages	630 (5.2)
Multi-colored topcoats	680 (5.7)
Specialty Coatings	840 (7.0)

Starting with Southern California, some areas in the U.S. have adopted stricter limits than the National Rule. In 2008, the South Coast Air Quality Management District (SCAQMD) amended their original "Rule 1151: Motor Vehicle and Mobile Equipment Non-Assembly Line Coating Operations". The revision limits clear coat VOC content to 2.1 lb./gal and basecoat VOC content to 3.5 lb./gal (Table 2).(13) Clear coats with only 2.1 lb./gal have been available for several years. However, currently available solvent-based basecoats contain 5-7lb./gal of VOC. As a result, auto body shops in the SCAQMD sought a waterborne basecoat that meets the 3.5 lb./gal rule.(14)

Currently, most of California and all of Canada are regulated to 3.5 lb./gal for basecoats(15,16). Many regions in the U.S. may be revising their regulation to the 3.5 lb./gal. limit, which will likely result in more auto body shops converting to the use of waterborne paint. In 2006, the Lake Michigan Air Directors Consortium began proposing the 3.5 lb./gal limit, following

SCAQMD's proposal. This will impact the states of Illinois, Indiana, Michigan, Wisconsin, and Ohio. In 2014, the Ozone Transport Commission (OTC) also proposed a similar reduction.[17] The OTC proposal will impact the states of Main, New Hampshire, Massachusetts, Rhode Island, Connecticut, New Jersey, Delaware, Maryland, Vermont, New York, Pennsylvania, Virginia, and Washington D.C.

Table 2 SCAQMD VOC Content Standards for Automobile Refinish Coatings

Coating Category	**SCAQMD VOC content limit g/L (lb./gal)**
Adhesion promoter	540 (4.5)
Clear Coating	250 (2.1)
Color Coating	420 (3.5)
Multi-Color Coating	690 (5.7)
Pretreatment Coating	660 (5.5)
Primer	250 (2.1)
Single-Stage Coating	340 (2.8)
Temporary Protective Coating	60 (0.5)
Truck Bed Liner Coating	310 (2.6)
Underbody Coating	430 (3.6)
Uniform Finishing Coating	549 (4.5)
Any Other Coating Type	250 (2.1)

2.1.2 Waterborne paints

The main difference between solvent-based and waterborne refinishing products is that in waterborne products, water is used to replace a significant portion of the solvents as the carrier and the solid fractions is greater. Typical solvent-based products may consist of up to 85% organic solvents by weight and 15% solids. Conversely, waterborne paints consist of about 10% organic solvent by weight, 70% water, and 20% solid.[18] Waterborne paints also contain polar solvents, such as acetone, tertiary butyl acetate, and Parachlorobenzotrifluoride that undergo negligible atmospheric photochemical reactions. Consequently, these solvents are exempt from VOC regulations, allowing the paints to comply with the National Rule.[14]

LHWMP's field observations have revealed that shops currently using waterborne coatings cite several advantages over solvent-based paints. First, the quality of finish is considered superior. Second, the use of waterborne basecoat has greatly decreased the irritating odor of organic solvents. Third, painters that use certain brands of waterborne paints report shorter finishing times and faster throughputs.[5] Fourth, waterborne paints have better color match with most newer automobiles because approximately 75 percent of original equipment manufacturer (OEM) assembly plants now use waterborne basecoats for their finishes.[14] Consequently, it is likely that the number of auto body shops that use waterborne paints will increase in Washington State and throughout the U.S.

Although waterborne paints contain lower concentrations of VOCs, this does not mean that they are y safer alternatives to traditional solvent-based products. For example, one of the major constituents of many waterborne auto body paints is 2-butoxyethanol, also known as ethylene glycol monobutyl ether (EGBE), Chemical Abstract Service (CAS) number 111-76-2. This glycol ether is currently regulated by OSHA with an 8-hour time weighted average (TWA) permissible exposure limit (PEL) of 50 ppm.[19] ACGIH recommends an 8-hour TWA TLV of 20 ppm for EGBE. NIOSH has an 8-hour TWA recommended exposure limit (REL) of 25 ppm, which is the same limit administered by the Washington State Division of Safety and Health.[20] OSHA also has a skin notation for EGBE, indicating that the dermal route of exposure can contribute to overall exposure. 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.[21] Acute human over-exposure to EGBE may result in irritation to the eyes, nose, and throat. A study of volunteers exposed to 195 ppm for 8 hours reported eye, nose, and throat discomfort. At 113 ppm for 4 hours, milder symptoms were experienced.[22] Humans appear to be less sensitive to the hematologic effect of EGBE than rats and mice; however, human red blood cells exposed *in vitro* showed increase fragility. In 1971, a worker experienced two separate episodes of hematuria (blood in urine due to kidney or other parts of the urinary tract allowing blood cells to leak into urine) after being exposed to unspecified concentrations of 2-butoxyethanol and diethylene glycol monobutyl ether.[23][24]

Currently in the United States, there is no complete waterborne refinish paint system available for auto body shops; only waterborne basecoats are used in the industry. The industry is concerned about the quality of the currently available waterborne primers and clear coats. Although waterborne primers are available, solvent-based primers contain mostly exempt solvents and therefore comply with VOC emission limits.[14]

Paint manufacturers face greater challenges in formulating waterborne clear coats for collision shop use than they do for OEMs. Waterborne paints must fully dehydrate for proper cross-linking and curing. However, the clear coats currently in use by automobile OEMs 2-6 times thicker than basecoats, which makes dehydration more difficult. These clear coats require specific work conditions that provide greater air movement than the technology currently available in most auto body shops.[14]

2.2 Spray application of waterborne paints in collision repair

For a regular refinishing job, waterborne or solvent-based refinishing products include wax and grease remover, primer, sealer, thinner, basecoat, and clear coat. Many of these refinishing products are available as traditional solvent-based products and some are available as waterborne products.

The spraying technique and technology required to apply waterborne paints can be very different compared to solvent-based paints.

Spraying is the most frequently used application technique in auto body repair. The common paint guns used for application are High Volume Low Pressure (HVLP) spray guns. HVLP spray guns reduce over-spray, the amount of hazardous chemicals released into the air, and the amount of paint needed to refinish a vehicle.[25] When spray painting, the painter holds the gun at the appropriate distance and angle to the surface and paints in a sweeping motion. For solvent-based paints, 50% overlap for each pass is required, but for waterborne paints 75-

80% overlap is required.[18] Painters report that waterborne basecoat finishes are approximately one-half the thickness of traditional solvent-based basecoats finishes. [18] For some brands of waterborne coatings, several coats of waterborne basecoats, with drying time in between, are often required for the color to match correctly.[5] For other brands whose waterborne paints contain 88% less solvent and 25% more pigment compared to solvent-based paints, they can achieve color match with one spray cycle without the drying time between each coat.[26] In addition, brands that use their unique wet-on-wet application (spray of colorless wet bed to merge spray-edges between each stroke also eliminate the drying time between each coat.[27] With fundamentally different spraying techniques between solvent-based and waterborne paints, painters' exposures may differ significantly. Therefore, it is important to characterize painters' airborne exposure when using waterborne paints.

2.3 Typical production cycle for a painter using waterborne products

The tasks required to complete the jobs of a given day are generally the same among auto body shops, with minor differences due to painters' work preferences. On average, a painter completes 4 to 6 jobs a day. A typical production cycle consists of the following activities:

- Reviews the work order provided by shop management.
- Inspects the work conducted by collision technicians (aka "bodymen") and begins preparing the vehicle for painting. This may include sanding, which occurs outside of the spray booth, taping and wiping down the car part with a tack cloth (typically done after the car has been driven into the spray booth). The purpose of using tack cloth is to remove loose particles of dust, dirt, and lint that would contaminate the surface that is about to be painted. Waterborne paints are especially susceptible to contaminants because they are a thinner coating than solvent-based paints.
- Mounts new (replacement) components, such as bumpers and quarter panels, on stands inside the spray booth. These items require minimal preparation.

- Mixes several basecoat paint products by weight to begin the color-matching process. The painter may utilize a “spray-out card” to test the color.
- Sprays a coat of solvent-based primer/sealer and bakes the vehicle in the paint booth. See Figure 1.
- Sprays waterborne base coat. Multiple coats may be needed, depending on the color and manufacturer of the coating. Some painters also apply a waterborne color-blending coating during this step.
- Allows the basecoat to dry in the paint booth using specialty air multipliers (venturi blowers specialized for drying waterborne paints).
- Sprays a coat of solvent-based clear coat and allows the job to bake in the booth.
- Removes the vehicle from the booth.

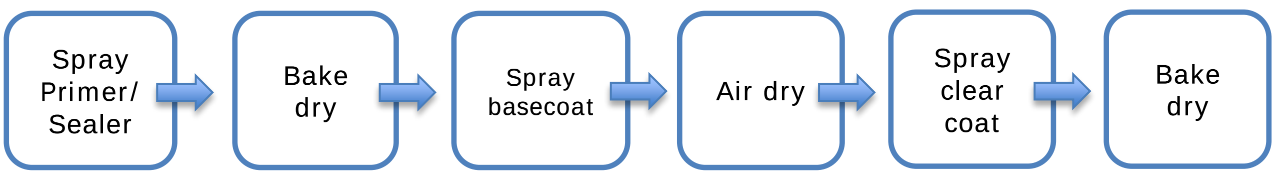


Figure 1 Steps taken for each spray cycle

2.3 Historical exposure analysis of solvent-based paints

Five historical studies were found, including two Health Hazard Evaluations (HHEs), and three in-depth survey reports on autobody repair control technology from NIOSH. The studies conducted similar personal exposure monitoring of painters in auto body shops that used solvent-based paints. The exposures (TLV fractions of geometric mean levels) of target analytes and their respective health end points are summarized in Table 3 and Table 4. As shown, in general the TLV fractions of solvent exposures were below one, except for toluene. Toluene had the highest number of studies with exposures above the ACGIH TLV, followed by methylene chloride and 2-ethoxyethyl acetate.

Table 3 Summary of semi quantitative summaries of TLV fraction of historical studies on auto body spray painting exposure

Background	TLV (2013) ppm	Historical Study TLV Fraction							
		Hanninen[(28)]	Elofsson[(29)]	Heitbrink[(30)]	Heitbrink[(31)]	Heitbrink[(32)]	Myer[(33)]	McCammon[(34)]	McCammon[(35)]
Year		1976	1980	1993	1993	1976	1993	1995	1995
n		54	106	6	22	12	30	8	10
Analyte									
Toluene	20	1.53	1.12	0.18	0.13	0.13	1.17	0.84	0.21
Xylene	100	0.058	0.032	0.015	0.008	0.011	0.020	0.039	0.0099
Styrene	20	-[3]	0.080	-	-	-	-	-	-
Ethanol	1000	0.0029	0.010	-	-	-	-	-	-
Butanol	20	-	0.10	-	-	-	-	-	-
Acetone	500	0.0062	-	-	-	0.0055	-	0.0046	0.0040
Methyl ethyl ketone	200	-	0.18	-	-	-	0.022	-	-
Methyl-iso-butyl ketone	20	0.085	0.026	-	-	-	0.35	-	-
Butyl acetate	150	0.045	0.0086	0.033	0.012	0.035	0.034	0.076	0.013
Ethyl acetate	400	0.0065	0.0049	0.0030	0.0060	-	0.024	-	-
Methylene chloride[1]	25	-	1.4	-	-	-	-	-	-
Trichloroethylene	10	-	0.23	-	-	-	-	-	-
Isopropanol[1]	400	0.0073	-	-	-	0.0025	-	-	-
2-Ethoxyethyl acetate[2]		-	-	-	-	-	4.9	-	-
Isobutyl Acetate	400	-	-	-	0.026	-	-	-	-

[1] OSHA PEL
[2] NIOSH REL
[3] – indicates analyte not sampled

Table 4 Summary of historical study analyte TLV basis

Analyte	Health end point			
	URT[1] irr[2]	Eye irr	CNS[3] impair	Other
Toluene				Visual impair, female reproductive, pregnancy loss
Xylene	Yes	Yes	Yes	
Styrene	Yes		Yes	Peripheral neuropathy
Ethanol	Yes			
Butanol	Yes	Yes		
Acetone	Yes	Yes	Yes	Hematologic effect
Methyl ethyl ketone	Yes	Yes		PNS[4] impair
Methyl-iso-butyl ketone	Yes			Dizziness, headache
Butyl acetate	Yes	Yes		
Ethyl acetate	Yes	Yes		
Methylene chloride	Yes	Yes	Yes	
Trichloroethylene	Yes	Yes	Yes	
Isopropanol[1]	Yes	Yes		
2-Ethoxyethyl acetate				Male reproductive

[1] Upper Respiratory Track
[2] Irritation
[3] Central Nervous System
[4] Parasympathetic nervous system

Also shown in Table 3 are the respective health end points for target analyte exposures. Most analytes had potential health end points of upper respiratory tract irritation, eye irritation, and CNS impairment. Toluene, which is commonly used in solvent-based paints, does not exhibit the typical health end points associated with other VOCs in solvent-based paints. However, toluene may cause visual impairment, female reproductive issues, and pregnancy loss.(36)

It is important to note that only one shop was sampled for each HHE and in-depth survey reports from NIOSH. Therefore the study results do not represent average exposure among autobody shops, rather the average exposure within the individual autobody shops. It is also noted that the historical exposure analysis occurred prior to the 1998 revision of the National Rule. Therefore it is likely that the paint contained higher levels of VOCs compared to solvent-based paints currently in use. Additionally, the spray gun used in the studies were not all HPLV spray guns, therefore may have caused higher exposure concentrations due to overspray. Finally, the configuration of the paint booths used in the historical studies may not be those used currently. Although some paint booths observed in our study dated back to 1980, a few shops had newer booths.

2.4 Waterborne paint standard operating procedures

Unlike solvent-based painting systems, standard operating procedures (SOPs) and best practices for using waterborne paints are not well-established. Because waterborne paints are advertised as safer alternatives, some painters are under the mistaken impression that they do not have to wear PPE, such as gloves and respirators (unpublished LHWMP field observations).

There are no standard guidelines for cleaning spray guns used for waterborne paints. Painters may develop their own methods for gun cleaning or may use the same methods they use with solvent-based paints, which may expose them to toxic chemicals such as lacquer thinners. There are also no standard procedures for handling waterborne wastes. Painters may be exposed to hazardous materials by inappropriately handling the wastes or failing to wear correct PPE. Inappropriate waste disposal may also harm the environment.

2.5 Barriers to converting to waterborne paints

There are many barriers that can prevent shops from converting to waterborne systems, such as quality of results and the time it takes to complete each job. The main barrier is the cost of altering the paint booth. Needed alterations may include refitting the paint booth to accelerate the drying of waterborne paints and upgrading the air compressor for the spray guns.

Solvent-based paints are usually cured in the booth at 120-175 °F. However, waterborne coatings do not require excess heat in order to dry, but require a large volume of airflow. Therefore this conversion requires equipment upgrades that increase air movement over the painted surfaces to provide efficient drying of waterborne finishes. This equipment may include hand-held air multipliers (which multiply the volume of air being expelled and filter out debris to prevent contaminants from sticking to the wet surface), spray booth-mounted ceiling fans, or corner – or ceiling-mounted air multipliers.[18] Mounting the air multipliers on the walls of the paint booth is more expensive, but most shops observed in this current study used corner-mounted as well as hand held multipliers (Figure 2). Depending on the painters' preference, they may use one or the other options more frequently.

a. b.

Figure 2 Examples of air multipliers

a. Wall-mounted (circled red)
b. Corner-mounted (circled yellow)

The cost of conversion may also include upgrading a facility's air compressors, and air filtration for the incoming spray booth air. The compressors must be able to provide an adequate volume of clean air at the appropriate pressure. The filters must be able to capture small particles, oil mist, and water vapor because the air used for spraying waterborne materials must be extremely clean.[18] Shops may also need to purchase dedicated stainless steel spray guns. Although the same spray gun may also be used for solvent-based paints, extensive cleaning is required when changing from one product type to the other.

Figure 3 Pneumatic waterborne gun cleaner

All shops visited in this current study had spray guns that were dedicated to one type of paint. Finally, some shops may choose to purchase pneumatically-operated gun cleaning systems (Figure 3) for the spray guns dedicated for waterborne paints. According to local businesses in King County, on average it costs approximately $10,000-$30,000 to convert (unpublished LHWMP field observation). This cost excludes replacing solvent-based paints, which may be an additional financial barrier. However paint manufacturers will reportedly offer considerable discounts if the shops commit to using their brand for a prescribed period of time (unpublished LHWMP field observation).

3. Methods

3.1 Human subjects protection

This study's protocols were approved by the Washington State Institution Review Board (Project D012714-U) and the Research Administrative Review Committee of Public Health-Seattle and King County.

3.2 Recruitment

The collision repair shops were recruited from four sources: LHWMP's Business Field Services database, the EnviroStars Program database, the Internet – searching for reference to waterborne coatings in business advertising, and referrals from owners and managers affiliated with other auto body shops. The owner of four businesses in a single franchise provided four study locations.

The EnviroStars Program was created in King County, WA in 1995 as an LHWMP service. The program provides assistance, incentives, and positive recognition for small businesses that reduce hazardous materials and waste to protect public health, municipal systems, and the environment.[(37)] In King County, the EnviroStars Program has had a long-standing relationship with several auto body shops. Four of the businesses that participated in this research were EnviroStar-certified.

To recruit businesses, telephone calls were placed to business owners or managers. We explained the purpose and significance of the study, described the sampling procedures, and emphasized their rights and protections during the study period. If the owners or managers were still interested in participating, recruitment visits were scheduled.

During our recruitment visits, the purpose and methods were explained to the shops' owners or managers. With their permission, we met with the painter(s) to describe the study. During this time, we confirmed that the painter(s) matched the eligibility criteria for enrollment:

1) Currently employed as an auto body painter in King County, WA;
2) Currently using waterborne paints;
3) Between the age of 18-65; and
4) Able to comprehend the English language, both verbal and written.

We also explained the painters' rights and responsibilities as study participants, including:

1) Participation is voluntary and they may leave the study any time without penalty;
2) They will be asked to identify the products used in the painting process;
3) They will wear an active personal sampling device during the painting process to capture the paint vapors in their breathing zones;
4) They have the right to ask questions and express concerns throughout the study; and
5) They will receive a copy of their personal sampling results, but all individual data and test results will be held confidential; only coded summary data without personal identifiers will be released.

Painters who agreed to participate in the study were enrolled as clients of Public Health-Seattle & King County and asked to provide informed consent by signing the appropriate form (Appendix A). Photo- and video- consent forms were also signed if the painters agreed to allow documentation of his tasks via still photography and video.

3.3 Personal sampling

Target analytes were selected by reviewing MSDSs (Appendix B) for products manufactured by Sherwin-Williams, PPG, Glasurit, R-M, Sikken, Lesonal, Wanda, Spies Hecker, and Standox. The target analytes were chosen based on the following criteria:

1) Widely used among different manufacturers; or
2) High percent weight in paint products; or
3) Low occupational exposure limit.

The selected target analytes were non-polar compounds (benzene, toluene, ethyl benzene, p-xylene, o-xylene, 1,2,4-trimethylbenzene, and petroleum distillate) and polar compounds (acetone, n-propanol, 2-butanol, 1-methoxy-2-propanol, ethyl-3-ethyoxypropionate, 4-hydroxy-4-methyl-2-pentanone, and 2-butoxyethanol). See Table 5 for abbreviations and basis of the TLV.

Table 5 Summary of target analyte names, abbreviations, and TLV basis

Chemical Name	Abbreviation	TLV Basis			
		URT[2] irr[3]	Eye irr	CNS[4] impair	Other
Benzene					Leukemia
Toluene					Visual impair, female reproductive, pregnancy loss
Ethyl benzene		Y			kidney damage, cochlear impair
p-xylene		Y	Y	Y	
m-xylene		Y	Y	Y	
o-xylene		Y	Y	Y	Asthma, hematologic eff[5]
1,2,4-Trimethylbenzene	124TMBZ			Y	
Petroleum Distillate[1]	PD	Y	Y		hematologic eff
Acetone		Y	Y	Y	
n-Propanol		Y	Y		
2-Butanol		Y	Y		
1-Methoxy-2-propanol	1MX2PAOH	Y	Y	Y	
Ethyl-3-ethoxypropionate	EEP	Y	Y		hematologic eff, skin irr
4-Hydroxy-4-methyl-2-pentanone	DAA	Y	Y		skin irr
Ethylene glycol monobutyl ether	EGBE	Y	Y		hematologic eff

[1] PD in concentration of mg/m^3
[2] Upper respiratory track
[3] Irritation
[4] Central nervous system
[5] Effect

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 (see the SOP in Appendix C). Coconut shell charcoal sorbent tubes (CSC) (SKC Anasorb CSC, 226-01A, 100/50 mg) were used to sample the non-polar compounds and ORBO 90 (O90) (Sigma-Aldrich ORBO 90 Carboxen 564, 160/80 mg) sorbent tubes were used for the polar compounds.

Preliminary air sampling at a local auto body painting training facility conducted at 100 mL/min revealed that the target analytes were either below or just above their respective MLOQs. Therefore, to increase the mass of material collected and protect against breakthough of thet more volatile compounds, two sampling flow rates, 100 mL/min and 400 mL/min were used for each sampling media with a sampling manifold attached to the pump. Two pumps were used per person, one with ORBO tubes and one with CSC tubes (Figure 4)

- Pump #1 / Manifold #1:
    - ORBO 90 at 400 mL/min
    - ORBO 90 at 100 mL/min
- Pump #2 / Manifold #2:
    - Coconut shell charcoal at 100 mL/min
    - Coconut shell charcoal at 400 mL/min

Figure 4 Two-pump setup
Red tape: manifold #1
Green tape: manifold #2

Laboratory analysis subsequently determined that no breakthrough occurred at 400mL/min. Therefore, only one pump was used per worker for the remaining sampling visits (at 400mL/min, with one sample manifold holding a single CSC and a single O90 sorbent tube, as shown in Figure 5).

Figure 5 One-pump setup
Red arrow: O90 sorbent tube
Green arrow: CSC sorbent tube

On the day of sampling, we arrived at the shop approximately 30 minutes before the painter applied his first basecoat. Our sampling workstation was set up close to the paint booth such that it did not disrupt the shop's operation and presented a clear view of the painting operation.

Before sampling, we described the sampling procedure to the painter and emphasized the importance of only sampling waterborne paints, and not solvent-based paints. The painter was asked to notify us prior to spraying waterborne paints so we could place the sampling unit (sampling pump and manifold) on the worker (Figure 6).

Figure 6 Placing sampling units on the painter

The pumps were switched on immediately before the painter entered the paint booth. The painter was also asked to notify us when he finished spraying waterborne paints so we could switch off the pumps and remove the sampling units. We also told the painter that we must switch off the pumps before he cleaned his spray gun, because some painters used lacquer thinner and other organic solvents.

Some jobs required multiple layers of basecoat, depending on the paint brand. In this case, the painter first sprayed one layer of basecoat, exited the paint booth, allowed the paint to dry, and re-entered the booth to spray the next layer. This process was repeated until the painter successfully matched the vehicle's color. In this situation, we switched off the pumps when the painter left 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 layers of 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 in the 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.

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 Lab (EH Lab) for analysis.

3.4 Ventilation measurements

Paint booth measurements were typically made on the day of sampling while the booths were empty. Because the booth in Shop 10 was occupied for the entire duration of our sampling visit, this booth was measured one month later. Additionally, because it was not possible to remove the vehicle parts from Booth 1 in Shop 08, measurements were made in the presence of a vehicle, quarter panels and bumpers.

A TSI Alnor VelociCalc 9565 hot wire anemometer was used to measure linear air velocity. All paint booths were downdraft models, with the exception of Shop 03 Booth 2, which was a side-draft prep-station. The anemometer was placed with the probe perpendicular to the direction of air flow, parallel to the floor. Measurements were made at the center of each ventilation grill and at three different heights: ceiling, breathing zone (approximately 5 feet above the booth's surface), and floor. We also measured the paint booths' dimensions and temperature.

Shop 01 Booth 2 and Shop 03 Booth 2 were prep-stations. For Shop 01 Booth 2, which was a downdraft booth, the measurements were made similar to the other paint booths. However, because this was not a contained booth (Figure 7), ceiling level measurements were made at approximately 12.5 feet from the floor. Shop 03 Booth 2 was a side draft booth and measurements were made by placing the anemometer probe perpendicular to the floor, perpendicular to the air flow. Similarly, measurements for Shop 03 Booth 2 were made at the center of each ventilation grill, at 12-inch increments.

(a) (b)

Figure 7 Difference between prep-station and spray booth
(a) Shop 01 Booth 2 prep-station: Painting station contained by industrial curtains on the sides but opened to the ceiling
(b) Contained downdraft booth

3.5 Documentation of waterborne paint work-practices

The Client Intake Form (Appendix D) and Waterborne Painting Data Form (Appendix E) were used to record painters' background information and waterborne paint work-practices. Information documented included the following:

- Painter's years of experience spray-painting with solvent-based paints and waterborne paints
- Frequency of the painter spraying waterborne paints per week
- Painter's use of PPE
- Spray gun use, including model/type of spray gun and gun cleaning procedures
- Waterborne waste disposal procedures

3.6 Analysis

3.6.1 Analyte concentrations

The UW EH Lab performed sample analysis according to their EHLSOP-06 method. Samples (O90) analyzed for polar analytes were desorbed according to NIOSH Method 2554 (85:15 $MeCl_2$:MeOH). n-Butanol was used as the internal standard. Samples (CSC) analyzed for non-polar analytes were desorbed using NIOSH method 1501. Propyl benzene was used as the internal standard. The petroleum distillates were quantified as heptane. Gas chromatography (GC) flame ionization detection (FID) (Agilent Technologies 7890A GC with Autosampler) was used to analyze all the samples. The GC column used was an Agilent Technologies DB-Was (60m x 0.25mm, 0.5 μm film thickness).

The GC FID method detected the analyte's mass (μg) per sample. To determine sample concentrations the volume for each sample was calculated:

$$flow\ rate\ [ml/min] = \frac{flow_{pre}[ml/min] + flow_{post}[ml/min]}{2}$$

$$volum[L] = flow\ rate[{}^{ml}/_{min}]\ \times time[\text{min}]/1000[ml/L]$$

- $Flow_{pre}$: pre-calibrated sampling flow rate
- $Flow_{post}$: post-calibrated sampling flow rate

Then sample concentration for each analyte was calculated with:

$$analyte\ concentration\ [ppm] = \frac{\frac{mass}{volume}[{}^{\mu g}/_{L}] \times 24.45[{}^{L}/_{mole}]}{analyte\ molecular\ weight\ [{}^{g}/_{mole}] \times 10^{-6}[{}^{\mu g}/_{g}]}$$

$$analyte\ concentration\ [\frac{mg}{m^3}]\ = \frac{mass}{volume}[{}^{\mu g}/_{L}] \times 10^{-3}[\frac{mg}{\mu g}] \times 1000[\frac{L}{m^3}]$$

The molecular weights were unknown for the peaks comprising the PD grouping. Therefore they were reported in the unit of mg/m^3.

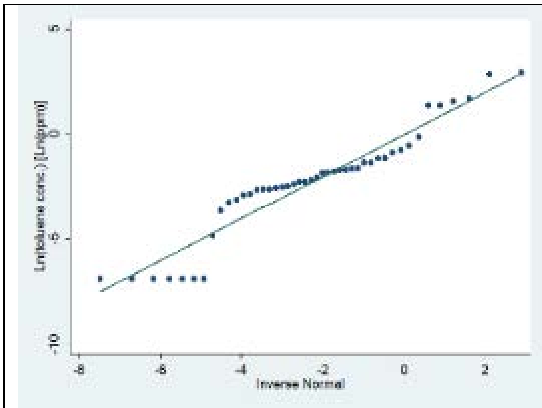
The EH Lab provided the reporting limit (RL) for each analyte, and the MLOQs for each analyte was calculated with:

$$MLOQ\ (Reporting\ concentration\ limit)[{}^{\mu g}/_{L}] = \frac{RL[{}^{\mu g}/_{sampled\ air\ volume}]}{volume\ [L]}$$

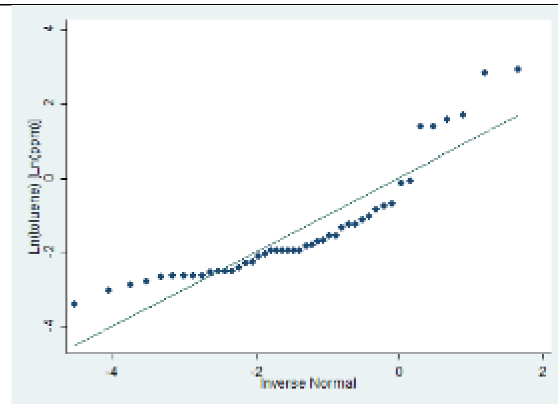
$$Reporting\ concentration\ limit[ppm] = \frac{RL[{}^{\mu g}/_{sampled\ air\ volume}] \times 24.45[{}^{L}/_{mole}]}{analyte\ molecular\ weight\ [{}^{g}/_{mole}]}$$

3.6.2 Exposure analysis

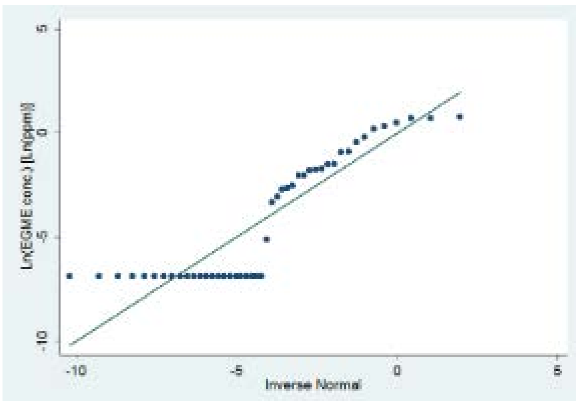
Stata Statistical Software 13 was used to perform exposure analysis. Q-Q plots were used to determine whether the data was log-normally distributed as well as observing the sample concentration below the MLOQ (Figure 8). In Figure 8, the flat line at the left end indicates substitution of zero concentrations to 0.0001 for log-transformation. The log-transformed distribution closely resembles the 1:1 line, indicating log-normality, therefore the log-transformed concentrations were used for subsequent analysis. The concentrations of target analytes that were below the MLOQs were replaced by MLOQ/$\sqrt{2}$.[(38)] The geometric means (GMs) and geometric standard deviations (GSDs), and 50^{th} and 90^{th} percentiles were calculated for each analyte. Parametric exceedance fractions (probability of exceedance, assuming a normal distribution based on the log-transformed concentrations sample results) and empiric exceedance fractions (the fraction that exceeds the limit according to the sample concentrations) were calculated for the ACGIH TLV and odor thresholds referenced in the NIOSH Pocket Guide to Chemical Hazards.[(39)] The analyte concentrations were not 8-hour time-weighted prior to computing the TLV exceedance fractions. Therefore the results are were worse case exposure scenario, assuming that the painters were exposed to the GM concentrations for eight hours. Odor thresholds were calculated because painters had expressed the reduced smell of VOCs after the conversion to using waterborne paints. ACGIH TLV and NIOSH odor thresholds were selected because data are available for most of the target analytes. Since the number of samples above their MLOQs were small, the parametric exceedance fractions are likely over estimated because the concentration standard deviation is underestimated.



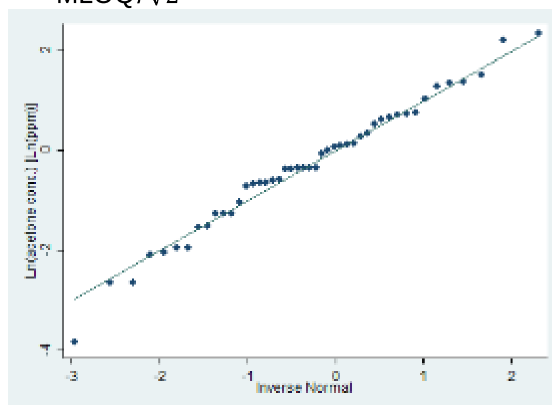
(a) Toluene



(b) Toluene <MLOQ replaced with MLOQ/$\sqrt{2}$



(c) Acetone



(d)Acetone <MLOQ replaced with MLOQ/$\sqrt{2}$

Figure 8 Selected Q-Q plot for sample concentrations showing log-normality.
(b) (d): Q-Q plots of sample concentrations after replacing <MLOQ concentrations with MLOQ/$\sqrt{2}$

For analytes with no NIOSH odor threshold (124TMBZ and 1-methoxy-2propanol), EPA or National Institute of Health (NIH) odor thresholds were used. When an odor threshold was presented as a range (e.g., 10-30 ppm), the lower value was used. Additionally, percentages of samples with analyte concentrations above their respective MLOQs were calculated with respect to each paint brand and compared to their composition, as provided on the MSDS.

The total solvent exposure TLV fraction was used to compare exposures using waterborne vs. solvent-based paints. TLV fractions were calculated using the GMs for each analyte used in this study and for those described in historical studies. The historical sampling results from NIOSH studies were presented as exposures for each painter, rather than as mean exposures. Therefore, we calculated the exposure for each analyte for the NIOSH studies. Historical study results reported by Elofsson et al.[29] were summarized in fractions of TLV using the 1980 TLVs. Therefore we converted the TLV fractions using 2013 TLVs in order to compare to our study results. To compare total solvent exposures between waterborne and solvent-based paints, analytes with the same health end point categories (irritations and central nervous system impairment) were summed separately as total solvent exposure TLV fractions, using:

$$\text{Total solvent exposure TLV fraction}^{(36)} = \frac{C_1}{TLV_1} + \frac{C_2}{TLV_2} + \cdots + \frac{C_x}{TLV_x}$$

All analyte concentrations from this study and historical studies were short-term sample results. Concentrations used to calculate the TLV fractions were not time-weighted average concentrations. Therefore, the TLVs used to calculate TLV fractions were used as a bench mark to compare exposures between solvent-based and waterborne paints during sampled time. The TLV fractions were not calculated to determine if the exposures exceeded the limit.

3.6.3 Ventilation

The relationship of ventilation performance to airborne concentrations was explored. This included evaluating the relationship between the booths' average linear air velocities at the breathing zone and the measured analyte concentrations. In addition, the efficiency of prep-station ventilation was explored by comparing the airborne concentrations in a spray-booth vs. a prep-station in the same shop.

4. Results

Eleven study subjects were recruited from ten auto body shops. Sampling visits were conducted from November 2014 through February 2015. The subjects' background information, including spray gun and PPE use are summarized in Table 7. Subjects had spray-painted for 2 to 35 years and had used waterborne paints for 1.5 to 5.5 years. The average number of jobs performed in a day depended on the season. Generally the winter season is the busiest, which is when this study was conducted. Painters typically completed 4 to 7 jobs per day. Forty-six airborne samples were collected total, with arithmetic means (AM) and arithmetic standard deviations (ASD) of sampling time summarized in Table 6.

Table 6 Sample ID and corresponding shop ID and sampling time

Sample ID		Shop ID	Sample Number (n=46)	Sampling Time AM (min)	Sampling Time ASD (min)
ORBO 90	CSC				
1-14	204-123	5	8	29	27
15-22	214-221	8	6	22	16
23-34	222-233	1	10	16	5.2
35-42	234-241	6	6	27	8.0
43-48	242-247	2	4	11	2.9
49-53	248-252	9	3	11	4.4
54-57	253-256	10	2	11	0.71
58-60	257-259	11	1	17	NA
61-65	260-254	3	3	9	0.58
66-70	265-269	4	3	19	8.0

Table 7 Subject background summary

Shop ID	Subject				Spray Gun			PPE		
	Subject ID	Race/ Ethnicity	Spray Paint Experience (years)	Waterborne Paint Experience (years)	Make/Model	Type	Nozzle Pressure (psi)	PPE worn	Respirator Cartridge change out frequency (per month)	Gloves type and change out frequency (per day)
1	A	Hispanic, Mexican	6	1.5	SATA 4000	HVLP[1]	Est.[2]	half-face APR[3], Shootsuit, gloves	0.5	Nitrile (5)
1	B	White, European American	26	4	SATA 4000	HVLP	Est.	half-face APR, cloth or leather work boots	1	
2	A	American Indian	13	2	AnestAwata LPH 400 SATA jet 4000	HVLP HVLP	Est. Est.	half-face APR, Shootsuit, cloth or leather work boots, gloves	0.5	Nitrile (6)
3	A	White, European American	2	1.5	SATA 4000	HVLP	30	half-face APR, Shootsuit, gloves	0.25	Nitrile (20)
4	A	White, European American	25	5.5	SATA jet 4000	HVLP	25-28	PAPR[4], Shootsuit, gloves	Not applicable	Nitrile (20)
5	A	White, European American	22	6	SATA R3000	HVLP	Est.	PAPR, Shootsuit, gloves	Not applicable	Nitrile (30)
6	A	White, European American	8	4	DevilbissTekna ProLite	HVLP	18	half-face APR, Shootsuit, gloves, cloth or leather work boots	0.5	Nitrile (20)
8	A	Asian, Filipino	5	4	Anest Awata LPH-4000	HVLP	Est.	half-face APR, disposable coveralls, gloves	0.25-0.5	Nitrile (20-30)
9	A	White, European American	28	3	SATA 3000	HVLP	Est.	half-face APR, Shootsuit, earplugs	Not regularly	
10	A	White, European American	35	1.5	SATA WB Jet 4000B	HVLP	Est.	PAPR , Shootsuit	Not applicable	Latex (1-2/wk)
11	A	White, European American	20	2	SATA 4000	HVLP	Est.	PAPR, Shootsuit, gloves, cloth or leather work boots	Not applicable	Nitrile (4)

[1] High velocity low pressure
[2] Estimated
[3] Air purifying respirator
[4] Pressured air purifying respirator

4.1 Breathing zone exposures

Analyte concentrations were typically below their respective MLOQs. As shown in Table 8, toluene (43%>MLOQ), PD (30%), acetone (57%), and EGBE (37%) had the highest percentage of sample concentrations above their MLOQs. As shown by the GMs, the exposures were low. Analytes with the highest GM exposures were PD (GM=2.6 mg/m^3, GSD=2.8), toluene (GM=0.24 ppm, GSD=4.6), acetone (GM=0.72 ppm, GSD=3.7), and EGBE (GM=0.18 ppm, GSD=3.7). The concentrations of all analytes were much lower than their respective TLVs.

Table 8 Airborne concentrations of target analytes

Analyte	AM MLOQ	% > MLOQ	TLV (ppm)	GM (ppm)	GSD	Min (ppm)	Max (ppm)	50th % (ppm)	90th % (ppm)	TLV fraction[2]
Non-polar										
Benzene	0.1	0	1	0.054	2.3	0.014	0.49	0.06	0.16	0.108
Toluene	0.2	43	20	0.24	4.6	0.033	18	0.14	4.21	0.012
Ethyl benzene	0.2	2	20	0.094	2.3	0.021	0.71	0.07	0.30	0.005
p-xylene	0.2	2	100	0.092	2.3	0.021	0.71	0.07	0.30	0.001
m-xylene	0.2	7	100	0.10	2.3	0.021	0.71	0.11	0.30	0.001
o-xylene	0.2	4	100	0.093	2.2	0.021	0.71	0.07	0.30	0.001
124TMBZ	0.2	2	25	0.086	2.2	0	0.034	0.02	0.71	0.003
PD[1]	2.9	30	350	2.6	2.8	0	42	0.71	42.08	0.007
Polar										
Acetone	0.6	57	500	0.72	3.7	0.02	10.47	0.71	3.90	0.001
n-Propanol	0.2	17.4	100	0.092	3.0	0.01	0.90	0.07	0.52	0.001
2-Butanol	0.1	15.2	100	0.080	3.6	0.01	2.29	0.07	0.72	0.001
1M2PAHO	0.1	23.9	100	0.086	2.8	0.01	0.83	0.07	0.28	0.001
EEP	0.1	8.7	NA[2]	0.05	2.8	0.00	0.61	0.05	0.18	NA
DAA	0.1	0	50	0.068	2.6	0.00	0.42	0.00	0.14	0.001
EGBE	0.2	37	20	0.18	3.7	0.01	2.83	0.14	1.74	0.009

AM = Arithmetic Mean
MLOQ = Method Limit of Quantitation
TLV = Threshold Limit Value
GM = Geometric Mean
GSD = Geometric Standard Deviation
50th % = 50th percentile
90th % = 90th percentile
NA = Not available
[1] PD concentrations in mg/m^3
[2] TLV fraction = GM/TLV

The parametric and empiric exceedance fractions for the ACGIH TLVs and NIOSH odor thresholds are shown in Table 9. In general, the exceedance fractions were low: the TLV empiric exceedance fractions were zero for all samples. The TLV parametric exceedance fractions were mostly zero, except for benzene (0.2) and EGBE (0.006). The odor empiric exceedance fractions were mostly zero, except for toluene (0.04), 2-butanol (0.1), and EGBE (0.2). The parametric exceedance fractions for odor threshold were higher than the empiric exceedance fractions. Acetone had the highest parametric exceedance fraction of 0.6, followed by EGBE (0.3), 1M2PAHO (0.07), toluene (0.007), and 2-butanol (0.01).

Table 9 Analyte concentration exceedance fractions

Analyte	**TLV (ppm)**	**TLV Parametric Exceedance Fraction**	**TLV Empiric Exceedance Fraction**	**NIOSH Odor threshold (ppm)**	**Odor Parametric Exceedance Fraction**	**Odor Empiric Exceedance**
non-polar						
Benzene	1	0.2	0	12	5.E-11	0
Toluene	20	0.00004	0	10-15	0.007	0.04
Ethyl benzene	20	0	0	140	0	0
P-xylene	100	0	0	200	0	0
M-xylene	100	0	0	200	0	0
O-xylene	100	0	0	200	0	0
124TMBZ	25	1.E-12	0	0.4*	0.03	0
PD[1]	350	9.E-07	0	NA	NA	NA
polar						
Acetone	500	3.E-06	0	20	0.6	0
n-Propanol	100	3.E-12	0	30	1.E-07	0
2-Butanol	100	2.E-08	0	0.4-2.5	0.1	0.0
1M2PAHO	100	6.E-12	0	10**	0.07	0
EEP	NA	NA	0	NA	NA	NA
Diacetone alcohol	50	3.E-12	0	0.28	0.07	0.04
EGBE	20	0.006	0	0.35	0.3	0.3

[1] PD concentrations in units of mg/m^3
[2] EPA odor threshold
[3] NIH odor threshold

Using the percentage of samples >MLOQs as an indicator of the analytes being present in the paints, Table 10 compares their presence to their paint compositions indicated in their MSDSs. As shown, the MSDSs provided limited information on paint composition. Airborne acetone and toluene were detected in all paint brands, but none listed it in their MSDSs. In general none of the polar analytes detected were listed in the MSDSs. No MSDSs accurately reflected the presence of the analytes detected in this study.

Table 11 compares the TLV fractions for our study vs. historical studies for solvent-based paints. Because benzene, toluene, and 2-ethoxyethyl acetate do not have the same health end point as the other analytes, they are compared separately. As shown, our study had the lowest toluene TLV fraction compared to historical studies. Comparing total TLV fractions for upper respiratory track (URT) and eye irritations, our study has a fraction of 0.032, which is 6.5 to 65 times lower than four of the six historical studies. Our study's total TLV fraction for URT and eye irritations was higher than two of the historical NIOSH studies (0.027 and 0.026). However, our study had the lowest total TLV fractions for central nervous system impairment compared to all historical studies.

Table 10 Comparison of analyte presence and samples and MSDS-indicated percent weight

Paint Brand		Benzene	Toluene	Ethyl benzene	p-xylene	m-xylene	o-xylene	1,2,4-TMBZ	PD	Acetone	n-propanol	2-butanol	1M2PAHO	EEP	DAA	EGBE
Spies Hecker (n=19)	% >MLOQ	0	32	0	0	0	0	5	21	40	13	0	20	0	0	0
	MSDS (% wt.)	-[1]	-	-	-	-	-	-	-	-	UK[2]	UK	UK	-	-	UK
Sherwin Williams (n=3)	% >MLOQ	0	0	0	0	0	0	0	0	40	13	0	20	0	0	0
	MSDS (% wt.)	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-
Glasurit (n=6)	% >MLOQ	0	83	0	0	0	0	0	67	57	0	100	14	14	0	100
	MSDS (% wt.)	-	-	-	-	-	-	0-5	0-5	-	-	0-20	-	0-30	-	0-60
Cromax (n=8)	% >MLOQ	0	25	0	0	0	0	0	25	63	75	0	13	0	0	0
	MSDS (% wt.)	-	-	-	-	-	-	-	UK	-	UK	UK	UK	-	-	UK
PPG (n=10)	% >MLOQ	0	70	10	10	30	20	0	40	50	0	0	40	30	0	60
	MSDS (% wt.)	-	-	-	-	-	-	-	0.5-1.5						0-1	5-10

[1]UK: Unknown
[2]-: not reported on MSDS

Table 11 TLV fraction comparison between solvent-based and waterborne paints

Study	**n**	**Benzene**	**Toluene**	**2-ethoxyethyl acetate**	**URT and eye irritation**	**CNS impair**
Our results	46	0.1	0.12	-	0.032	0.005
Hanninen[28]	54	-	1.5	-	0.21	0.064
Elofsson[29]	106	-	1.2	-	0.21	0.067
Myer[33]	30	-	1.2	4.92	2.1	0.020
Heitbrink[30]	6	-	0.182	-	0.051	0.015
Heitbrink[31]	22	-	0.13	-	0.026	0.008
Heitbrink[32]	12	-	0.126	-	0.054	0.017
McCammon[34]	30	-	0.84	-	0.12	0.043
McCammon[35]	8	-	0.21	-	0.027	0.014

[1]-: not sampled for the study

4.2 Ventilation

Personal samples were collected in 15 spray booths (Table 12) and their linear air velocities were measured. The booths were built ranging from 1980 to 2005. All booths were prefabricated and assembled in the paint shops. All booths were downdraft models, with the exception of Shop 01 Booth 02 (downdraft prep-station), and Shop 03 Booth 02 (side-draft prep-station). Individual measurements of each paint booth are presented in Appendix G.

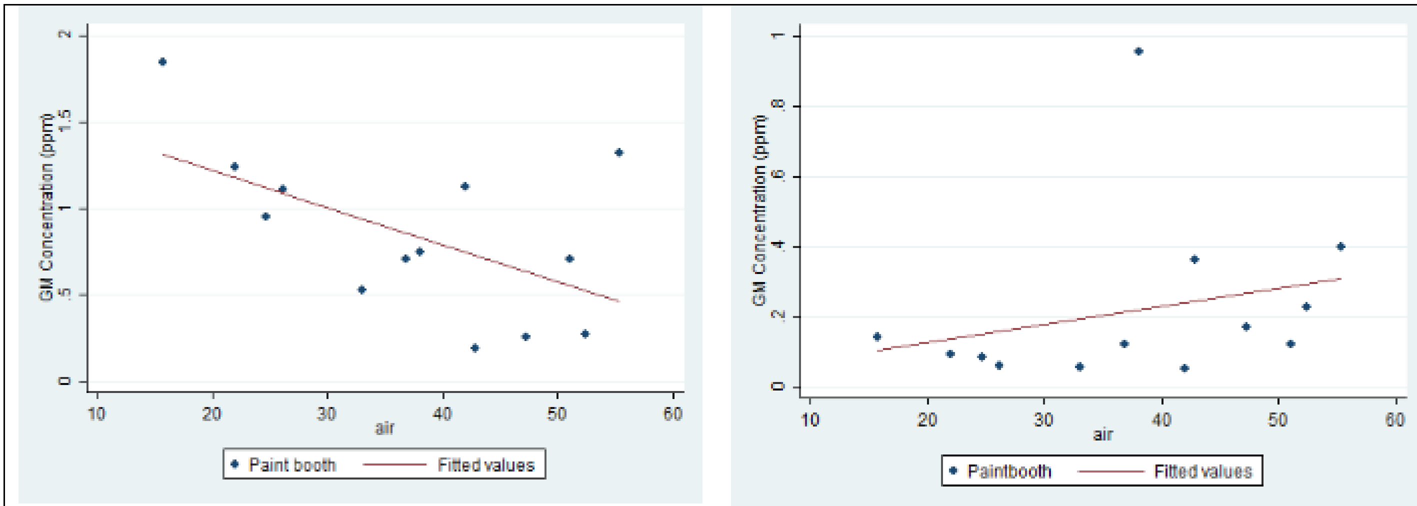
According to OSHA regulation 1910.107(b)(5)(i), "*spraying operations except electrostatic spraying operations shall be designed, installed, and maintained that the average air velocity over the open face of the booth (or cross section during spraying operations) shall be not less than 100 linear feet per minute.*" None of the shops visited met this requirement. The average linear air velocity at workers' breathing zone ranged from 3 to 89 ft./min.

Table 12 Shop waterborne system and spray booth summary

	Waterborne Coating		**Spray Booth**									
Shop ID	Paint Brand	Avg. waterborne paint use (times/week)	Spray booth ID	Model	Year	Floor filter change schedule	Days since last floor filter change	Height (in.)	Length (in.)	Width (in.)	Temp (F)	Avg. linear velocity[2] (ft./min)
1	Sherwin Williams	10	1	Devilbiss Concept/Cure	1990	2-4 weeks	10	108	296	156	55.4	52.4
			2	Devilbiss Concept/Cure	1990	2-4 weeks	10	150[1]	400	310		89.1
2	Spies-Hecker	25	1	AFC 7000	1980	1 week	3	107	289	168	71.2	55.3
3	Cromax	60	1	K40 Raptor	2005	2 weeks	7	105	314	156	71.8	36.8
			2	K40 Raptor	2005	2 weeks	7	100	307	235	65.3	23.3
4	Cromax	35	1	Eagle	1980	1 week	1	120	286	161	83.2	42.0
5	Spies-Hecker	22	1	Team Blowtherm Ultra 2000B	1998	1 week	4	110	295	174	64	47.3
6	Sherwin Williams	20	1	Blowthernm Concept II Cure	2002	2 weeks	9	110	323	168	71	22.0
8	Glasurit	20	1	Team Blowtherm	NA[4]	50 hours	14	109	323.5	283		42.8
			2	Spraybake	NA	50 hours	14	118.5	282	164.5	72.8	38.0
9	Spies-Hecker	40	1	GFS Devilbiss	1996	2 weeks		108	276	156	90.9	26.1
			2	GFS Devilbiss	1992	2 weeks	~60[3]	110	295	156	78.7	15.7
			3	GFS Devilbiss	2005	2 weeks		107	369	278	64.9	51.0
10	Cromax	20	1	Blowtherm 2000	1990	2-3 months	21	111	259	156	76	24.7
11	Glasurit	12	1	GFS Ultramax	NA	Not regularly	~60[3]	105	324	158	80.6	33.0

[1] From floor to filter housing. Another 150" to ceiling.
[2] At breathing zone
[3] Worker expressed that he changed filters about every two months and that he should be changing the filter around the time of sampling visit, but the shop had been too busy for filter change-out.
[4] Unknown to shop

Figure 9(a) shows the relationship of the GM analyte breathing zone concentrations to the spray booths' average linear air velocities at the breathing zone (excluding prep-station measurements). There is no significant relationship between linear air velocity and analyte mean concentration. As demonstrated by acetone and toluene, which have more samples greater than their respective MLOQs, higher linear air velocity is associated with lower acetone mean concentrations, but the inverse is true for toluene.



(a) Relationship between ventilation and sampled acetone GM concentration

(b) Relationship between ventilation and sampled toluene GM concentration

Figure 9 Relationship between spray booth ventilation and analyte concentrations

Table 13 Analyte concentrations in spray booths vs. prep-stations

Shop ID	Booth ID	Booth Type	Number of jobs sprayed	Total Analyte Concentration (mg/m^3)
1	1	Spray booth	3	15.3
	2	Prep-station	2	381
3	1	Spray booth	2	3.90
	2	Prep-station	1	8.04

Of the shops visited, only Shop 1 and 3 regularly sprayed vehicle parts in their prep-stations. Table 13 shows the relationship between type of ventilation and airborne analyte concentrations. The Shop 1 prep station was essentially a downdraft booth that was only contained on the four sides with industrial curtains. The top side was open to the shop environment. In Shop 3, the prep-station was a crossdraft both. The prep-station had a low ceiling; therefore the top side was contained. The four sides of the prep-station were also contained with industrial curtains (Figure 10). In both shops, the total airborne exposures to analytes were higher in the prep-stations than in the spray booths, despite having fewer jobs sprayed in the prep-stations.

Figure 10 Shop 03 prep-station

4.3 Work practices

4.3.1 Personal protective equipment

To minimize exposures to waterborne paints, painters generally relied on paint booth ventilation and PPE. Painters were responsible for the basic maintenance of the paint booths, including cleanliness, filter change-out, and notifying management if major maintenance was needed. Generally, shops had regular filter change-out schedules (Table 12), except for Shop 11. For most shops, floor filters were changed every two weeks. However, painters noted that depending on the number of jobs completed, they might change filters more frequently, especially when they subjectively noticed decreased air flow.

The basic PPE worn by painters included respirators, Shootsuits/coveralls, gloves, and work boots (Table 7). All painters wore protective clothing during spraying operations, except for Shop 01 Subject B, who wore street clothing. Respirators commonly used by the painters included half-face air purifying respirators (APRs) and powered air purifying respirators (PAPRs). Painters who used half-face APRs did not wear eye protection because they were concerned that this would compromise their ability to apply a high-quality finish. Filter cartridges used by painters who wore half-face APRs were organic vapor cartridges with particulate filters. Painters changed their cartridge filters ranging from weekly, bi-weekly to monthly. No painters smelled paint during spraying when they wore their respirators.

Nitrile gloves were worn by most painters. Two painters did not wear gloves and one wore latex gloves. Those who wore nitrile gloves routinely changed them 20 to 30 times a day. Painters usually changed their gloves between tasks to prevent contaminating their jobs with wet paint.

4.3.2 Gun cleaning

Painters usually wore full PPE when cleaning their guns because they were cleaned right after finishing a paint job. However, they often removed their respirators. Not all mixing rooms were equipped with ventilation systems.

Gun cleaning procedures varied amongl shops (Table 14). Although many painters used waterborne gun-cleaning devices, the cleaning agents used varied. The most common procedure observed was:

1. Remove the paint cup from the paint gun (Figure 11)
2. Rinse the gun with a waterborne cleaner.
3. Dry the gun with compressed air.
4. Perform a final rinse with a highly volatile solvent.

Figure 11 Example of an HPLV spray gun with disposable paint cup attached

There were other ways that painters cleaned their gun. Some painters used only lacquer thinner and did not dry with compressed air. Some painters used waterborne cleaners for the first rinse and used more hazardous cleaners, such as Naked Gun® and Clean Shot™

(Figure 12) for the final rinse. These cleaners may contain methylene chloride, which is a potential carcinogen. Other painters used acetone, for the final rinse.

Painters collected the waterborne cleaning rinsate and allowed the paint to settle in the containers. The remaining liquid was reused as a waterborne gun cleaner. Painters noted that because they could recycle and reuse the waterborne cleaning agents, they seldom had to replenish them.

Figure 12 Spray-cans containing hazardous cleaning agents

Table 14 Gun cleaning procedure summary

Shop ID	Pneumatic cleaning system	Procedure
1	Yes	1. Rinsed guns solely with lacquer thinner
2	Yes	1. Rinsed guns with OneChoice SX100 waterborne paint cleaner 2. Used acetone in a squeeze bottle to rinse the gun
3	No	1. Rinsed the gun with Water Wave Waterborne Cleaning Solution 2. Dried the gun with an air hose and expelled the rinsate onto mixing room floor
4	No	1. Rinsed the gun with 50% solution of DuPont FinalKlean V-3921S surface cleaner 2. Used hand pressurized dispenser to rinse through guns. 3. Blew air through guns and rinsed with lacquer thinner
5	Yes	1. Rinsed guns with OneChoice SX100 waterborne paint cleaner 2. Used acetone in a squeeze bottle to rinse the gun
6	No	1. Broke down guns (separated the parts) 2. Sprayed gun nozzles with Clean Shot (done over a drum container so the liquid could be captured)
8	Yes	1. Rinsed guns using waterborne cleaner 2. Rinsed guns with lacquer thinner
9	Yes	Unknown
10	No	1. Rinsed guns with waterborne cleaner into an open container 2. Dried guns with air gun nozzle
11	yes	1. Ran guns through waterborne cleaner 2. Scrubbed the outside of guns with lacquer thinner 3. Pressure dried guns

4.3.3 Waste disposal

Wastes generated that were unique to waterborne paint systems included the rinsate from gun cleaning and excess paints remaining in the spray cup from each paint job. Unlike gun cleaning, painters did not usually wear PPEs, such as coveralls and gloves, when processing waterborne wastes because they did not handle wastes immediately after generating them. For example, rinsate from gun cleaning was directly captured into a larger container and allowed to settle. The excess paints in paint cups were left until they were no longer needed for smaller jobs or "touch-ups". Painters collected and disposed of the excess paints at the end of the day or when the painters had time. As a result, when painters were handling waterborne wastes, they were usually wearing street clothing, occasionally wearing gloves.

Excess paints were disposed of in three general ways (Table 15). First, some painters sprayed the paint on cardboard, which was baked in the booth until dry. The cardboard was then disposed of in the shop's dumpster (i.e. the municipal waste stream). Second, several painters collected excess paints in large containers and added flocculent until they solidified (Figure 13). The solidified paint was disposed of in the municipal waste stream. Third, the liquids were stored in waste drums dedicated to waterborne wastes (Figure 14) and collected by a hazardous waste collection vendor.

Figure 13 Solidified paint waste

Figure 14 Designated waterborne waste drum (red arrow)

Table 15 Waste disposal procedure summary

Shop ID	Process of paint disposal
1	Spread excess paint on cardboard and dried it through several booth cycles. Then placed cardboard in the shop's dumpster.
2	Solidified leftover paints with Homax Paint Hardener in 5 gallon bucket and then placed in the shop's dumpster
3	Added flocculants to waste paint in 5 gallon drum. At the time of study Shop 03 had not generated enough waste yet to dispose of.
4	Liquid collected in 55 gallon barrel with closable filter funnel. All waste paint in this barrel had been sampled by Safety Kleen but no results received yet.
5	Added flocculent to paint then in the shop's dumpster
6	Leftover paint transferred to 5 gallon container via a funnel. When container became full, contents were transferred to a 55 gallon drum, which was stored at another location. When full the 55 gallon drum was collected by Evergreen Services.
8	Liquid waste placed in a 55 gallon waterborne waste drum. When full the drum was picked up by Emerald Services
9	Discarded leftover liquid paint in the shop's dumpster– in plastic paint reservoirs.
10	Unknown
11	Unknown

5. Discussion

This study was comprised of painter interviews, air sample collection, and ventilation measurements. The objectives were to gather information about: 1) demographics of the waterborne spray-painting industry; 2) painters' airborne exposure to waterborne paint components during spraying; 3) spray booth performance and its relationship with airborne exposures; and 4) work practices related to waterborne paints and potential routes of exposure.

The study suggests that painters' exposures to waterborne paints are typically low. By standardizing work practices, waterborne painting systems have the potential to be safer alternatives to solvent-based paints.

5.1 Demographics

The results of this study shows that the painters are not traditionally underserved individuals. Eight of the eleven painters were White/European American, and the other three painters were Asian/Filipino, Hispanic/Mexican, and American Indian. All painters were able to comprehend both verbal and written English. None were excluded from the study because of limited English language comprehension.

5.2 Airborne exposure analysis

Painter's exposures to waterborne paint solvents were low. The parametric and empiric exceedance fractions to the TLVs were low. The concentrations of solvents that are frequently seen in solvent-based paints, such as toluene and xylene, had much lower airborne concentrations in waterborne paints. However, analytes such as EGBE, which are not normally seen in solvent-based paints, were present in waterborne paints at relatively high airborne concentrations compared to other constituents.

The analyte parametric exceedance fraction for the odor thresholds were slightly higher than those for the TLVs. However, the odor parametric exceedance fractions were still low. Therefore it is unlikely that painters would experience irritation due to the smell of the paints. This also supports painters' observations that the use of waterborne basecoat has greatly decreased the irritating odor of organic solvents.

Comparing our study to historical studies of solvent-based paint exposure, painters' exposures to VOCs in waterborne paints is relatively low. The exposure to toluene, which is a major constituent in both waterborne and solvent-based paints, is lowest in waterborne paints. The total TLV fractions of the same health end points were up to 56 times lower than exposure to solvent-based paints. Two historical studies, one HHE and one in-depth survey report, had total TLV fractions lower than our study. However both the HHE and the in-depth survey report only sampled one shop each. Therefore the study results do not represent average VOC exposures among shops that use solvent-based paints, but rather average exposure of painters working in the two individuals shops. Additionally, the in-depth surveys were conducted to investigate booth performances between different types of spray booths. Therefore, the samples were collected in more controlled environment.

5.3 Booth performance

Booth performance varied among the shops. We found that higher average linear air velocity at the painters' breathing zones was associated with lower exposures to airborne paints. This relationship was most clearly observed in analytes with a relatively large fraction of samples above MLOQs. The performance of prep-stations appears be inferior to enclosed downdraft spray booths, which is consistent with OSHA's findings on control technology for auto body shops. OSHA observed that air velocities around the car at a prep-station may be too low to provide meaningful control of paint overspray, and some situations, such as in side-draft booths, can generate airflow patterns that transport overspray directly into the painter's breathing zone.[40]

5.4 Work practices and potential routes of exposure

One of the most significant findings of our study is the inconsistency of painters' exposure control practices. Unlike the situation for solvent-based paints, there are no standardized practices for many aspects of handling waterborne paints. Although the potential for exposure to harmful constituents in waterborne paints appears relatively low, painters may still be put at risk of exposure during none spraying operation to not only constituents traditionally in solvent-based paints, such as toluene, but also to constituents unique to waterborne paints, such as EGBE.

Our study found that MSDSs often do not reflect the composition of the paints clearly. Analytes such as m-, o-, and p-xylene; 1,2,4-TMBZ; petroleum distillate; acetone; n-propanol; 2-butanol; and EGBE, were all detected in at least one sample, but they were not always listed on the MSDSs. The MSDS reporting limit threshold for non-carcinogenic compounds is 0.1 % weight. Therefore, it is possible that the detected analytes were not listed in the MSDSs because they do not exceed the reporting threshold. However, in other cases, analytes were listed on the MSDSs, but the range of percent weights were wide, or were listed with “unknown” percent weight. As a result, painters cannot rely on MSDSs to determine the appropriate control measures to prevent exposure. For example, EGBE is one of the main constituents detected in our study, and can be dermally absorbed. However it is listed with unclear percent weights in many MSDSs. Consequently, if painters rely solely on the information provided from the MSDSs, they may not know to wear protective clothing or gloves when handling waterborne paints. This was observed (not consistently documented) during in our study when some painters handled waterborne waste without wearing any gloves.

Therefore, this study shows the importance of standardizing guidelines for best practices and standard PPE, regardless of the brand of paint they use. This will allow painters to have information they need to prevent exposures.

The two major possible routes of exposure to waterborne paints are through gun-cleaning and waste handling. There are a few guidelines provided by SATA and PPG for gun-cleaning methods.[41][42] SATA suggests using waterborne gun-cleaning machines and waterborne cleaners, and PPG suggests using hand-pressurized pumps and waterborne cleaning solutions for gun-cleaning. However, in our study, only one shop used a hand-pressurized pump, while the others used either a variation of the SATA guidelines, or their own methods. Painters cleaned their guns with a range of cleaning agents, ranging from less hazardous materials (waterborne cleaners and acetone), to more hazardous materials (lacquer thinner). In many shops, painters used spray cans containing phenol and methylene chloride for the final rinse of the guns. These cleaning agents are not recommended by SATA or PPG and using them may expose painters to the hazardous solvents.

Although painters usually wore coveralls and gloves when cleaning their guns, they did not usually wear respirators or eye protection. This can be especially hazardous when they use compressed air to expel the cleaning agents (waterborne or methylene chloride containing cleaning agenst), because the liquid can be aerosolized and inhaled and/or contact the painters' skin and eyes.

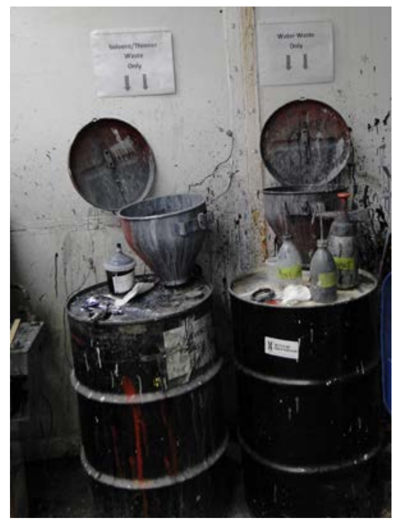


Figure 15 Waste drums with funnels to capture waterborne waste

There were also no standardized procedures for handling hazardous waste. Not only does this have environmental implications, painters can also be at risk of exposure. Most shops accumulated their wastes before processing and disposal. Painters could be exposed to wastes when transferring material between containers. Some containers were enclosed and painters poured the wastes into the containers through funnels (Figure 15). However, many containers had large openings and loose-fitting lids for ease of pouring (Figure 16). Wastes could easily overflow or splash outside of the container and contaminate the

Figure 16 Improperly stored waterborne waste

surrounding working surfaces. This increases the potential of exposing painters to the wastes by dermal contact or by inhalation.

5.5 Strengths and limitations

To our knowledge, there are no peer reviewed studies concerning painters' exposures to waterborne paint solvents. Our study is the first comprehensive study of waterborne paint exposure among painters in the United States. Although our study provided insights into potential routes of exposure, we cannot be certain of the representativeness of the data.

First, the sample size of ten shops was small; therefore we cannot conclude that the study is representative of all waterborne spray painting operations. In addition, because waterborne painting technology is relatively new in Washington State, and conversion is voluntary, the shops that participated were likely to be some of the more progressive in terms of worker safety and waste management. As a result, this may have biased the results towards lower exposures. However, during our visits, a wide array of work environments were observed, including the presence spray booths manufactured from 1980 to 2005. Therefore, this study likely captured the different levels of exposures from poor-to-good working conditions.

Second, more than half of the samples had analyte concentrations below MLOQs. Therefore, we cannot accurately determine the average exposure levels of airborne waterborne paints. However, the original intent of the sampling plan was to subsequently determine the relationship between bulk sample concentrations and airborne concentrations for future studies. Therefore we did not increase the sampling time for each set of sorbent tubes by aggregating the tasks in order to achieve the analytes' respective MLOQs.

Third, this study performed task-based sampling rather than full-shift sampling. Only exposures during spraying were captured. As observed during field visits, there were many opportunities to airborne exposures in addition to spraying operations, such as during gun cleaning and paint mixing in the mixing room. Our study did not capture the exposures to waterborne paints during spraying related operations, such as mixing paints, gun cleaning, and waste handling.

Finally, there are no direct exposure comparisons between waterborne paints and solvent-based paints. We were only able to compare the two systems using total fraction of TLVs between our study and historical studies on solvent-based paints. This may not be an appropriate comparison because the historical studies occurred prior to the 1998 final ruling of the National Rule. Therefore, the composition of solvent-based paints in the historical studies may not be representative of the current solvent-based composition, and therefore not representative of painters' exposures to solvent-based paints. Furthermore, the GM concentrations used to calculate TLV fractions were not time-weighted average concentrations. Therefore, by comparing the TLV fractions between solvent-based and waterborne paints, we cannot conclude that one is more likely to exceed the TLVs. The TLV fractions can only be used as bench marks to compare exposures between solvent-based and waterborne paints during sampled time.

In addition, the historical studies did not sample for the same analytes as this study. Additionally, the historical studies sampled for many fewer analytes; fewer analyte TLV fractions were aggregated. Therefore, we conclude from this current study that the aggregate health effects are lower among painters who spray waterborne paints compared to those who spray solvent-based paints. Finally, historical studies sampled for multiple stages of spraying, including primers, basecoats, and clear coats, whereas our study only sampled for spraying basecoats. Therefore it is likely that primers and clear coats contributed to the higher exposures in historical studies. However, because solvent-based basecoats consists of the highest concentration of VOCs compared to other coating, most

VOC emissions in the auto body industry are contributed by basecoats, rather than primers and clear coats.

For future studies, it will be beneficial to perform the same sampling procedures for target analytes in shops that use solvent-based paints. This will allow a direct comparison to determine whether waterborne paints are safer alternatives to current solvent-based paints. Additionally, it will be beneficial to sample for waterborne paint exposure during non-spraying operations in order to fully capture the exposures of using waterborne paints.

6. Conclusions

This study shows that painter exposure to waterborne paints may have lower aggregate health effects than to solvent-based paints, but due to the lack of guidelines in work-practices, painters may be at greater risk of exposures waterborne paints and other hazardous materials during non-spraying operations. Painters' exposures to target compounds when applying waterborne basecoats were typically below their respective MLOQs and regulatory limits. Additionally, the TLV fractions of waterborne paints during spraying were generally lower than the TLV fractions of solvent-based paints. This study also provides insights into the potential routes of exposures when handling waterborne paints. With the anticipation of reduced VOC emission limits, more shops will be converting to using waterborne painting systems. Without adequate guidelines on safe practices for all aspects of handling the paints, painters can still be at risk of exposures to waterborne paints and other hazardous chemicals through inhalation or dermal exposures during spraying and non-spraying operations. Therefore, it is important to characterize the chemical composition of the bulk products and waste generated from waterborne paint systems in order to inform best practices for spray gun cleaning, waste disposal and other practices that painters can be in contact with waterborne paints.

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Appendix A Subject Consent Form

Local Hazardous Waste Management Program in King County
Consent to Participate in a Research Study
Adult Subjects
Biomedical Form

Title of Study: Characterizing waterborne coatings in auto body shops

Principal Investigator: Stephen G. Whittaker, Ph.D.
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What are some general things you should know about research studies?

You are being asked to take part in a research study. Joining the study is voluntary. You may refuse to join or you may withdraw for any reason.

Research studies are designed to obtain new information that may help other people in the future. You may not receive any direct benefit from being in a research study. There also may be risks to being in a research study.

Quitting the study will not affect your relationship with the Local Hazardous Waste Management Program. Quitting will not affect any benefits you receive from any government program.

Details about this study are given below. It is important that you understand this information so that you can decide if you want to take part. You get a copy of this consent form. You should ask the researcher named above, or staff members who may assist them, any questions you have at any time.

What is the purpose of this study?

You are being asked to participate in a research project on waterborne coatings. The purpose of this study is to measure how much chemical is in the air when you spray waterborne coatings. You are being asked to be in the study because you work in the auto-body shop and are spray-painting cars and car parts.

How many people will take part in this study?

About 12 to 18 painters are in this research study.

How long will your part in this study last?

You are asked to participate for one workday.

What will happen if you take part in the study?

You will be asked to an air sampler that will be attached to your collar. A hose will run from the sampler to a small pump. The pump weighs about two pounds and is worn on a belt around your waist.
You and your employer will receive a written summary of your air sampling results, and ideas to reduce chemical exposures in the future. This report will be available between six months and a year after the study is completed.

What are the possible benefits from being in this study?
Research is designed to benefit society by gaining new knowledge. There is little chance you will benefit from being in this research study. The results will help us find the best way to measure the chemicals in the air when you spray waterborne coatings and reduce exposures to these chemicals in the future.

What are the possible risks or discomforts involved with being in this study?
We do not anticipate any risks or discomfort over and above what you typically experience in a normal work day. See below for information about your privacy and the confidentiality of your data.

How will your privacy be protected?
To protect your privacy you will be assigned a code number. All personal information and test results will be stored by your code number and not your name. The link between your name and the code number will be available only to Dr. Whittaker. The link will be stored in a separate location from where data files are kept. Your code number will be kept in the electronic data files forever. The files that link your name to your code number will be kept for no longer than three years from now.

Nobody will be identified in any report or publication about this study. However, information collected from this study would be made available if someone filed a public disclosure request.

What if you want to stop before your part in the study is complete?
You can quit at any time without penalty. The research team also has the right to stop you from taking part. This could be because you have failed to follow instructions or because the entire study has been stopped.

Will you receive anything for being in this study?
You will be receiving a $25 supermarket gift card at the end of the day that we collect the air samples.

Will it cost you anything to be in this study?
It will not cost you anything in addition to your time to be in this study. We expect your employer to pay you for any time you spend during the recruitment process and study procedures.

Who is funding this study?
This study is being funded by the Local Hazardous Waste Management Program in King County. The researchers do not have a direct financial interest in the final results of the study.

What if you have questions about this study?
You have the right to ask, and have answered, any questions you may have about this research. If you have questions, or if a research-related injury occurs, you should contact the researcher listed on the first page of this form. If you have questions about your rights

as research subjects you can call the Washington State Institutional Review Board (WSIRB) at 1-800-583-8488. The WSIRB works to protect the rights of people like you who take part in research.

____ ___________
Signature of Researcher Date

<u>Participant's Statement</u>:

"The study described above has been explained to me. I voluntarily consent to take part in this activity. I have been told that I can refuse to answer any question or quit from the study at any time at no cost to me. I have had a chance to ask questions. I have been told that future questions I may have about the research or about my rights as a participant will be answered by one of the investigators above."

_______________________________________ ___________
Signature of Participant Date

Copies to: Participant
Investigator's file

Appendix B Waterborne Paint (M)SDS Summary

Table 16 MSDS brand & weight, occurrence

Chemical Name	CAS	AWX Performance Plus WB Basecoat, Effect Black (Sherwin-Williams)	Envirobase HP (PPG)	Aquabase Plus (PPG)	90 Line (Glasurit BASF)	Onyx HD Waterborne (R-M BASF)	Autowave MM 888 series (Sikken AkzoNobel)	Autowave MM (Sikken AkzoNobel)	Cromax Pro (DuPont Axalta Coating Systems)	Basecoat WB MM 192P (Lesonal AkzoNobel)	Wanda Waterborne (Wanda AkzoNobel)	Permahyd Hi-TEC (Spies Hecker Axalta)	Standoblue (Standox Axalta)	Number of Products that use this chemical
		Waterborne Basecoats, % weight Product name (Manufacturer)												
1-propoxy-2-propanol	**1569-01-3**	2												1
1,2,4-trimethylbenzene	**95-63-6**				0-5	0-5								2
2-(2-methoxyethoxy)-ethanol	**111-77-3**	3												1
2-amino-2-methyl-1-propanol	**124-68-5**								-			-	-	3
3-butoxypropan-2-ol	**5131-66-8**		1-5	1-5										2
acetone	**67-64-1**								-			-	-	3
acrylic polymer-A	**NA**								-			-	-	3

Chemical Name	CAS	Waterborne Basecoats, % weight Product name (Manufacturer) AWX Performance Plus WB Basecoat, Effect Black (Sherwin-Williams)	Envirobase HP (PPG)	Aquabase Plus (PPG)	90 Line (Glasurit BASF)	Onyx HD Waterborne (R-M BASF)	Autowave MM 888 series (Sikken AkzoNobel)	Autowave MM (Sikken AkzoNobel)	Cromax Pro (DuPont Axalta Coating Systems)	Basecoat WB MM 192P (Lesonal AkzoNobel)	Wanda Waterborne (Wanda AkzoNobel)	Permahyd Hi-TEC (Spies Hecker Axalta)	Standoblue (Standox Axalta)	Number of Products that use this chemical
acrylic polymer-B	**NA**								-			-	-	3
acrylic polymer-C	**146753-99-3**								-			-	-	3
acrylic polymer-D	**70587-60-9**								-			-	-	3
acrylic resin	**NA**								-			-	-	3
acrylic resin - waterborne	**NA**								-			-	-	3
acrylic resin (ts)	**NA**								-			-	-	3
aliphatic polyisocyanate resin-A	**28182-81-2**								-					1
aliphatic polyisocyanate resin-B	**666723-27-9**								-					1
dipropylene glycol methyl ether	**34590-94-8**								-			-	-	3

Chemical Name	CAS	AWX Performance Plus WB Basecoat, Effect Black (Sherwin-Williams)	Envirobase HP (PPG)	Aquabase Plus (PPG)	90 Line (Glasurit BASF)	Onyx HD Waterborne (R-M BASF)	Autowave MM 888 series (Sikken AkzoNobel)	Autowave MM (Sikken AkzoNobel)	Cromax Pro (DuPont Axalta Coating Systems)	Basecoat WB MM 192P (Lesonal AkzoNobel)	Wanda Waterborne (Wanda AkzoNobel)	Permahyd Hi-TEC (Spies Hecker Axalta)	Standoblue (Standox Axalta)	Number of Products that use this chemical
		Waterborne Basecoats, % weight Product name (Manufacturer)												
dispersing agent	**35545-57-4**								-			-	-	3
ethanediol	**107-21-1**		0.1-1	0.1-1										2
ethanol, 2-(2-butoxyethoxy)-	**112-34-5**		1-5	1-5					-					3
ethyl 3-ethoxypropionate	**763-69-9**				0-30	0-30								2
ethylene glycol (mono)butyl ether	**111-76-2**		5-10	5-10	0-60	15-60	25-50	2.5-10	-	5-10	1-5	-	-	11
hydrotreated heavy naphtha (petroleum)	**64742-48-9**		0.5-1.5	0.5-1.5	0-5	0-5			-			-	-	7
hydroxyfunctional acrylic resin	**NA**								-					1
isopropyl alcohol	**67-63-0**								-			--	-	3
monoazo pigment	**12236-**		0.1-1	0.1-1										2

Chemical Name	CAS	Waterborne Basecoats, % weight Product name (Manufacturer)												Number of Products that use this chemical
		AWX Performance Plus WB Basecoat, Effect Black (Sherwin-Williams)	Envirobase HP (PPG)	Aquabase Plus (PPG)	90 Line (Glasurit BASF)	Onyx HD Waterborne (R-M BASF)	Autowave MM 888 series (Sikken AkzoNobel)	Autowave MM (Sikken AkzoNobel)	Cromax Pro (DuPont Axalta Coating Systems)	Basecoat WB MM 192P (Lesonal AkzoNobel)	Wanda Waterborne (Wanda AkzoNobel)	Permahyd Hi-TEC (Spies Hecker Axalta)	Standoblue (Standox Axalta)	
	62-3													
n-Methyl-2-Pyrrolidone	**872-50-4**								-			-	-	3
N-pentanol	**71-41-0**		0-1											
N-propanol	**71-23-8**								-			-	-	3
N,n-dimethylethanolamine	**108-01-0**								-			-	-	3
phosphorous acid ester, polymer	**NA**				0-5	0-5	1-2.5		-					4
polyether modified siloxane	**NA**								-			-	-	3
polypropylene glycol	**25322-69-4**								-					1
polyurethane resin-A	**NA**								-					1
polyurethane resin-B	**NA**								-			-	-	3

Chemical Name	CAS	Waterborne Basecoats, % weight Product name (Manufacturer)												Number of Products that use this chemical
		AWX Performance Plus WB Basecoat, Effect Black (Sherwin-Williams)	Envirobase HP (PPG)	Aquabase Plus (PPG)	90 Line (Glasurit BASF)	Onyx HD Waterborne (R-M BASF)	Autowave MM 888 series (Sikken AkzoNobel)	Autowave MM (Sikken AkzoNobel)	Cromax Pro (DuPont Axalta Coating Systems)	Basecoat WB MM 192P (Lesonal AkzoNobel)	Wanda Waterborne (Wanda AkzoNobel)	Permahyd Hi-TEC (Spies Hecker Axalta)	Standoblue (Standox Axalta)	
propanol, 1(or 2)-ethoxy-	**1569-02-4**								-			-	-	3
proprietary copper compound	**NA**								-					1
propylene glycol methyl ether	**107-98-2**								-			-	-	3
propylene glycol monomethyl ether acetate	**108-65-6**	3							-			-	-	4
sec-butyl alcohol	**78-92-2**								-					1
solvent naphtha (petroleum), light aromatic	**64742-95-6**				0-20	0-20								2
solvent naphtha (petroleum), medium aliphatic	**64742-88-7**				0-5	0-5	2.5-10							3
urea-formaldehyde	**9011-05-**				0-5	0-5	2.5-10							3

Chemical Name	CAS	Waterborne Basecoats, % weight Product name (Manufacturer)												Number of Products that use this chemical
		AWX Performance Plus WB Basecoat, Effect Black (Sherwin-Williams)	Envirobase HP (PPG)	Aquabase Plus (PPG)	90 Line (Glasurit BASF)	Onyx HD Waterborne (R-M BASF)	Autowave MM 888 series (Sikken AkzoNobel)	Autowave MM (Sikken AkzoNobel)	Cromax Pro (DuPont Axalta Coating Systems)	Basecoat WB MM 192P (Lesonal AkzoNobel)	Wanda Waterborne (Wanda AkzoNobel)	Permahyd Hi-TEC (Spies Hecker Axalta)	Standoblue (Standox Axalta)	
condensation polymer	**6**													
water	**7732-18-5**								-			-	-	3
Xylene	**1330-20-7**								-			-	-	3
DAA	**123-42-2**						1-2.5							1

NA: not available
-: unknown

Table 17 Summary MSDS composition regulatory limits

Chemical Name	Regulatory Limits: OSHA, PEL				ACGIH, TLV						NIOSH, REL				WAC, PEL				
	ppm	Respirable mg/m^3	Total mg/m^3	Skin notation	ppm	Respirable mg/m^3	Total mg/m^3	STEL ppm	Ceiling ppm	Skin notation	ppm	STEL ppm	mg/m^3	Skin notation	ppm	Respirable mg/m^3	Total mg/m^3	STEL ppm	Skin notation
1-propoxy-2-propanol																			
1,2,4-trimethylbenzene					25						25								
2-(2-methoxyethoxy)-ethanol																			
2-amino-2-methyl-1-propanol																			
3-butoxypropan-2-ol																			
acetone	1000				500			750			250				750			1000	
acrylic polymer-A																			
acrylic polymer-B																			
acrylic polymer-C																			
acrylic polymer-D																			
acrylic resin																			
acrylic resin - waterborne																			
acrylic resin (ts)																			
aliphatic																			

Chemical Name	OSHA, PEL				ACGIH, TLV						NIOSH, REL				WAC, PEL				
	ppm	Respirable mg/m3	Total mg/m3	Skin notation	ppm	Respirable mg/m3	Total mg/m3	STEL ppm	Ceiling ppm	Skin notation	ppm	STEL ppm	mg/m3	Skin notation	ppm	Respirable mg/m3	Total mg/m3	STEL ppm	Skin notation
polyisocyanate resin-A																			
aliphatic polyisocyanate resin-B																			
dipropylene glycol methyl ether	100		600	skin	100			150		skin	100	150		skin	100			150	skin
dispersing agent																		150	
ethanediol							100												
ethanol, 2-(2-butoxyethoxy)-					10														
ethyl 3-ethoxypropionate																			
ethylene glycol (mono)butyl ether	50		240	skin	200		100			skin	5			skin	25			38	skin
hydrotreated heavy naphtha (petroleum)	500				100								350		100				
hydroxyfunctional acrylic resin																			
isopropyl alcohol	400				200				500		400	500			400			500	
monoazo pigment																			
n-Methyl-2-Pyrrolidone																			
N-pentanol																			

Chemical Name	Regulatory Limits																		
	OSHA, PEL				ACGIH, TLV						NIOSH, REL				WAC, PEL				
	ppm	Respirable mg/m^3	Total mg/m^3	Skin notation	ppm	Respirable mg/m^3	Total mg/m^3	STEL ppm	Ceiling ppm	Skin notation	ppm	STEL ppm	mg/m^3	Skin notation	ppm	Respirable mg/m^3	Total mg/m^3	STEL ppm	Skin notation
N-propanol	250				100						200	250		skin					skin
N,n-dimethylethanolamine																			
phosphorous acid ester, polymer																			
polyether modified siloxane																			
polypropylene glycol																			
polyurethane resin-A																			
polyurethane resin-B																			
propanol, 1(or 2)-ethoxy-																			
proprietary copper compound																			
propylene glycol methyl ether					100						100	100							
propylene glycol monomethyl ether acetate																			
sec-butyl alcohol	150				100						100	150			100			150	

Chemical Name	Regulatory Limits																		
	OSHA, PEL				ACGIH, TLV						NIOSH, REL				WAC, PEL				
	ppm	Respirable mg/m^3	Total mg/m^3	Skin notation	ppm	Respirable mg/m^3	Total mg/m^3	STEL ppm	Ceiling ppm	Skin notation	ppm	STEL ppm	mg/m^3	Skin notation	ppm	Respirable mg/m^3	Total mg/m^3	STEL ppm	Skin notation
solvent naphtha (petroleum), light aromatic																			
solvent naphtha (petroleum), medium aliphatic	100				400						100				100			150	
urea-formaldehyde condensation polymer																			
water																			
Xylene	100				100			150			100	150			100				
DAA		50				50													

Appendix C Field Sampling Standard Operating Procedure

1. Supplies & equipment:
    - SKC personal sampling pump
    - Coconut shell charcoal sorbent tubes (CSC)
    - ORBO 90 sorbent tubes (O90)
    - Camera
    - Half-face respirator with OV cartidges
    - Pen
    - Sharpie
    - Cooler
    - Icepacks
    - Ziplock bags
    - Clipboard
    - Safety glasses
    - Nitrile gloves
    - Waterborne Painting Data Form
    - Product Data Form
    - Waste Data Form
    - Personal Air Sampling Data Form
    - Client Intake Form
    - Field Research and Consultation Group Field Data Sheet (digital file)
    - Measuring tape
    - Airflow velocity meter (Hot wire anemometer)
    - PID
    - Duct tape
    - Rotameter
    - Defender Primary Standard Calibrator (DryCal)
    - Tubing
    - Quat adjustable Low Flow Tube holders with plastic cover
    - Labels
    - Powder Puffer
    - Belts
    - Duct tape
    - PPE
        - Safety glasses
        - Boots
        - Gloves
        - Tyvec suit
        - Respirator
2. Procedure

2.1 Supplies and equipment preparation

1. Assemble the personal sampling pumps, including pump, tubing, and Quad Adjustable Low Flow Tube holders.
2. Label 1-4 on top of each holders
3. Place calibrating-use sorbent tubes in the tube holders in 1-4 order as CSC, CSC, O90, O90 format.
4. Connect first CSC to the DryCal and turn on both instruments.
5. Adjust the flow rate for first CSC to 100 ml/min

6. Repeat steps 3 and 4 for second CSC 400ml/min.
7. Repeat steps 3-5 for O90.
8. Repeat procedures 3-6 and make sure all flow rates are within 1ml/min deviation from the desired flow rate.
9. Detach the calibrating-use sorbent tubes and attach plastic covers to the tube holders.
10. Repeat steps 1-8 for two additional backup pumps.
11. Place unused sorbent tubes in separate Ziplock bags for SCS and O90.

2.2 Field Personal Air Sampling

2.2.1 Introduction

1. Upon arrival of the facility, identify us to the shop manager and painter and explain our reasons being there.
2. Review the **Study Summary** with the worker and answer any questions or concerns.
3. Ask the worker to identify the jobs being performed today. Ask the worker to point out the jobs that will require waterborne paints.
4. Fill out portions of the **Waterborne Painting Data Form** with information that can be obtained from the worker, such as:
   - spray gun
   - waterborne paints
   - gloves

   Other information will be filled out by our observation during sampling.
5. Ask the workers to show us the paints that will be used for waterborne spray painting jobs, and visually confirm that the products are waterborne paints.
6. Address the worker the importance that we do not sample for solvent based paints during a paint job. Emphasize that the worker must communicating what type of paint they are working on prior to beginning a job in order to prevent error of sampling solvent based paints.
7. Reiterate that we do not want to interfere with their jobs, therefore they can freely communicate with us if they have any concerns.
8. Work out a procedure with the worker that will allow us to easily identify when to turn on and off the pump to ensure we do not sample for solvent based paints.
9. Before each paint job, worker will prepare the paints. Tell the workers that we need to sample the paint mixture (approximately 50ml), and ask them to factor in the additional volume needed when preparing the paints.
10. Collect the paint mixture from the mixing cup.
11. Record the product information on the **Product Data Form**

2.2.2 Sampling

1. Label a set of sorbent tubes with the correct sample ID.
2. Assemble the sampling pump with the labeled sorbent tubes in CSC, CSC, O90, O90 order, and put on the covers
3. Place the sampling pump on the painter's belt outside of their protective clothing or in the pocket of the protective clothing.
4. Place the sorbent tubes on the side of the lapel which is worker's dominant hand either by placing the tubing under the worker's armpit or over the worker's shoulder. Make sure the placement of the sampling pump and accessories are not interfering with the worker's movements.
5. Tape excess tubing on the back of the worker with duct tape so our sampling does not interfere with their work.
6. Verbally confirm that the worker is spraying waterborne paint prior to each task

7. Ask worker if the paint job is likely to last more than 10 minutes. If yes use a new set of sampling tubes, if not, use the set of tubes designated for aggregating smaller paint job.
8. Turn on the pump prior to worker entering the paint booth to spray waterborne paint.
9. Record the time pump is turned on the **Personal Air Sampling Data Form**
10. When worker exit the paint booth after painting the base coat, turn off the sampling pump and record the time it is turned off on the **Personal Air Sampling Data Form**.
11. If worker is not performing the tasks of interest for more than 10 minutes (such as having lunch), the sorbent tubes will be taken off the sampling device and stored with caps on.
12. Change the set of sorbent tubes if the following mixture of base coat used after reentering the paint booth is not the same mixture, or if the maximum sampling time of 50 minutes is reached.
13. Collected samples will be capped and placed in the Ziplock bag and stored in the cooler with the icepacks.
14. When the sampling procedures are complete, retrieve the sampling pump from the worker.
15. Communicate with the worker that we will process the samples and the results will be provided to them after the study is complete. The information will be presented to the shop or mailed to the worker if worker is no longer employed at the shop.
16. Encourage the worker to call LHWMP to set up a meeting or discuss the results on the telephone.
17. Before leaving the shop, connect with the manager or supervisor of the shop and let them know our sampling is complete. Inform them that the result of the samples will be provided to the shop after the study is complete.
18. After the sampling visit, place the collected samples in the refrigerator in the Field Group.
19. Transfer information from on the **Personal Air Sampling Data Form** into the digital file, Field Research and Consultation Group Field Data Sheet
20. When approximately 60 sorbent tubes are collected, send the samples to EH lab along with the digital files for analysis.

3. Quality Control

10% of sorbent tubes per sampling location will be the number of blanks for each type of sorbent tubes. One additional field blank will be added for every ten sampled sorbent tubes. We do not anticipate more than ten paint jobs per work shift.

Field blanks: unused sorbent tubes will be opened and capped right away for every blanks.
Lab blanks: unused sorbent tubes will be sent in with the samples for laboratory analysis.

4. Observations to make
   - PPE used during different tasks. For example: paint mixing, paint gun cleaning (**Waterborne Painting Data Form**)
   - Ventilation of the paint booth, including: dimensions, air flow velocity, type of ventilation (down draft, Semi-downdraft, Cross-draft, custom…), worker’s breathing zone in relation to the air flow (**Waterborne Painting Data Form**)

5. Labeling and Record Keeping
   - All ORBO 90 sorbent tubes are labeled as 1, 2, 3, 4…. All SCS sorbent tubes are labeled as 200, 201, 202, 203…

- One designated sheet of Personal Air Sampling Data form is used for each sorbent tube unless additional sheet is needed per specific sorbent tubes.

Appendix D Intake Form

Client Intake Form

Public Health—Seattle & King County
Local Hazardous Waste Management Program
401 Fifth Ave., Suite 1100
Seattle WA 98104

Client Name:_______________________________________ Today's Date: ____________
Place of Employment: ____
Best telephone number: _________________ Email address:__________________

1. What is your date of birth? ___________________
2. What is your gender? ☐☐Male ☐☐Female
3. How long have you been working as a spray painter? ________________ (years)
4. How long have you been using waterborne coatings? ________________ (years)
5. How many times this month have you spray-painted waterborne coatings? ____
6. How many times in the past week have you spray-painted waterborne coatings?
7. Which manufacturer provides your waterborne coatings? ___________________
8. In a typical week, which coatings do you use and how frequently?:

Product ____ sprayed _____ times per week
Product ____ sprayed _____ times per week
Product ____ sprayed _____ times per week
Product ____ sprayed _____ times per week
Product ____ sprayed _____ times per week
Product ____ sprayed _____ times per week
Product ____ sprayed _____ times per week
Product ____ sprayed _____ times per week
Product ____ sprayed _____ times per week
Product ____ sprayed _____ times per week

9. What is your race or ethnicity? (Check all that apply)

- ☐ **American Indian and Alaska Native**
  - ☐ **American Indian / Native American**
  - ☐ **Alaska Native**
  - ☐ **Other (please list): _____**
- ☐ **Asian**
  - ☐ **Asian American**
  - ☐ **Asian Indian**
  - ☐ **Chinese**
  - ☐ **Filipino**
  - ☐ **Japanese**
  - ☐ **Korean**
  - ☐ **Vietnamese**
  - ☐ **Other (please list): _____**
- ☐ **Black or African American**
  - ☐ **African American**
  - ☐ **Ethiopian**
  - ☐ **Somali**
  - ☐ **Other (please list): _____**
- ☐ **Hispanic or Latino**
  - ☐ **Mexican or Mexican American**
  - ☐ **Puerto Rican**
  - ☐ **Other (please list): _____**
- ☐ **Native Hawaiian and Other Pacific Islander**
  - ☐ **Guamanian**
  - ☐ **Native Hawaiian**
  - ☐ **Samoan**
  - ☐ **Other (please list): _____**
- ☐ **White**
  - ☐ **European American**
  - ☐ **Russian**
  - ☐ **Ukrainian**
  - ☐ **Other (please list): _____**
- ☐ **Some Other Race**
  - ☐ **Iranian**
  - ☐ **Iraqi**
  - ☐ **Other (please list): _____**
- ☐ **Other (please list): _____**

Date: ________
Shop # ________
Subject # ________

Appendix E Painter Data Form

Painter: Is the personal protective equipment you are wearing, the location where you are painting, and other equipment you are using typical of how you usually spray-paint waterborne coatings? ___Yes ___No

If "No", please explain how this situation is different:
____
____

1. Spray Gun

Type: Conventional / HVLP
Make / Model: ____
Model No.: ____
Nozzle Pressure: _______________________________________

2. Paint Booth

Type: Downdraft / Semi-downdraft / Cross-draft / Prep station
Prefabricated or custom?
Make / Model / Year: ____
Is there a filter change schedule? Yes / No
How frequently are filters usually changed?:_________________
When were filters changed last (mo/day/yr):_________________

Height:____
Length: ____
Width: ____
Temperature:____
Multi-point linear air velocities (LFM): ___ ___ ___ ___ ___ ___ ___ ___
___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___
___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___
Average linear air velocity: _______ FPM
Resulting volumetric flow rate: _______ CFM
Pressure drop across filter media: ______CFM

3. Waterborne paints:

	Task 1	Task 2	Task 3	Task 4	Task 5
Coating product					
Pure product or mixture?					
Bulk sample #					

6. PPE worn while spray-painting waterborne products:

- ❒ Respirator
- ❒ Safety glasses
- ❒ Goggles
- ❒ Face shield
- ❒ Head sock
- ❒ Earplugs or muffs
- ❒ Gloves
- ❒ Shoot suit
- ❒ Fabric coveralls
- ❒ Disposable coveralls
- ❒ Cloth or leather work boots
- ❒ Rubber boots
- ❒ Disposable boot covers
- ❒ Other? (describe) ___________________

7. Respirator used while spray-painting waterborne products:

- ❒ Dust mask (filtering face piece)
- ❒ Disposable half-face type with cartridges (entire unit disposable – both the face-piece and cartridges)
- ❒ Half-face type with replaceable cartridges
- ❒ Full-face type with cartridges
- ❒ Half-face type with an air supply hose
- ❒ Full-face type with an air supply hose
- ❒ Hood or head covering with air supply hose
- ❒ Hood-type powered air-purifying respirator (PAPR)
- ❒ Other? (describe) __________________________________
- ❒ None

8. Respirator use continued

Question for painter upon exit: "Could you smell or taste solvent? Y / N
For cartridge style respirators:

1. What type of cartridges are used: _____________________
2. On what basis are the cartridges replaced
   Daily / Weekly / Monthly (Other describe): ______________
3. When were your cartridges last replaced: _______________
4. Have you ever been fit-tested? Yes / No

9. Gloves used while painting

- ❒ Latex
- ❒ Natural rubber
- ❒ Nitrile
- ❒ Neoprene
- ❒ PVC
- ❒ Laminated polyethylene
- ❒ Cloth/leather
- ❒ Other? (describe) ____________________
- ❒ None

"Exam style" Yes / No?

10. Gloves used while mixing paint in paint room

- ❒ Latex
- ❒ Natural rubber
- ❒ Nitrile
- ❒ Neoprene
- ❒ PVC
- ❒ Laminated polyethylene
- ❒ Cloth/leather
- ❒ Other? (describe) ____________________
- ❒ None
- ❒

"Exam style" Yes / No?

11. Gloves used while cleaning paint guns or decontaminating equipment or surfaces

- ❒ Latex
- ❒ Natural rubber
- ❒ Nitrile
- ❒ Neoprene
- ❒ PVC
- ❒ Laminated polyethylene
- ❒ Cloth/leather
- ❒ Other? (describe) ____________________
- ❒ None

"Exam style" Yes / No?

12. Gloves used while removing tape and overspray covers from painted vehicles

- ❒ Latex
- ❒ Natural rubber
- ❒ Nitrile
- ❒ Neoprene
- ❒ PVC
- ❒ Laminated polyethylene
- ❒ Cloth/leather
- ❒ Other? (describe) ____________________
- ❒ None

"Exam style" Yes / No?

Appendix F Sample Results

Shop ID	Sample ID		Sample Time (min)	
	ORBO90 (polar)	CSC (non-polar)	AM	ASD
1	23-34	222-233	16	5.1
2	43-48	242-247	11	2.9
3	61-65	260-254	8.7	0.58
4	66-70	265-269	19	8
5	5-14	204-123	14	5.4
6	35-42	234-241	27	8.0
8	15-22	214-221	22	16
9	49-53	248-252	11	4.4
10	54-57	253-256	11	4.4
11	58	257	11	-

Environmental Health Laboratory
Department of Environmental and Occupational Health Sciences
University of Washington

12/10/14

To	Grace Liao DEOHS Grad Student Box 357234 University of Washington Seattle, WA 98195-7234 gracel4@uw.edu	Steve Whittaker, Ph.D. Local Hazardous Waste Mgmt Program Public Health-Seattle & King County 401 Fifth Ave., Suite 1100 Seattle, WA 98104 steve.whittaker@kingcounty.gov
CC	Dr. Marty Cohen FRCG DEOHS BOX 354695 University of Washington Seattle, WA 98195-4695	

From Nick Potter

Subject ANALYSIS REPORT

EHL Reference	Client Reference	Sampling Site
11411015	None	Shop 01, 05, 08

Dates

Sampling	Receipt	Preparation	Analysis
11/5-12/2014	11/18/14	12/3/14	12/3/14

Method EHLSOP-06 VOCs BY GAS CHROMATOGRAPHY
based on NIOSH 2554 Glycol Ethers

Media Supelco 20358: ORBO 90 Carboxen-564

Results

Sample ID	Acetone (µg/sample)	n-Propanol (µg/sample)	2-Butanol (µg/sample)	1-Methoxy-2-propanol (µg/sample)	Ethyl-3-ethoxypropionate (µg/sample)	4-Hydroxy-4-methyl-2-pentanone (µg/sample)	Ethylene glycol monobutyl ether (µg/sample)
5	< 2	< 0.8	< 0.8	< 0.9	< 0.9	< 2	< 2
6	4	< 0.8	< 0.8	< 0.9	< 0.9	< 2	< 2
7	< 2	< 0.8	< 0.8	< 0.9	< 0.9	< 2	< 2
8	< 2	< 0.8	< 0.8	< 0.9	< 0.9	< 2	< 2
9	< 2	< 0.8	< 0.8	< 0.9	< 0.9	< 2	< 2
10	< 2	< 0.8	< 0.8	< 0.9	< 0.9	< 2	< 2
11	< 2	< 0.8	< 0.8	< 0.9	< 0.9	< 2	< 2
12	< 2	< 0.8	< 0.8	< 0.9	< 0.9	< 2	< 2
13	4	< 0.8	< 0.8	< 0.9	< 0.9	< 2	< 2
14	16	3.5	< 0.8	2.3	< 0.9	< 2	< 2
15	< 2	< 0.8	0.9	< 0.9	< 0.9	< 2	5
16	3	< 0.8	4.8	< 0.9	< 0.9	< 2	19
17	< 2	< 0.8	< 0.8	< 0.9	< 0.9	< 2	< 2
18	< 2	< 0.8	< 0.8	< 0.9	< 0.9	< 2	< 2
19	4	< 0.8	1.8	< 0.9	< 0.9	< 2	2
20	19	< 0.8	7.6	< 0.9	< 0.9	< 2	11
21	< 2	< 0.8	26.7	< 0.9	< 0.9	< 2	32
22	5	< 0.8	116	< 0.9	2.9	< 2	160
23	< 2	< 0.8	< 0.8	< 0.9	< 0.9	< 2	< 2
24	< 2	< 0.8	< 0.8	< 0.9	< 0.9	< 2	9
25	< 2	< 0.8	< 0.8	< 0.9	< 0.9	< 2	< 2
26	< 2	< 0.8	< 0.8	< 0.9	< 0.9	< 2	< 2
27	< 2	< 0.8	< 0.8	< 0.9	< 0.9	< 2	< 2

28	5	< 0.8	< 0.8	< 0.9	< 0.9	< 2	< 2
29	57	< 0.8	< 0.8	1.3	7.1	< 2	7
30	181	< 0.8	< 0.8	6.5	30.7	< 2	34
31	6	< 0.8	< 0.8	1.2	< 0.9	< 2	13
32	26	< 0.8	< 0.8	5.3	1.6	< 2	51
33	< 2	< 0.8	< 0.8	< 0.9	< 0.9	< 2	< 2
34	< 2	< 0.8	< 0.8	< 0.9	< 0.9	< 2	4

Sample ID	Units	Acetone	n-Propanol	2-Butanol	1-Methoxy-2-propanol	Ethyl-3-ethoxypropionate	4-Hydroxy-4-methyl-2-pentanone	Ethylene glycol monobutyl ether
5	mg/m3	< 0.9	< 0.4	< 0.4	< 0.4	< 0.4	< 0.9	< 0.9
6	mg/m3	0.5	< 0.1	< 0.1	< 0.1	< 0.1	< 0.2	< 0.2
7	mg/m3	NA	NA	NA	NA	NA	NA	NA
8	mg/m3	NA	NA	NA	NA	NA	NA	NA
9	mg/m3	< 0.3	< 0.1	< 0.1	< 0.1	< 0.1	< 0.3	< 0.3
10	mg/m3	< 0.07	< 0.03	< 0.03	< 0.03	< 0.03	< 0.07	< 0.07
11	mg/m3	< 3	< 1	< 1	< 1	< 1	< 3	< 3
12	mg/m3	< 0.7	< 0.3	< 0.3	< 0.3	< 0.3	< 0.7	< 0.7
13	mg/m3	3.0	< 0.5	< 0.5	< 0.6	< 0.6	< 1	< 1
14	mg/m3	2.7	0.6	< 0.1	0.4	< 0.2	< 0.3	< 0.3
15	mg/m3	< 0.8	< 0.3	0.4	< 0.4	< 0.4	< 0.8	1.9
16	mg/m3	0.30	< 0.08	0.49	< 0.09	< 0.1	< 0.2	2
17	mg/m3	NA	NA	NA	NA	NA	NA	NA
18	mg/m3	NA	NA	NA	NA	NA	NA	NA
19	mg/m3	9.0	< 2	4	< 2	< 2	< 5	6
20	mg/m3	11.0	< 0.5	4.4	< 0.5	< 0.6	< 1	7
21	mg/m3	< 0.5	< 0.2	6.6	< 0.2	< 0.2	< 0.5	7.9
22	mg/m3	0.3	< 0.05	6.95	< 0.06	0.17	< 0.1	9.6
23	mg/m3	< 0.9	< 0.4	< 0.4	< 0.4	< 0.4	< 0.8	< 0.9
24	mg/m3	< 0.2	< 0.1	< 0.1	< 0.1	< 0.1	< 0.2	1.1
25	mg/m3	NA	NA	NA	NA	NA	NA	NA
26	mg/m3	NA	NA	NA	NA	NA	NA	NA
27	mg/m3	< 2	< 0.8	< 0.8	< 0.9	< 0.9	< 2	< 2
28	mg/m3	1.3	< 0.2	< 0.2	< 0.2	< 0.2	< 0.5	< 0.5
29	mg/m3	24.9	< 0.3	< 0.3	0.6	3.1	< 0.8	3.1
30	mg/m3	21.4	< 0.1	< 0.1	0.8	3.6	< 0.2	4
31	mg/m3	5	< 0.6	< 0.6	1	< 0.7	< 1	10
32	mg/m3	4.8	< 0.2	< 0.2	1	0.3	< 0.4	9.7
33	mg/m3	< 2	< 0.6	< 0.6	< 0.7	< 0.8	< 1	< 2
34	mg/m3	< 0.4	< 0.2	< 0.2	< 0.2	< 0.2	< 0.4	0.8

Sample ID	Sampling Volume (L)	Acetone (ppm)	n-Propanol (ppm)	2-Butanol (ppm)	1-Methoxy-2-propanol (ppm)	Ethyl-3-ethoxypropionate (ppm)	4-Hydroxy-4-methyl-2-pentanone (ppm)	Ethylene glycol monobutyl ether (ppm)
5	2.113	< 0.4	< 0.2	< 0.1	< 0.1	< 0.08	< 0.2	< 0.2
6	8.138	0.2	< 0.04	< 0.03	< 0.03	< 0.02	< 0.05	< 0.05
7	FB	NA	NA	NA	NA	NA	NA	NA
8	FB	NA	NA	NA	NA	NA	NA	NA
9	7.244	< 0.1	< 0.05	< 0.04	< 0.03	< 0.02	< 0.05	< 0.06
10	27.903	< 0.03	< 0.01	< 0.01	< 0.009	< 0.006	< 0.01	< 0.01
11	0.704	< 1	< 0.5	< 0.4	< 0.4	< 0.2	< 0.6	< 0.6
12	2.713	< 0.3	< 0.1	< 0.1	< 0.09	< 0.06	< 0.1	< 0.2
13	1.509	1.1	< 0.2	< 0.2	< 0.2	< 0.1	< 0.3	< 0.3
14	5.813	1.1	0.25	< 0.05	0.11	< 0.03	< 0.07	< 0.07

15	2.373	< 0.4	< 0.1	0.1	< 0.1	< 0.07	< 0.2	0.4
16	9.824	0.13	< 0.03	0.16	< 0.03	< 0.02	< 0.04	0.41
17	FB	NA	NA	NA	NA	NA	NA	NA
18	FB	NA	NA	NA	NA	NA	NA	NA
19	0.413	4	< 0.8	1.4	< 0.6	< 0.4	< 1	1
20	1.709	4.6	< 0.2	1.5	< 0.1	< 0.09	< 0.2	1.4
21	4.024	< 0.2	< 0.08	2.19	< 0.06	< 0.04	< 0.1	1.6
22	16.659	0.12	< 0.02	2.29	< 0.01	0.029	< 0.02	1.98
23	2.198	< 0.4	< 0.1	< 0.1	< 0.1	< 0.07	< 0.2	< 0.2
24	8.072	< 0.1	< 0.04	< 0.03	< 0.03	< 0.02	< 0.05	0.22
25	FB	NA	NA	NA	NA	NA	NA	NA
26	FB	NA	NA	NA	NA	NA	NA	NA
27	1.047	< 0.8	< 0.3	< 0.3	< 0.2	< 0.2	< 0.4	< 0.4
28	3.844	0.6	< 0.09	< 0.07	< 0.06	< 0.04	< 0.1	< 0.1
29	2.303	10.5	< 0.1	< 0.1	0.1	0.51	< 0.2	0.6
30	8.457	9.03	< 0.04	< 0.03	0.21	0.61	< 0.05	0.83
31	1.267	2.1	< 0.3	< 0.2	0.3	< 0.1	< 0.3	2.2
32	5.314	2	< 0.06	< 0.05	0.27	0.05	< 0.07	2
33	1.256	< 0.7	< 0.3	< 0.2	< 0.2	< 0.1	< 0.3	< 0.3
34	4.613	< 0.2	< 0.07	< 0.06	< 0.05	< 0.03	< 0.09	0.17

Quality Assurance

Parameter	Acetone	n-Propanol	2-Butanol	1-Methoxy-2-propanol	Ethyl-3-ethoxypropio	4-Hydroxy-4-methyl-2-	Ethylene glycol
R^2, Calibration	0.9985	0.9999	0.9998	0.9999	0.9999	0.9991	0.9999
Reporting Limit, (ug)	2	0.8	0.8	0.9	0.9	2	2
SR Efficiency	87.0%	109%	110%	108%	89.3%	101%	93.3%

Notes

Results were not corrected for spike recovery efficiency.
Results were corrected for matrix blank values.

Field blanks, when submitted, are analyzed and reported as samples; no corrections are made for field blank values.
It is solely the submitter's decision on how to utilize the field blank values.
Results apply only to the samples tested.
Unless otherwise noted, the conditions of the samples as received were satisfactory.

Analyst Comments: None

Reviewed by 12/15/14

Susan Tao, Ph.D. QAC — Date
206-221-4548

12/15/14

Russell Dills, Ph.D. EHL Director — Date
206-543-3263

Environmental Health Laboratory
Department of Environmental and Occupational Health Sciences
University of Washington

12/3/14

To

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From Nick Potter

Subject ANALYSIS REPORT

EHL Reference	Client Reference	Sampling Site
11411016	NA	Shop 01, 05, 08

Dates

Sampling	Receipt	Preparation	Analysis
11/5 - 12/14	11/18/14	11/21/14	11/21/14

Method EHLSOP-06 VOCs BY GAS CHROMATOGRAPHY
based on NIOSH 1501 Hydrocarbons, Aromatic

Media SKC 226-01: Anasorb CSC, Coconut Charcoal

Results

Sample ID	Benzene (µg/sample)	Toluene (µg/sample)	Ethyl benzene (µg/sample)	p-Xylene (µg/sample)	m-Xylene (µg/sample)	o-Xylene (µg/sample)	1,2,4-Trimethylbenzene (µg/sample)	Petroleum Distillate (µg/sample)
204	< 0.9	< 2	< 2	< 2	< 2	< 2	< 2	< 7
205	< 0.9	3	< 2	< 2	< 2	< 2	< 2	< 7
206	< 0.9	< 2	< 2	< 2	< 2	< 2	< 2	< 7
207	< 0.9	< 2	< 2	< 2	< 2	< 2	< 2	< 7
208	< 0.9	< 2	< 2	< 2	< 2	< 2	< 2	< 7
209	< 0.9	< 2	< 2	< 2	< 2	< 2	< 2	< 7
210	< 0.9	< 2	< 2	< 2	< 2	< 2	< 2	< 7
211	< 0.9	< 2	< 2	< 2	< 2	< 2	< 2	< 7
212	< 0.9	< 2	< 2	< 2	< 2	< 2	< 2	< 7
213	< 0.9	4	< 2	< 2	< 2	< 2	< 2	20
214	< 0.9	< 2	< 2	< 2	< 2	< 2	< 2	< 7
215	< 0.9	< 2	< 2	< 2	< 2	< 2	< 2	< 7
216	< 0.9	< 2	< 2	< 2	< 2	< 2	< 2	< 7
217	< 0.9	8	< 2	< 2	< 2	< 2	< 2	< 7
218	< 0.9	2	< 2	< 2	< 2	< 2	< 2	10
219	< 0.9	31	< 2	< 2	< 2	< 2	< 2	29
220	< 0.9	3	< 2	< 2	< 2	< 2	< 2	17
221	< 0.9	12	< 2	< 2	< 2	< 2	3.0	124
222	< 0.9	< 2	< 2	< 2	< 2	< 2	< 2	< 7
223	< 0.9	2	< 2	< 2	< 2	< 2	< 2	< 7
224	< 0.9	< 2	< 2	< 2	< 2	< 2	< 2	< 7
225	< 0.9	< 2	< 2	< 2	< 2	< 2	< 2	< 7
226	< 0.9	< 2	< 2	< 2	< 2	< 2	< 2	< 7
227	< 0.9	4	< 2	< 2	< 2	< 2	< 2	< 7
228	< 0.9	153	< 2	< 2	< 2	< 2	< 2	92
229	< 0.9	546	2	2	5	3	< 2	327
230	< 0.9	20	< 2	< 2	< 2	< 2	< 2	20
231	< 0.9	82	< 2	< 2	4.0	2.0	< 2	117
232	< 0.9	< 2	< 2	< 2	< 2	< 2	< 2	< 7
233	< 0.9	6	< 2	< 2	4.0	< 2	< 2	< 7

Sample ID	Units	Benzene	Toluene	Ethyl benzene	p-Xylene	m-Xylene	o-Xylene	1,2,4-Trimethylbenzene	Petroleum Distillate
204	mg/m3	< 0.4	< 0.9	< 0.9	< 0.9	< 0.9	< 0.9	< 0.9	< 3
205	mg/m3	< 0.1	0.4	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.8
206	mg/m3	NA	NA	NA	NA	NA	NA	NA	NA
207	mg/m3	NA	NA	NA	NA	NA	NA	NA	NA
208	mg/m3	< 0.7	< 2	< 2	< 2	< 2	< 2	< 2	< 5
209	mg/m3	< 0.2	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 1
210	mg/m3	< 1	< 3	< 3	< 3	< 3	< 3	< 3	< 9
211	mg/m3	< 0.3	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7	< 2
212	mg/m3	< 0.5	< 1	< 1	< 1	< 1	< 1	< 1	< 4
213	mg/m3	< 0.1	0.6	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	3
214	mg/m3	< 0.4	< 0.9	< 0.9	< 0.9	< 0.9	< 0.9	< 0.9	< 3
215	mg/m3	NA	NA	NA	NA	NA	NA	NA	NA
216	mg/m3	NA	NA	NA	NA	NA	NA	NA	NA
217	mg/m3	< 2	20	< 5	< 5	< 5	< 5	< 5	< 20
218	mg/m3	< 0.09	0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	1
219	mg/m3	< 0.5	18	< 1	< 1	< 1	< 1	< 1	16
220	mg/m3	< 0.2	0.7	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	4
221	mg/m3	< 0.05	0.7	< 0.1	< 0.1	< 0.1	< 0.1	0.2	7.2
222	mg/m3	< 0.4	< 1	< 1	< 1	< 1	< 1	< 1	< 3
223	mg/m3	< 0.1	0.3	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.8
224	mg/m3	NA	NA	NA	NA	NA	NA	NA	NA
225	mg/m3	NA	NA	NA	NA	NA	NA	NA	NA
226	mg/m3	< 0.9	< 2	< 2	< 2	< 2	< 2	< 2	< 7
227	mg/m3	< 0.2	1	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 2
228	mg/m3	< 0.4	69.6	< 0.9	< 0.9	< 0.9	< 0.9	< 0.9	42
229	mg/m3	< 0.1	63.9	0.2	0.3	0.6	0.3	< 0.2	38.3
230	mg/m3	< 0.7	15.0	< 2	< 2	< 2	< 2	< 2	15.0
231	mg/m3	< 0.2	15.1	< 0.4	< 0.4	0.7	0.4	< 0.4	21.0
232	mg/m3	< 0.7	< 2	< 2	< 2	< 2	< 2	< 2	< 6
233	mg/m3	< 0.2	1.2	< 0.4	< 0.4	0.8	< 0.4	< 0.4	< 1

Sample ID	Sampling Volume (L)	Benzene (ppm)	Toluene (ppm)	Ethyl benzene (ppm)	p-Xylene (ppm)	m-Xylene (ppm)	o-Xylene (ppm)	1,2,4-Trimethylbenzene (ppm)	Petroleum Distillate (ppm)
204	2.324805	< 0.1	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	NA
205	8.84583	< 0.03	0.1	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	NA
206	FB	NA	NA	NA	NA	NA	NA	NA	NA
207	FB	NA	NA	NA	NA	NA	NA	NA	NA
208	1.332	< 0.2	< 0.4	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	NA
209	5.05476	< 0.05	< 0.1	< 0.09	< 0.09	< 0.09	< 0.09	< 0.08	NA
210	0.774935	< 0.4	< 0.7	< 0.6	< 0.6	< 0.6	< 0.6	< 0.5	NA
211	2.94861	< 0.09	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.1	NA
212	1.660575	< 0.2	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.2	NA
213	6.31845	< 0.04	0.16	< 0.07	< 0.07	< 0.07	< 0.07	< 0.06	NA
214	2.29586	< 0.1	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	NA
215	FB	NA	NA	NA	NA	NA	NA	NA	NA
216	FB	NA	NA	NA	NA	NA	NA	NA	NA
217	0.39928	< 0.7	5	< 1	< 1	< 1	< 1	< 1	NA
218	10.115985	< 0.03	0.06	< 0.05	< 0.05	< 0.05	< 0.05	< 0.04	NA
219	1.76278	< 0.2	4.7	< 0.3	< 0.3	< 0.3	< 0.3	< 0.2	NA
220	3.89298	< 0.07	0.2	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	NA
221	17.187105	< 0.02	0.18	< 0.03	< 0.03	< 0.03	< 0.03	0.03	NA
222	2.093175	< 0.1	< 0.3	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	NA
223	8.14632	< 0.03	0.07	< 0.06	< 0.06	< 0.06	< 0.06	< 0.05	NA
224	FB	NA	NA	NA	NA	NA	NA	NA	NA
225	FB	NA	NA	NA	NA	NA	NA	NA	NA
226	0.99675	< 0.3	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.4	NA
227	3.8792	< 0.07	0.3	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	NA
228	2.19285	< 0.1	18.5	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	NA
229	8.53424	< 0.03	17.0	0.06	0.06	0.15	0.07	< 0.05	NA
230	1.319955	< 0.2	4.0	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	NA
231	5.451355	< 0.05	4.0	< 0.08	< 0.08	0.16	0.09	< 0.07	NA
232	1.1961	< 0.2	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.3	NA
233	4.65504	< 0.06	0.3	< 0.1	< 0.1	0.18	< 0.1	< 0.09	NA

Quality Assurance

Parameter	Benzene	Toluene	Ethyl benzene	p-Xylene	m-Xylene	o-Xylene	1,2,4-Trimethylbenzene	Petroleum Distillate
R^2, Calibration	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Reporting Limit, (µg)	0.9	2	2	2	2	2	2	7
SR Efficiency	98.0%	99.1%	99.7%	97.7%	97.9%	94.8%	95.9%	101.6%

Notes

Results were not corrected for spike recovery efficiency.
Results were corrected for matrix blank values.

Field blanks, when submitted, are analyzed and reported as samples; no corrections are made for field blank values.
It is solely the submitter's decision on how to utilize the field blank values.
Results apply only to the samples tested.
Unless otherwise noted, the conditions of the samples as received were satisfactory.

Analyst Comments

Petroleum distallates (PD) were quantitated against a heptane calibration curve.
Samples 228 and 229 had results for PD for the back sorbent (< 10%) and were added to front sorbent results.
All non-target peaks were considered as PD.
If other chemicals, such as water based paint solvents, were desorbed, they would be included in PD result.

Reviewed by Susan Tao 12/3/14 — Susan Tao, Ph.D. QAC, Date, 206-221-4548

R Dills 12/3/14 — Russell Dills, Ph.D. EHL Director, Date, 206-543-3263

Environmental Health Laboratory
Department of Environmental and Occupational Health Sciences
University of Washington

12/9/14

To

Grace Liao
DEOHS Grad Student
Box 357234
University of Washington
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Steve Whittaker, Ph.D.
Local Hazardous Waste Mgmt Program
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401 Fifth Ave., Suite 1100
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CC

Dr. Marty Cohen
FRCG
DEOHS
BOX 354695
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Seattle, WA 98195-4695

From Nick Potter

Subject ANALYSIS REPORT

EHL Reference	Client Reference	Sampling Site
11411023	None	Shop 6

Dates

Sampling	Receipt	Preparation	Analysis
11/25/14	11/26/14	12/3/14	12/3/14

Method EHLSOP-06 VOCs BY GAS CHROMATOGRAPHY
based on NIOSH 2554 Glycol Ethers

Media Supelco 20358: ORBO 90 Carboxen-564

Results

Sample ID	Acetone (µg/sample)	n-Propanol (µg/sample)	2-Butanol (µg/sample)	1-Methoxy-2-propanol (µg/sample)	Ethyl-3-ethoxypropionate (µg/sample)	4-Hydroxy-4-methyl-2-pentanone (µg/sample)	Ethylene glycol monobutyl ether (µg/sample)
35	5	< 0.8	< 0.8	< 0.9	< 0.9	< 2	3
36	18	< 0.8	< 0.8	1.8	< 0.9	< 2	11
37	< 2	< 0.8	< 0.8	< 0.9	< 0.9	< 2	< 2
38	< 2	< 0.8	< 0.8	< 0.9	< 0.9	< 2	< 2
39	5	< 0.8	< 0.8	< 0.9	< 0.9	< 2	< 2
40	20	< 0.8	< 0.8	2.3	< 0.9	< 2	5
41	20	< 0.8	< 0.8	< 0.9	< 0.9	< 2	< 2
42	73	< 0.8	< 0.8	< 0.9	< 0.9	< 2	3

Sample ID	Units	Acetone	n-Propanol	2-Butanol	1-Methoxy-2-propanol	Ethyl-3-ethoxypropionate	4-Hydroxy-4-methyl-2-pentanone	Ethylene glycol monobutyl ether
35	mg/m3	1.3	< 0.2	< 0.2	< 0.2	< 0.3	< 0.5	0.8
36	mg/m3	1.2	< 0.06	< 0.06	0.12	< 0.07	< 0.1	0.8
37	mg/m3	NA	NA	NA	NA	NA	NA	NA
38	mg/m3	NA	NA	NA	NA	NA	NA	NA
39	mg/m3	2.2	< 0.4	< 0.4	< 0.4	< 0.4	< 0.9	< 0.9
40	mg/m3	2.4	< 0.1	< 0.1	0.3	< 0.1	< 0.2	0.6
41	mg/m3	9.2	< 0.4	< 0.4	< 0.4	< 0.4	< 0.8	< 0.9
42	mg/m3	8.5	< 0.09	< 0.09	< 0.1	< 0.1	< 0.2	0.4

Environmental Health Laboratory
Department of Environmental and Occupational Health Sciences
University of Washington

Sample ID	Sampling Volume (L)	Acetone (ppm)	n-Propanol (ppm)	2-Butanol (ppm)	1-Methoxy-2-propanol (ppm)	Ethyl-3-ethoxypropionate (ppm)	4-Hydroxy-4-methyl-2-pentanone (ppm)	Ethylene glycol monobutyl ether (ppm)
35	3.734	0.5	< 0.09	< 0.07	< 0.07	< 0.04	< 0.1	0.2
36	14.483	0.52	< 0.02	< 0.02	0.03	< 0.01	< 0.03	0.16
37	FB	NA	NA	NA	NA	NA	NA	NA
38	FB	NA	NA	NA	NA	NA	NA	NA
39	2.119	0.9	< 0.2	< 0.1	< 0.1	< 0.07	< 0.2	< 0.2
40	8.22	1	< 0.04	< 0.03	0.08	< 0.02	< 0.05	0.13
41	2.22	3.9	< 0.1	< 0.1	< 0.1	< 0.07	< 0.2	< 0.2
42	8.611	3.59	< 0.04	< 0.03	< 0.03	< 0.02	< 0.05	0.08

Quality Assurance

Parameter	Acetone	n-Propanol	2-Butanol	1-Methoxy-2-propanol	Ethyl-3-ethoxypropionate	4-Hydroxy-4-methyl-2-pentanone	Ethylene glycol monobutyl ether
R^2, Calibration	0.9985	0.9999	0.9998	0.9999	0.9999	0.9991	0.9999
Reporting Limit, (µg)	2	0.8	0.8	0.9	0.9	2	2
SR Efficiency	87.0%	109%	110%	108%	89.3%	101%	93.3%

Notes

Results were not corrected for spike recovery efficiency.
Results were corrected for matrix blank values.

Field blanks, when submitted, are analyzed and reported as samples; no corrections are made for field blank values.
It is solely the submitter's decision on how to utilize the field blank values.
Results apply only to the samples tested.
Unless otherwise noted, the conditions of the samples as received were satisfactory.

Analyst Comments: None

Reviewed by [signature] 12/9/14
Susan Tao, Ph.D. QAC — Date
206-221-4548

[signature] 12/10/14
Russell Dills, Ph.D. EHL Director — Date
206-543-3263

Environmental Health Laboratory
Department of Environmental and Occupational Health Sciences
University of Washington

12/15/14

To

Grace Liao	Steve Whittaker, Ph.D.
DEOHS Grad Student	Local Hazardous Waste Mgmt Program
Box 357234	Public Health-Seattle & King County
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gracel4@uw.edu	steve.whittaker@kingcounty.gov

CC

Dr. Marty Cohen
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Seattle, WA 98195-4695

From Nick Potter

Subject ANALYSIS REPORT

EHL Reference	Client Reference	Sampling Site
11411024	NA	Shop 06

Dates

Sampling	Receipt	Preparation	Analysis
11/25/14	11/26/14	12/9/14	12/9/14

Method EHLSOP-06 VOCs BY GAS CHROMATOGRAPHY
based on NIOSH 1501 Hydrocarbons, Aromatic

Media SKC 226-01: Anasorb CSC, Coconut Charcoal

Results

Sample ID	Benzene (µg/sample)	Toluene (µg/sample)	Ethyl benzene (µg/sample)	p-Xylene (µg/sample)	m-Xylene (µg/sample)	o-Xylene (µg/sample)	1,2,4-Trimethylbenzene (µg/sample)	Petroleum distillate (µg/sample)
234	< 0.9	< 2	< 2	< 2	< 2	< 2	< 2	< 7
235	< 0.9	4	< 2	< 2	< 2	< 2	< 2	28
236	< 0.9	< 2	< 2	< 2	< 2	< 2	< 2	< 7
237	< 0.9	< 2	< 2	< 2	< 2	< 2	< 2	< 7
238	< 0.9	< 2	< 2	< 2	< 2	< 2	< 2	< 7
239	< 0.9	5	< 2	< 2	< 2	< 2	< 2	22
240	< 0.9	< 2	< 2	< 2	< 2	< 2	< 2	8
241	< 0.9	2	< 2	< 2	< 2	< 2	< 2	43

Sample ID	Units	Benzene	Toluene	Ethyl benzene	p-Xylene	m-Xylene	o-Xylene	1,2,4-Trimethylbenzene	Petroleum distillate
234	mg/m3	< 0.2	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 2
235	mg/m3	< 0.06	0.3	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	2
236	mg/m3	NA	NA	NA	NA	NA	NA	NA	NA
237	mg/m3	NA	NA	NA	NA	NA	NA	NA	NA
238	mg/m3	< 0.4	< 1	< 1	< 1	< 1	< 1	< 1	< 3
239	mg/m3	< 0.1	0.6	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	3
240	mg/m3	< 0.5	< 1	< 1	< 1	< 1	< 1	< 1	4
241	mg/m3	< 0.1	0.3	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	5

Sample ID	Sampling Volume (L)	Benzene (ppm)	Toluene (ppm)	Ethyl benzene (ppm)	p-Xylene (ppm)	m-Xylene (ppm)	o-Xylene (ppm)	1,2,4-Trimethylbenzene (ppm)	Petroleum distillate (ppm)
234	3.644	< 0.08	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	NA
235	14.704	< 0.02	0.08	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	NA
236	FB	NA	NA	NA	NA	NA	NA	NA	NA
237	FB	NA	NA	NA	NA	NA	NA	NA	NA
238	2.068	< 0.1	< 0.3	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	NA
239	8.346	< 0.03	0.16	< 0.06	< 0.06	< 0.06	< 0.06	< 0.05	NA
240	1.872	< 0.1	< 0.3	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	NA
241	8.743	< 0.03	0.07	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	NA

Environmental Health Laboratory
Department of Environmental and Occupational Health Sciences
University of Washington

Quality Assurance

Parameter	Benzene	Toluene	Ethyl benzene	p-Xylene	m-Xylene	o-Xylene	1,2,4-Trimethylben	Petroleum distillate
R^2, Calibration	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	NA
Reporting Limit, (ug)	0.9	2	2	2	2	2	2	7
SR Efficiency	89.1%	91.4%	93.7%	91.6%	91.8%	88.7%	89.7%	NA

Notes

Results were not corrected for spike recovery efficiency.
Results were corrected for matrix blank values.
NA = Not Applicable

Field blanks, when submitted, are analyzed and reported as samples; no corrections are made for field blank values.
It is solely the submitter's decision on how to utilize the field blank values.
Results apply only to the samples tested.
Unless otherwise noted, the conditions of the samples as received were satisfactory.

Analyst Comments

Petroleum distillates (PD) were quantitated against a heptane calibration curve.
All non-target peaks were considered as PD.
If other chemicals, such as water based paint solvents, were desorbed, they would be included in PD result.

Reviewed by Susan Tao 12/16/14
Susan Tao, Ph.D. QAC Date
206-221-4548

12/17/14
Russell Dills, Ph.D. EHL Director Date
206-543-3263

Environmental Health Laboratory
Department of Environmental and Occupational Health Sciences
University of Washington

1/9/15

To

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Steve Whittaker, Ph.D.
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To

Dr. Marty Cohen
FRCG
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BOX 354695
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Seattle, WA 98195-4695

From Nick Potter

Subject ANALYSIS REPORT

EHL Reference	Client Reference	Sampling Site
11412014	None	Shop 2

Dates

Sampling	Receipt	Preparation	Analysis
12/10/14	12/19/14	12/23/14	12/23/14

Method EHLSOP-06 VOCs BY GAS CHROMATOGRAPHY
based on NIOSH 2554 Glycol Ethers

Media Supelco 20358: ORBO 90 Carboxen-564

Results

Sample ID	Acetone (µg/sample)	n-Propanol (µg/sample)	2-Butanol (µg/sample)	1-Methoxy-2-propanol (µg/sample)	Ethyl-3-ethoxypropionate (µg/sample)	4-Hydroxy-4-methyl-2-pentanone (µg/sample)	Ethylene glycol monobutyl ether (µg/sample)
43	< 8	< 2	< 1	< 2	< 2	< 0.9	< 2
44	< 8	2	< 1	2	< 2	< 0.9	< 2
45	< 8	< 2	< 1	< 2	< 2	< 0.9	< 2
46	< 8	< 2	< 1	< 2	< 2	< 0.9	< 2
47	< 8	< 2	< 1	< 2	< 2	< 0.9	< 2
48	< 8	< 2	< 1	< 2	< 2	< 0.9	< 2

Sample ID	Units	Acetone	n-Propanol	2-Butanol	1-Methoxy-2-propanol	Ethyl-3-ethoxypropionate	4-Hydroxy-4-methyl-2-pentanone	Ethylene glycol monobutyl ether
43	mg/m3	< 6	< 1	< 1	< 1	< 1	< 0.7	< 2
44	mg/m3	< 2	0.5	< 0.3	0.5	< 0.4	< 0.2	< 0.4
45	mg/m3	NA	NA	NA	NA	NA	NA	NA
46	mg/m3	NA	NA	NA	NA	NA	NA	NA
47	mg/m3	< 10	< 2	< 2	< 2	< 2	< 1	< 2
48	mg/m3	< 3	< 0.6	< 0.5	< 0.7	< 0.7	< 0.3	< 0.7

Environmental Health Laboratory
Department of Environmental and Occupational Health Sciences
University of Washington

Sample ID	Sampling Volume (L)	Acetone (ppm)	n-Propanol (ppm)	2-Butanol (ppm)	1-Methoxy-2-propanol (ppm)	Ethyl-3-ethoxypropionate (ppm)	4-Hydroxy-4-methyl-2-pentanone (ppm)	Ethylene glycol monobutyl ether (ppm)
43	1.309	< 3	< 0.5	< 0.3	< 0.4	< 0.2	< 0.1	< 0.3
44	4.5722	< 0.7	0.2	< 0.1	0.1	< 0.07	< 0.04	< 0.09
45	FB	NA	NA	NA	NA	NA	NA	NA
46	FB	NA	NA	NA	NA	NA	NA	NA
47	0.8055	< 4	< 0.8	< 0.6	< 0.6	< 0.4	< 0.2	< 0.5
48	2.8137	< 1	< 0.2	< 0.2	< 0.2	< 0.1	< 0.07	< 0.1

Quality Assurance

Parameter	Acetone	n-Propanol	2-Butanol	1-Methoxy-2-propanol	Ethyl-3-ethoxypropionate	4-Hydroxy-4-methyl-2-pentanone	Ethylene glycol monobutyl ether
R^2, Calibration	0.9985	0.9999	0.9998	0.9999	0.9998	0.9997	0.9999
Reporting Limit, (ug)	8	2	1	2	2	0.9	2
SR Efficiency	95.2%	115%	111%	112%	86.1%	105%	94.2%

Notes
Results were not corrected for spike recovery efficiency.
Results were corrected for matrix blank values.
NA - Not Applicable

Field blanks, when submitted, are analyzed and reported as samples; no corrections are made for field blank values.
It is solely the submitter's decision on how to utilize the field blank values.
Results apply only to the samples tested.
Unless otherwise noted, the conditions of the samples as received were satisfactory.

Analyst Comments: None

Reviewed by: Susan Tao 1/9/15
Susan Tao, Ph.D. QAC — Date
206-221-4548

1/12/15
Russell Dills, Ph.D. EHL Director — Date
206-543-3263

Environmental Health Laboratory
Department of Environmental and Occupational Health Sciences
University of Washington

1/6/15

To	Grace Liao DEOHS Grad Student Box 357234 University of Washington Seattle, WA 98195-7234 gracel4@uw.edu	Steve Whittaker, Ph.D. Local Hazardous Waste Mgmt Program Public Health-Seattle & King County 401 Fifth Ave., Suite 1100 Seattle, WA 98104 steve.whittaker@kingcounty.gov
CC	Dr. Marty Cohen FRCG DEOHS BOX 354695 University of Washington Seattle, WA 98195-4695	

From Nick Potter

Subject ANALYSIS REPORT

EHL Reference	Client Reference	Sampling Site
11412015	None	Shop 2

Dates

Sampling	Receipt	Preparation	Analysis
12/10/14	12/19/14	12/23/14	12/23/14

Method EHLSOP-06 VOCs BY GAS CHROMATOGRAPHY
based on NIOSH 1501 Hydrocarbons, Aromatic

Media SKC 226-01: Anasorb CSC, Coconut Charcoal

Results

Sample ID	Benzene (µg/sample)	Toluene (µg/sample)	Ethyl benzene (µg/sample)	p-Xylene (µg/sample)	m-Xylene (µg/sample)	o-Xylene (µg/sample)	1,2,4-Trimethylbenzene (µg/sample)	Petroleum Distillate (µg/sample)
242	< 0.9	4	< 2	< 2	< 2	< 2	< 2	< 7
243	< 0.9	9	< 2	< 2	< 2	< 2	< 2	17
244	< 0.9	< 2	< 2	< 2	< 2	< 2	< 2	< 7
245	< 0.9	< 2	< 2	< 2	< 2	< 2	< 2	< 7
246	< 0.9	< 2	< 2	< 2	< 2	< 2	< 2	< 7
247	< 0.9	< 2	< 2	< 2	< 2	< 2	< 2	< 7

Sample ID	Units	Benzene	Toluene	Ethyl benzene	p-Xylene	m-Xylene	o-Xylene	1,2,4-Trimethylbenzene	Petroleum Distillate
242	mg/m3	< 0.6	3	< 1	< 1	< 1	< 1	< 1	< 5
243	mg/m3	< 0.2	1.8	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	4
244	mg/m3	NA	NA	NA	NA	NA	NA	NA	NA
245	mg/m3	NA	NA	NA	NA	NA	NA	NA	NA
246	mg/m3	< 1	< 2	< 2	< 2	< 2	< 2	< 2	< 8
247	mg/m3	< 0.3	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7	< 2

Sample ID	Sampling Volume (L)	Benzene (ppm)	Toluene (ppm)	Ethyl benzene (ppm)	p-Xylene (ppm)	m-Xylene (ppm)	o-Xylene (ppm)	1,2,4-Trimethylbenzene (ppm)	Petroleum Distillate (ppm)
242	1.3464	< 0.2	0.9	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	NA
243	4.9271	< 0.06	0.5	< 0.09	< 0.09	< 0.09	< 0.09	< 0.08	NA
244	FB	NA	NA	NA	NA	NA	NA	NA	NA
245	FB	NA	NA	NA	NA	NA	NA	NA	NA
246	0.8286	< 0.3	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.5	NA
247	3.0321	< 0.09	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.1	NA

Quality Assurance

Parameter	Benzene	Toluene	Ethyl benzene	p-Xylene	m-Xylene	o-Xylene	1,2,4-Trimethylbenzene	Petroleum Distillate
R^2, Calibration	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	NA
Reporting Limit, (µg)	0.9	2	2	2	2	2	2	7
SR Efficiency	91.5%	93.2%	95.8%	93.8%	94.7%	91.0%	93.2%	NA

Environmental Health Laboratory
Department of Environmental and Occupational Health Sciences
University of Washington

Notes
Results were not corrected for spike recovery efficiency.
Results were corrected for matrix blank values.
NA = Not Applicable

Field blanks, when submitted, are analyzed and reported as samples; no corrections are made for field blank values.
It is solely the submitter's decision on how to utilize the field blank values.
Results apply only to the samples tested.
Unless otherwise noted, the conditions of the samples as received were satisfactory.

Analyst Comments
Petroleum distallates (PD) were quantitated against a heptane calibration curve.
All non-target peaks were considered as PD.
If other chemicals, such as water based paint solvents, were desorbed, they would be included in PD result.

Reviewed by Susan Tao 1/6/15

Susan Tao, Ph.D. QAC — Date
206-221-4548

1/7/15

Russell Dills, Ph.D. EHL Director — Date
206-543-3263

Environmental Health Laboratory
Department of Environmental and Occupational Health Sciences
University of Washington

3/11/15

To Grace Liao
DEOHS Grad Student
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Steve Whittaker, Ph.D.
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CC Dr. Marty Cohen
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Seattle, WA 98195-4695

From Nick Potter

Subject ANALYSIS REPORT

EHL Reference	Client Reference	Sampling Site
11502009	None	Shops 9, 10, 11

Dates

Sampling	Receipt	Preparation	Analysis
1/21/15 - 2/4/15	2/6/15	3/4/15	3/4/15

Method EHLSOP-06 VOCs BY GAS CHROMATOGRAPHY
based on NIOSH 1501 Hydrocarbons, Aromatic

Media SKC 226-01: Anasorb CSC, Coconut Charcoal

Results

Sample ID	Benzene (µg/sample)	Toluene (µg/sample)	Ethyl benzene (µg/sample)	p-Xylene (µg/sample)	m-Xylene (µg/sample)	o-Xylene (µg/sample)	1,2,4-Trimethylbenzene (µg/sample)	Petroleum Distillate (µg/sample)
248	< 0.9	3	< 2	< 2	< 2	< 2	< 2	7
251	< 0.9	3	< 2	< 2	< 2	< 2	< 2	44
252	< 0.9	< 2	< 2	< 2	< 2	< 2	< 2	< 7
253	< 0.9	13	< 2	< 2	3	< 2	< 2	11
254	< 0.9	< 2	< 2	< 2	< 2	< 2	< 2	< 7
255	< 0.9	< 2	< 2	< 2	< 2	< 2	< 2	< 7
256	< 0.9	5	< 2	< 2	< 2	< 2	< 2	14
257	< 0.9	< 2	< 2	< 2	< 2	< 2	< 2	< 7
259	< 0.9	< 2	< 2	< 2	< 2	< 2	< 2	< 7
50	< 0.9	< 2	< 2	< 2	< 2	< 2	< 2	< 7
51	< 0.9	< 2	< 2	< 2	< 2	< 2	< 2	8
59	< 0.9	< 2	< 2	< 2	< 2	< 2	< 2	< 7

Sample ID	Units	Benzene	Toluene	Ethyl benzene	p-Xylene	m-Xylene	o-Xylene	1,2,4-Trimethylbenzene	Petroleum Distillate
248	mg/m3	< 0.3	1.1	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7	2
251	mg/m3	< 0.1	0.4	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	7
252	mg/m3	< 0.3	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 2
253	mg/m3	< 0.2	3.1	< 0.5	< 0.5	0.8	< 0.5	< 0.5	3
254	mg/m3	NA	NA	NA	NA	NA	NA	NA	NA
255	mg/m3	NA	NA	NA	NA	NA	NA	NA	NA
256	mg/m3	< 0.2	1	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	3
257	mg/m3	< 0.1	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 1
259	mg/m3	NA	NA	NA	NA	NA	NA	NA	NA
50	mg/m3	NA	NA	NA	NA	NA	NA	NA	NA
51	mg/m3	NA	NA	NA	NA	NA	NA	NA	NA
59	mg/m3	NA	NA	NA	NA	NA	NA	NA	NA

Sample ID	Sampling Volume (L)	Benzene (ppm)	Toluene (ppm)	Ethyl benzene (ppm)	p-Xylene (ppm)	m-Xylene (ppm)	o-Xylene (ppm)	1,2,4-Trimethylbenzene (ppm)	Petroleum Distillate (ppm)
248	3.07024	< 0.09	0.3	< 0.2	< 0.2	< 0.2	< 0.2	< 0.1	NA
251	6.14048	< 0.04	0.12	< 0.08	< 0.08	< 0.08	< 0.08	< 0.07	NA
252	3.45402	< 0.08	< 0.2	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	NA
253	4.16525	< 0.07	0.8	< 0.1	< 0.1	0.2	< 0.1	< 0.1	NA
254	FB	NA	NA	NA	NA	NA	NA	NA	NA
255	FB	NA	NA	NA	NA	NA	NA	NA	NA

256	4.581775	< 0.06	0.3	< 0.1	< 0.1	< 0.1	< 0.1	< 0.09	NA
257	6.84182	< 0.04	< 0.08	< 0.07	< 0.07	< 0.07	< 0.07	< 0.06	NA
259	FB	NA	NA	NA	NA	NA	NA	NA	NA
50	FB	NA	NA	NA	NA	NA	NA	NA	NA
51	FB	NA	NA	NA	NA	NA	NA	NA	NA
59	FB	NA	NA	NA	NA	NA	NA	NA	NA

Quality Assurance

Parameter	Benzene	Toluene	Ethyl benzene	p-Xylene	m-Xylene	o-Xylene	1,2,4-Trimethylbenzene	Petroleum Distillate
R^2, Calibration	0.9999	0.9999	0.9999	1.0000	1.0000	0.9999	1.0000	NA
Reporting Limit, (ug)	0.9	2	2	2	2	2	2	7
SR Efficiency	89.6%	91.4%	91.5%	91.7%	91.8%	88.8%	89.7%	NA

Notes

Results were not corrected for spike recovery efficiency.
Results were corrected for matrix blank values.
NA - Not Applicable
Field blanks, when submitted, are analyzed and reported as samples; no corrections are made for field blank values.
It is solely the submitter's decision on how to utilize the field blank values.
Results apply only to the samples tested.
Unless otherwise noted, the conditions of the samples as received were satisfactory.

Analyst Comments

Petroleum distillates (PD) were quantitated against a heptane calibration curve.
All non-target peaks were considered as PD.
If other chemicals, such as water based paint solvents, were desorbed, they would be included in PD result.
Guide 34 standards were unavailable.

Reviewed by Susan Tao 3/12/15

Susan Tao, Ph.D. QAC — Date
206-221-4548

Russell Dills 3/13/15

Russell Dills, Ph.D. EHL Director — Date
206-543-3253

Environmental Health Laboratory
Department of Environmental and Occupational Health Sciences
University of Washington

3/11/15

To	Grace Liao DEOHS Grad Student Box 357234 University of Washington Seattle, WA 98195-7234 gracel4@uw.edu	Steve Whittaker, Ph.D. Local Hazardous Waste Mgmt Program Public Health-Seattle & King County 401 Fifth Ave., Suite 1100 Seattle, WA 98104 steve.whittaker@kingcounty.gov
CC	Dr. Marty Cohen FRCG DEOHS BOX 354695 University of Washington Seattle, WA 98195-4695	

From Nick Potter

Subject ANALYSIS REPORT

EHL Reference	Client Reference	Sampling Site
11502013	None	Shop 03

	Sampling	Receipt	Preparation	Analysis
Dates	2/11/15	2/13/15	3/4/15	3/4/15

Method EHLSOP-06 VOCs BY GAS CHROMATOGRAPHY
based on NIOSH 1501 Hydrocarbons, Aromatic

Media SKC 226-01: Anasorb CSC, Coconut Charcoal

Results

Sample ID	Benzene (µg/sample)	Toluene (µg/sample)	Ethyl benzene (µg/sample)	p-Xylene (µg/sample)	m-Xylene (µg/sample)	o-Xylene (µg/sample)	1,2,4-Trimethylbenzene (µg/sample)	Petroleum Distillate (µg/sample)
260	< 0.9	< 2	< 2	< 2	< 2	< 2	< 2	< 7
261	< 0.9	< 2	< 2	< 2	< 2	< 2	< 2	< 7
262	< 0.9	< 2	< 2	< 2	< 2	< 2	< 2	< 7
263	< 0.9	< 2	< 2	< 2	< 2	< 2	< 2	< 7
264	< 0.9	3	< 2	< 2	< 2	< 2	< 2	< 7

Sample ID	Units	Benzene	Toluene	Ethyl benzene	p-Xylene	m-Xylene	o-Xylene	1,2,4-Trimethylbenzene	Petroleum Distillate
260	mg/m3	< 0.3	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 2
261	mg/m3	NA	NA	NA	NA	NA	NA	NA	NA
262	mg/m3	< 0.2	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 2
263	mg/m3	NA	NA	NA	NA	NA	NA	NA	NA
264	mg/m3	< 0.2	0.9	< 0.6	< 0.6	< 0.6	< 0.6	< 0.6	< 2

Sample ID	Sampling Volume (L)	Benzene (ppm)	Toluene (ppm)	Ethyl benzene (ppm)	p-Xylene (ppm)	m-Xylene (ppm)	o-Xylene (ppm)	1,2,4-Trimethylbenzene (ppm)	Petroleum Distillate (ppm)
260	3.223	< 0.08	< 0.2	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	NA
261	FB	NA	NA	NA	NA	NA	NA	NA	NA
262	3.626	< 0.08	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	NA
263	FB	NA	NA	NA	NA	NA	NA	NA	NA
264	3.626	< 0.08	0.2	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	NA

Quality Assurance

Parameter	Benzene	Toluene	Ethyl benzene	p-Xylene	m-Xylene	o-Xylene	1,2,4-Trimethylbenzene	Petroleum Distillate
R^2, Calibration	0.9999	0.9999	0.9999	1.0000	1.0000	0.9999	1.0000	NA
Reporting Limit, (µg)	0.9	2	2	2	2	2	2	7
SR Efficiency	89.5%	91.4%	93.4%	91.7%	91.8%	88.8%	89.7%	NA

Notes Results were not corrected for spike recovery efficiency.
Results were corrected for matrix blank values.

NA - Not Applicable

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Results apply only to the samples tested.

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Analyst Comments

Petroleum distallates (PD) were quantitated against a heptane calibration curve.
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Guide 34 standards were unavailable.

Reviewed by Susan Tao 3/12/15 — Russell Dills 3/13/15

Susan Tao, Ph.D. QAC — Date
206-221-4548

Russell Dills, Ph.D. EHL Director — Date
206-543-3263

Environmental Health Laboratory
Department of Environmental and Occupational Health Sciences
University of Washington

3/11/15

To Grace Liao
DEOHS Grad Student
Box 357234
University of Washington
Seattle, WA 98195-7234
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Steve Whittaker, Ph.D.
Local Hazardous Waste Mgmt Program
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CC Dr. Marty Cohen
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BOX 354695
University of Washington
Seattle, WA 98195-4695

From Nick Potter

Subject ANALYSIS REPORT

EHL Reference	Client Reference	Sampling Site
11502022	None	Shop 04

	Sampling	Receipt	Preparation	Analysis
Dates	2/18/15	2/23/15	3/4/15	3/4/15

Method EHLSOP-06 VOCs BY GAS CHROMATOGRAPHY
based on NIOSH 1501 Hydrocarbons, Aromatic

Media SKC 226-01: Anasorb CSC, Coconut Charcoal

Results

Sample ID	Benzene (µg/sample)	Toluene (µg/sample)	Ethyl benzene (µg/sample)	p-Xylene (µg/sample)	m-Xylene (µg/sample)	o-Xylene (µg/sample)	1,2,4-Trimethylbenzene (µg/sample)	Petroleum Distillate (µg/sample)
265	< 0.9	24	< 2	< 2	< 2	< 2	< 2	12
266	< 0.9	< 2	< 2	< 2	< 2	< 2	< 2	< 7
267	< 0.9	< 2	< 2	< 2	< 2	< 2	< 2	< 7
268	< 0.9	13	< 2	< 2	< 2	< 2	< 2	24
269	< 0.9	3	< 2	< 2	< 2	< 2	< 2	< 7

Sample ID	Units	Benzene	Toluene	Ethyl benzene	p-Xylene	m-Xylene	o-Xylene	1,2,4-Trimethylbenzene	Petroleum Distillate
265	mg/m3	< 0.08	2.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	1.1
266	mg/m3	NA	NA	NA	NA	NA	NA	NA	NA
267	mg/m3	NA	NA	NA	NA	NA	NA	NA	NA
268	mg/m3	< 0.1	1.7	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	3.1
269	mg/m3	< 0.2	0.5	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 1

Sample ID	Sampling Volume (L)	Benzene (ppm)	Toluene (ppm)	Ethyl benzene (ppm)	p-Xylene (ppm)	m-Xylene (ppm)	o-Xylene (ppm)	1,2,4-Trimethylbenzene (ppm)	Petroleum Distillate (ppm)
265	11.277	< 0.02	0.58	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	NA
266	FB	NA	NA	NA	NA	NA	NA	NA	NA
267	FB	NA	NA	NA	NA	NA	NA	NA	NA
268	7.936	< 0.03	0.45	< 0.06	< 0.06	< 0.06	< 0.06	< 0.05	NA
269	4.594	< 0.06	0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.09	NA

Quality Assurance

Parameter	Benzene	Toluene	Ethyl benzene	p-Xylene	m-Xylene	o-Xylene	1,2,4-Trimethylbenzene	Petroleum Distillate
R^2, Calibration	0.9999	0.9999	0.9999	1.0000	1.0000	0.9999	1.0000	NA
Reporting Limit (µg)	0.9	2	2	2	2	2	2	7
SR Efficiency	89.6%	91.4%	93.5%	91.7%	91.8%	88.8%	89.7%	NA

Notes
Results were not corrected for spike recovery efficiency.
Results were corrected for matrix blank values.
NA - Not Applicable
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Environmental Health Laboratory
Department of Environmental and Occupational Health Sciences
University of Washington

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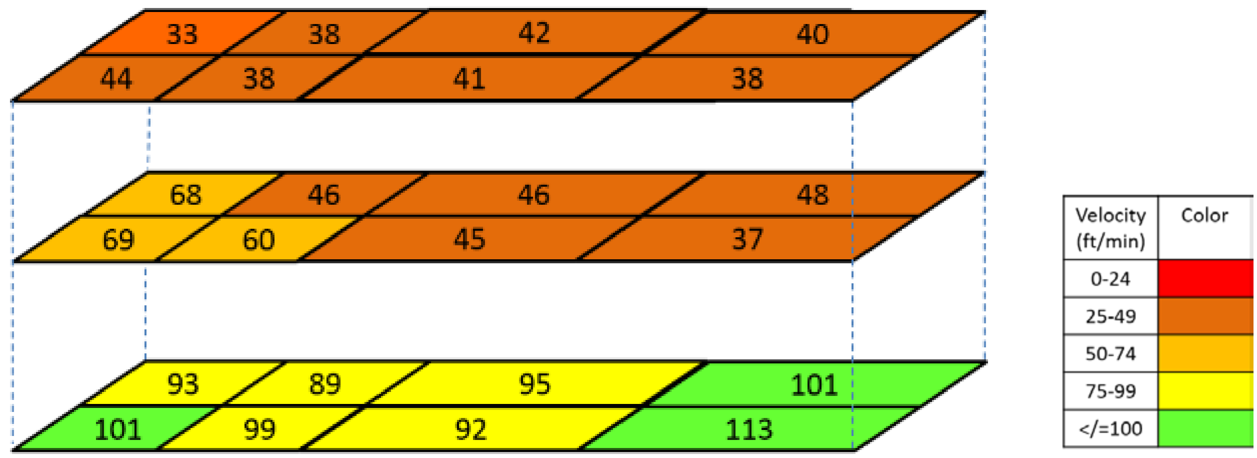
Guide 34 standards were unavailable.

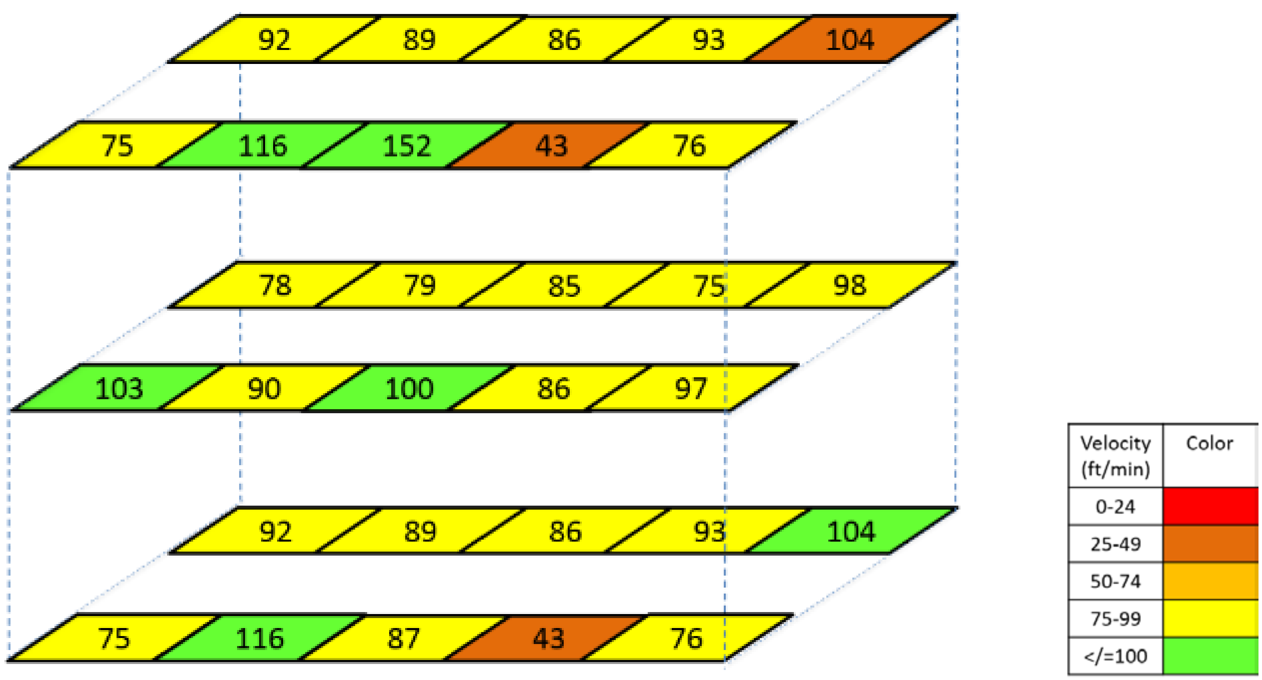
Reviewed by Susan Tao 3/12/15 — Susan Tao, Ph.D. QAC, Date, 206-221-4548

3/13/15 — Russell Dills, Ph.D. EHL Director, Date, 206-543-3263

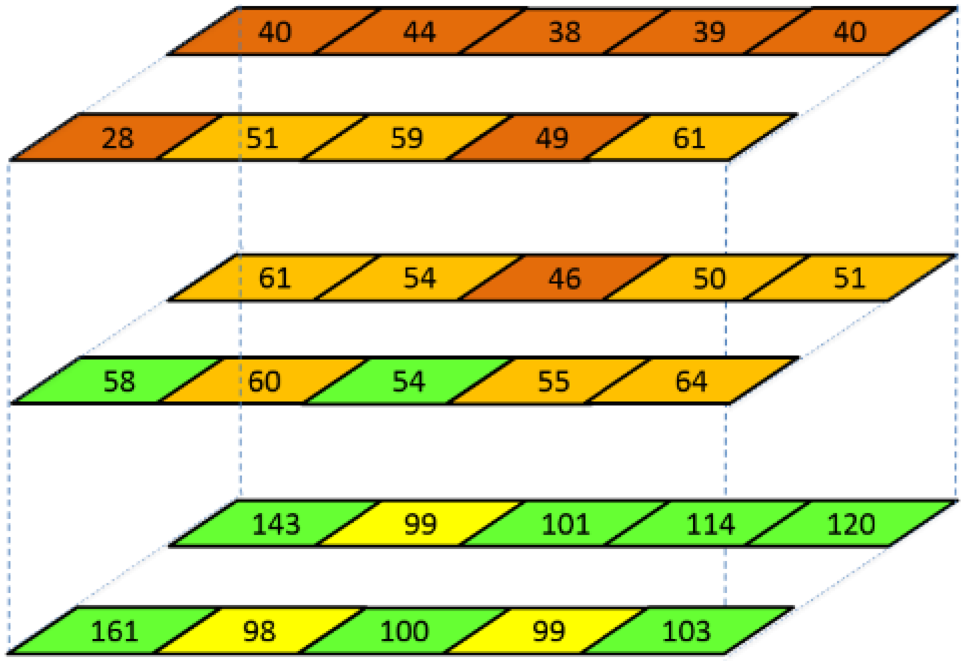
Appendix G Paint booth ventilation measurement graphic display



Shop 1 Booth A

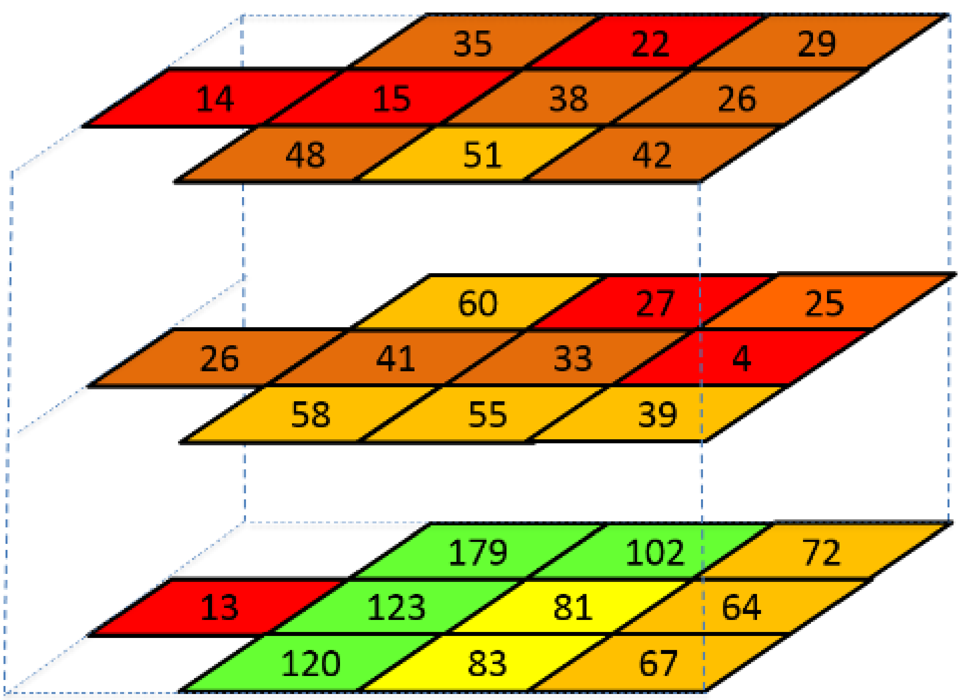


Shop 1 Booth B



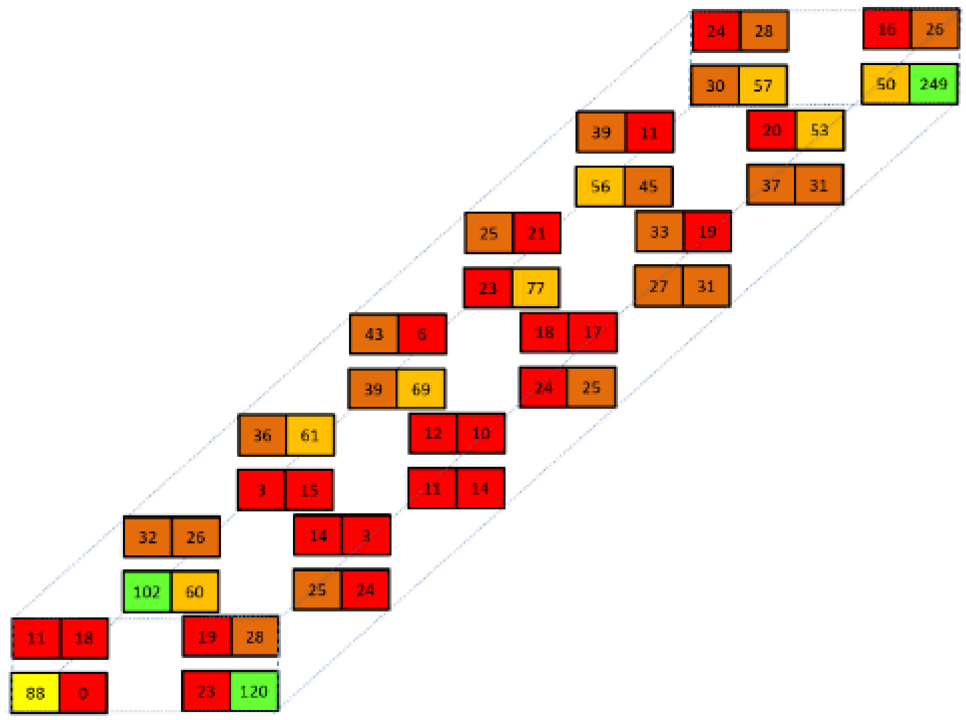
Velocity (ft/min)	Color
0-24	
25-49	
50-74	
75-99	
</=100	

Shop 02



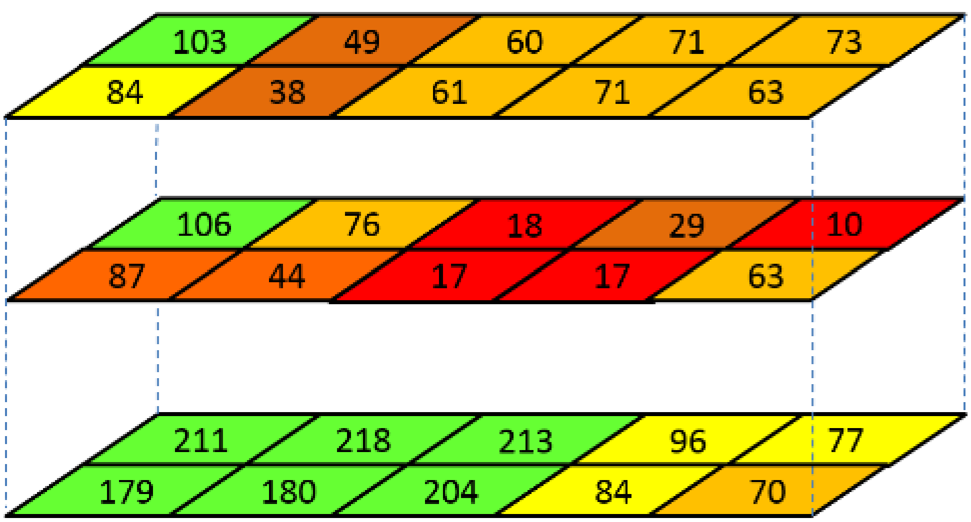
Velocity (ft/min)	Color
0-24	
25-49	
50-74	
75-99	
</=100	

Shop 03 Booth A



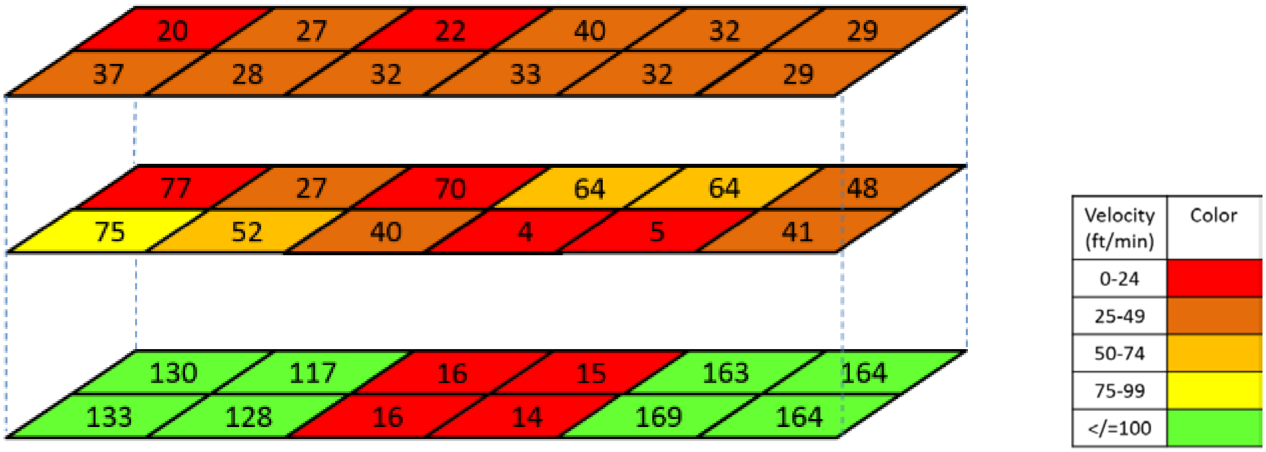
Shop 03 Booth B (Prep station)

Velocity (ft/min)	Color
0-24	
25-49	
50-74	
75-99	
</=100	

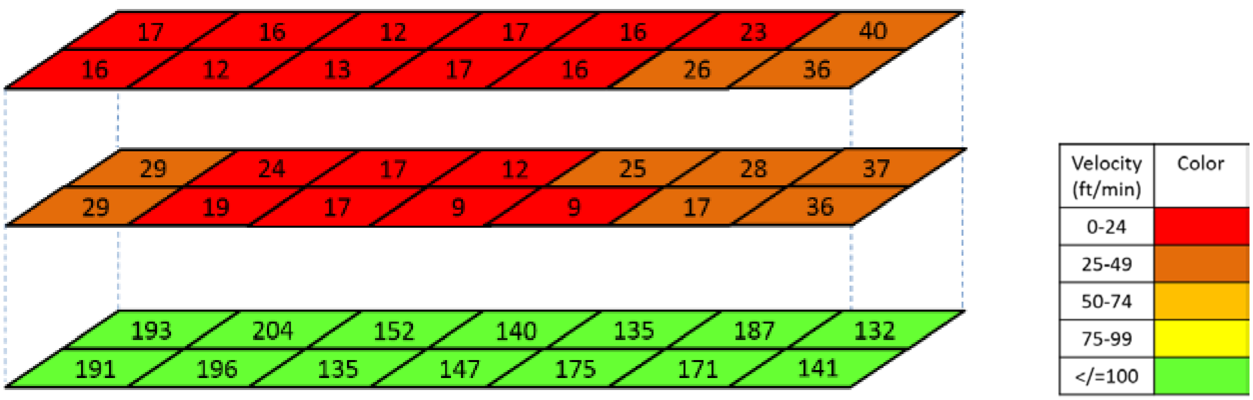


Shop 04

Velocity (ft/min)	Color
0-24	
25-49	
50-74	
75-99	
</=100	

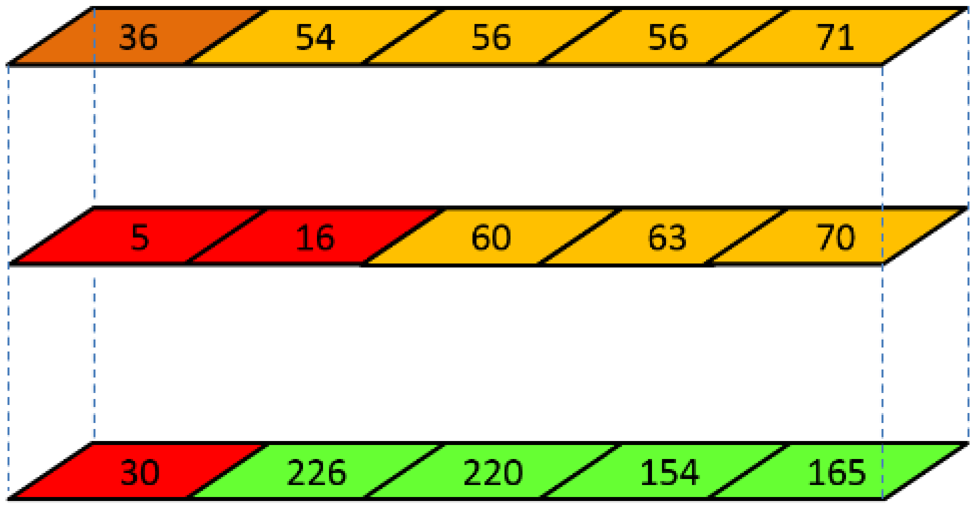


Shop 05



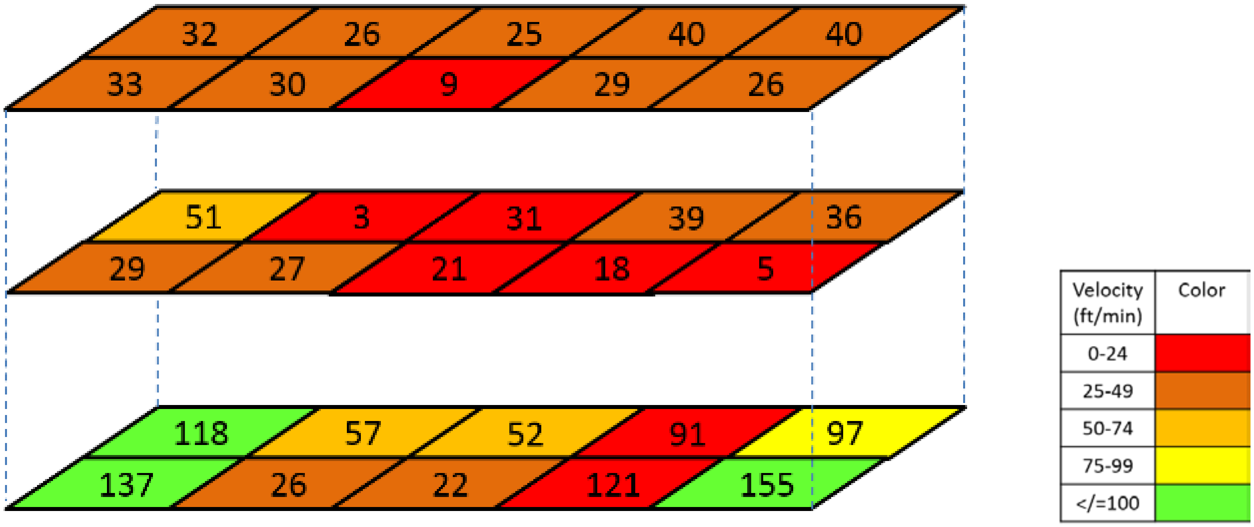
Shop 06

Shop 08 Booth A

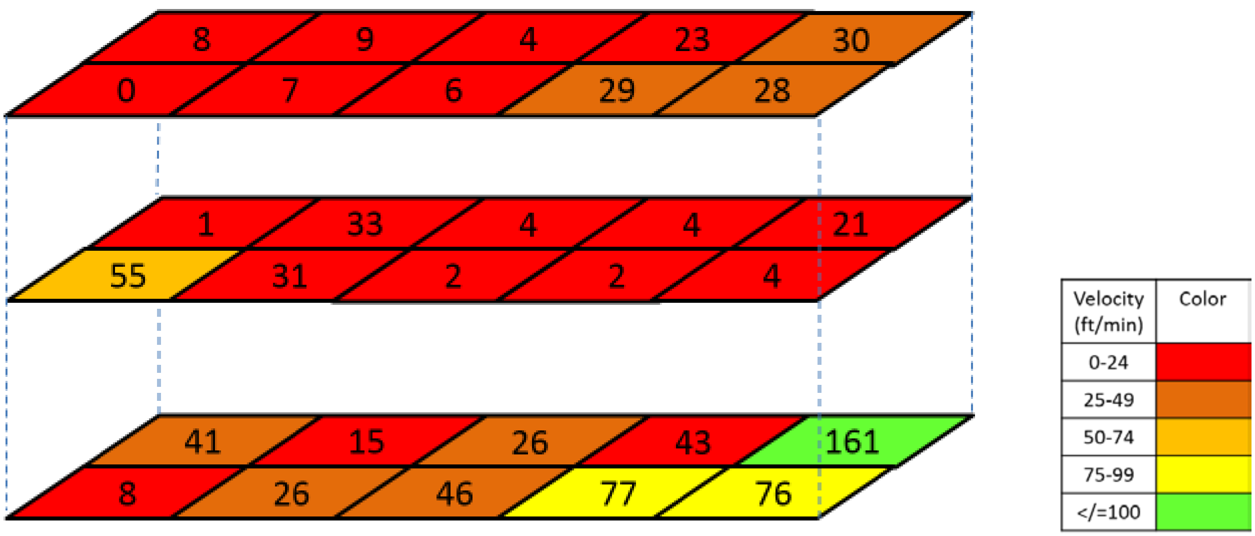


Shop 08 Booth B

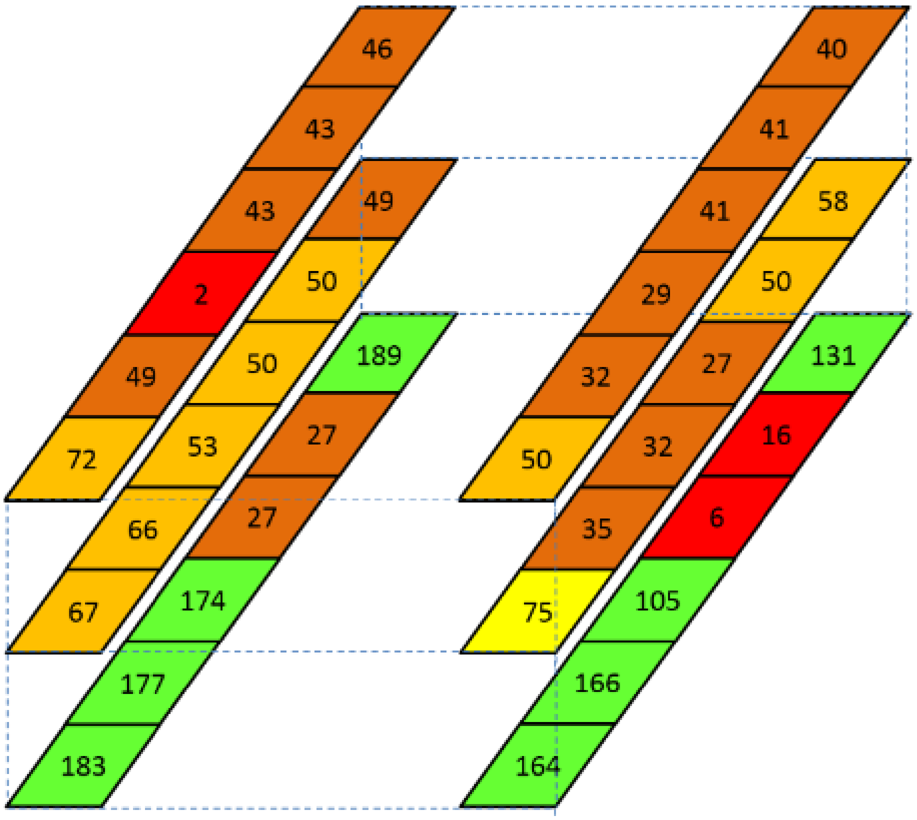
Velocity (ft/min)	Color
0-24	red
25-49	orange
50-74	amber
75-99	yellow
</=100	green



Shop 09 Booth A

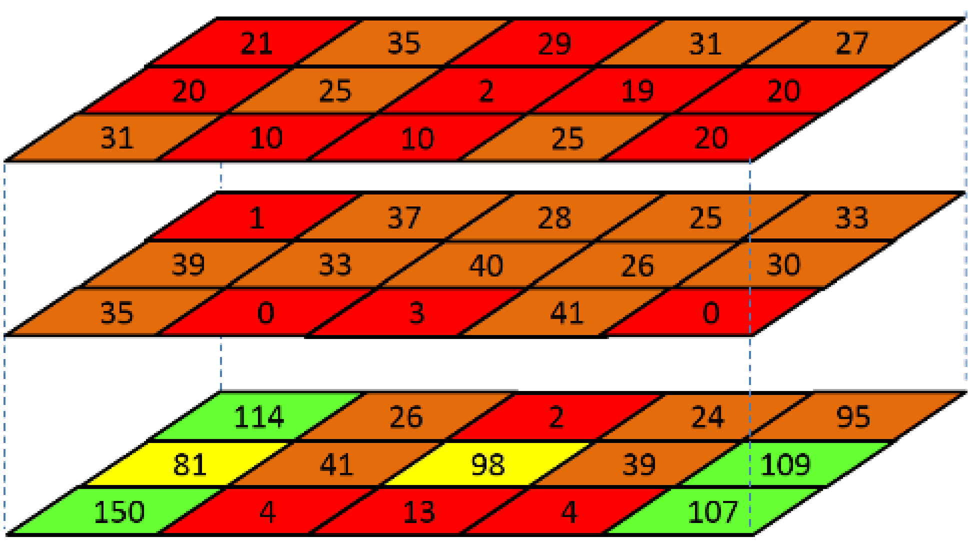


Shop 09 Booth B



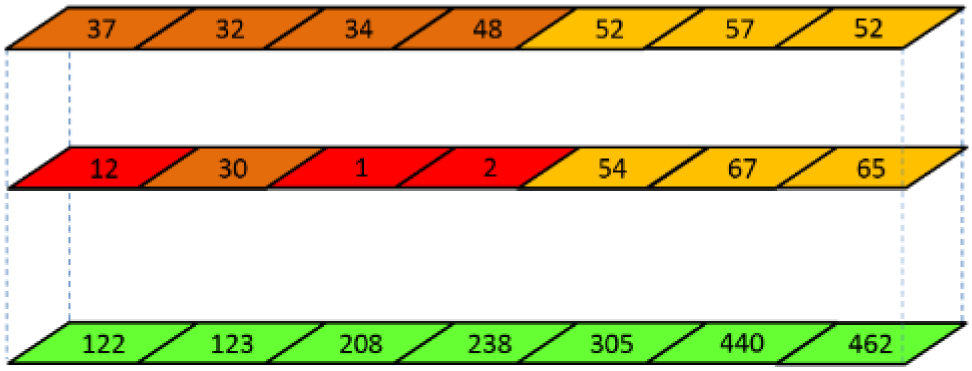
Velocity (ft/min)	Color
0-24	
25-49	
50-74	
75-99	
</=100	

Shop 09 Booth C.
Note: there's a wide distance between the two rows



Velocity (ft/min)	Color
0-24	
25-49	
50-74	
75-99	
</=100	

Shop 10



Shop 11

Velocity (ft/min)	Color
0-24	
25-49	
50-74	
75-99	
</=100	