Local Hazardous Waste Management Program in King County, Washington

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Final Report

Characterizing Waterborne Paints Used In Automotive Collision Repair

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

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ACRONYMS AND ABBREVIATIONS

ACGIH	American Conference of Governmental Industrial Hygienists
AM	Arithmetic Mean
APR	Air Purifying Respirator
CAS	Chemical Abstract Service
CSC	Coconut Shell Charcoal
EGBE	Ethylene Glycol Monobutyl Ether
EH Lab	Environmental Health Laboratory
EPA	Environmental Protection Agency
EU	European Union
FID	Flame Ionization Detector
g	Gram
GC-FID	Gas chromatography with flame ionization detection
GM	Geometric Mean
GSD	Geometric Standard Deviation
HOC	Halogenated Organic Compound
HVLP	High Volume Low Pressure
IARC	International Agency for Research on Cancer
KCEL	King County Environmental Laboratory
L	Liter
L/m^3	Liters per cubic meter
L/mole	Liters per mole
lbs./gal	Pounds per gallon
LHWMP	Local Hazardous Waste Management Program
MDL	Method Detection Limit
$MeCl_2$	Dichloromethane
MEOH	Methanol
mg/kg	Milligrams per kilogram
mg/m^3	Milligrams per cubic meter
mg/µg	Milligrams per microgram
ml	Milliliter
ml/L	Milligrams per liter
ml/min	Milligrams 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
RDL	Reporting Detection Limit
SCAQMD	South Coast Air Quality Management District
ASD	Arithmetic Standard Deviation
TLV	Threshold Limit Value
TWA	Time Weighted Average
µg	Microgram
µg/g	Micrograms per gram
µg/AIR	Micrograms per sampled air volume
µg/L	microgram per liter
UK	United Kingdom
UW	University of Washington
VOC	Volatile Organic Compound
WSIRB	Washington State Institutional Review Board

EXECUTIVE SUMMARY

Many auto body shops are making the transition from solvent basecoats to waterborne basecoats. In some jurisdictions, this transition was prompted by more stringent air quality standards than are administered nationally. In King County, this transition has been voluntary and does not reflect any regulatory change. The purpose of this study was to understand how waterborne coatings are used to perform collision repair in auto body shops, with the ultimate goal of evaluating their safety relative to traditional solvent-based coatings. The specific objectives of this study were to: 1) document painters' work practices while using waterborne basecoats; 2) measure painters' personal breathing zone exposures to waterborne basecoat ingredients; 3) evaluate the performance of the spray booths used for paint application; 4) determine the ethylene glycol monobutyl ether (EGBE) content of the waterborne basecoats (EGBE is a glycol ether and common constituent of waterborne coatings that may be absorbed through the skin); 5) document waste management practices for excess waterborne coatings and associated products; and 6) designate the waterborne waste streams according to Washington state's dangerous waste regulations.

Eleven painters from ten auto body shops in King County, WA that use waterborne coatings were recruited to participate in this study.

Painter's work practices were generally equivalent in all shops because the required tasks were similar. Differences were noted in the use of personal protective equipment (PPE) (especially respirators) and the number of basecoat layers required to produce an acceptable finish. We also noted considerable variation in the way painters cleaned their spray guns. Other minor differences reflected the quantity of vehicles that required painting during the workday and the availability of assistants to help with vehicle preparation.

Breathing zone concentrations of waterborne basecoat constituents were much lower than their occupational exposure limits.

Painting was conducted primarily in prefabricated downdraft spray booths, but the air flow rates typically failed to meet Occupational Safety and Health Administration (OSHA) requirements. We noted higher concentrations of airborne chemicals when painting took place in un-enclosed "prep stations".

The glycol ether, EGBE, was detected in waterborne basecoats manufactured by PPG, Sherwin-Williams, and BASF, but was undetected in Spies-Hecker and Cromax products.

Procedures for disposing of waterborne coating wastes varied between shops. Waterborne wastes sampled in this study were not persistent according to Washington state-only dangerous waste criteria. Nonetheless, many shops were disposing of their waterborne paint wastes without adequate characterization.

We conclude that although the chemical composition of waterborne basecoats varies by manufacturer, these products appear to be preferable to solvent-based basecoats.

Although airborne exposures to the constituents of all the waterborne basecoats evaluated in this study were relatively low, these products are not hazard-free. Consequently, painters should wear appropriate PPE whenever they handle paints and wastes, with a particular emphasis on preventing dermal exposures. Attention should also be paid to performance and maintenance of spray booths, cleaning of paint guns, and management of waste streams.

INTRODUCTION

The Local Hazardous Waste Management Program in King County (LHWMP) recently determined that approximately 10-20% of auto body shops that perform collision repair in King County, WA are using waterborne basecoats, rather than the traditional solvent-based basecoats.(1) The number of auto body shops that use waterborne basecoats in King County will likely increase as the performance benefits of using these products become more widely appreciated in the industry. Consequently, we considered it important to characterize painters' exposures to waterborne basecoat components and determine whether shops are using these products safely and disposing of the waste streams according to best management practices and local regulations.

Solvent-based coatings

Solvent-based coatings consist of binders, resins, or polymers; pigments; and liquid carriers.(2) These products are classified as solvent-based because the primary carrier is 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.(3)

Many of these solvents are regarded as volatile organic compounds (VOCs), which contribute to the creation of ground-level ozone, 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 variety of human health effects, agricultural crop loss, and damage to forests and ecosystems.(4) Because auto body refinish coatings contribute a significant amount of VOC emissions, in 1998 the 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".(4) The aim of this "National Rule" is to reduce VOC emissions during automotive painting and standardize VOC regulations across the US by placing limits on the VOC content of products.(4)

VOCs also have health implications for the workers who use solvent-based coatings. Many VOCs are irritants to workers' eyes, skin, respiratory systems, and affect the central nervous system.(5) Additionally, some frequently-used solvent-based coatings, such as specialty products and clearcoats, are mixed with hardeners. These two-component products usually contain isocyanates, which are powerful irritants to the mucous membranes of the eyes and the gastrointestinal- and respiratory- tracts.(6) Isocyanates can also sensitize workers' immune systems, subjecting them to severe asthma attacks when re-exposed. Workers may be sensitized to isocyanates through both dermal and respiratory exposures.(7)(8)(9)

Regulatory limits on VOC emissions

National VOC limits vary by type of automotive coating, as presented in Table 1. These rules apply to the manufacturers and the importers of coating materials. The VOC content of basecoats (also known as topcoats) is regulated at 5-6 pounds per gallon (lb./gal); clearcoats are not regulated.[10]

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)

However, some areas in the US are either considering or have adopted stricter limits than those stipulated by the National Rule. For example, in 2008, the California South Coast Air Quality Management District (SCAQMD) limited the VOC content of clearcoat and basecoat to 2.1 lb./gal and 3.5 lb./gal, respectively (Table 2).[11] Although clearcoats containing 2.1 lb./gal VOCs have been available for several years, the available solvent-based basecoats contained 5-7 lb./gal. Consequently, auto body shops in the SCAQMD sought a waterborne basecoat that met the 3.5 lb./gal rule.[12]

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)

Waterborne coatings

History and usage

The first commercial waterborne coatings were introduced in the automotive industry in the 1990s.[(13)] These coatings were developed in anticipation of air quality rules related to VOC emissions in the United Kingdom (UK), which were soon to also be adopted by the European Union (EU).[(14)]

In waterborne products, water is used to replace a significant portion of the organic solvents as the carrier and the fraction of solids is relatively high. Typical solvent-based products may contain up to 85% organic solvents by weight and 15% solids. Conversely, waterborne coatings contain about 10% organic solvent by weight, 70% water, and 20% solids.[(15)] Waterborne coatings also contain polar solvents, such as acetone, tertiary butyl acetate, and parachlorobenzotrifluoride, which undergo negligible atmospheric photochemical reactions. These coatings comply with the National Rule because the polar solvents are exempt.[(12)]

Currently, only waterborne basecoats are widely available in the US. Although waterborne primers are available, solvent-based primers contain mostly exempt organic solvents and therefore comply with VOC emission limits.[(12)]

Paint manufacturers face greater challenges in formulating waterborne clearcoats for auto body shops than they do for original equipment manufacturers (OEMs), because the waterborne products must fully dehydrate for proper cross-linking and curing. The clearcoats currently used by automobile OEMs are 2-6 times thicker than the basecoats, which makes dehydration more difficult. These clearcoats require greater air movement to ensure adequate dehydration than can be achieved in most auto body shops.[12]

LHWMP's field observations revealed that shops currently using waterborne basecoats cite several advantages over solvent-based paints (unpublished data). First, the quality of finish is considered superior. Second, the use of waterborne basecoat has decreased the irritating odor of organic solvents. Third, painters that use certain brands of waterborne basecoats report faster finishing times and vehicle throughput.[16] Fourth, the color matching of waterborne basecoats to newer vehicles is superior, because approximately 75 percent of OEMs now use waterborne basecoats during assembly.[12]

Health concerns

Although waterborne coatings contain relatively low concentrations of VOCs, they contain several ingredients that may be of concern, especially from a human health perspective. Most notably, many waterborne products contain EGBE (also known as 2-butoxyethanol); 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.[17] The American Conference of Government Industrial Hygienists (ACGIH) recommends an 8-hour TWA TLV of 20 ppm for EGBE. The National Institute of Occupational Safety and Health (NIOSH) has an 8-hour TWA recommended exposure limit (REL) of 25 ppm, which is the same limit administered by the Washington state's Division of Safety and Health (DOSH).[18] OSHA assigns a skin notation to EGBE, indicating that dermal contact 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.[19] Acute human over-exposure to EGBE may result in irritation to the eyes, nose, and throat. Volunteers exposed to 195 ppm for 8 hours reported eye, nose, and throat discomfort. Milder symptoms were experienced at 113 ppm for four hours.[20] Although humans appear to be less sensitive to the hematologic effect of EGBE than rats and mice, 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.[21][22] The International Agency for Research on Cancer (IARC) concluded that 2-butoxyethanol is not classifiable as to its carcinogenicity to humans, based on inadequate evidence in humans and limited evidence in experimental animals.[23]

Spray application

The spraying technique and technology required to apply waterborne paints can differ from that for solvent-based paints. Most painters currently use High Volume Low Pressure (HVLP) spray guns with both solvent-based and waterborne coatings. HVLP spray guns reduce over-spray and therefore the amount of hazardous chemical released into the air and the amount of paint needed to refinish a vehicle.[24] 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 necessary.[15] Painters report that waterborne basecoat finishes are approximately one-half the thickness of those from solvent-based basecoats.[15] For some brands, several coats of waterborne basecoat may be required to achieve the desired color match.[16] Some brands contain 88% less solvent and 25% more pigment than solvent-based paints, allowing the painter to achieve an acceptable color match in a single spray application.[25] The wet-on-wet application technique (i.e., a spray of colorless "wet bed" product to merge spray-edges between each stroke) also eliminates the need to dry the paint between coats.[26]

Barriers to converting to waterborne coatings

Waterborne coatings require a large volume of airflow to achieve drying, rather than heat. Therefore, shops must purchase spray booth ceiling fans or air multipliers. These multipliers may be hand-held, mounted on portable stands, or installed permanently at the corners or on the ceiling of the spray booth.[15] (see Figure 1). Additional costs may include painter training and the need to re-spray some paint jobs as the painter is perfecting the technique.

Shops' air compressors and filtration systems may also require upgrading. The compressors must 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.[15] 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. Finally, some shops may choose to purchase pneumatically-operated cleaning systems for the spray guns used for waterborne paints (see Figure 2).

According to shops in King County, the cost of conversion varies considerably, depending on the incentives provided by the paint manufacturer and their policy with regard to accepting used solvent basecoat product. Typically, the cost to convert is approximately $5,000-$30,000, although two study shops reported that they had no material cost; their only expenditures were for painter training (unpublished LHWMP data).

Work practices

Best practices for using waterborne coatings are not well-established. This is of particular concern because these products are marketed as safer alternatives to solvent-based coatings. Consequently, some painters are under the mistaken impression that they need not wear appropriate PPE while handling the products and wastes (unpublished LHWMP field observations).

Many painters continue to clean the spray guns they use for waterborne coatings based on the same methods they use for solvent-based paints. This practice can expose painters to hazardous chemicals such as lacquer thinner and chlorinated solvents. Water-based cleaning products are readily available and a final rinse with acetone is typically all that is required.

There are also no standard procedures for handling waterborne wastes. Painters may be exposed to hazardous materials by failing to wear correct PPE and inappropriate waste disposal may also have adverse environmental consequences.

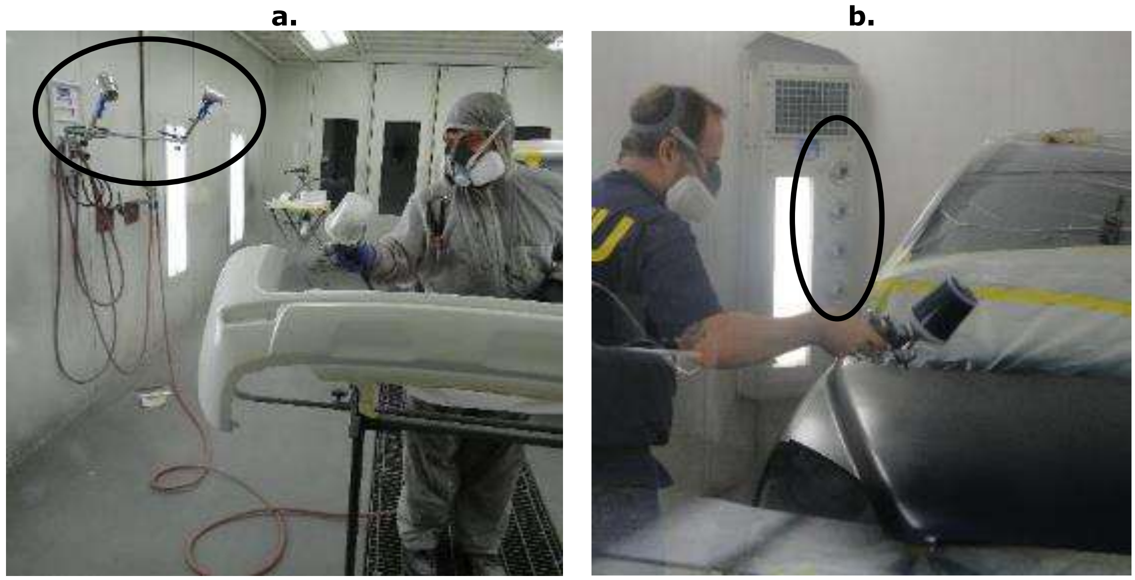

Figure 1 Examples of air multipliers
a. Wall-mounted
b. Corner-mounted

Figure 2 Pneumatic waterborne gun cleaning system

Current study

The goal of this current study was to:

1) Document painter's work practices while using waterborne basecoats;
2) Measure painters' personal breathing zone exposures to waterborne basecoat ingredients;
3) Evaluate the performance of the spray booths used for paint application;
4) Determine the EGBE content of the waterborne basecoats;
5) Document waste management practices for excess waterborne coatings and associated products; and
6) Designate the waterborne waste streams according to Washington state's dangerous waste regulations.

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METHODS

Human subjects protection

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

Recruitment

Auto body shops were recruited in September through December 2014 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 recognition for small businesses that reduce hazardous materials and waste to protect public health, municipal systems, and the environment.[(27)] Four of the businesses that participated in this study were EnviroStar-certified.

To recruit businesses, telephone calls were placed to shop owners or managers using a WSIRB-approved telephone script. 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 the recruitment visits, the purpose and methods were explained to the shop's owner or manager. With his or her 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 basecoats;
3) Between the ages of 18 and 65; and
4) Able to comprehend the English language, both verbal and written.

We also explained the painter's rights and responsibilities as study subjects, 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 chemicals 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 as study subjects were enrolled as clients of Public Health-Seattle & King County using a Client Intake Form (Appendix A). Painters were also asked to provide informed consent by signing a Subject Consent Form (Appendix B). Painters were also asked to read and sign photo- and video- consent forms, if they agreed to allow documentation via still photography and video. Painters received a $25 supermarket gift card in return for their participation.

Documentation of waterborne coating work-practices

The Client Intake Form (Appendix A) and Waterborne Painting Data Form (Appendix C) were used to record painters' background information and work-practices, including:

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

Personal air sampling

Target analytes were selected by reviewing MSDSs (see Appendix D) 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) Present at relatively high concentrations; 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 (synonym: diacetone alcohol), and ethylene glycol monobutyl ether (EGBE) (synonym: 2-butoxyethanol).

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

Preliminary task-based air sampling conducted at 100 mL/min revealed that the target analytes were either below or just above their respective Method Limits of Quantitation (MLOQs). Therefore, to increase the mass of material collected and protect against breakthrough of the more volatile compounds, we used two sampling flow rates (100 mL/min and 400 mL/min) for each sampling media at the study shops. This was accomplished by attaching a sampling manifold to a pump and adjusting the flow to 100 mL/min on one tube and 400 mL/min on the other, using the adjustment screws on each arm of the manifold.

Two pumps were used per painter, each of which was equipped with a manifold that held two tubes (see Figure 3):

- Pump #1 / Manifold #1:
  - ORBO 90 at 400 mL/min and 100 mL/min

- Pump #2 / Manifold #2:
  - CSC at 100 mL/min and 400 mL/min

We subsequently determined that no breakthrough of volatile compounds occurred at 400 mL/min. Therefore, only one pump was used per painter for the remaining sampling visits (at 400 mL/min, with one sample manifold holding a single CSC and a single O90 sorbent tube, as shown in Figure 4).

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

Before sampling, we described the sampling procedure to the painter and emphasized the importance of sampling only waterborne basecoats, and not solvent-based products. The painter was asked to notify us prior to spraying waterborne basecoats so we could attach the sampling pump and manifold (Figure 5).

In order to conduct the task-based sampling, 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 basecoats 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 use lacquer thinner and other organic solvents.

Figure 3 Two-pump setup

Red tape: manifold #1
Green tape: manifold #2

Figure 4 One-pump setup

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

Figure 5 Placing sampling units on the painter

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

The original sampling plan was to use one pair of sorbent tubes (i.e., one CSC tube and one O90 tube) per complete basecoat application. However, because some applications lasted less than 10 minutes, we used the same pair of sorbent tubes to sample subsequent applications that were also of limited duration.

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

Analysis of air samples

Analyte concentrations

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

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

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

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

- $Flow_{pre}$: 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:

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

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

Exposure analysis

Stata Statistical Software 13 was used to perform exposure analysis. Q-Q plots were used to determine whether the data were log-normally distributed.

Bulk sampling and analysis of waterborne basecoats

Once the painter had completed spray-application of the basecoat, the remaining product was decanted from the spray gun cup directly into a 40 ml capacity VOA vial. Samples were stored at room temperature because we noted that the paint constituents frequently separated into distinct layers at low temperatures.

Basecoat samples were analyzed for EGBE content by the King County Environmental Laboratory (KCEL). A 0.1 g portion of sample was weighed into a tared 40 ml capacity VOA vial. The sample was spiked with a known concentration of surrogate (4-methoxyphenol) and 20 ml of deionized water was added to the vial. The sample was shaken for 10 seconds to ensure adequate mixing. Approximately 5-6 ml of the paint extract was poured into a glass 10 ml syringe fitted with a 0.45 micron filter. The extract was pushed through the filter into a 15 ml capacity screw-top test tube. One ml of the filtered extract was pipetted into an amber autosampler for analysis by GC-FID (Agilent 6980p). The capillary column was a Restek Stabilwax (30 m x 0.32 mm, 0.5 µm film thickness).

Ventilation measurements

Paint booth measurements were typically made on the day of sampling when the booths were empty. However, the booth in Shop 10 was measured one month later because it was occupied for the entire duration of our sampling visit. Measurements were made in the presence of a vehicle, quarter panels and bumpers in Shop 08's Booth #1.

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's 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 five feet above the booth's surface), and floor. We also measured the paint booths' dimensions and temperature.

Shop 01's Booth #2 and Shop 03's Booth #2 were prep-stations. For Shop 01's Booth #2, which was a downdraft prep-station, the measurements were made similarly to the other paint booths. However, because this was not a contained booth (Figure 6), ceiling level measurements were made at approximately 12.5 feet from the floor. Shop 03's Booth #2 was a side draft prep station and measurements were made by placing the anemometer probe perpendicular to the floor, perpendicular to the air flow. Measurements for Shop 03's Booth #2 were made at the center of each ventilation grill, at 12-inch increments.


(a)


(b)

Figure 6 Prep-station and spray booth
(a) Shop 01's Booth #2 – a prep-station
(b) Downdraft booth

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 evaluated by comparing the airborne concentrations in a spray booth vs. a prep-station in the same shop.

Sampling and analysis of waste streams

Three samples of waste derived from waterborne basecoats were collected from three shops in 250 ml capacity wide-mouthed glass I-CHEM jars:

- Shop 03: Semi-hardened waterborne paint waste;
- Shop 05: Black waterborne paint mixed with flocculant; and
- Shop 06: Mixed semi-solid waterborne paint waste.

Samples were stored at room temperature and submitted to AmTest Laboratories (Kirkland, Washington) for analysis.

Preliminary sampling revealed that waterborne paint wastes may contain halogenated organic compounds (HOCs).(1) Consequently, HOC content was determined according to Ecology's *Chemical Test Methods for Designating Dangerous Waste*.(28) An Ecology representative recommended the use of SW-846 Method 5050 (Bomb Preparation Method for Solid Wastes) followed by Method 9056 (Determination of Inorganic Anions by Ion Chromatography) (personal communication between Alex Stone (Ecology) and Steve Whittaker (LHWMP), June 11, 2015).

In addition to the wastes, a sample of a PPG product, *High Strength Phthalo Green* (Product Code T431) was submitted for analysis as a "positive control". According to the MSDS, this product contains 3-7% phthalocyanine green (polychloro copper phthalocyanine, CAS number 1328-53-6), a highly chlorinated organic pigment.

RESULTS

Eleven study subjects were recruited from ten auto body shops. Field visits were conducted between November 2014 and February 2015.

Painter characteristics and spray painting procedures

The painters' background information, including spray gun- and PPE- use are summarized in Table 3. Subjects had spray-painted for 2 to 35 years and had used waterborne paints for 1.5 to 5.5 years. Painters typically completed 4 to 7 jobs per day.

The tasks conducted by the painters were very similar in all study shops. Any minor differences typically reflected the painters' personal preferences, availability of assistants to help prepare vehicles, and workload. A typical production cycle consisted of the following activities:

- Reviewed the work order provided by shop management.
- Inspected the work conducted by collision technicians (aka "bodymen") and prepared the vehicle for painting. This could include sanding (outside of the spray booth), taping, and wiping the surfaces to be painted with a tack cloth (typically performed in the spray booth). The tack cloth is used to remove loose particles of dust, dirt, and lint.
- Mounted new (replacement) components, such as bumpers and quarter panels, on stands inside the spray booth. These items typically required minimal preparation.
- Sprayed a coat of solvent-based primer/sealer and baked the vehicle in the paint booth. See Figure 7.
- Mixed several pigmented basecoat products by weight according to a prescribed formula to achieve color-matching. The painter occasionally used a "spray-out card" to test the color and modify the formulation to achieve an acceptable match.
- Sprayed waterborne basecoat. Multiple coats were occasionally needed, depending on the color and manufacturer of the coating. Some painters also applied a waterborne color-blending coating during this step (i.e., a "wet bed").
- Dried the basecoat in the paint booth using specialty air multipliers (Venturi nozzles specialized for drying waterborne paints).
- Sprayed a coat of solvent-based clearcoat and allowed the job to bake in the booth.
- Removed the vehicle from the booth.
- Removed tape and other coverings from the vehicle.

Table 3 Subject background summary

Shop ID	Subject: Subject ID	Subject: Race/ Ethnicity	Subject: Spray Paint Experience (years)	Subject: Waterborne Coating Experience (years)	Spray Gun: Make/Model	Spray Gun: Type	Spray Gun: Nozzle Pressure (psi)	PPE: PPE worn	PPE: Respirator Cartridge change out frequency (per month)	PPE: Gloves type and change out frequency (per day)
01	A	Hispanic, Mexican	6	1.5	SATA 4000	HVLP[1]	Est.[2]	half-face APR[3], Shootsuit, gloves	0.5	Nitrile (5)
01	B	White, European American	26	4	SATA 4000	HVLP	Est.	half-face APR, cloth or leather work boots	1	
02	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)
03	A	White, European American	2	1.5	SATA 4000	HVLP	30	half-face APR, Shootsuit, gloves	0.25	Nitrile (20)
04	A	White, European American	25	5.5	SATA jet 4000	HVLP	25-28	PAPR[4], Shootsuit, gloves	Not applicable	Nitrile (20)
05	A	White, European American	22	6	SATA R3000	HVLP	Est.	PAPR, Shootsuit, gloves	Not applicable	Nitrile (30)
06	A	White, European American	8	4	DevilbissTekna ProLite	HVLP	18	half-face APR, Shootsuit, gloves, cloth or leather work boots	0.5	Nitrile (20)
08	A	Asian, Filipino	5	4	Anest Awata LPH-4000	HVLP	Est.	half-face APR, disposable coveralls, gloves	0.25-0.5	Nitrile (20-30)
09	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

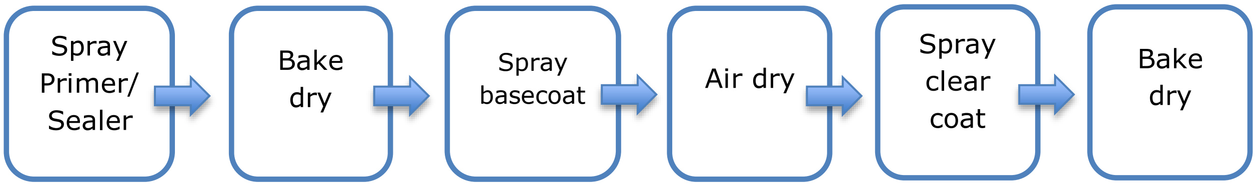


Figure 7 Typical paint application procedure

Personal protective equipment

Painters typically relied on paint booth ventilation and PPE to minimize their exposures to waterborne basecoats and other coatings. Booth maintenance procedures are described in *Spray booth maintenance and ventilation*, below.

The basic PPE worn by most painters included respirators, Shootsuits/coveralls, gloves, and work boots (Table 3). All painters wore protective clothing during spraying operations, except Subject B in Shop 01, 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 reported detecting the odor of waterborne basecoats while wearing their respirators.

Most painters wore disposable exam-style nitrile gloves. 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 subsequent jobs with wet paint.

Gun cleaning

Spray guns were typically cleaned in the paint mixing room. Painters usually wore gloves and coveralls when cleaning their spray guns because they were cleaned immediately following painting. However, they often removed their respirators. We noted that not all mixing rooms were equipped with ventilation systems.

Gun cleaning procedures varied among shops (see Table 4). 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 8)
2. Rinse the gun with a waterborne cleaner.
3. Dry the gun with compressed air.
4. Perform a final rinse with a volatile solvent.

Table 4 Gun cleaning procedures

Shop ID	Pneumatic cleaning system?	Procedure
01	Yes	1. Rinsed guns solely with lacquer thinner
02	Yes	1. Rinsed guns with OneChoice SX100 waterborne paint cleaner 2. Used acetone in a squeeze bottle to rinse the gun
03	No	1. Rinsed gun with Water Wave Waterborne Cleaning Solution 2. Dried gun with an air hose and expelled the rinsate onto mixing room floor
04	No	1. Rinsed 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
05	Yes	1. Rinsed guns with OneChoice SX100 waterborne paint cleaner 2. Used acetone in a squeeze bottle to rinse the gun
06	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)
08	Yes	1. Rinsed guns using waterborne cleaner 2. Rinsed guns with lacquer thinner
09	Yes	1. Rinsed guns using waterborne cleaner 2. Rinsed guns with lacquer thinner in enclosed unit
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. Blew air through guns

Figure 8 HPLV spray gun

However, some painters used only lacquer thinner and did not dry the gun with compressed air. Some painters used waterborne cleaners for the first rinse and then aerosol cleaners, such as Naked Gun® and Clean Shot™, (see Figure 9) for the final rinse. These cleaners may contain methylene chloride, which is a potential carcinogen. Other painters used acetone for the final rinse.

Figure 9 Aerosol gun cleaners

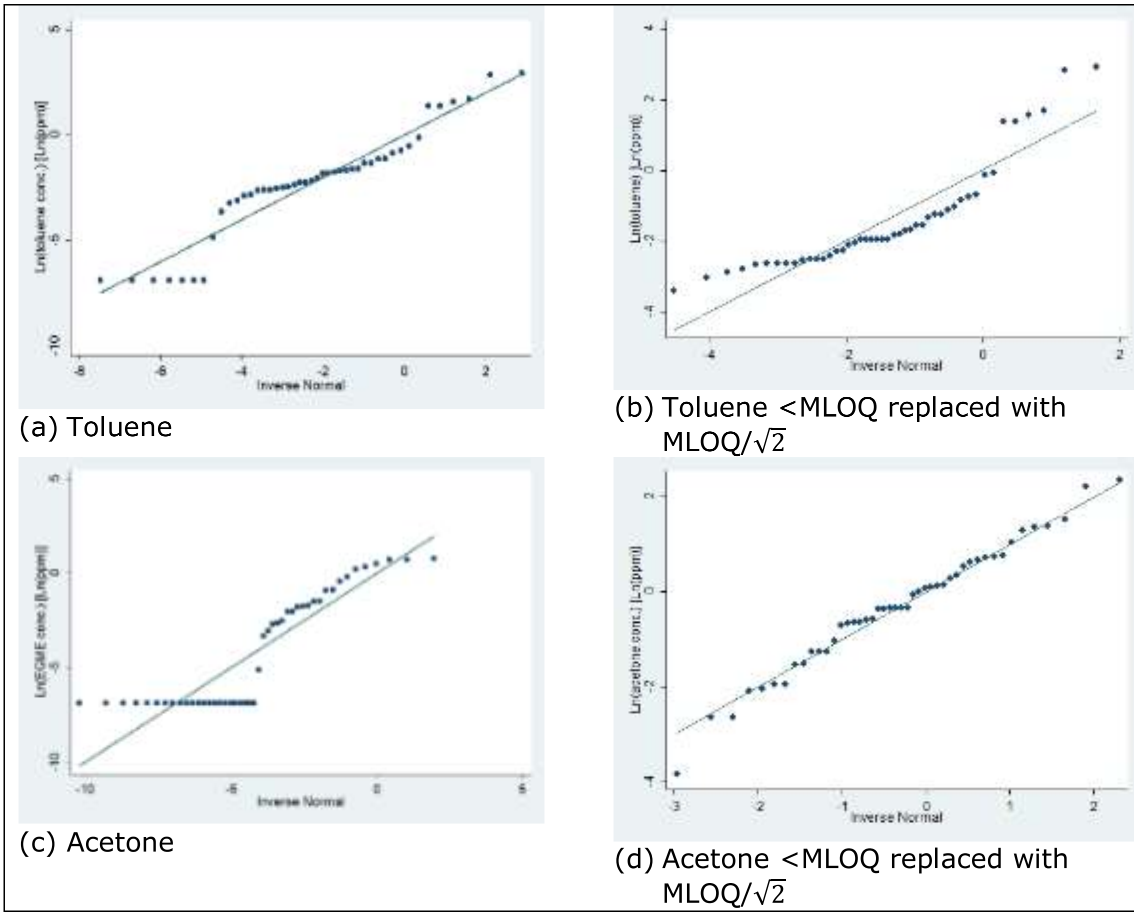
Painters collected the waterborne cleaning rinsate and allowed the paint to settle in the containers. The remaining liquid was reused as a waterborne gun cleaner. Painters noted they seldom had to replenish the waterborne cleaning agents because they could recycle and reuse the product.

Air sampling and breathing zone exposures

Forty-six air samples were collected from the 11 painters at 10 auto body shops.

Q-Q plots for airborne toluene and acetone concentrations are presented in Figure 10. In Figure 10a and 10c, the horizontal line in the bottom left quadrants reflects substitution of zero concentrations for 0.0001 for log-transformation. The log-transformed distributions (Figure 10b and 10d) closely match the 1:1 line, indicating log-normal distributions. Therefore, the log-transformed concentrations were used for subsequent analysis.

The concentrations of target analytes below their MLOQs were replaced by MLOQ/$\sqrt{2}$.[29] The geometric means (GMs) and geometric standard deviations (GSDs), and 50th and 90th percentiles were calculated for each analyte. The GM analyte concentrations were compared to their respective occupational exposure limits (ACGIH TLVs) by calculating a TLV fraction (i.e., GM/TLV).



(a) Toluene

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

(c) Acetone

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

Figure 10 Selected Q-Q plots for airborne concentrations

The arithmetic means (AM) and arithmetic standard deviations (ASD) sampling times are summarized in Table 5.

Table 5 Sampling times

Shop ID	Number of samples (n=46)	Sampling Time AM (min)	Sampling Time ASD (min)
01	10	16	5.2
02	4	11	2.9
03	3	9	0.58
04	3	19	8.0
05	8	29	27
06	6	27	8.0
08	6	22	16
09	3	11	4.4
10	2	11	0.71
11	1	17	NA

The data reported by the UW EH Lab are presented in Appendix F. Analyte concentrations were typically below their respective MLOQs. As shown in Table 6, the following analytes had the highest percentage of sample concentrations above their MLOQs: toluene (43%>MLOQ), PD (30%), acetone (57%), and EGBE (37%). However, the airborne concentrations of these analytes were low relative to their TLVs. Analytes with the highest GM concentrations were: Petroleum Distillate (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).

It is noteworthy that acetone and toluene were detected in at least one air sample derived from every paint brand sprayed in this study. However, neither of these chemicals were listed on any product's MSDSs.

EGBE was detected above the MLOQ in at least one air sample from shops that used the following manufacturer's products: PPG (Shop 01), Sherwin-Williams (Shop 06), and BASF (Shops 08 and 11). EGBE concentrations were <MLOQ in the air samples collected from the other shops.

Table 6 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
1,2,4-TMB	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	100	0.092	3.0	0.01	0.90	0.07	0.52	0.001
2-butanol	0.1	15	100	0.080	3.6	0.01	2.29	0.07	0.72	0.001
1M2PAHO	0.1	24	100	0.086	2.8	0.01	0.83	0.07	0.28	0.001
EEP	0.1	9	NA[2]	0.05	2.8	0.00	0.61	0.05	0.18	NA
Diacetone alcohol	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

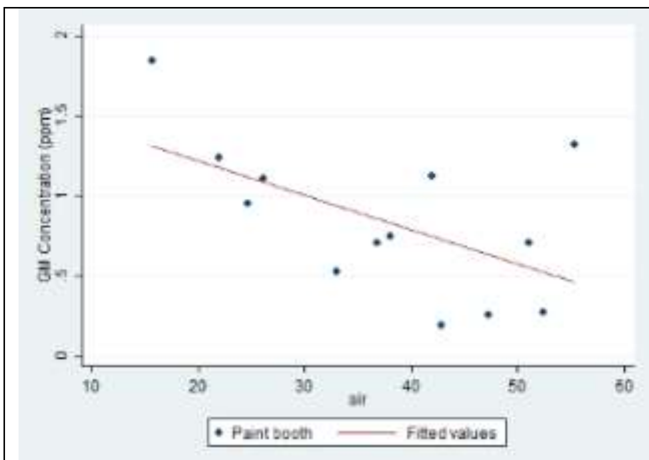
AM = Arithmetic Mean
MLOQ = Method Limit of Quantitation
TLV = Threshold Limit Value
GM = Geometric Mean
GSD = Geometric Standard Deviation
50^{th} % = 50^{th} percentile
90^{th} % = 90^{th} percentile
NA = Not available
[1] PD concentrations in mg/m^3
[2] TLV fraction = GM/TLV

Spray booth maintenance and ventilation

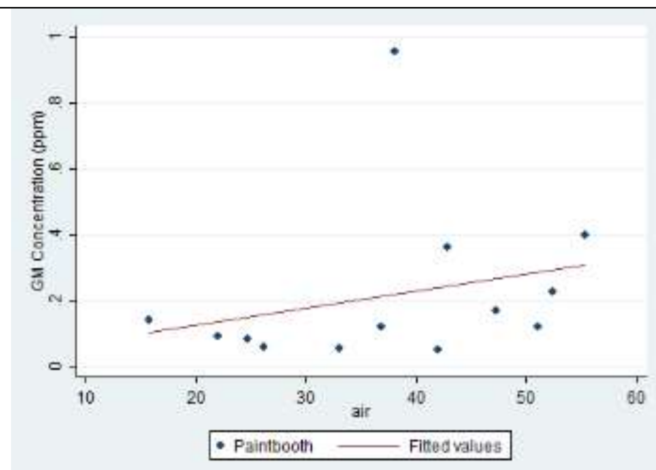
Painters were responsible for the routine maintenance of the paint booths, including cleanliness, filter change-out, and notifying management if major maintenance was needed. With the single exception of Shop 11, shops typically had regular filter change-out schedules (see Table 7). For most shops, floor filters were changed every two weeks. However, painters stated they may change the filters more frequently if they noticed a reduction in air flow.

Linear air velocities were measured in 15 spray booths (see Table 7), which were manufactured from 1980 to 2005. All booths were prefabricated downdraft models, with the exception of Shop 01's Booth #2 (downdraft prep-station), and Shop 03's Booth #2 (side-draft prep-station). The linear air velocities are presented graphically in Appendix G.

Figure 11 shows the relationship of the breathing zone concentrations of acetone and toluene (expressed as GMs) to the average linear air velocities at the breathing zone in the spray booths (excluding the prep-stations). There was no statistically significant relationship between linear air velocity and analyte concentration. Although a higher linear air velocity was associated with lower acetone concentrations, the inverse was true for toluene.



(a) Relationship between ventilation and GM acetone concentration



(b) Relationship between ventilation and GM toluene concentration

Figure 11 Relationship between spray booth ventilation and analyte concentrations

Table 7 Shop waterborne system and spray booth summary

	Waterborne Coating		Spray Booth									
Shop ID	**Coating Brand**	**Avg. waterborne coating 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 (ºF)**	**Avg. linear velocity[2] (ft./min)**
01	PPG Envirobase	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
02	Spies-Hecker	25	1	AFC 7000	1980	1 week	3	107	289	168	71.2	55.3
03	DuPont Cromax Pro	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
04	DuPont Cromax Pro	35	1	Eagle	1980	1 week	1	120	286	161	83.2	42.0
05	Spies-Hecker	22	1	Team Blowtherm Ultra 2000B	1998	1 week	4	110	295	174	64	47.3
06	Sherwin Williams	20	1	Blowthernm Concept II Cure	2002	2 weeks	9	110	323	168	71	22.0
08	BASF Glasurit 90	20	1	Team Blowtherm	NA[4]	50 hours	14	109	323.5	283	NA	42.8
			2	Spraybake	NA	50 hours	14	118.5	282	164.5	72.8	38.0
09	Spies-Hecker	40	1	GFS Devilbiss	1996	2 months		108	276	156	90.9	26.1
			2	GFS Devilbiss	1992	2 months	~60[3]	110	295	156	78.7	15.7
			3	GFS Devilbiss	2005	2 months		107	369	278	64.9	51.0
10	DuPont Cromax Pro	20	1	Blowtherm 2000	1990	2-3 months	21	111	259	156	76	24.7
11	BASF Glasurit 90	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

Only Shops 01 and 03 regularly sprayed vehicle parts in prep-stations. Table 8 shows the relationship between type of ventilation and airborne analyte concentrations. The Shop 01 prep station was essentially a downdraft booth that was contained on the four sides with heavy-gauge plastic curtains. The top side was open to the shop environment (see Figure 6a). In Shop 03, the prep-station was a crossdraft model. This prep-station had a low ceiling, so the top side was essentially contained. The four sides of the prep-station were also contained within heavy-gauge plastic curtains (Figure 12). In both shops, the total airborne analyte concentrations were higher in the prep-stations than in the spray booths.

Table 8 Analyte concentrations in spray booths vs. prep-stations

Shop ID	Booth #	Booth Type	Number of jobs sprayed	Total Analyte Concentration (mg/m^3)
01	1	Spray booth	3	15.3
	2	Prep-station	2	381
03	1	Spray booth	2	3.90
	2	Prep-station	1	8.04

Figure 12 Shop 03's prep-station

EGBE content of bulk basecoat samples

EGBE was present above the Method Detection Limit (MDL) and Reporting Detection Limit (RDL) in all basecoat samples collected from shops that used the following manufacturer's products: PPG (Shop 01), Sherwin-Williams (Shop 06), and BASF (Shops 08 and 11). The EGBE concentrations ranged from 32,000 mg/kg to 80,000 mg/kg, which is reasonably consistent with information provided in the manufacturers' MSDSs. EGBE was not listed as an ingredient in Spies-Hecker or DuPont Cromax products and was not detected in the samples of bulk basecoats from these manufacturers. (Note that the arithmetic mean MDL for EGBE in the basecoat samples was 4900 mg/kg (range: 2600 to 4354 mg/kg) and the arithmetic mean RDL was 9840 mg/kg (range: 5280 to 8720 mg/kg).)

Waterborne waste management

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. There was considerable variability in waste management practices.

Aqueous rinsate from gun cleaning was directly captured into a larger container and allowed to settle. The excess paint in paint cups retained in the mixing room until it was no longer needed for smaller jobs or "touch-ups".

Some shops stored their paint wastes prior to disposal in open buckets located on the shop floor (see Figure 13), whereas others placed their wastes directly into drums that were designated specifically for waterborne- or solvent-based waste (see Figure 14).

Figure 13 Waterborne waste in an open bucket

Painters did not usually wear any PPE, such as coveralls and gloves, when handling waterborne wastes.

Excess waterborne basecoats were disposed of using several different methods (see Table 9). One painter poured excess paint on to cardboard, and allowed it to dry in the booth. The cardboard was then disposed of in the shop's dumpster (i.e. the municipal waste stream). Several painters collected excess paints in large containers and added flocculant until they solidified (see Figure 15). The solidified paint was disposed of in the shop's dumpster. In some shops, the liquids were stored in waste drums dedicated to waterborne wastes and collected by a hazardous waste vendor. Two painters allowed surplus paint to dry in open spray gun cups and then disposed of the "pucks" in the shop's dumpster.

Figure 14 Waste drums for storing solvent- (left) and waterborne- waste (right).

Figure 15 Solidified paint waste

Table 9 Waste disposal practices

Shop ID	Process of basecoat disposal
01	Spread excess basecoat on cardboard and dried it through several booth cycles. Then placed cardboard in the shop's dumpster.
02	Solidified leftover paints with Homax Paint Hardener in 5 gallon bucket and then placed in the shop's dumpster
03	Added flocculants to waste basecoat in 5 gallon drum. At the time of study Shop 03 had not generated enough waste yet to dispose of.
04	Liquid collected in 55 gallon barrel with closable filter funnel. All waste basecoat in this barrel had been sampled by Safety Kleen but no results received yet.
05	Added flocculant to basecoat then placed in the shop's dumpster
06	Leftover basecoat 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.
08	Liquid waste placed in a 55 gallon waterborne waste drum. When full the drum was picked up by Emerald Services
09	Allowed paint to dry in paint cups and then placed dried paint in the shop's dumpster
10	Liquid waste placed in a drum for disposal
11	Allowed paint to dry in paint cups and then placed dried paint in the shop's dumpster

Characterization of waterborne wastes

None of the three samples of waterborne waste failed the Washington state-only criteria for persistence (see Table 10 and Appendix H). However, it is noteworthy that the percent recovery for total organic chloride (determined from the matrix spike) was 75.9% (see Appendix H). Consequently, the HOC content in the samples from Shops 03 and 06 may be closer to the threshold for state-only persistence (100 ppm) than is indicated by the analytical result.

The sample of phthalocyanine green product, which was included as a positive control, contained 7200 µg/g (ppm) total organic chloride, <10 µg/g total organic fluoride, and <10 µg/g total organic bromide.

Table 10 Waste characterization results

Shop ID	Sample Description	HOC Conc. (ppm)[1]
03	Semi-hardened waterborne paint waste	94
05	Black waterborne paint mixed with flocculant	47
06	Mixed semi-solid waterborne paint waste	78

[1] Total HOC concentration calculated from the sum of total organic chloride + total organic fluoride + total organic bromide. Censored data (i.e., values less than Method Reporting Limits) were divided by 2 and then included in the calculation.

DISCUSSION

The objectives of this study were to: 1) document painters' work practices while using waterborne basecoats; 2) measure painters' personal breathing zone exposures to waterborne basecoat ingredients; 3) evaluate the performance of the spray booths used for paint application; 4) determine the EGBE content of the waterborne basecoats; 5) document waste management practices for excess waterborne coatings and associated products; and 6) designate the waterborne waste streams according to Washington state's dangerous waste regulations.

Painter's work practices

Painter's work practices were generally very similar in all shops because the required tasks were similar. Differences were noted in the use of PPE (especially respirators) and the number of basecoat layers required to yield an acceptable finish. Other minor differences reflected the quantity of vehicles that required painting during the workday and the availability of assistants to help with vehicle preparation.

Despite the finding that all painters' tasks were similar, we noted a lack of standardized practices for many aspects of handling waterborne paints and associated wastes.

Gun cleaning practices were extremely variable and some techniques presented opportunities for chemical exposure. SATA and PPG provide guidelines for gun-cleaning. SATA recommends using waterborne gun-cleaning systems with waterborne cleaners.[30] PPG suggests using hand-pressurized pumps and waterborne cleaning solutions (personal communication between Steve Whittaker and a PPG representative). However, we noted that 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 chemicals (waterborne cleaners and acetone), to more hazardous materials (lacquer thinner and methylene chloride).

Although painters typically 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 because the liquid can be aerosolized and inhaled and/or contact the painters' skin and eyes.

Painters typically did not wear PPE when handling the wastes, presenting opportunities for exposure via dermal contact and inhalation.

Consequently, the potential exists for painters to be exposed to chemicals found in both solvent-based paints (e.g., toluene) and those unique to waterborne basecoats (e.g., EGBE). However, the information provided on MSDSs is frequently not sufficient to allow painters to select appropriate control measures.

Painters' breathing zone exposures

Painters' exposures to the ingredients of waterborne basecoats were low. The airborne concentrations of solvents that are frequently seen in solvent-based basecoats, such as toluene and xylene, were a fraction of their respective TLVs. However, analytes such as EGBE, which are not normally present in solvent-based paints, were present in some waterborne basecoats at relatively high airborne concentrations compared to other constituents (although still much lower than occupational exposure limits).

Spray booth performance

Booth performance varied among the shops. There was no straightforward relationship between average linear air velocity at the painters' breathing zones and their exposure to basecoat constituents. However, the performance of prep-stations appeared to be inferior to enclosed downdraft spray booths, which is consistent with OSHA's findings on control technology for auto body shops.[31] 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.[31]

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 during this study met this requirement; the average linear air velocity at workers' breathing zone ranged from 3 to 89 ft./min.

Subsequent discussions with painters and shop owners revealed that that air baffles located beneath the floor filters are occasionally adjusted by shop personnel, and this adjustment may compromise the booth's air flow. Others suggested that OSHA's target flow rate of 100 ft./min is not achievable, even in the newest spray booths.

EGBE content of waterborne basecoats

Waterborne basecoats manufactured by PPG, Sherwin-Williams, and BASF contained detectable concentrations of EGBE in both the bulk- and air- samples. Because dermal contact is considered by OSHA to contribute to overall EGBE exposure, painters may be subject to dermal exposure when they are spray painting, cleaning their spray guns, and handling wastes. The airborne concentrations of EGBE were below occupational exposure limits.

Waste management and characterization

Although none of the waste samples from this study exceeded the state-only criteria for persistence, the results from two samples were close to the regulatory benchmark of 100 ppm. Wastes from the sampled shops could fail the state-only persistence criteria if a higher proportion of basecoats that contain chlorinated pigments were used in the future.

Procedures for disposing of waterborne coating wastes varied between shops. Waterborne wastes must be managed as dangerous waste unless the generator obtains a waste clearance from Public Health – Seattle & King County. Without a clearance, the shop may not have adequately characterized the paint waste. Consequently, some shops were disposing of their waterborne paint wastes in violation of Washington state's dangerous waste regulations.

Strengths and limitations

To our knowledge, this study is the first comprehensive evaluation of waterborne basecoat usage and exposure in the United States. The fact that we spent entire work shifts recording painter exposures and work practices yielded a comprehensive understanding of how waterborne basecoats are used in auto body shops.

However, we recognize the following limitations of this study:

- First, with a sample size of ten shops, the findings may not be representative of all waterborne spray painting operations. In addition, because waterborne painting technology is relatively new in Washington state, and conversion is voluntary, participating shops were likely to be some of the most progressive in terms of worker safety and waste management. However, we observed a wide array of work conditions and practices, including the use of poorly-functioning spray booths and prep stations and inappropriate methods for cleaning spray guns and managing waste streams.

- Second, more than one-half of the samples had analyte concentrations below their MLOQs. Therefore, we cannot accurately determine the average exposure levels to waterborne paint constituents.

- Third, this study conducted task-based sampling rather than full-shift sampling; only exposures during waterborne basecoat spray-painting were captured. However, we noted many additional opportunities for inhalation exposures, such as during gun cleaning and mixing paints.

- Fourth, despite the fact that EBGE may be dermally absorbed, resource constraints prevented us from measuring skin deposition and biomarkers of exposure. Consequently, this study represents an incomplete evaluation of EGBE exposure.

- Fifth, we did not compare waterborne basecoat exposures to solvent basecoat exposures. It was beyond the scope of this study to evaluate solvent-based basecoats and a review of the Internet, the peer-reviewed literature, and enquiries made of NIOSH failed to identify studies with sufficient methodological detail to allow a valid comparison. One challenge was that historical studies were frequently conducted 10 to 20 years ago, when paint formulations were likely different from those used today.

- Finally, the only waste characterization test performed on the waterborne wastes was for Washington state-only persistence (i.e., HOC content). Although this test was selected based on consultation with subject-matter experts, including Ecology staff, these wastes may have designated as hazardous according to other state-only and/or federal waste requirements if additional tests had been conducted.

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CONCLUSIONS AND RECOMMENDATIONS

The overall conclusions from this study of waterborne basecoats are:

1. The absence of high concentrations of VOCs in the bulk products and the relatively low airborne exposures experienced by painters indicate that waterborne basecoats are likely safer alternatives to traditional solvent-based paints.
2. Painters should wear the same PPE to spray waterborne basecoats that they use to apply solvent-based clearcoats and primers, including adequate respirators, protective gloves, coveralls, and eye protection. Special attention should be paid to ensuring adequate dermal protection, since components of waterborne paints pass readily through the skin.
3. The methods by which painters cleaned their paint guns was extremely variable. A best practice observed at some shops was the use of water-based products in conjunction with an enclosed pneumatic gun washing system. A final rinse with acetone was typically sufficient, rather than using lacquer thinner and other hazardous solvents.
4. Waterborne paint waste management practices varied between shops. Some shops were likely managing their wastes in violation of Washington state's dangerous waste regulations.
5. The spray booths in many shops did not conform to OSHA air flow requirements. Booths should be maintained according to manufacturers' specifications and periodically evaluated by a ventilation engineer to ensure that air baffles and other features are adjusted to ensure adequate air flow.

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APPENDIX A:

CLIENT INTAKE FORM

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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): _____**

APPENDIX B:

SUBJECT CONSENT FORM

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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.
Public Health Researcher
Local Hazardous Waste Management Program
Public Health—Seattle & King County
401 Fifth Ave., Suite 1100
Seattle WA 98104
Phone: 206.263.8499
Fax: 206.296.0189
Email: steve.whittaker@kingcounty.gov

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

Participant's Statement:

"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

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APPENDIX C:

PAINTER DATA FORM

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Date: _________
Shop # _________
Subject # _________

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 #					

Date: __________
Shop # __________
Subject # __________

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?

Date: __________
Shop # __________
Subject # __________

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?

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APPENDIX D:

WATERBORNE BASECOAT MSDS SUMMARY

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Waterborne Basecoats, % weight
Product name (Manufacturer)

Chemical Name	**CAS**	AWX Performance Plus WB Basecoat, Effect Black	Enviro-base HP	Aqua-base Plus	90 Line	Onyx HD Water-borne	Autowave MM 888 series	Autowave MM	Cromax Pro	Basecoat WB MM 192P	Wanda Water-bourne	Permahyd Hi-TEC	Standoblue	No. Products using this chemical
		Sherwin-Williams	PPG	PPG	Glasurit BASF	R-M BASF	Sikken Akzo-Nobel	Sikken Akzo-Nobel	DuPont Axalta Coating Systems	Lesonal Akzo-Nobel	Wanda Akzo-Nobel	Spies Hecker Axalta	Standox Axalta	
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
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	Waterborne Basecoats, % weight Product name (Manufacturer)												No.Products using this chemical
		AWX Performance Plus WB Basecoat, Effect Black Sherwin-Williams	Enviro-base HP PPG	Aqua-base Plus PPG	90 Line Glasurit BASF	Onyx HD Water-borne R-M BASF	Autowave MM 888 series Sikken Akzo-Nobel	Autowave MM Sikken Akzo-Nobel	Cromax Pro DuPont Axalta Coating Systems	Basecoat WB MM 192P Lesonal Akzo-Nobel	Wanda Water-bourne Wanda Akzo-Nobel	Permahyd Hi-TEC Spies Hecker Axalta	Standoblue Standox Axalta	
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	**12236-62-3**		0.1-1	0.1-1										2
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

Waterborne Basecoats, % weight
Product name (Manufacturer)

Chemical Name	**CAS**	AWX Performance Plus WB Basecoat, Effect Black	Enviro-base HP	Aqua-base Plus	90 Line	Onyx HD Water-borne	Autowave MM 888 series	Autowave MM	Cromax Pro	Basecoat WB MM 192P	Wanda Water-bourne	Permahyd Hi-TEC	Standoblue	No.Products using this chemical
		Sherwin-Williams	PPG	PPG	Glasurit BASF	R-M BASF	Sikken Akzo-Nobel	Sikken Akzo-Nobel	DuPont Axalta Coating Systems	Lesonal Akzo-Nobel	Wanda Akzo-Nobel	Spies Hecker Axalta	Standox Axalta	
polyurethane resin-A	**NA**								-					1
polyurethane resin-B	**NA**								-			-	-	3
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 condensation polymer	**9011-05-6**				0-5	0-5	2.5-10							3
water	**7732-18-5**								-			-	-	3
Xylene	**1330-20-7**								-			-	-	3
DAA	**123-42-2**						1-2.5							1

NA: not available
-: unknown

APPENDIX E:

FIELD SAMPLING STANDARD OPERATING PROCEDURE

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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.

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APPENDIX F:

AIR SAMPLE RESULTS

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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	-

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12/10/14

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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	< 0.1	< 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

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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 [signature] 12/15/14
Susan Tao, Ph.D. QAC — Date
206-221-4548

[signature] 12/15/14
Russell Dills, Ph.D. EHL Director — Date
206-543-3263

Environmental Health Laboratory
Department of Environmental and Occupational Health Sciences
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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	< 3	< 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	28	< 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	10.115965	< 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

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-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 distillates (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, 206-221-4518

Russell 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
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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
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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
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

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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 analysed 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 12/9/14 — Susan Tao, Ph.D. QAC, Date, 206-221-4548

Russell Dills 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 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
11411024	NA	Shop 06

	Sampling	Receipt	Preparation	Analysis
Dates	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	9
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

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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, (μg)	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

1411024_kingcnty.xls

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2/2

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

1/9/15

To Grace Liao
DEOHS Grad Student
Box 357234
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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

To 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
11412014	None	Shop 2

	Sampling	Receipt	Preparation	Analysis
Dates	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

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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, (µg)	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

141204_KngCnty_LHWMP.xls — This test report shall not be reproduced except in full without written approval of the laboratory. — 2/2

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 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 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

11412015_KngCnty_LHWMP.xls

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
11502009	None	Shops 9, 10, 11

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

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University of Washington

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%	91.1%	93.5%	91.7%	91.5%	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 Lian, 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

Dates

Sampling	Receipt	Preparation	Analysis
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

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.
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

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
11502022	None	Shop 04

Dates

Sampling	Receipt	Preparation	Analysis
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	< 0.1	< 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
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.
Guide 34 standards were unavailable.

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

Susan Tao, Ph.D. QAC Date
206-221-1548

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

APPENDIX G:

PAINT BOOTH VENTILATION MEASUREMENTS

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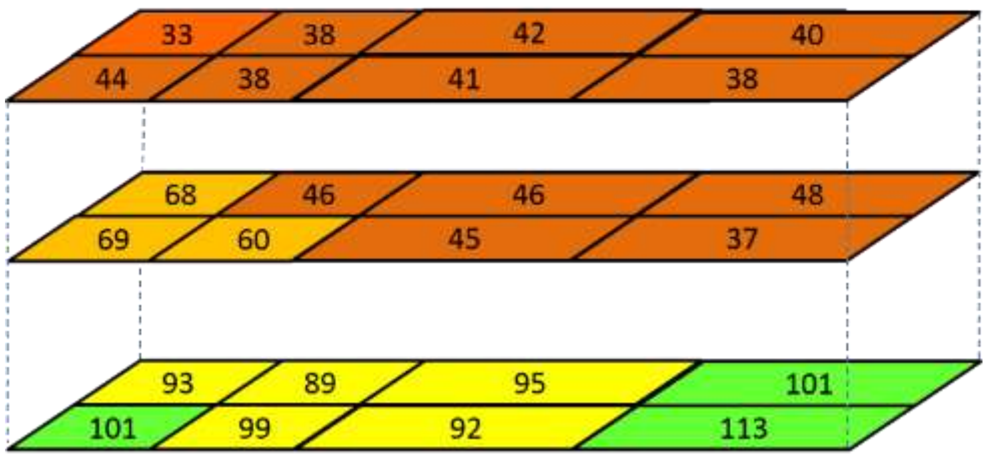
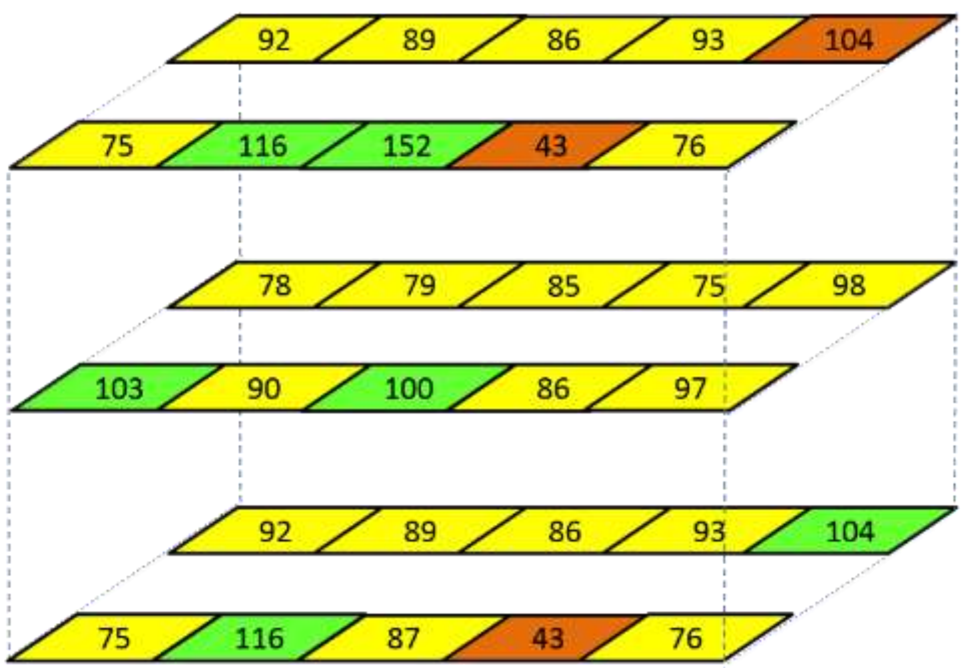
Appendix G Paint booth ventilation measurement graphic display



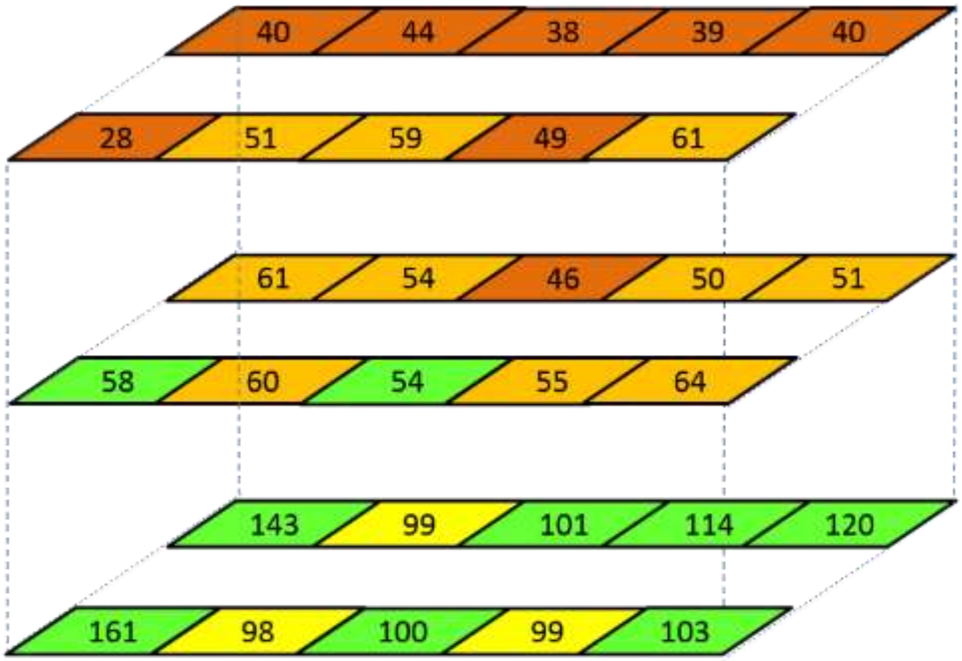
Velocity (ft/min)	Color
0-24	
25-49	
50-74	
75-99	
</=100	

Shop 1 Booth A



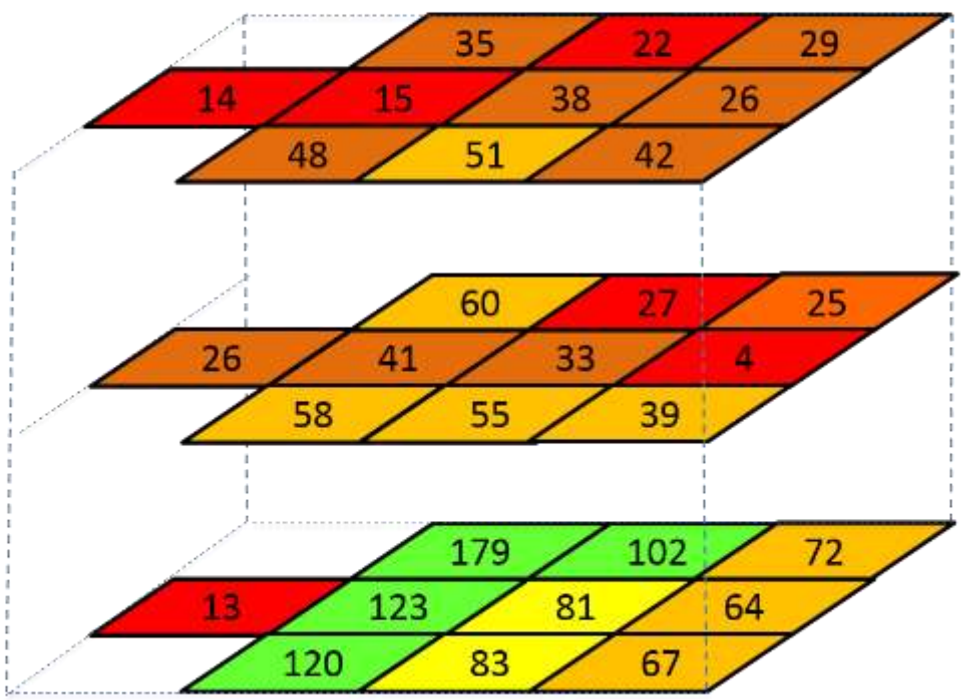
Velocity (ft/min)	Color
0-24	
25-49	
50-74	
75-99	
</=100	

Shop 1 Booth B



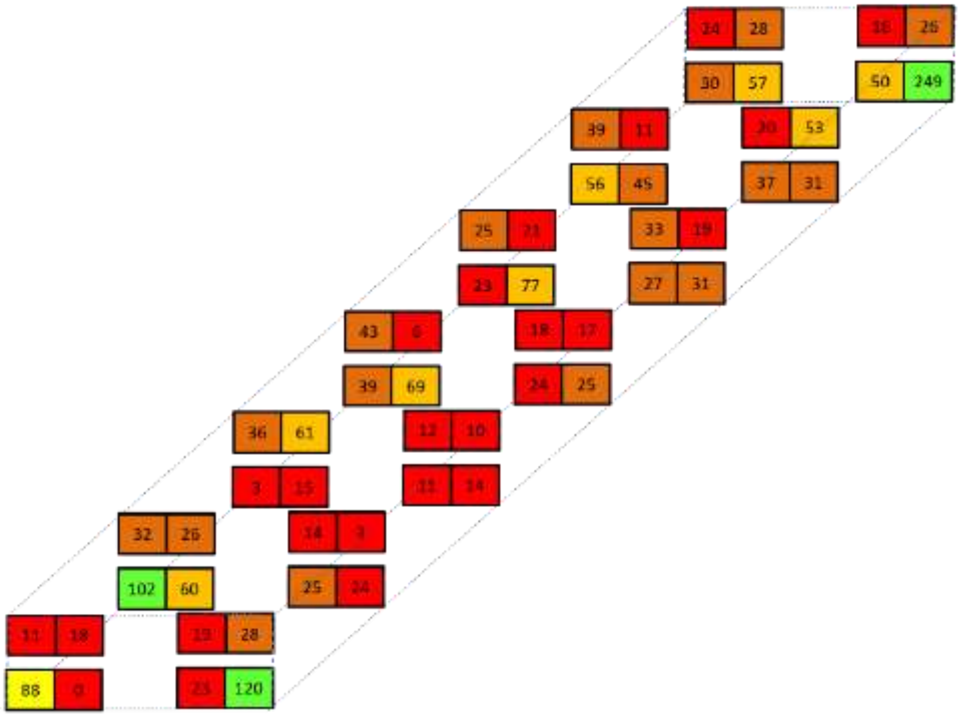
Shop 02

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



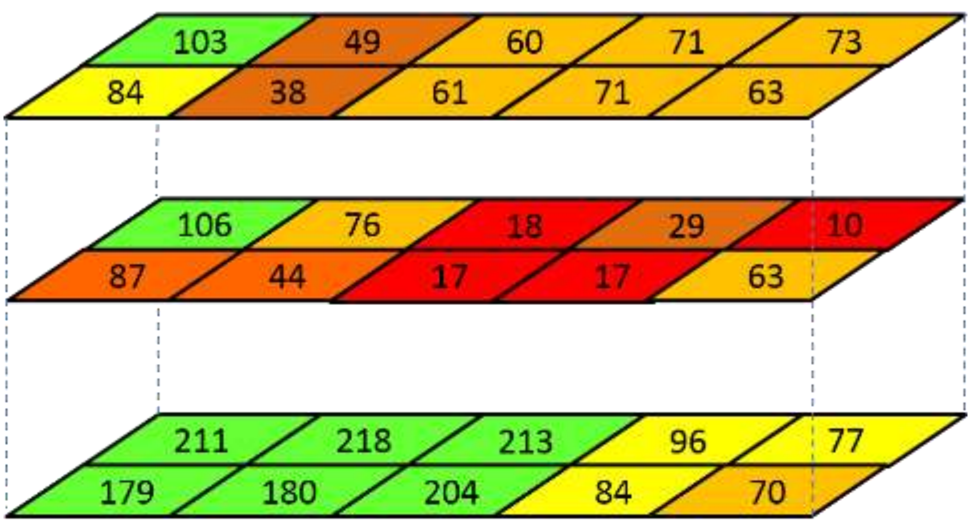
Shop 03 Booth A

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



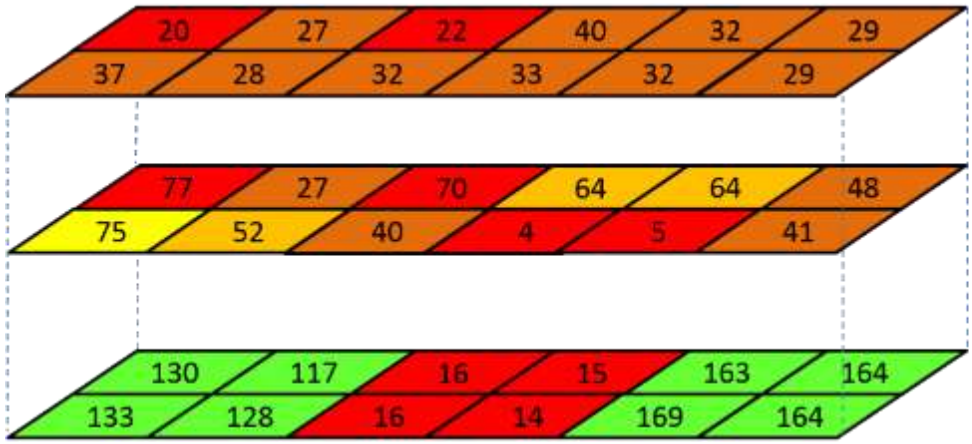
Shop 03 Booth B (Prep station)

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



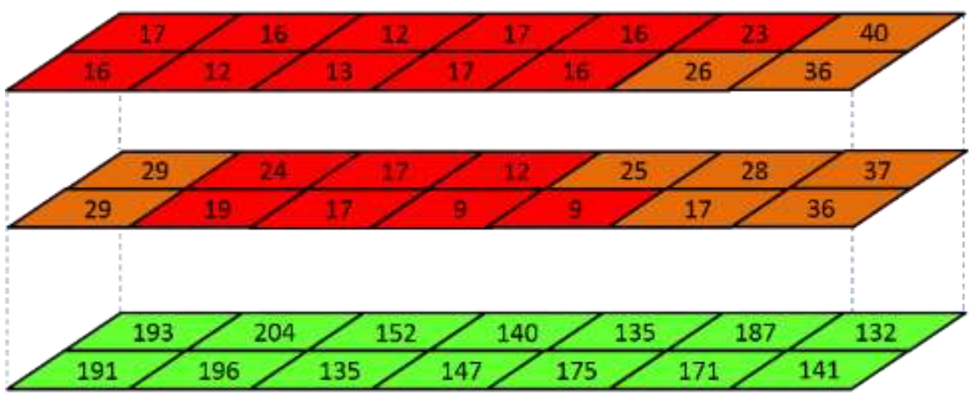
Shop 04

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



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

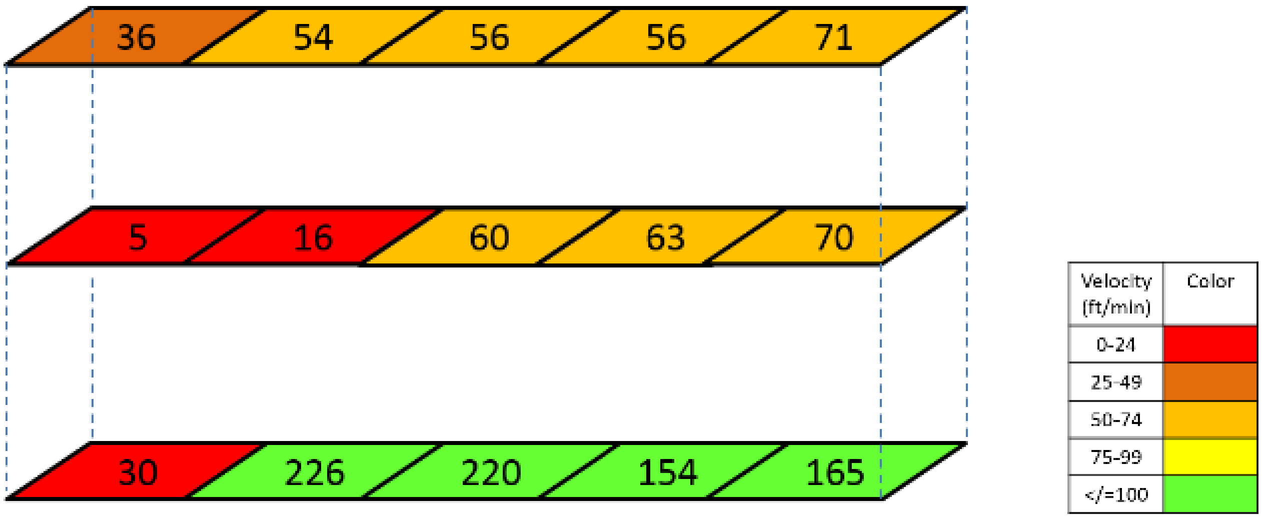
Shop 05



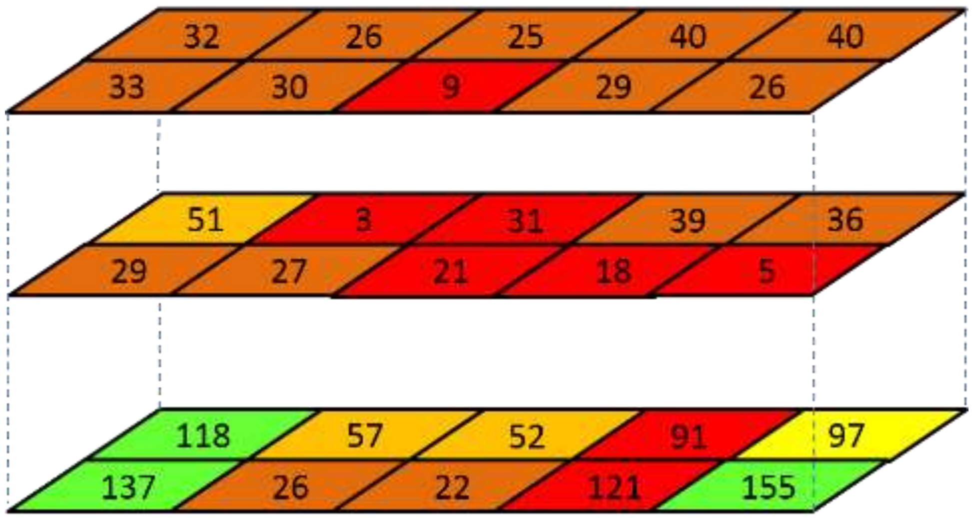
Velocity (ft/min)	Color
0-24	
25-49	
50-74	
75-99	
</=100	

Shop 06

Shop 08 Booth A

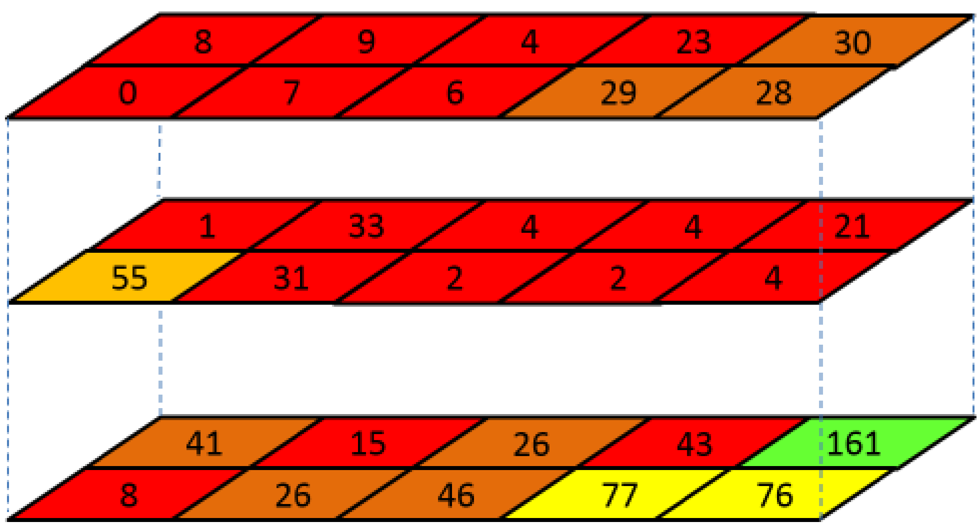


Shop 08 Booth B



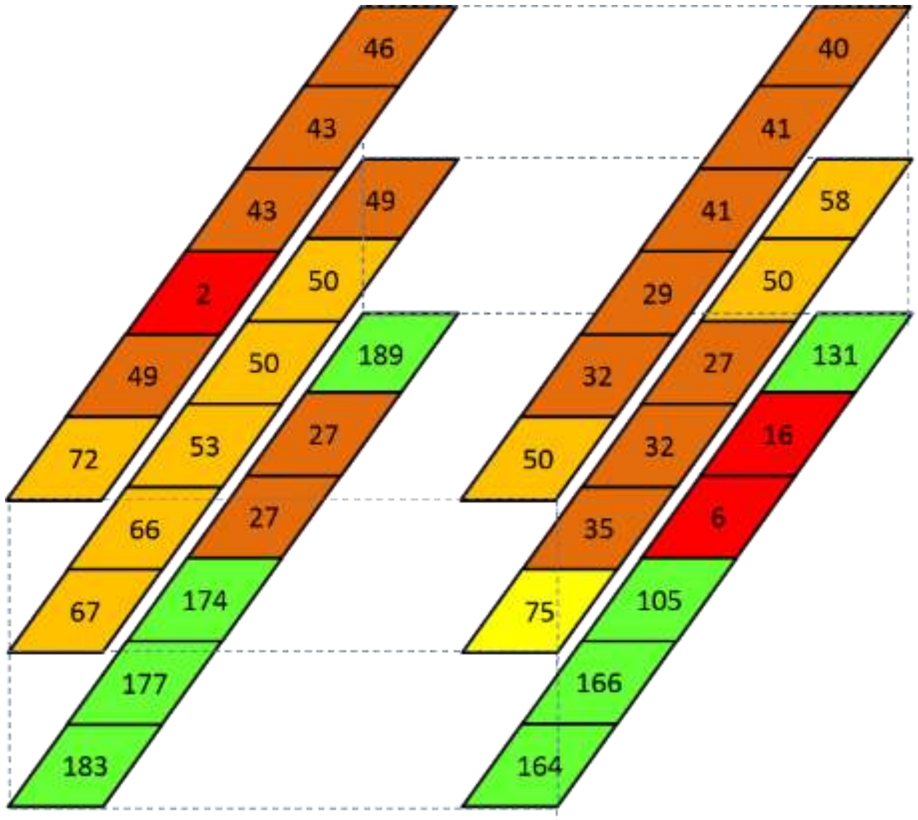
Shop 09 Booth A

Velocity (ft/min)	Color
0-24	Red
25-49	Orange
50-74	Light orange
75-99	Yellow
</=100	Green



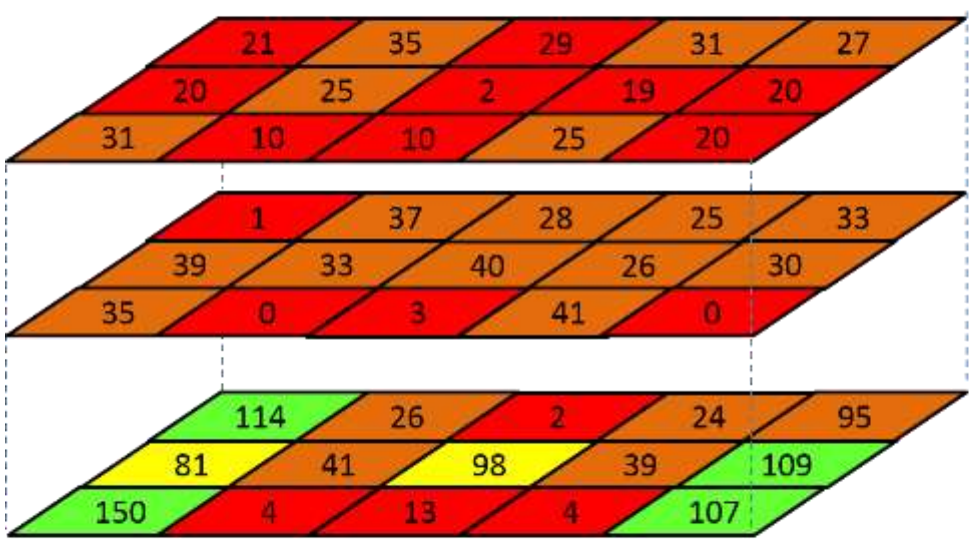
Shop 09 Booth B

Velocity (ft/min)	Color
0-24	Red
25-49	Orange
50-74	Light orange
75-99	Yellow
</=100	Green



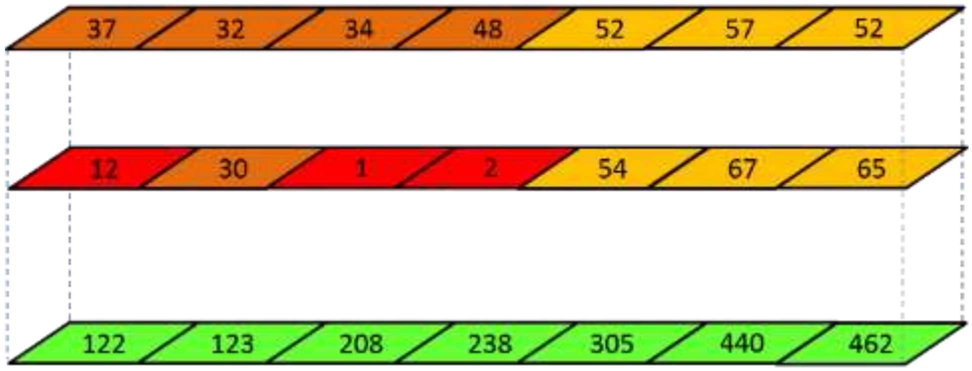
Velocity (ft/min)	Color
0-24	
25-49	
50-74	
75-99	
</=100	

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



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

Shop 11

APPENDIX H:

WASTE CHARACTERIZATION DATA

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Am Test Inc.
13600 NE 126TH PL
Suite C
Kirkland, WA 98034
(425) 885-1664
www.amtestlab.com

AMTEST LABORATORIES

Professional Analytical Services

ANALYSIS REPORT

Public Health Seattle&King Cty
401 5th Ave, Suite 1100
Seattle, WA 98104-1818
Attention: Steve Whittaker
Project Name: Waterborne paint waste characteriz
All results reported on an as received basis.

Date Received: 07/02/15
Date Reported: 7/22/15

AMTEST Identification Number 15-A010222
Client Identification GL021115_03_W01
Sampling Date

Miscellaneous

PARAMETER	RESULT	UNITS	Q	D.L.	METHOD	ANLST	DATE
Total Organic Fluoride	< 10	ug/g			SW846 5050/9056	MR	07/10/15
Total Organic Chloride	84.	ug/g			SW846 5050/9056	MR	07/10/15
Total Organic Bromide	< 10	ug/g			SW846 5050/9056	MR	07/10/15

AMTEST Identification Number 15-A010223
Client Identification GL110514_05_W01
Sampling Date

Miscellaneous

PARAMETER	RESULT	UNITS	Q	D.L.	METHOD	ANLST	DATE
Total Organic Fluoride	24.	ug/g			SW846 5050/9056	MR	07/10/15
Total Organic Chloride	18.	ug/g			SW846 5050/9056	MR	07/10/15
Total Organic Bromide	< 10	ug/g			SW846 5050/9056	MR	07/10/15

AMTEST Identification Number 15-A010224
Client Identification GL112514_06_W01
Sampling Date

Miscellaneous

PARAMETER	RESULT	UNITS	Q	D.L.	METHOD	ANLST	DATE
Total Organic Fluoride	< 10	ug/g			SW846 5050/9056	MR	07/10/15
Total Organic Chloride	68	ug/g			SW846 5050/9056	MR	07/10/15
Total Organic Bromide	< 10	ug/g			SW846 5050/9056	MR	07/10/15

AMTEST Identification Number **15-A010225**
Client Identification **SW050114_P01**
Sampling Date

Miscellaneous

PARAMETER	RESULT	UNITS	Q	D.L.	METHOD	ANLST	DATE
Total Organic Fluoride	< 10	ug/g			SW846 5050/9056	MR	07/10/15
Total Organic Chloride	7200	ug/g			SW846 5050/9056	MR	07/13/15
Total Organic Bromide	< 10	ug/g			SW846 5050/9056	MR	07/10/15

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Professional Analytical Services

QC Summary for sample numbers: 15-A010222 to 15-A010225

DUPLICATES

SAMPLE #	ANALYTE	UNITS	SAMPLE VALUE	DUP VALUE	RPD
15-A010225	Total Organic Fluoride	ug/g	< 10	< 10	
15-A010225	Total Organic Bromide	ug/g	< 10	< 10	

MATRIX SPIKES

SAMPLE #	ANALYTE	UNITS	SAMPLE VALUE	SMPL+ SPK	SPK AMT	RECOVERY
15-A010225	Total Organic Fluoride	ug/g	< 10	24.	29.	82.76 %
15-A010225	Total Organic Chloride	ug/g	7200	9400	2900	75.86 %
15-A010225	Total Organic Bromide	ug/g	< 10	24.	29.	82.76 %

STANDARD REFERENCE MATERIALS

ANALYTE	UNITS	TRUE VALUE	MEASURED VALUE	RECOVERY
Total Organic Fluoride	ug/g	200	210	105. %
Total Organic Chloride	ug/g	200	210	105. %
Total Organic Chloride	ug/g	200	210	105. %
Total Organic Bromide	ug/g	200	210	105. %

BLANKS

ANALYTE	UNITS	RESULT
Total Organic Fluoride	ug/g	< 10
Total Organic Chloride	ug/g	< 10
Total Organic Chloride	ug/g	< 10
Total Organic Bromide	ug/g	< 10