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Ethyl methacrylate and methyl methacrylate exposure among fingernail sculptors

Adam Marty
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Ethyl Methacrylate and Methyl Methacrylate Exposure among Fingernail Sculptors

by

Adam Marty

A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science in Public Health
Department of Environmental and Occupational Health
College of Public Health
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April 5, 2007

Keywords: acrylic nails, artificial nails, nails salons, cosmetologists, ventilation

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Dedication

This thesis is dedicated to my parents, Phillip and Marianne Marty, with love. You have always believed in me, pushed me to succeed, and supported me in all my scholastic endeavors and I truly thank you both.
Acknowledgments

First and foremost I would like to thank my Lord and Savior, Jesus Christ.

I would like to take this opportunity to thank my committee members Dr. Steve Mlynarek, Dr. Yehia Hammad, and Dr. Eugene Szonntag for guiding me through this lengthy process. I would also like to thank them and Dr. Thomas Bernard for providing me with an outstanding experience, quality education, and for always taking the time to answer any questions I had. I would like to thank the National Institute of Occupational Safety and Health for providing the funds to cover the costs of my education and living expenses. I would also like to thank the American tax payers whose taxes paid for my NIOSH funding. I would like to thank the Wisconsin Occupational Health Laboratory for helping me select an appropriate analytical method, for providing me with extra information, and for providing outstanding service. Additionally, I would like to thank my schoolmate Lt. Scott Dunn for being there when we felt like we were in the trenches. We were not called “the A Team” for nothing!!
# Table of Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>List of Tables</td>
<td>iii</td>
</tr>
<tr>
<td>List of Figures</td>
<td>iv</td>
</tr>
<tr>
<td>Abstract</td>
<td>v</td>
</tr>
<tr>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>Purpose</td>
<td>2</td>
</tr>
<tr>
<td>Literature Review</td>
<td>4</td>
</tr>
<tr>
<td>Toxicology</td>
<td>5</td>
</tr>
<tr>
<td>Health Effects Associated with Exposure</td>
<td>6</td>
</tr>
<tr>
<td>Background</td>
<td>12</td>
</tr>
<tr>
<td>Related Studies</td>
<td>13</td>
</tr>
<tr>
<td>Study Design</td>
<td>17</td>
</tr>
<tr>
<td>Methods</td>
<td>19</td>
</tr>
<tr>
<td>Task Analysis</td>
<td>19</td>
</tr>
<tr>
<td>Salon Lay-Out</td>
<td>19</td>
</tr>
<tr>
<td>Ventilation Assessment</td>
<td>19</td>
</tr>
<tr>
<td>Sampling Strategy</td>
<td>20</td>
</tr>
<tr>
<td>Sample Analysis</td>
<td>21</td>
</tr>
<tr>
<td>Results</td>
<td>23</td>
</tr>
<tr>
<td>Task Analysis</td>
<td>23</td>
</tr>
<tr>
<td>Salon Lay-Out</td>
<td>28</td>
</tr>
<tr>
<td>Ventilation Assessment</td>
<td>32</td>
</tr>
<tr>
<td>Analytical Results</td>
<td>33</td>
</tr>
<tr>
<td>Discussion and Conclusion</td>
<td>37</td>
</tr>
<tr>
<td>Discussion</td>
<td>38</td>
</tr>
<tr>
<td>Conclusion</td>
<td>42</td>
</tr>
<tr>
<td>Recommendations for Future Research</td>
<td>43</td>
</tr>
<tr>
<td>References Cited</td>
<td>45</td>
</tr>
<tr>
<td>Bibliography</td>
<td>49</td>
</tr>
</tbody>
</table>
Table of Contents (Continued)

<table>
<thead>
<tr>
<th>Appendices</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appendix A: OSHA Method 7</td>
<td>50</td>
</tr>
<tr>
<td>Appendix B: Desorption/QC development spreadsheet</td>
<td>51</td>
</tr>
<tr>
<td>Appendix C: Ventilation assessments for both nail salons</td>
<td>61</td>
</tr>
<tr>
<td>Appendix D: Pump calibration information</td>
<td>65</td>
</tr>
<tr>
<td>Appendix E: Analytical Laboratory Reports and COCs</td>
<td>66</td>
</tr>
<tr>
<td></td>
<td>69</td>
</tr>
</tbody>
</table>
List of Tables

Table 1  Allergic contact dermatitis studies associated with EMA and MMA exposure  8
Table 2  Occupational asthma studies associated with MMA exposure  11
Table 3  Previous studies of nail technicians’ exposures to EMA  16
Table 4  Task analysis for the application of a full set of artificial nails  25
Table 5  Task analysis for a fill-in of artificial nails  26
Table 6  Estimate of the total time spent working with the liquid monomer  27
Table 7  Ventilation assessment for nail salon 1  33
Table 8  Summary of personal sample and calibration information  34
Table 9  Summary of personal exposures to MMA and EMA  34
List of Figures

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 1</td>
<td>Interior lay-out of nail salon 1</td>
<td>30</td>
</tr>
<tr>
<td>Figure 2</td>
<td>Interior lay-out of nail salon 2</td>
<td>31</td>
</tr>
</tbody>
</table>
Ethyl Methacrylate and Methyl Methacrylate Exposure among Fingernail Sculptors

Adam Marty

ABSTRACT

Fingernail sculptors may be exposed to ethyl methacrylate and methyl methacrylate in their workplace. The literature suggests that these chemicals may cause sensitization in individuals who are exposed to sufficient quantities. Cases of occupational asthma and allergic contact dermatitis have been reported among persons who work with these chemicals. Little personal exposure data exists on nail technicians’ exposures to these chemicals, especially ethyl methacrylate. The literature suggests that the industrial hygiene practices used for methyl methacrylate also be applied to ethyl methacrylate since more is known about methyl methacrylate. Previous exposure studies have revealed relatively low exposures to these chemical. There are no U.S. occupational exposure limits for ethyl methacrylate.

The objectives of this study were to measure nail sculptors’ exposure to ethyl methacrylate and/or methyl methacrylate vapors in their personal breathing zone, describe the interior lay-out of the nail salon in relation to where the chemical vapors were generated, and quantify the volume of air supplied by the HVAC. This study was designed to further characterize and quantify nail technicians’ exposures to ethyl methacrylate and methyl methacrylate.
Two nail salons were identified as study sites. A total of five fingernail sculptors volunteered to participate. Personal sampling pumps and activated charcoal media were used to collect organic vapors in the personal breathing zones of the participants. The samples were collected for an entire work shift and analyzed by gas chromatography with dual flame ionization detection, per a modified OSHA 7 Protocol.

The 8-hour time weighted averages ranged from < 1 – 31 parts per million of ethyl methacrylate and <1 – 5.2 parts per million methyl methacrylate. These levels were similar to those already reported in the literature. These levels were below any U.S. occupational exposure level in place or suggested. Local exhaust ventilation appeared to make a difference, as did natural ventilation. The results of this study strongly suggested that methyl methacrylate was used at one salon despite a ban on its use in nail products.
INTRODUCTION

Nail technicians may be exposed to the chemicals ethyl methacrylate (EMA) and/or methyl methacrylate (MMA) during the application of acrylic liquid used in the sculpting of artificial nails. Acrylates are a class of chemicals that include methacrylates, both EMA and MMA (Bisesi, 2001). The various acrylate monomers generally exist in a liquid form. These monomers can undergo polymerization to form products that range from hard, solid plastics to emulsion polymers (Bisesi, 2001). Methacrylates are used in surgical organ repair, contact eye lenses, surgical and dental cement, artificial nail products, and for other applications (Bisesi, 2001). Nail technicians’ exposures to EMA and/or MMA may lead to the development of skin and respiratory disorders (Thorne, 2001). These disorders may lead to decreased quality of life and may even be life threatening. Unfortunately, little information exists on nail technicians’ personal exposure to these chemicals and even less information exists on the prevalence of the disorders associated with chronic exposure. This study was designed to further characterize and quantify nail technicians’ exposure to EMA and MMA.

Two nail salons were selected based on convenience. Volunteer nail technicians were equipped with air sampling media to measure the amounts of EMA and/or MMA in their personal breathing zone (PBZ). A task analysis of each nail technician’s work activity was performed. The nail salon’s dimensions and lay-out, including positions of the manicure tables, any windows and exits, and the heating, ventilating, and air
conditioning system’s (HVAC) diffusers and returns were measured and drawn. The salon’s HVAC system was also assessed to determine the air flow within the salon. This information will add substantially to the limited information that exists on this topic.

Chronic exposures to EMA and MMA can lead to serious health problems. Little personal exposure data exists on nail technicians’ exposures to these chemicals. Because previous studies have not included some of the objectives contained in this study, this research was unique. The research did have its limitations. The study design only provided a snapshot of the data collected on one day. The information captured only applied to the conditions encountered on the day the exposure assessment was performed. It may not apply to other nail salons and it may not predict other nail technicians’ exposures. However, the research design did provide needed information on nail technicians’ exposures to EMA and MMA and under what conditions these exposures occurred. This study therefore provided a valuable source of information that furthers the previous research on this topic.

**Purpose**

The purpose of this research was to quantify nail technicians’ exposures to EMA and MMA vapors and characterize the conditions under which these exposures occurred. Specifically, the objectives of this research were:

1. To quantify and describe nail technicians’ exposures to EMA and MMA vapors;
   a. The concentration of EMA and/or MMA vapors breathed by nail technicians was determined.
   b. The number of clients seen on the day of sampling was determined.
   c. The duration of the nail technicians’ work shift was determined.
   d. The percentage of the time spent working with the liquid methacrylate was determined.
2. To describe the interior lay-out of the nail salon in relation to where the chemical vapors were generated;
   a. The interior dimensions of the nail salons were measured and the interior volumes were determined.
   b. The locations of the manicure tables were determined in relation to windows, exits, and heating, ventilating, and air conditioning (HVAC) diffusers and returns.

3. To quantify the volume of air supplied by the nail salons’ HVAC system;
   a. The number of air changes per hour was determined.
   b. The HVAC system was qualitatively assessed for evidence of fresh air introduction.
LITERATURE REVIEW

MMA, C₅H₈O₂, has a molecular weight of 100.13, a boiling point of 101°C, a relative vapor density (Air = 1) of 3.45, and a vapor pressure of 40 mm Hg at 25°C (Bisesi, 2001). MMA has an odor threshold of less than 0.4 parts per million (ppm) (ACGIH, 2001) and is immediately dangerous to life and health (IDLH) at a concentration of 1000 ppm and above (NIOSH, 2005). The odor threshold and IDLH for EMA were not available. EMA, C₆H₁₀O₂, has a molecular weight of 114.14, a boiling point of 117°C, a relative vapor density (Air = 1) of 3.94 (Bisesi, 2001), and a vapor pressure of 21 mm Hg at 20°C (Haz Map, 2007).

EMA, on the molecular level, has only one CH₂ group more than the MMA molecule. Because the EMA molecule is slightly heavier, the chemical has an increased boiling point, vapor density, and a decreased vapor pressure. Both chemicals are monomers and rapidly polymerize (Bisesi, 2001).

Nail technicians working in nail salons may be exposed to EMA and/or MMA monomers during the application of acrylic liquid for the sculpting of artificial nails. Exposure may result from physical contact between the chemical and the skin or through inhalation of the chemical vapors. Persons exposed to these chemicals may develop irritation at the site of exposure. Persons exposed to these chemicals may also develop an immune mediated response in the organs exposed resulting in organ sensitization (Thorne, 2001). Sufficient skin contact may cause dermal sensitization resulting in a
condition known as allergic contact dermatitis (Thorne, 2001). Sufficient inhalation of the vapors may cause an immune mediated asthmatic response known as occupational asthma (Thorne, 2001). The signs associated with these conditions usually subside when the exposure is removed (Thorne, 2001). These conditions can be serious since sensitized individuals may have reactions to even the most minute amounts of these chemicals (Thorne, 2001).

Prior to 1975, MMA was used as the primary monomer in the liquid acrylic (Jackson, 1999). The Food and Drug Administration subsequently banned MMA for use in nail products due to reports of several cases of severe allergic contact dermatitis associated with its use (Fisher and Baran, 1991). Some literature suggests MMA may still be used due to its relatively inexpensive price, $20-$60/gallon compared to EMA at approximately $200/gallon, as well as a lack of regulatory oversight (Jones, 2003).

Toxicology

EMA and MMA can cause health problems when persons are exposed to sufficient amounts of these chemicals. The main routes of exposure are by direct skin contact and through inhalation of the chemical’s vapors (Bisesi, 2001). Both chemicals are irritating to the skin, eyes, and mucus membranes (Bisesi, 2001). Both can cause allergic contact dermatitis (Bisesi, 2001; Kanerva et al, 1992; Kanerva et al, 1997, Van Der Walle et al, 1982; Condé-Salazar et al, 1986; Condé-Salazar et al, 1988) and persons sensitized to one acrylate may show cross-sensitization to other acrylates (Fisher, 1980). Cases of occupational asthma have been associated with exposure to MMA vapors (Lozewicz et al, 1985; Pickering et al, 1986; Marez et al, 1993; Piirila et al, 1998; Jedrychowski, 2003).
Health Effects Associated with Exposure

The literature suggests that both EMA and MMA are dermal sensitizers; although the extent to which has been debated. Allergic contact dermatitis (ACD) is a condition that results from repeated exposures to certain chemicals (Mathias, 1994). ACD is characterized by inflammation and redness of the skin that frequently is seen in areas distal from the initial site of exposure (Mathias, 1994). The development of ACD is preceded by repeated exposures that immunologically sensitize the worker (Mathias, 1994). The actual condition does not manifest itself until after the individual is sensitized. Once sensitized, the worker may show symptoms of ACD to very low levels of the offending chemical hours to days after the exposure (Mathias, 1994). Symptoms may decrease with cessation of the exposure; however, in certain individuals symptoms may persist for longer periods of time (Mathias, 1994).

Several studies have documented dermal sensitization to these chemicals in an occupational setting (See Table 1). Ten years of patch testing with (meth)acrylates
(Kenerva et al, 1997) revealed that between 6.5 % - 8.2 % of persons patch tested with 2 % MMA reacted positively and between 4.8 % - 10.1 % of persons patch tested with 2 % EMA reacted positively. Condé-Salazar et al (1986) reported that a 17-year-old woman who had been working with artificial nails developed dermatitis after 3 months. She was subsequently patch tested with a variety of compounds including EMA and MMA monomers. Both concentrations of the compounds were 10 % in petroleum. EMA yielded a “+” result after 48 hours and a “+” result after 96 hours. MMA yielded a “++” result after 48 hours and a “+++” result after 96 hours; however, it was unclear what a “+” or “++” result meant in this report. ACD has also been reported among car mechanics and car assembly workers who worked with acrylic sealants (Condé-Salazar et al, 1988). Patch tests of six workers revealed dermal sensitivity to EMA and MMA, 83 % of cases and 50 % of cases respectively. Kanerva et al (1992) also reported ACD in an orthodontist. Patch testing with 2 % EMA and 2 % MMA resulted in abundant redness and swelling on the six day reading. The sensitizing potential of EMA and MMA has also been examined in a guinea pig model using the guinea pig maximization test (GPMT). In that report, Van Der Walle et al (1982) reported that approximately 20 % - 30 % of guinea pigs tested could be sensitized to MMA and approximately 10 % could be sensitized to EMA. Additionally, the documentation for the American Conference of Governmental Hygienists’ (ACGIH) Threshold Limit Value (TLV) for MMA also called it a “potent skin sensitizer” (ACGIH, 2001). The evidence clearly shows that both EMA and MMA can cause allergic contact dermatitis.
### Table 1: Allergic contact dermatitis studies associated with EMA and MMA exposure

<table>
<thead>
<tr>
<th>Study</th>
<th>Study description</th>
<th>MMA Concentration</th>
<th>MMA Results</th>
<th>EMA Concentration</th>
<th>EMA Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kanerva et al, 1997</td>
<td>Patch test of 275 patients with a history of exposure to (meth)acrylates</td>
<td>2% w/w petroleum</td>
<td>7.4 % of 271 tested</td>
<td>2% w/w petroleum</td>
<td>7.4 % of 243 tested</td>
</tr>
<tr>
<td>Condé-Salazar et al, 1986</td>
<td>Patch test of a nail technician who presented with dermatitis</td>
<td>10% in petroleum</td>
<td>+ after 48 hrs ++ after 96 hrs 20 controls −</td>
<td>10% in petroleum</td>
<td>+ after 48 hrs + after 96 hrs 20 controls −</td>
</tr>
<tr>
<td>Condé-Salazar et al, 1988</td>
<td>Patch test of 6 patients who presented with dermatitis and also worked with acrylic sealants</td>
<td>10% in petroleum</td>
<td>Patient 1 − Patient 2 − Patient 3 − Patient 4 + Patient 5 ++ Patient 6 ++ 20 controls −</td>
<td>10% in petroleum</td>
<td>Patient 1 − Patient 2 + Patient 3 ++ Patient 4 ++ Patient 5 + Patient 6 ++ 20 controls −</td>
</tr>
<tr>
<td>Kanerva et al, 1992</td>
<td>Orthodontist suspected of developing occupational pharyngitis. Patch testing revealed dermal sensitivity to EMA and MMA</td>
<td>2% w/w petroleum</td>
<td>3+ 3 indicates abundant redness and swelling</td>
<td>2% w/w petroleum</td>
<td>3+ 3 indicates abundant redness and swelling</td>
</tr>
<tr>
<td>Van der Walle et al, 1982</td>
<td>Guinea pig sensitization to (meth)acrylates using the guinea pig maximization test (GPMT) and/or the Freund's complete adjuvant test (FCAT)</td>
<td>Varied</td>
<td>GPMT = 20% - 30% of animals sensitized FCAT = 25% of animals sensitized</td>
<td>Varied</td>
<td>GPMT = 10% of animals sensitized FCAT = 33% of animals sensitized</td>
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</tbody>
</table>
EMA and MMA can cause ACD; however, the degree to which each is a dermal sensitizer has been debated. It has been suggested that part of this debate could originate from how the studies have reported their findings; percentages have been used, descriptors such as weak or potent have been used, and symbols such as “+” have been used. The problems seem to arise when the results are interpreted across the studies. It is difficult to compare a “++” result to a result described as potent. Furthermore, the exposure strategies used in patch tests may not be typical of the exposures encountered in a work setting.

Occupational asthma, sometimes referred to as allergic occupational asthma, is a condition that results because of an increased response of the airways in the lungs to irritants encountered in the work environment (Demeter, 1990). Asthma, in general, costs the American public billions of dollars each year (Sipkoff, 2006). It is estimated that approximately 5 – 25 percent of newly diagnosed asthma cases fall within the occupational asthma definition (Sipkoff, 2006). In workers with occupational asthma, the worker is usually sensitized over a period of time to the offending irritant with no adverse reaction (Demeter and Cordasco, 1994). Once the worker is sensitized, the airway response is triggered through an immune mediated pathway (Demeter and Cordasco, 1994). Occupational asthma is also characterized by decreasing symptoms with time away from the work environment (Demeter and Cordasco, 1994). Workers with occupational asthma must have their exposures reduced since even the smallest exposures can elicit a life threatening asthma attack in which breathing can become very difficult (Sipkoff, 2006).
Several studies have documented occupational asthma associated with exposures to MMA in an occupational setting (See Table 2); however, little information exists on the association between EMA exposure and occupational asthma. Piirilä et al (1998) reported respiratory hypersensitivity to acrylates in dental personnel. One patient was inhalation challenge tested with MMA, resulting in a decreased forced expiratory volume (FEV₁) in one second of 6 % and a decreased peak expiratory flow (PEF) of 20 %. Marez et al (1993) studied workers exposed to MMA. Pre-shift and post-shift lung function tests were performed. Although post-shift/pre-shift ratios for forced vital capacity (FVC), FEV₁, and FEV₁/FVC were not statistically significant, they did find statistical significance in the post-shift/pre-shift ratios for maximum expiratory flow when 50 % of the FVC remained (MEF₅₀) and the MEF₅₀/MEF ratio, p = 0.04 and p = 0.01 respectively. In this study, MEF₅₀ and MEF₅₀/MEF may have been a more sensitive indicator for obstruction in the smaller airways of the lung (Baum and Wolinsky, 1983). Pickering et al (1986) documented occupational asthma in an orthopedic operating theater worker. Inhalation challenge testing with MMA resulted in a 25 % decrease in FEV₁ 13 hours after the challenge. Lozewicz et al (1985) reported a dental assistant with occupational asthma. Inhalation challenge testing with MMA provoked a similar 24 % reduction in PEF in two challenge tests conducted one week apart. Lung obstruction syndrome, a general condition that includes occupational asthma, has also been reported by Jedrychowski (1982) in workers exposed to styrene and MMA; however, the study did not isolate the effects of either compound. The evidence clearly shows that MMA can cause occupational asthma.
<table>
<thead>
<tr>
<th>Study</th>
<th>Study description</th>
<th>Study findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Piirilä et al, 1998</td>
<td>Goal of the study was to report respiratory hypersensitivity in dental personnel to acrylates. Flow-volume spirometry, skin-prick, and inhalation challenge tests were performed.</td>
<td>A dental nurse was symptomatic of occupational asthma. Challenge test with liquid MMA reduced Max FEV₁ by 6% and PEF by 20%. Skin-prick test was negative for MMA.</td>
</tr>
<tr>
<td>Marez et al, 1993</td>
<td>Study of 40 workers exposed to MMA for more than 5 yrs and 45 controls. Questionnaires were administered for sample selection and flow-volume spirometry was measured before and after shift.</td>
<td>No statistically significant findings for before shift observed/predicted spirometric measurements among the exposed group and controls. There was statistical significance in after shift/before shift ratios for MEF₅₀ and MEF₅₀/MEF in the exposed group, p=0.04 and p=0.01, respectively.</td>
</tr>
<tr>
<td>Pickering et al, 1986</td>
<td>A case report of an orthopedic operating theater worker who developed work related asthmatic symptoms. Inhalation challenge tests were performed using water as a control and MMA. Flow-volume spirometry was subsequently performed.</td>
<td>Lung function tests were normal when the worker was not working. Lung function tests were normal after inhalation challenge with water. Lung function tests were abnormal starting 6 hrs after inhalation challenge with MMA. FEV₁ was reduced 25% 13 hrs after the challenge.</td>
</tr>
<tr>
<td>Lozewicz et al, 1985</td>
<td>Case report of a dental assistant who mixed liquid MMA with powdered poly-MMA on a regular basis. Experienced chest tightness, dyspnoea, and cough after working with MMA for several yrs. Underwent two inhalation challenges with MMA one week apart. Lung function tests were performed after each challenge. &quot;No formal control test was made.&quot;</td>
<td>First inhalation test provoked a 24% reduction in PEF. Second test provoked similar results. PEF measurements between the two tests showed little variation (&lt;10%) except upon waking in the morning.</td>
</tr>
<tr>
<td>Jedrychowski, 1982</td>
<td>Study assessed the prevalence of lung obstruction syndrome in 454 workers exposed to styrene and MMA and 683 controls. Included area air monitoring, interviews on health status, and lung function tests.</td>
<td>Study found the prevalence of lung obstruction was: Non-smokers or ex-smokers = 13.6% of controls and 42.4% of exposed current smokers = 21.0% of controls and 46.5% of exposed. Study did not isolate the effects of either compound.</td>
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Background

Nail technicians and their customers’ breathing zones are often within 2 feet of where the liquid acrylic is applied. The liquid is volatile and vapor inhalation is a concern (Sandmeyer and Kirwin, 1981). The application of liquid acrylic usually does not take place in the proximity of local exhaust ventilation. Nail technicians have the potential to be exposed to greater amounts of the chemical when applying several sets of artificial nails throughout the workday and especially when more than one nail set is being applied in the same room. Only the monomer forms of EMA and MMA are a health concern and they quickly react to form polymers (Spencer et al., 1997). When industrial hygiene sampling is performed, personal exposures are converted to an eight-hour workday, time weighted average (8-hr TWA) since most occupational exposure limits are based on this average (Klonne, 2003). This calculation takes into account shorter or longer workdays and assumes a 40 hour work week (Klonne, 2003). The National Institute of Occupational Safety and Health (NIOSH) and the Occupational Safety and Health Administration (OSHA) have established a Recommended Exposure Limit (REL) and a Permissible Exposure Limit (PEL) of 100 ppm 8-hr TWA for MMA, respectively. The American Conference of Government Industrial Hygienists has recommended a Threshold Limit Value of 50 ppm 8-hr TWA; however, no established United States’s occupational exposure limits (OELs) exist for EMA (NIOSH, 2005). Patty’s Industrial Hygiene and Toxicology, 3rd revised ed., has recommended that the same criteria used to evaluate MMA also be applied to EMA due to their chemical similarity (Sandmeyer and Kirwin, 1981). The Netherlands’s government has
recommended an OEL of 10 ppm 8-hr TWA; Sweden and the former Soviet Union have established an OEL of 11 ppm 8-hr TWA for EMA. However, this recommendation does not appear to be based on any human epidemiological evidence as they noted that very limited human data was available (Health Council of the Netherlands, 1994).

Nail technicians may work with MMA or EMA during the application of artificial nails. There are typically three scenarios in which the chemicals are used: during application of a full set of artificial nails, during a fill-in of a previously applied set of nails, or during the repair of a broken artificial nail. The time that the nail technician may work with the chemicals varies according to procedure being done with a full set generally taking the most time and a repair the least.

**Related Studies**

The literature suggests that available data on EMA toxicology and EMA exposure is limited and controversial (Jackson, 1999). Lowenstein (2006) suggests that a “combination of circumstances contributes to the lack of information on the topic.” Roelofs (2006) suggests that small businesses, like nail salons, are not well characterized. This could be because most nail salons have less than ten employees and are not required to maintain OSHA injury and illness records (OSHA, 2000 revised). In a self-report survey, Roelofs (2006) reported that 31% of nail techs reported respiratory irritation, 18% reported breathing difficulty, and 30% reported that these symptoms declined away from work. Roelofs (2006) also reported that 79% of nail techs reported an irritating smell at work.
The goal of this research was to further characterize nail technicians’ exposures to EMA and/or MMA vapors via inhalation. Knowing the extent of nail technicians’ exposures to EMA and/or MMA was important because there were approximately 43,800 licensed, active nail specialist in the state of Florida alone as of November, 2005 (Board of Cosmetology, 2006). The few studies that have been conducted do not adequately document the inhalation route of exposure in this population of workers (See Table 3). The Spencer et al (1997) study evaluated the effectiveness of a modified, ventilated table versus a non-ventilated table. Although these researchers found low levels of EMA, 15 ppm or less TWA, they used students who lack experience and tended to have slower application rates compared to an experienced nail technician. Additionally, the Spencer et al (1997) study seemed to indicate that only one nail set was being applied at any one time. Perhaps more than one set could be applied by different nail technicians within the salon at any given time.

Decker and Beasley (1992) performed a NIOSH Health Hazard Evaluation (HHE) at a Springdale, Ohio nail salon. This salon had two employees, only one was working on the day of the HHE, where 5 – 12 nail sets would be completed per day. Although low levels of EMA were detected, only one of ten air samples taken was a personal breathing zone (PBZ) sample; of the area samples, only one was a full day and the other eight were short-term samples.

Almaguer and Blade (1992) performed a NIOSH HHE at a Norman, Oklahoma nail salon. Two employees were employed at this salon; however, the number of clients seen that day was unclear. They found short-term, 14 minutes or less, PBZ samples
approaching 28 ppm; however, only three PBZ samples were taken. Froines and Garabrant (1986) performed PBZ sampling in several nail salons and found nail technicians were being exposed to both EMA and MMA. Both active and passive sampling media were used; however, it was unclear when either was used. The study also lacked details regarding sampling times, number of nail technicians working at the salon, and the number of clients seen.

Hiipakka and Samimi (1987) also found that nail techs were being exposed to low levels of EMA. Interestingly, they had planned to sample on a cold winter day so as to capture the worst-case scenario; however, the weather was spring-like and the salons’ windows were open. They (Hiipakka and Samimi, 1987) also noted that “considerable intersalon differences in mean personal organic vapor exposures were found to exist, in that air levels ranged from <0.1 ppm of all vapors to 46.4 ppm for isopropyl alcohol.” These differences in isopropyl alcohol concentrations could serve as a surrogate for EMA variability.

The literature also suggests that even low levels of EMA can cause health problems. LoSasso et al (2001) concluded that exposure to even low levels of chemicals common in nail salons, including EMA, may result in mild cognitive and neurosensory changes similar to those observed among documented solvent-exposed workers in other settings. Although this study did not isolate EMA as the single cause for these health problems, it highlights the need for further research.
Table 3: Previous studies of nail technicians’ exposures to EMA

<table>
<thead>
<tr>
<th>Study</th>
<th>Study description</th>
<th>PBZ samples taken for EMA</th>
<th>Strengths</th>
<th>Weaknesses</th>
<th>EMA concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spencer et al, 1994</td>
<td>The Colorado Department of Health requested NIOSH assist in the evaluation and control of nail technicians’ exposures at a cosmetology school. Examined differences in exposures under conditions utilizing a modified manicure table with downdraft ventilation or an unventilated manicure table.</td>
<td>10 short-term w/ unvent table 8 short-term w/ vent table 3 samples &gt; 5 hours w/ unvent table 3 samples &gt; 5 hours w/ vent table</td>
<td>Established the effectiveness of modified ventilated table Included diagram of facility and location of manicure table relative to exhaust fan in wall Active sampling media used</td>
<td>Student nail techs lacked experience and were slower Appeared only one set of nails was being applied at any one time General ventilation and air changes per hour were not measured</td>
<td>Short-term PBZ w/ unvent table = 10.6 ppm GM Short-term PBZ w/ vent table = 0.8 ppm GM PBZ &gt; 5 hours w/ unvent table = 7.0 – 12.8 ppm GM PBZ &gt; 5 hours w/ vent table = 0.4 – 1.5 ppm GM</td>
</tr>
<tr>
<td>Hiipakka and Samimi, 1987</td>
<td>In-depth study that measured exposures of nail techs to organic vapors and methacrylate dust. Samples were collected in six different nail salons. Self-administered symptom questionnaires completed by nail techs and controls.</td>
<td>17 samples using active sampling media</td>
<td>Included evaluation of nail techs’ symptom prevalence Revealed that regular ventilated tables do not produce enough capture velocity to reduce EMA exposure</td>
<td>Lacked details regarding sampling times, number of nail techs at each salon, and number of clients seen General ventilation and air changes per hour were not measured</td>
<td>4.5 ± 4.6 ppm mean TWA Range &lt;0.1 to 17 ppm</td>
</tr>
<tr>
<td>Froines and Garabrant, 1986</td>
<td>Eight nail salons and their employees sampled for MMA, four of which were also sampled for EMA. Both active and passive sampling media were used.</td>
<td>25 mean intermittent samples for MMA 59 mean continuous samples for MMA 15 mean intermittent samples for EMA 32 mean continuous samples for EMA</td>
<td>Captured both EMA and MMA exposure Included direct reading instrumentation for est. continuous methacrylate exposure Appeared all samples taken were PBZ samples</td>
<td>Lacked details regarding sampling times, number of nail techs at each salon, and number of clients seen General ventilation and air changes per hour were not measured Unclear when active or passive sampling media were used</td>
<td>Mean intermittent exposure for MMA = 9.1 – 47.6 ppm Mean continuous exposure for MMA = 2.1 – 8.8 ppm Mean intermittent exposure for EMA = 7.0 – 18.0 ppm Mean continuous exposure for EMA = 2.4 – 9.2 ppm</td>
</tr>
<tr>
<td>Almaguer and Blade, 1992</td>
<td>NIOSH conducted a Health Hazard Evaluation (HHE) at the request of a nail salon owner.</td>
<td>3 short term Samples, 14 min or less</td>
<td>Qualitative evaluation of general ventilation Some IEQ parameters measured Active sampling media</td>
<td>Lacked details regarding numbers of clients seen Lacked long-term PBZ samples</td>
<td>7 min sample = 27.4 ppm 14 min sample = 16.9 ppm 37 min sample = 4 ppm*</td>
</tr>
<tr>
<td>Decker and Beasley, 1992</td>
<td>NIOSH conducted a HHE at the request of adjacent business owners who noted a “terrible smell” emanating from salon.</td>
<td>One long-term sample (321 mins) during which five clients were seen</td>
<td>Qualitative evaluation of general ventilation Active sampling media</td>
<td>Lacked long-term PBZ samples</td>
<td>PBZ sample = ND (LOD = 1 ppm) One Area sample = 7 ppm (4.6 L air)</td>
</tr>
</tbody>
</table>
Study Design

This research project was an industrial hygiene study of nail technicians’ exposures to ethyl methacrylate and methyl methacrylate. The hypothesis of this research was that nail technicians were exposed to measurable concentrations of one or both of these chemicals; however, the research was not designed to assess the presence of any disease. The design did provide actual concentrations of nail technicians’ personal exposures to EMA and MMA on the day of sampling and under what conditions these exposures occurred. This type of design was necessary since little information exists on these types of exposures.

This research project was a pilot study designed to capture nail technicians’ exposures on a busy workday. Therefore, the nail salons’ nail technicians were sampled on their historically busiest day of the week and arrangements were made to perform the exposure assessment based on appointment schedules and past information.

Two nail salons served as study sites, including an Asian owned salon. Having an Asian owned salon incorporated into the design was important because approximately 37% of nail salons in the U.S. are Asian owned (EPA, 2006). Nail technicians employed by these sites were asked to volunteer as research subjects. Six to eight volunteers were expected from both sites. Only nail technicians who volunteer participated. Only nail technicians who worked with artificial nails for more than half their shift were considered. A University of South Florida Institutional Review Board (IRB) Application for Initial Review was submitted and IRB requirements were subsequently waived.
This research design had its limitations. The study design only provided a snapshot of the data collected on that day. The information captured only applied to the conditions encountered on the day the exposure assessment was performed. It does not apply to other nail salons and it may not predict other nail technicians’ exposures. However, the research design did provide needed information on nail technicians’ exposures to ethyl methacrylate and/or methyl methacrylate and under what conditions they occurred. This may provide important information for further assessment and research.
METHODS

Task Analysis

A task analysis of the nail application process was performed at each study site. Each nail technician was observed for at least one entire nail procedure for each type of nail procedure that they performed. These observations were performed to assess the time spent on each task of the artificial nail application process. Each nail technician was also asked to record the numbers of procedures that they performed. These task analyses were necessary for determining the proportion of time spent working with the liquid related to the total time of the procedure.

Salon Lay-Out

The two participating nail salons’ interior lay-outs were drawn. The interior dimensions of the salons were measured. Placements of all manicure tables were measured from a wall to the mid-point of the table. All windows, exits, and locations of HVAC vents and return(s) were also measured and recorded. Diagrams of the salons are provided in Figures 1 and 2.

Ventilation Assessment

The nail salon’s HVAC system was assessed. An Alnor Balometer (APM 150, Alnor, Skokie, Illinois), an instrument used to quantify air flow, was used to measure the air flows through the HVAC system’s vents and returns. These air flow measurements were used to determine the amount of air movement within the nail salon measured in
supply air changes per hour. This measure was important in determining the time it takes to recycle one volume of inside air. The HVAC system was also assessed for evidence of outside air introduction.

**Sampling Strategy**

Research subjects were equipped with a Buck personal sampling pump (Basic-5, A.P. Buck Inc., Orlando, Florida) and activated coconut shell charcoal sampling media connected via Tygon tubing. The sampling apparatus was pre-calibrated and post-calibrated according to the OSHA protocol of ± 5% (OSHA, 2007). A factory calibrated mini-Buck calibrator (M-5, A.P. Buck Inc., Orlando, Florida) was used for this purpose. Nail technicians’ personal breathing zones were continuously sampled at an approximate flow rate of 42 milliliters of air per minute (ml/min). Each personal sample was collected over an approximate four hour period. Two samples per nail technician were collected whenever it was possible. This flow rate and sample time should have yielded a minimum mass of the chemicals that satisfies the minimum detection limit of the analytical method, Wisconsin Occupational Health Laboratory (WOHL) Method WG006 which is based on OSHA Method 7 (See Appendix A). An area sample was collected at an approximate flow rate of 40 ml/min over the entire day in each nail salon in the area where the chemicals are stored. Additionally, an air sample was taken from a partially full liquid monomer bottle supplied by each salon. The sampling media was inserted into the one gallon bottle of the monomer and positioned approximately 3 inches from the surface of the liquid. The air space above the liquid was sampled for 15 minutes at a flow rate of 200 ml/min. These grab vapor samples from the one gallon bottles were
collected to quantify the vapor mixture at high concentrations since the sampling media would be nearly saturated. Appropriate sample blanks were also submitted for analyses. All samples were packed on ice and shipped overnight to the WOHL for analyses.

*Sample Analysis*

Samples were analyzed according to WOHL Method WG006, which is a modified version of the OSHA Method 7 protocols. The Wisconsin Occupational Health Laboratory developed WG006 to accommodate a variety of organic solvents including EMA and MMA. The method allowed for the sampling and analysis of both chemicals at the same time. The method used SKC Anasorb CSC (catalog # 226-01) activated coconut shell charcoal sampling media with a 20/40 mesh particle size to collect organic vapors which were subsequently desorbed with carbon disulfide and analyzed by gas chromatography with flame ionization detection. The analytes were separated by two different analytical columns, a primary and confirming column, and quantified against valid calibration curves.

WOHL Method WG006 was chosen after careful discussions with the WOHL’s organic laboratory supervisor. The WOHL is an AIHA accredited laboratory and recommended this method for a few reasons. First, the WOHL reported that they did not get good recoveries of EMA from XAD-2 media using NIOSH Method 2537; although it works well for MMA. Second, the WOHL uses WG006 (modified OSHA Method 7 protocol) for the analyses of EMA and MMA with good recoveries of the analytes. The WOHL has provided documentation of multiple EMA/MMA spiked quality control samples. See Appendix B for the Desorption/QC Development Spreadsheet. Third,
WOHL Method WG006, OSHA Method 7, and the EMA specific OSHA Method PV2100 are all virtually identical in all other aspects.
RESULTS

Task Analysis

The task analysis was separated into three general steps: nail prep, work with liquid monomer, and fine finish. The nail prep consisted of removing the old nail polish, filing, trimming, and shaping the real nail, gluing the artificial nail extension on to the real nail, trimming the nail extension to an appropriate length, and roughening and priming the surface of the nail. The only difference between a full set and a fill-in was in this step, because a fill-in did not require the artificial extensions. Interestingly, a Dremel-like tool with a variable speed foot control was used in the roughening of the nail. The work with liquid monomer step consisted of the time the nail technician spent forming the artificial nail. The nail technician dipped a small brush into a small container of the liquid monomer, then into a container of powdered polymer, and then applied the mixture to the nail and formed it. During this step, the liquid container remained open the entire time and the smell of the vapors was very noticeable. The openings of the containers were approximately one and quarter inch in diameter. The fine finish step consisted of filing and shaping the artificial nail some more and smoothing the surface of the nail. The Dremel-like tool was also used in the fine finish. For the purpose of this analysis, the fine finish step ended when the customer was sent to wash the nail dust off their hands, although the nails may have been painted after washing. These procedures were used at both locations.
Nail salon 1 had four nail technicians working on the day of sampling. Three of the four nail technicians, nail tech A, B, and D, worked six or more hours. Nail technician C worked approximately 4 hours and went home early. Nail salon 2 had two employees who worked with artificial nails; however, arrangements were made so that only one of them would perform the majority of artificial nail work on the day of sampling. Therefore, only this nail technician served as a study subject. This nail technician worked approximately nine hours on the day of sampling.

The results of the task analyses for the application of a full set of artificial nails are reported in Table 4. For the purpose of this analysis, a procedure called a back-fill, which is a major fill-in, was grouped in the full set category. This decision was made because the time spent on each task and the amount of the liquid monomer used in a back-fill was similar to a full set of artificial nails. Unfortunately, nail salon 1 performed only four such procedures on the day of sampling and none of them was observed from the beginning. Therefore, only the time spent working with the liquid monomer, 15 minutes, was captured in a task analysis of nail technician B at nail salon 1. Nail salon 2 performed three full set procedures. A task analysis of one procedure revealed that 14 minutes were spent on nail preparation, 10 minutes were spent working with the liquid monomer, and 18 minutes were spent doing the fine finish. The percentage of time spent working with the liquid monomer was 24% of the total time of the procedure.
Table 4: Task analysis for the application of a full set of artificial nails

<table>
<thead>
<tr>
<th>Site Location</th>
<th>Nail Technician</th>
<th>Nail Prep (min)</th>
<th>Work with Liquid Monomer (Min)</th>
<th>Fine Finish (Min)</th>
<th>Total Time for Procedure (Min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salon 1</td>
<td>B</td>
<td>NR</td>
<td>15</td>
<td>NR</td>
<td>NA</td>
</tr>
<tr>
<td>Salon 2</td>
<td>TTM</td>
<td>14</td>
<td>10</td>
<td>18</td>
<td>42</td>
</tr>
</tbody>
</table>

NR = Not recorded
NA = Not Applicable

The results of the task analyses for the fill-in of a previously applied set of artificial nails are reported in Table 5. Nail salon 1 performed 22 such procedures. Nail technicians A, B, and D were observed once from start to finish and once again during the work with the liquid monomer. Therefore, the average of each technician’s time spent working with the liquid monomer was used in the overall task analyses. A task analysis of nail technician A revealed that 26 minutes were spent on nail prep, 17.5 minutes were spent working with the liquid monomer, and 17 minutes were spent on the fine finish. The percentage of time spent working with the liquid monomer was 29% of the total time of the procedure. A task analysis of nail technician B revealed that eight minutes were spent on nail prep, six minutes were spent working with the liquid monomer, and 14 minutes were spent on the fine finish. The percentage of time spent working with the liquid monomer was 21% of the total time of the procedure. A task analysis of nail technician D revealed that five minutes were spent on nail prep, eleven minutes were spent working with the liquid monomer, and 15 minutes were spent on the fine finish. The percentage of time spent working with the liquid monomer was 35% of the total time of the procedure.
Table 5: Task analysis for a fill-in of artificial nails

<table>
<thead>
<tr>
<th>Site Location</th>
<th>Nail Technician</th>
<th>Nail Prep (min)</th>
<th>Work with Liquid Monomer (Min) N=2†</th>
<th>Fine Finish (Min)</th>
<th>Total Time for Procedure (Min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>26</td>
<td>17.5</td>
<td>17</td>
<td></td>
<td>60.5</td>
</tr>
<tr>
<td>Salon 1</td>
<td>B</td>
<td>8</td>
<td>6</td>
<td>14</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>5</td>
<td>11</td>
<td>15</td>
<td>31</td>
</tr>
<tr>
<td>Salon 2</td>
<td>TTM</td>
<td>9</td>
<td>9</td>
<td>23</td>
<td>41</td>
</tr>
</tbody>
</table>

†Average of two observations

Nail salon 2 performed at least eight fill-in procedures. Task analyses of nail technician TTM revealed that nine minutes were spent doing nail prep, nine minutes were spent working with the liquid monomer, and 23 minutes were spent on the fine finish. The percentage of time spent working with the liquid monomer was 22 % of the total time of the procedure.
An estimate of each nail technician’s time spent working with the liquid monomer was calculated, see Table 6. The calculations were based on the sum of total numbers of each procedure times the estimated amount of time spent working with the liquid monomer for that procedure, respectively. Since nail technician C was not observed during either procedure, the time spent working with the liquid monomer was estimated from the averages of nail technicians A, B, D, and TTM for each procedure, respectively. Since nail technician D was not observed for a full set procedure, the time spent working with the liquid monomer for this procedure was estimated from the averages of B and TTM since they were the only nail technicians who were actually observed performing this procedure. Nail technician A spent an estimated 105 minutes working with the liquid monomer during the sampling periods. Nail technician B spent an estimated 78 minutes working with the liquid monomer during the sampling periods. Nail technician C spent

### Table 6: Estimate of the total time spent working with the liquid monomer

<table>
<thead>
<tr>
<th>Nail Technician</th>
<th># of Events</th>
<th>Estimated time working with liquid/Event (Min)</th>
<th># of Events</th>
<th>Estimated time working with liquid/Event (Min)</th>
<th>Total time working with liquid (Min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>17.5</td>
<td>105</td>
</tr>
<tr>
<td>B</td>
<td>2</td>
<td>15</td>
<td>8</td>
<td>6</td>
<td>78</td>
</tr>
<tr>
<td>C</td>
<td>1</td>
<td>12.5</td>
<td>2</td>
<td>10.9</td>
<td>34.3</td>
</tr>
<tr>
<td>D</td>
<td>1</td>
<td>12.5</td>
<td>6</td>
<td>11</td>
<td>78.5</td>
</tr>
<tr>
<td>TTM</td>
<td>3</td>
<td>10</td>
<td>8</td>
<td>9</td>
<td>102</td>
</tr>
</tbody>
</table>

*Time spent working with liquid monomer for both procedures estimated from averages of A - D and TTM

‡Time spent working with liquid monomer for full set estimated from averages of B and TTM
an estimated 34.3 minutes working with the liquid monomer during the sampling period.
Nail technician D spent an estimated 78.5 minutes working with the liquid monomer
during the sampling periods. Nail technician TTM spent an estimated 102 minutes
working with the liquid monomer during the sampling periods.

The work practices of the nail technicians varied considerably. At nail salon 1, it
was common for the nail technicians to eat and drink at their manicure tables whereas
this practice was not observed at salon 2. None of the salon 1 nail technicians used latex
gloves to guard against direct chemical contact with the skin; however, the salon 2 nail
technicians did. At both sites, nail debris was observed flying while clipping the nails
and using the Dremel-like tool and air-borne dust was generated during the filing process.
At nail salon 1, nail technician B used proper protective eye wear while nail technician A
relied on corrective lenses; nail technicians C and D did not use eye protection. Nail
technicians A and D did use dust masks; however, the masks did not appear to be very
tight fitting. The salon 2 nail technicians did use dust masks and appeared to use them
correctly; however, they did not wear protective eyewear.

Salon Lay-Out

Figure 1 shows the detailed interior lay-out of nail salon 1. This salon was 23 feet
wide, 36.8 feet long, and 7.9 feet high, and the internal volume of the salon was 6686.6
cubic feet. This salon had one air handler. Five supply diffusers and one return were
noted. No evidence of outside air introduction into the HVAC system was observed.
The salon had one window located in the bathroom, which does not appear in the
drawing, and one door. Four manicure tables were used for the purpose of applying
artificial nails. On the day of sampling, all four tables were used, labeled A, B, C, and D. Manicure tables A and B had local exhaust ventilation. Each nail technician worked at their respectively labeled manicure table.

Figure 2 shows the interior lay-out of nail salon 2. This salon was 31.6 feet wide, 34.7 feet long, and 8.3 feet high, and the internal volume of the salon was 9101.1 cubic feet. The salon’s owner stated that this salon had two separate air handlers. Ten supply diffusers and three returns were noted. No evidence of outside air introduction into the HVAC system was observed. This salon had one window located in the back corner and one door. Three manicure tables were used for applying artificial nails, and none of these tables had local exhaust ventilation. On the day of sampling, only two of the tables were used, labeled M and MN. Nail technician TTM worked at the tables labeled M interchangeably. The table labeled N represents the location of area sample TTN.
Figure 1: Interior lay-out of nail salon 1 (Not to Scale)

Legend

= Diffusers  = Return  = Manicure Table
Figure 2: Interior lay-out of nail salon 2 (Not to Scale)

Legend

= Diffusers
= Returns
= Manicure Table
= Window
Ventilation Assessment

The HVAC systems were evaluated for the total volume of air supplied and total air returned to the units. The air flows were measured in cubic feet per minute and taken with the doors and windows open and with them closed. This evaluation took place one week prior to the exposure assessment which was necessary to minimize the inconveniences imposed had this evaluation taken place on the day of the exposure assessment. Nail salon 1 operated their HVAC system with the doors and window closed on the day of sampling. Table 7 shows the different air volumes measured through the individual supply diffusers and the return, as well as the total supply volume. Based on the internal volume of the salon and the total volume of the air supplied by the HVAC, the calculated supplied air changes per hour (ACH) were six ACH with the door and the window closed. Nail salon 2 did not operate their HVAC systems but instead opened the window and the door to provide natural ventilation. Details regarding the air volumes and the supply ACH of both salons with the doors and windows open and with them closed are included in Appendix C.
Table 7: Ventilation assessment for nail salon 1

<table>
<thead>
<tr>
<th>Diffuser #</th>
<th>Air flow with door/window closed* (cfm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>120</td>
</tr>
<tr>
<td>1</td>
<td>137</td>
</tr>
<tr>
<td>2</td>
<td>137</td>
</tr>
<tr>
<td>3</td>
<td>178</td>
</tr>
<tr>
<td>4</td>
<td>92</td>
</tr>
<tr>
<td><strong>Total Supply (cfm)</strong></td>
<td><strong>664</strong></td>
</tr>
<tr>
<td><strong>Total Return Volume (cfm)</strong></td>
<td><strong>713</strong></td>
</tr>
</tbody>
</table>

*One door and one window

Analytical Results

Personal and area sampling were performed at nail salon 1 on Friday, February 2, 2007. The temperature and relative humidity inside this nail salon were 20.2 °C and 60.5 %, respectively. Personal and area sampling were performed at nail salon 2 on Saturday, February 3, 2007. The temperature and relative humidity inside this nail salon were 23.4 °C and 52.9 %, respectively. These two days were reported to be their busiest days of the week based on past information from the salons’ owners.

Detectable levels of both EMA and MMA were measured in both nail salons. Information regarding personal sample designation, sample times, sample volumes, and calibration information appears in Table 8 and Appendix D. A summary of the personal sample results and 8-hour time weighted averages (TWA) appears in Table 9. The 8-hour TWA was calculated under the conservative assumption that the exposure during the unsampled time was similar to the sampled time.
Table 8: Summary of personal sample and calibration information

<table>
<thead>
<tr>
<th>Location</th>
<th>Nail Technician</th>
<th>Sample Designation</th>
<th>Sample Time (min)</th>
<th>Sample Volume (Liters)</th>
<th>Percent Difference Pre and Post Pump Calibrations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salon 1</td>
<td>A</td>
<td>A1</td>
<td>190</td>
<td>7.670</td>
<td>4.0%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A2</td>
<td>198</td>
<td>7.478</td>
<td>6.7%</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>B1</td>
<td>275</td>
<td>11.477</td>
<td>1.3%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B2</td>
<td>258</td>
<td>10.780</td>
<td>1.5%</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>C1</td>
<td>206</td>
<td>8.721</td>
<td>5.5%</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>D1</td>
<td>309</td>
<td>12.952</td>
<td>2.5%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>D2</td>
<td>74</td>
<td>3.136</td>
<td>4.2%</td>
</tr>
<tr>
<td>Salon 2</td>
<td>TTM</td>
<td>TTM1</td>
<td>244</td>
<td>10.703</td>
<td>0.5%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TTM2</td>
<td>217</td>
<td>9.508</td>
<td>0.7%</td>
</tr>
</tbody>
</table>

Table 9: Summary of personal exposures to MMA and EMA

<table>
<thead>
<tr>
<th>Site Location</th>
<th>Personal Sample</th>
<th>MMA (ppm)</th>
<th>EMA (ppm)</th>
<th>Time (Min)</th>
<th>MMA (ppm)</th>
<th>EMA (ppm)</th>
<th>Time (Min)</th>
<th>8 - Hour TWA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salon 1</td>
<td>A</td>
<td>0.13</td>
<td>6.40</td>
<td>190</td>
<td>0.17</td>
<td>10.00</td>
<td>198</td>
<td>0.15</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>0.15</td>
<td>8.60</td>
<td>275</td>
<td>0.15</td>
<td>9.90</td>
<td>285</td>
<td>0.15</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>0.70</td>
<td>31.00</td>
<td>206</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>0.70</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>0.24</td>
<td>13.00</td>
<td>309</td>
<td>0.18</td>
<td>11.00</td>
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<tr>
<td>Salon 2</td>
<td>TTM</td>
<td>2.90</td>
<td>0.036†</td>
<td>244</td>
<td>7.7</td>
<td>0.041†</td>
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<tr>
<td></td>
<td>TTN*</td>
<td>2.60</td>
<td>0.033†</td>
<td>291</td>
<td>5.3</td>
<td>0.044†</td>
<td>218</td>
<td>3.76</td>
</tr>
</tbody>
</table>

* Indicates an area sample taken in the vicinity of the personal breathing zone
†Less than or equal to. The analyte was detected but at a level too low to accurately quantify.

One area sample was set up in the vicinity of the chemical storage area of nail salon 1. In this case it was a small room, not shown on the salon diagram, where towels were also washed. The door to this room remained open during the sample period. The
sample period lasted from 12:13 PM until 7:38 PM for a total sample time of 445 minutes at a flow rate of 39.9 ml/min. This area sample, sample E1, yielded a concentration of 7.5 ppm for EMA and 0.14 for MMA. Analysis of a three liter sample of the vapors from the liquid monomer bottle supplied by this salon yielded a concentration of 5300 ppm of EMA and 100 ppm of MMA (see Sampling Strategy). However, these values should be considered approximate values since the EMA concentration was above the upper calibration standard of the analytical method and both samples contained analytes on the back-up section of the charcoal tube. A sample blank submitted with the nail salon 1 samples was reported below the detection limits for both chemicals. No air was sampled through this sample blank. A copy of the WOHL Analytical Laboratory Report for the nail salon 1 samples appears in Appendix E.

An area sample was attached to the light of manicure table MN at nail salon 2. This area sample was positioned directly over the work space and approximately one and a half feet from nail technician TTM’s face. Two area samples were collected at this table. The first area sample, sample TTN1, was collected from 9:30 AM until 2:21 PM for a total time of 291 minutes at a flow rate of 40.1 ml/min. Sample TTN1 yielded a concentration of 2.6 ppm of MMA and approximately 0.03 ppm of EMA. The later value was only approximate because the analyte was detected but at a level too low to be accurately quantified. The second area sample, sample TTN2, was taken from 2:30 PM until 6:08 PM for a total time of 218 minutes at a flow rate of 39.8 ml/min. Sample TTN2 yielded a concentration of 5.3 ppm of MMA and approximately 0.04 ppm of EMA. The later value was considered approximate for the same reason as described
above. The TWA for these area samples, based on the time sampled, were 3.8 ppm MMA and approximately 0.04 ppm EMA.

One area sample was set up in the vicinity of the chemical storage area of nail salon 2. In this case it was a room, not shown on the salon diagram, that also contained a refrigerator and a bed. The door to this room remained closed during the sample period. The sample period lasted from 10:19 AM until 6:17 PM for a total sample time of 478 minutes at a flow rate of 39.5 ml/min. This area sample, sample TTP1, yielded a concentration of 1.1 for MMA and 0.03 ppm for EMA. Analysis of a three liter sample of the vapors from the liquid monomer bottle supplied by this salon yielded a concentration of 5400 ppm of MMA and 4.1 ppm of EMA (see Sampling Strategy). These values should be considered approximate values since the MMA concentration was above the upper calibration standard of the analytical method and both samples contained analytes on the back-up section of the charcoal tube. A sample blank submitted with the nail salon 2 samples was reported below the detection limits for both chemicals. No air was sampled through this sample blank. A copy of the WOHL Analytical Laboratory Report for the nail salon 2 samples also appears in Appendix E.
DISCUSSION AND CONCLUSIONS

The purpose of this study was to characterize nail technicians’ exposures to ethyl methacrylate (EMA) and methyl methacrylate (MMA). The literature was reviewed for information regarding occupational exposure to these chemicals, the associated health effects, and more specifically, for information on nail technicians’ exposure to these chemicals. This review indicated that allergic contact dermatitis and occupational asthma may be associated with chronic exposure to these chemicals. The review also indicated that nail technicians’ exposures to these chemicals have not been well characterized.

This study sought to quantitatively evaluate nail technicians’ personal exposure to EMA and/or MMA vapors and describe the conditions under which the exposures occurred. The breathing zones of nail technicians were sampled over the course of a workday. Additionally, a task analysis was performed to determine the total number of clients seen by each nail technician, the time spent with one client, the percentage of time spent working with the liquid monomer, and the approximate time each nail technician spent working with the liquid monomer during the sampling periods. The interiors of two different nail salons were described in detail in relation to where the artificial nail processes took place. The HVAC systems were assessed to determine the number of supply air changes per hour that could have been provided on the day of sampling with the doors and windows open and then closed. This study captured personal exposures to both chemicals and was successful in determining how and under what conditions these
exposures occurred. This information was necessary for a complete understanding of the personal exposures.

Discussion

The analytical results reported in this study appear consistent with what other studies have reported. One aspect that made this study unique was the fact that the majority of samples collected were personal. Another important aspect of this study was the completeness of the exposure assessment. Also, this study attempted to use an Asian owned nail salon and was successful in doing so. This was important because a large number of nail salons in the U.S. are Asian owned.

Detectable levels of EMA and MMA were found in air samples of nail technicians’ personal breathing zones taken at the nail salon 1 site. Nail technicians at this site were mainly exposed to EMA. Personal exposures ranged from 8.2 – 31.0 ppm EMA as an 8-hour TWA. A number of variables, such as the time spent with a client, the time spent working with the liquid monomer, presence of local exhaust ventilation, and proximity to HVAC diffusers, likely contributed to the differences in personal exposures seen between nail technicians. Nail technician A was the owner of this nail salon and her total time spent performing a fill-in procedure was about twice the time that the other two nail technicians, who were task analyzed, spent on this same procedure. She conversed extensively with her clients because she likely had developed a rapport with them over time. At the same time, her workers may have worked faster so as to make more money. Interestingly, although the total time spent on this procedure was quite different, the percentage of time spent working with the liquid monomer was similar between nail
technicians at this site, approximately one-quarter to one-third of the total time of the procedure. In fact, the percentage of time working with the liquid was similar between both procedures and both sites.

It was noted in the results section that manicure tables A and B at this salon were equipped with local exhaust ventilation. This ventilation was not assessed for its effectiveness; however, both were operational. Nail technician A worked closely over the local exhaust and nail debris and dust were observed being captured. Nail technician B however did not work as closely over the local exhaust with little debris observed being picked up by the exhaust system. Initially, it was expected that there would be a larger difference between nail technician A and B’s personal exposures, 8.2 ppm and 9.3 ppm, respectively. This initial expectation was based not only on the behavior of nail debris and nail dust entering the local exhaust but also on the fact that extensive nail dust was collected on nail technician B’s sampling tube holder bypass. This was not observed on nail technician A’s tube holder. There did, however, seem to be a difference in these individuals’ exposures when compared to nail technicians C and D, who did not have local exhaust provisions. Nail technician C had an 8-hour TWA, based on an approximate three and a half hour sample time, of 31 ppm of EMA and nail technician D had a 12.6 ppm 8-hour TWA for EMA. It may be possible that the local exhaust ventilation played a role in reducing nail technician A and B’s exposure.

Nail technician C at the salon 1 site who had an EMA exposure of 31 ppm had her sample collected over a period of 206 minutes. She performed only one full set and two fill-in procedures; yet her exposure was almost three times higher than the next highest
personal exposure at this salon. It may be possible that this measured exposure was in fact their personal exposure from their job; however, work practices that were not observed could have likely played a role in this higher exposure. Another possible explanation for this result was that the personal sample was tampered with, but no evidence of this was observed.

Detectable levels of EMA and MMA were measured at nail salon 2. Personal air sampling of one nail technician and an area sample set up in the vicinity of his personal breathing zone indicated that MMA was the main chemical exposure at this nail salon. Nail technician TTM’s 8-hour TWA indicated a personal exposure to 5.2 ppm MMA and the area samples, TTN1 and TTN2, yielded a TWA concentration of 3.8 ppm MMA. The area sample was likely lower because the nail technician did not work solely at that particular manicure table. The results from the grab vapor sample and the personal and area samples clearly suggested that MMA was being used in this nail salon despite the FDA’s ban on its use in nail products. This result was particularly surprising since the bottle that the grab vapor sample was taken from was labeled “No MMA.”

Nail salon 1 operated its HVAC unit during the exposure assessment and the door and window were closed. This was not the case at nail salon 2. The door and window were open and the HVAC system was not used. A strong cross-draft through the salon was noted throughout the day. Nail salon 2 had lower personal exposures to MMA compared to the levels of EMA found at nail salon 1. It is possible that natural ventilation played a role in lowering the concentrations of airborne chemicals at nail salon 2, especially since MMA has a higher vapor pressure and more chemical vapors
should have been generated. Hiipakka and Samimi (1987) also suggested that natural ventilation could help reduce airborne chemical exposures in nail technicians.

The HVAC systems were evaluated at both sites; however, this information was only relevant to nail salon 1 where the HVAC was in operation. Both evaluations are included in Appendix C. Nail salon 1’s HVAC provided six supply air changes per hour (ACH) with the door and window closed. There are no recommended air change rates provided by Burton for nail salons or beauty shops (Burton, 1995). If the light factory operations category for typical air change rates is applied to salon operations, six supply ACH seemed like a reasonable amount and possibly within the lower ranges of the recommendation (Burton, 1995). The American Society of Heating, Refrigerating, and Air-Conditioning Engineers recommends 25 cubic feet per minute of outside air per person be introduced into a beauty shop (ASHRAE, 2001). It was not clear if this recommendation was met. It was initially thought that diffuser locations and the air flows through them might influence the exposure; however, it was impossible to deduce how that interaction might have occurred.

The exposures that occurred at nail salon 1 may more closely resemble nail technicians’ personal exposures in the Tampa Bay area. Most of the year it is hot and humid here and it is likely that most small businesses, like nail salons, would keep their doors and windows closed and operate their HVAC systems to keep the indoor environment comfortable. It is also likely that most nail salons would be using EMA since MMA has been banned for nail use. Although personal exposures to these chemicals are highly variable, it is likely that personal exposures would be low. The
United States does not have any Occupational Exposure Limits (OELs) for EMA. If the Occupational Safety and Health Administration’s Permissible Exposure Level for MMA, which is 100 ppm for an 8-hour TWA, is applied to EMA, the exposures obtained in this study are much less than half of this value. If the American Conference of Governmental Industrial Hygienist’s Threshold Limit Value for MMA, which is 50 ppm for an 8-hour TWA, is also applied to EMA, only nail technician B’s exposure would have exceeded the action level, which is one-half the TLV. Interestingly though, some of the exposures obtained from nail salon 1 would have exceeded the OELs that some other nations, such as the Netherlands, Sweden, and the former Soviet Union, have recommended or established.

The nail technicians at salon 1 were not observed using gloves to protect against chemical contact with the skin. It was therefore likely some chemical contact with the skin could have occurred; although, this was not actually observed. Because direct skin contact has been associated with the development of allergic contact dermatitis (ACD), the possibility of these workers developing ACD exists. NIOSH does not recommend the use of latex gloves for this application because of the potential for chemical permeation; however, the recommended gloves made of polyvinyl alcohol or laminates of plastic films would probably not be appropriate due to the limitations in dexterity that these materials would impose (NIOSH, 2005).

**Conclusion**

Detectable levels of ethyl methacrylate and methyl methacrylate were both measured at two Tampa Bay area nail salons. Personal exposures ranged <1 – 31 ppm of EMA and
<1 – 5.2 ppm MMA. These levels were below any U.S. occupational exposure level in
place or suggested. Local exhaust ventilation seemed to make a difference in reducing
personal exposure levels. The type of general ventilation, whether HVAC use or natural,
used in the salon also seemed to make a difference in exposure levels. Natural ventilation
seemed to dilute the concentrations of airborne chemicals in the salon by the introduction
of outside air.

The analytical results strongly suggested that MMA was being used at nail salon 2.
A manufacture’s bottle of liquid monomer stated that it contained “NO MMA.” The
possibility therefore exists that MMA substitution is occurring in some nail salons despite
a ban on its use.

Task analyses of the different nail procedures resulted in considerable differences in
the time it took different nail technicians to perform a procedure; however, the percentage
of time spent working with the liquid monomer was similar between nail technicians and
nail procedures. The time spent working with the liquid monomer varied between 20 –
35 % of the total procedure.

Recommendations for Future Research
Based on the findings from this study, the following recommendations for future research
are provided. These include:

- Expand the study and select a more representative sample of nail salons in the
  community to better characterize personal exposure levels of EMA and/or
  MMA in the Tampa Bay area.
• Expand the time frame to include more personal monitoring of nail technicians at the same sites on different days.

• Conduct a cross-sectional epidemiological study that uses surveys designed to measure current health problems and personal sampling to assess the exposure.

• Conduct a prospective epidemiological study, with physiological measures, to determine what, if any, long-term health effects occur to chronic, low level exposures to EMA and MMA.

• Conduct inhalation challenge testing, coupled with spirometry and other physiological measures, of volunteer nail technicians to assess the extent of airway reactivity in this population of workers.

• Sample all nail salons in the city to determine the frequency of use of MMA.
REFERENCES CITED


BIBLIOGRAPHY


APPENDICES
Appendix A: OSHA Method 7

Organic Vapors

(See section 4)

Method no.: 07

Matrix: Air

OSHA PELs: Section 4

Procedure: Collection on charcoal, extraction with an organic solvent, and analysis by gas chromatography with flame ionization detector.

Recommended air volume and sample rate: Section 4

Status of method: This method has been used extensively in the OSHA Salt Lake Technical Center. With slight modification, this method is a generalized version of validated NIOSH methodology.

Date: May 1979

Last Update: May 2000

By: Organic Methods Evaluation Branch
By: Methods Development Team

Methods Development Team
Industrial Hygiene Chemistry Division
OSHA Salt Lake Technical Center
Salt Lake City, UT 84115-1802

1. General Discussion

1.1 Background

Background information on the analytes may be obtained from a number of sources such as NIOSH Criteria Documents, chemical dictionaries and Industrial hygiene manuals. Solvents are used for degreasing, for dry cleaning, and in the manufacture of many materials ranging from paints, varnishes, shells, and lacquers to rubber and synthetic resins. When not being used as solvents, they may function as fuels or act as chemical intermediates with or without regard to their ability to put materials into solution. Toxic effects of the analytes vary with many acting as irritants or causing narcosis, and some having more hazardous effects.

1.2 Statistical parameters

1.2.1 Each analyte included in this general procedure has a validated NIOSH method, (Ref. 5.1) and/or a validated OSHA method. One of the NIOSH validation requirements is that the
Appendix A (Continued)

results obtained be within ±25% of the true values at the 95% confidence level at the air concentration equal to the OSHA standard. Although the OSHA evaluation procedure differs from that of NIOSH, the same validation requirements are used.

1.2.2 Refer to the validated NIOSH methods, (Ref. 5,1) for detailed information on individual analytes.

1.3 Advantages

1.3.1 The sampling device is small, portable, and involves no liquids.

1.3.2 The analysis is by a quick instrumental method.

1.3.3 Interferences can be eliminated by altering chromatographic conditions in most cases.

1.3.4 The method allows simultaneous analysis of two or more analytes.

1.4 Disadvantages

1.4.1 The air volume sampled is limited by the capacity of the charcoal tubes. Exceeding the capacity of the charcoal tube results in loss of sample. The adsorptive capacity is decreased by high humidity.

1.4.2 The method is limited by the reproducibility of the pressure drop across the tubes. The pressure drop affects the flow rate causing the air volume to be imprecise.

1.4.3 The analyst must work with toxic solvents.

1.4.4 When many components are present, elimination of interferences becomes difficult.

2. Sampling Procedure

2.1 Apparatus

2.1.1 A calibrated personal sampling pump whose flow can be determined within ±5% at the recommended flow rate with the sampling device attached.

2.1.2 Charcoal tubes: Glass tubes with both ends flame sealed, 7 cm long with a 6-mm o.d. and 4-mm i.d. containing two sections of 20/40 mesh activated charcoal separated by a 2-mm portion of urethane foam. The activated charcoal is prepared from coconut shells and is fired at 600°C prior to packing. The adsorbing section contains 100 mg of charcoal, the backup section 50 mg. A 5-mm portion of urethane foam is placed between the outlet end of the tube and the backup section. A plug of silanized glass wool is placed in front of the adsorbing section. The pressure drop across the tube must be less than 1 in. of mercury at a flow rate of 1 L/min.

2.1.3 Certain analytes require petroleum base charcoal instead of coconut base charcoal. This requirement is specified in Section 4.

2.2 Reagents

None required in sampling procedure.

2.3 Technique

2.3.1 Immediately before sampling, break the ends of the tube to provide an opening at least

one-half the internal diameter of the tube (2 mm).

2.3.2 The smaller section of charcoal is used as a backup and should be positioned nearest the sampling pump.

2.3.3 The charcoal tube should be placed vertically during sampling to minimize channeling.

2.3.4 Air being sampled should not be passed through any hose or tubing before entering the charcoal tube.

2.3.5 Do not exceed the recommended air volume.

2.3.6 The charcoal tubes should be capped with the supplied plastic caps immediately after sampling. Under no circumstances should rubber caps be used.

2.3.7 One tube should be handled in the same manner as the sample tube (break, seal and transport) except that no air is sampled through this tube. This tube should be labeled as a blank.

2.3.8 Capped charcoal tubes should be wrapped end to end with official OSHA seals. They should be packed tightly and padded before they are shipped to minimize tube breakage during shipping.

2.3.9 For certain analytes where migration on the charcoal is a significant problem, it may be requested that two charcoal tubes be used in series in order that breakthrough may be distinguished from migration. These tubes must be separated and individually capped and sealed before shipping.

2.4 Breakthrough

Breakthrough data is presented on each analyte in its respective validated NIOSH method (Ref. 5.1).

2.5 Extraction efficiency

2.5.1 The back end of a charcoal tube is opened and the backup portion of activated charcoal is removed, leaving the front 100-mg portion of activated charcoal intact in the tube. The activated charcoal must be of the same lot as that in the tubes used to collect the samples. A known amount of analyte is injected directly into the activated charcoal with a microsyringe and the tube is capped.

2.5.2 Six tubes at each of three concentration levels (3.5, 1, and 2 times the standard) are prepared by adding an amount of analyte equivalent to that present in a recommended air sample at the selected level. The tubes are allowed to stand at least overnight to assure complete adsorption of the analyte onto the charcoal. These tubes are referred to as the samples. A parallel blank tube should be treated in the same manner except that no analyte is added to it. The sample and blank tubes are extracted and analyzed in exactly the same manner as the sampling tube described in Section 3.

2.5.3 The extraction efficiency \( E_E \) equals the average weight in milligrams recovered from the tube divided by the weight in milligrams added to the tube, or

\[
E_E = \frac{M_E}{M_B}
\]

where: \( E_E \) is extraction efficiency

Appendix A (Continued)

Organic Vapors

$M_R$ is mass recovered
$M_S$ is mass spiked

2.5.4 If there is a significant change in extraction efficiency over the range of loadings studied, a plotted curve of $E_E$ versus mass recovered must be used to correct for adsorption losses.

2.5.5 If there is no significant change in $E_E$ over the range studied, reconfirmations need only be carried out at one loading in the middle of the range.

2.6 Recommended air volume and sample rate

See Section A. for recommended air volume and sampling rate.

2.7 Interferences

2.7.1 It is important to be aware of other components in the atmosphere which may interfere with the collection of the analyte.

2.7.2 High relative humidity may significantly affect the collection of some analytes.

2.8 Safety precautions

2.8.1. Care must be taken when opening the sealed ends of charcoal tubes to avoid cuts to the hands.

2.8.2. Safety glasses should be worn when opening the sealed ends of charcoal tubes to avoid injury to the eyes from glass splinters.

3. Analytical procedure

3.1 Apparatus

3.1.1 Gas chromatograph equipped with flame ionization detector.

3.1.2 Columns. A variety of columns are suitable. Two good selections are a 60-m x 0.32 mm DB-1 capillary column with 1μm df or a 60-m x 0.52 mm DB-Wax capillary column with 1 μm df. Similar columns from other manufactures are acceptable.

3.1.3 A suitable method of measuring peak areas, such as an electronic integrator or data system.

3.1.4 Two-milliliter vials with either screw-on or crimp-on caps which contain PTFE-lined septa.

3.1.5 Microliter syringes; one-microliter for GC injections and 10-μL for standard preparation, or other suitable sizes.

3.1.6 Pipets for dispensing extracting solvent (ES). A Gilson 1-mL reagent dispenser is adequate and convenient.

3.1.7 Volumetric Flasks, Five-milliliter and other convenient sizes.

3.1.8 Glass tubing cutter.

http://www.osha.gov/dts/uste/organic/or067/or067.html

3/16/2007
Appendix A (Continued)

3.2 Reagents

3.2.1 Chromatographic quality extracting solvent (ES). Although carbon disulfide is commonly used as the ES, certain analytes can be more effectively extracted with the use of alternate solvents or solvent solutions. These alternate ESs are listed in Chemical Sampling Information located at http://www.osha.gov and are normally used when the single analyte is requested or when the requested analytes are known to be effectively extracted with that ES. When analysis for a number of analytes requiring different extracting solutions is requested, the preferred ES will usually be carbon disulfide.

3.2.2 Analyte standard, reagent grade.

3.2.3 Internal standard, (optional) reagent grade. p-Cymene and n-hexylbenzene are suitable internal standards for many solvents.

3.2.4 Chromatographic quality helium, nitrogen, hydrogen, and air.

3.3 Standard preparation

3.3.1 Prepare analyte standard at a concentration of 1 μL of analyte per milliliter of ES by adding 5 μL of analyte to a 5-mL volumetric flask partially filled with ES. Fill the volumetric flask to the mark and invert 3 or 4 times for proper mixing. Other size volumetric flasks may also be used to prepare the 1 μL/mL analyte standards. At least two standards at 1 μL/ML are prepared. Standards must be used the day they are prepared. In some cases, analytic standards in concentrations other than 1 μL/ML may be more suitable, especially with analytes that have extremely high or low OSNA standards.

3.3.2 Injection of standards is accomplished with a 1-μL or other suitable syringe. The syringe is rinsed thoroughly in carbon disulfide between standards. Injector septa should be checked for wear daily.

3.3.3 Injection sizes other than 1-μL and injection by means of a gas chromatograph autosampler are acceptable in most cases.

3.4 Preparation of samples

3.4.1 The status of the seals on each charcoal tube is noted and recorded as intact, broken, or none.

3.4.2 The field identification number, the laboratory identification number and signature of the industrial hygienist on each sample seal are checked with those on the sample identification sheets.

3.4.3 The seal is removed and the charcoal tube is opened with a glass tubing cutter at the end containing the larger portion of charcoal. The front and back sections of charcoal are transferred to separate 2-mL capped vials. The glass wool plug and the small wad of urethane foam separating the two sections of charcoal are discarded.

3.4.4 The charcoal lot number is noted in order that the proper extraction efficiency is used in later calculations.

3.4.5 Gas chromatography parameters are set as recommended in the Instruments manual. Oven temperature and column are varied until an optimum chromatogram is produced by the analyte standard.

3.4.6 Once the internal standard has been verified as not interfering with other peaks in the chromatogram, the samples are extracted. One milliliter of ES is dispensed into each sample


3/16/2007
Appendix A (Continued)

viial. The viial is immediately sealed. Each viial is swirled periodically to increase the rate of extraction. Twenty to thirty minutes is typical for the extraction process.

3.5 Analysis

3.5.1 The data processor can be calibrated to provide results directly in units of mass. With a few of the analytes an additional similar correction may be necessary due to extraction efficiencies that change with concentration. The linear nature of the flame ionization detector allows the use of a point calibration, but the bracketing of samples with analytical standards is a good practice. The calculation of the equivalent air concentration for an analytical standard is detailed in Section 3.7.1.

3.5.2 Sample injection is accomplished with a 1-µL or other suitable syringe. The syringe is rinsed thoroughly in carbon disulfide between samples. Injector septa should be checked for wear periodically. Injection by means of a gas chromatograph autosampler is acceptable.

3.5.3 Bracket the samples with analytical standards if detected concentrations are above the PEL.

3.5.4 When the identity of a suspected analyte peak is in question, it should be confirmed by GC/MS, GC/IR, or by retention time on at least two GC columns containing different packing material. The identity of the analyte should be considered suspect when detected concentrations are above the PEL.

3.6 Interferences

Interferences to the analytical method will in most cases appear as poor resolution of the analyte peak from other components. This may be overcome by prudent selection of a more suitable chromatographic condition or column.

3.7 Calculations

3.7.1 An equivalent air concentration for analytical standards is used to calibrate the data processor such that analytical results are obtained directly in mass, mg.

\[ W = V_s \times d \]

Where:
- \( W \) is weight of analyte in µg
- \( V_s \) is volume of analyte in µL
- \( d \) is density of analyte in µg/µL

\[ C_V = \frac{V_s W}{M_r V E_E} \]

Where:
- \( C_V \) is air concentration reported to IH
- \( V_M \) is molar volume at 25°C and 760 mmHg, 24.46 L/mol
- \( W \) is weight of analyte
- \( M_r \) is molecular weight of the analyte
- \( V \) is air volume sampled
- \( E_E \) is extraction efficiency


56
3.7.2 The following example is the calculation for toluene:

\[ W = 867 \, \mu g \times 1 \, \mu L \times 867 \, \mu g/\mu L \]

\[ C_V = \frac{(24.45 \, L/mo)(867 \, \mu g)}{(92.15 \, g/mo)(10 \, L)(0.97)} \]

The calculations should be considered an example only, and various parameters confirmed before used in actual analysis.

3.8 Safety precautions

3.8.1 Care must be taken when opening charcoal tubes to avoid cuts to the hands.

3.8.2 Safety glasses must be worn throughout the analytical procedure.

3.8.3 Work involving solvents open to the atmosphere must be performed in a hood.

3.9 Reporting results

3.9.1 When results uncorrected for air volume are greater than 10 ppm, three significant digits will be reported. For results below 10 ppm, the chemist will use his judgment, but in no cases report more than three significant digits.

3.9.2 The estimated detection limit based on the lowest mass per sample injected as a standard.

3.9.3 All concentration levels down to the detection limit are reported.

3.9.4 If the concentration of analytes found on the back section of the charcoal tube is equal to or greater than 25% of the concentration found on the front section, the charcoal tube is considered to be saturated and reported as such on the analyst worksheet.

3.9.5 The presence of significant peaks caused by unrequested components in the sample is noted on the analyst worksheet and they are identified and quantitated if possible.

3.9.6 All data processor print-outs and chart recorder chromatograms are filed in a central file according to laboratory sample identification number.

3.9.7 Analytical data and results are checked by a fellow chemist before the completed analyst worksheets are given to the team leader.

1. Analytes

The following table contains those analytes which can be analyzed by this procedure. Standard size charcoal tubes containing coconut base charcoal are used unless specified otherwise in the table. Listed PELs are 8-h time weighted averages unless denoted as a ceiling concentration with a "(C)", before the PEL value. Before taking samples, the OSHA Chemical Sampling Information at [http://www.osha.gov](http://www.osha.gov) should be consulted for additional and more detailed information.

<table>
<thead>
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<th>Analyte</th>
<th>PEL</th>
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Table 4. Recommended Sampling Parameters for Analytes Covered by This Procedure.

3/16/2007

### Appendix A (Continued)

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<th>Analyte</th>
<th>PEL (ppm)</th>
<th>air vol (L)</th>
<th>max rate (L/min)</th>
<th>NIOSH Method</th>
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<tbody>
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<td>10</td>
<td>0.2</td>
<td>1402</td>
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<td>48</td>
<td>0.2</td>
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<td>125</td>
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3/16/2007

58
### Appendix A (Continued)

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Appendix A (Continued)

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*Use two charcoal tubes in series for sampling.
**Use petroleum base charcoal for sampling.

References

## Desorption/QC Development Spreadsheet

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<th>Substance</th>
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<th>Instrument (FID)</th>
<th>Solvent</th>
<th>Description solvent</th>
<th>Sequence file</th>
<th>Column</th>
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<td>806</td>
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**Spreadsheet Details:**
- **Prep Date:** 3/05/2002
- **Prepared by:** DP
- **Notebook Reference:** Spilled neat
- **Density:** 1.058 g/cc
- **Standard (mg, let):** Aldrich Lot BL 05310 PU
- **Data received/opened:** 5/18/2000
- **Matrix:** SKG SCT lot 2003 in injection vials

### Standards

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<th>Area 2</th>
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### Samples

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<th>Rf (ug)</th>
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### Conclusions:

The notes on the old curve state that the curve was not the best fit at the low end, which is verified here. The new curve approximates this set of data better than the old curve.
Appendix B (continued)

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Appendix B (Continued)

Desorption/QC Development Spreadsheet

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<td>Analytical:</td>
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<td>Standard (mfg, lot):</td>
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<td>Date (received, opened):</td>
<td>11/12/2003</td>
<td></td>
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<tr>
<td>Media:</td>
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Standards

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<th>Standard prep reference</th>
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<td>917</td>
<td>2749909</td>
<td>3.335E-04</td>
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Samples

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<th>Area</th>
<th>Recov (ug)</th>
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<th>Corrected Results</th>
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<tr>
<td>320E - 1</td>
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<td>0.000</td>
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<td>55.189</td>
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<td>55.592</td>
<td>80.803</td>
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<td>98.517</td>
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<td>218.164</td>
<td>79.303</td>
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<td>95.302</td>
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<td>76.850</td>
<td>97.532</td>
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<td>81.904</td>
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<td>320E - 23</td>
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<td>102.716</td>
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<td>4598701</td>
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<td>85.619</td>
<td>103.488</td>
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<td>1624</td>
<td>4598700</td>
<td>1544.065</td>
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Conclusions:

Data was used to set a desorption curve of final result = recovered/(0.001/0.077*recovered*recovered+0.00298*recovered+0.6269)
## Appendix C: Ventilation assessments for both nail salons

**Table 9: Ventilation assessment for both nail salons***

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<thead>
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<th>Nail Salon 1</th>
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<th>Nail Salon 2</th>
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<tr>
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<td>Door/Window</td>
<td>Door/Window</td>
<td>Door/Window</td>
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<tr>
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<td>Open (cfm)</td>
<td>Closed (cfm)</td>
<td>Open (cfm)</td>
<td>Closed (cfm)</td>
</tr>
<tr>
<td>0</td>
<td>118</td>
<td>120</td>
<td>184</td>
<td>177</td>
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<tr>
<td>1</td>
<td>140</td>
<td>137</td>
<td>197</td>
<td>200</td>
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<tr>
<td>2</td>
<td>135</td>
<td>137</td>
<td>168</td>
<td>164</td>
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<td>3</td>
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<tr>
<td>5</td>
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<td>NA</td>
<td>175</td>
<td>171</td>
</tr>
<tr>
<td>6</td>
<td>NA</td>
<td>NA</td>
<td>182</td>
<td>181</td>
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<tr>
<td>7</td>
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<tr>
<td>9</td>
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<tr>
<td>Total Supply (cfm)</td>
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<td>664</td>
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<td>Return Volume (cfm)</td>
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<td>713</td>
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<td>ACH</td>
<td>5.9</td>
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*One door and one window
## Appendix D: Pump calibration information

<table>
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<tr>
<th>Location/Site</th>
<th>Nail salon 1</th>
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<tbody>
<tr>
<td><strong>Method</strong></td>
<td>WOHL WG006</td>
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<tr>
<td><strong>Pump Info</strong></td>
<td>AP Buck - A</td>
</tr>
<tr>
<td><strong>WOHL Lot #</strong></td>
<td>2000</td>
</tr>
<tr>
<td><strong>Tube #</strong></td>
<td>1676418010</td>
</tr>
<tr>
<td><strong>Sample ID</strong></td>
<td>A1 A2 A3</td>
</tr>
<tr>
<td><strong>Calibration Date</strong></td>
<td>Pre-cal Post-Cal Pre-cal Post-Cal Pre-cal Post-Cal</td>
</tr>
<tr>
<td>02/02/07</td>
<td>1024 1334</td>
</tr>
<tr>
<td><strong>Average L/min</strong></td>
<td>0.0412 0.0403 0.0422 0.0415 0.0412 0.0433</td>
</tr>
<tr>
<td><strong>Percent Difference</strong></td>
<td>4.0 1.3 -5.5</td>
</tr>
<tr>
<td><strong>AVERAGE L/min</strong></td>
<td>0.0404 0.0417 0.0423</td>
</tr>
<tr>
<td><strong>Total Sample Time (min)</strong></td>
<td>190 275 206</td>
</tr>
<tr>
<td><strong>Total Air Volume (L)</strong></td>
<td>7.670 11.477 8.721</td>
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<table>
<thead>
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<th>Location/Site</th>
<th>Nail Salon 1</th>
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</thead>
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<td>WOHL WG006</td>
</tr>
<tr>
<td><strong>Pump Info</strong></td>
<td>AP Buck - D</td>
</tr>
<tr>
<td><strong>WOHL Lot #</strong></td>
<td>2000</td>
</tr>
<tr>
<td><strong>Tube #</strong></td>
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<tr>
<td><strong>Sample ID</strong></td>
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<tr>
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<td>02/02/07</td>
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<tr>
<td><strong>Average L/min</strong></td>
<td>0.0425 0.0419 0.0399 0.0400 0.0391 0.0365</td>
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<tr>
<td><strong>Percent Difference</strong></td>
<td>2.5 -0.7 6.7</td>
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<tr>
<td><strong>AVERAGE L/min</strong></td>
<td>0.0419 0.0399 0.0378</td>
</tr>
<tr>
<td><strong>Total Sample Time (min)</strong></td>
<td>309 445 198</td>
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<tr>
<td><strong>Total Air Volume (L)</strong></td>
<td>12.952 17.741 7.478</td>
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## Appendix D (Continued)

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<td></td>
<td>AP Buck - D</td>
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<td>0.0414</td>
<td>0.0417</td>
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</table>

| Average L/min | 0.0415 | 0.0421 | 0.0415 | 0.0433 |

| Percent Difference | -1.5 | -4.2 |

| AVERAGE L/min     | 0.0418 | 0.0424 |

| Total Sample Time (min) | 258 | 74 |

| Total Air Volume (L) | 10.780 | 3.136 |
Appendix D (Continued)

<table>
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<tr>
<td>WOHL Lot #</td>
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<tr>
<td>Tube #</td>
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<table>
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<th>TTP1 (area chem storage)</th>
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<th>TTN1 (attached to Light)</th>
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<th>Post-Cal 1817</th>
<th>Pre-cal 1012</th>
<th>Post-Cal 1416</th>
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<td>0.0390</td>
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<td>0.0436</td>
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<td>0.0407</td>
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</table>

| Average L/min | 0.0400 | 0.0391 | 0.0438 | 0.0440 | 0.0397 | 0.0405 |
| Percent Difference | 2.3 | -0.5 | -1.8 |

| AVERAGE L/min | 0.0395 | 0.0439 | 0.0401 |
| Total Sample Time (min) | 478 | 244 | 291 |
| Total Air Volume (L) | 18.889 | 10.703 | 11.669 |

---

<table>
<thead>
<tr>
<th>Location/Site</th>
<th>Nail Salon 2</th>
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<td>Method</td>
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</tr>
<tr>
<td>Pump Info</td>
<td>AP Buck - D</td>
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<td>WOHL Lot #</td>
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<td>Tube #</td>
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<th>TTN2 (attached to light)</th>
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<th>Post-Cal 1758</th>
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<th>Post-Cal 1808</th>
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<td>0.0436</td>
<td>0.0439</td>
<td>0.0398</td>
<td>0.0398</td>
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</tbody>
</table>

| Average L/min | 0.0440 | 0.0437 | 0.0398 | 0.0397 |
| Percent Difference | 0.7 | 0.3 |

| AVERAGE L/min | 0.0438 | 0.0398 |
| Total Sample Time (min) | 217 | 218 |
| Total Air Volume (L) | 9.508 | 8.669 |
Appendix E: Analytical Laboratory Reports and COCs

Analytical Laboratory Report

February 20, 2007
ADAM MARTY

Report ID: 9056584

PROJ

Date Collected: 2/2/2007
Date Received: 2/6/2007
Date of Analysis: 2/13/2007
Date Reported: 2/20/2007

Analyst:

PATRICK RILEY, Chemist
rileypl@mail.slb.wisc.edu

Reviewer:

STEVE STREBEL, Organic Supervisor
st}@mail.slb.wisc.edu

WOHL uses only verified, secured electronic signatures on reports. These signatures are as valid as original handwritten signatures.
If you have any questions regarding this report please feel free to contact the laboratory via email (as listed above) or via telephone at 800-446-0403

Report ID: 9056584
<table>
<thead>
<tr>
<th>LAB NUMBER</th>
<th>DESCRIPTION</th>
<th>AIR VOLUME</th>
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<td>Ethyl Methacrylate</td>
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<tr>
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<td>Methyl Methacrylate</td>
<td>0.13 ppm</td>
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<td>230 µg/sample</td>
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<tr>
<td></td>
<td>3.9 µg/sample</td>
<td>0.51 mg/m³</td>
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<tr>
<td>COMMENTS:</td>
<td>800 µg, 75 mg/m³, and 32 ppm of Acetone and 190 µg, 6.1 mg/m³, and 2.8 ppm of Ethyl Alcohol present in sample #1250485.</td>
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</tr>
<tr>
<td>1250486</td>
<td></td>
<td>11.477</td>
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<td>B1</td>
<td>Ethyl Methacrylate</td>
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</tr>
<tr>
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<td>0.35 ppm</td>
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<tr>
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<td>460 µg/sample</td>
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<tr>
<td></td>
<td>6.3 µg/sample</td>
<td>0.50 mg/m³</td>
</tr>
<tr>
<td>COMMENTS:</td>
<td>740 µg, 64 mg/m³, and 27 ppm of Acetone and 246 µg, 21 mg/m³, and 1.9 ppm of Ethyl Alcohol present in sample #1250486.</td>
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</tr>
<tr>
<td>1250487</td>
<td></td>
<td>8.721</td>
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<tr>
<td>C1</td>
<td>Ethyl Methacrylate</td>
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<tr>
<td></td>
<td>1300 µg/sample</td>
<td>140 mg/m³</td>
</tr>
<tr>
<td></td>
<td>25 µg/sample</td>
<td>2.3 mg/m³</td>
</tr>
<tr>
<td>COMMENTS:</td>
<td>650 µg, 74 mg/m³, and 31 ppm of Acetone and 226 µg, 24 mg/m³, and 1.4 ppm of Ethyl Alcohol present in sample #1250487.</td>
<td></td>
</tr>
<tr>
<td>1250488</td>
<td></td>
<td>10.780</td>
</tr>
<tr>
<td>D1</td>
<td>Ethyl Methacrylate</td>
<td>0.0 ppm</td>
</tr>
<tr>
<td></td>
<td>Methyl Methacrylate</td>
<td>0.15 ppm</td>
</tr>
<tr>
<td></td>
<td>500 µg/sample</td>
<td>46 mg/m³</td>
</tr>
<tr>
<td></td>
<td>67 µg/sample</td>
<td>0.63 mg/m³</td>
</tr>
<tr>
<td>COMMENTS:</td>
<td>700 µg, 65 mg/m³, and 27 ppm of Acetone and 210 µg, 19 mg/m³, and 1.0 ppm of Ethyl Alcohol present in sample #1250488.</td>
<td></td>
</tr>
<tr>
<td>1250489</td>
<td></td>
<td>12.951</td>
</tr>
<tr>
<td>D1</td>
<td>Ethyl Methacrylate</td>
<td>33 ppm</td>
</tr>
<tr>
<td></td>
<td>Methyl Methacrylate</td>
<td>0.24 ppm</td>
</tr>
<tr>
<td></td>
<td>760 µg/sample</td>
<td>59 mg/m³</td>
</tr>
<tr>
<td></td>
<td>33 µg/sample</td>
<td>0.38 mg/m³</td>
</tr>
<tr>
<td>COMMENTS:</td>
<td>1000 µg, 78 mg/m³, and 33 ppm of Acetone and 250 µg, 19 mg/m³, and 1.0 ppm of Ethyl Alcohol present in sample #1250489.</td>
<td></td>
</tr>
<tr>
<td>1250490</td>
<td></td>
<td>3.136</td>
</tr>
<tr>
<td>D2</td>
<td>Ethyl Methacrylate</td>
<td>11 ppm</td>
</tr>
<tr>
<td></td>
<td>Methyl Methacrylate</td>
<td>0.18 ppm</td>
</tr>
<tr>
<td></td>
<td>150 µg/sample</td>
<td>49 mg/m³</td>
</tr>
<tr>
<td></td>
<td>2.3 µg/sample</td>
<td>0.73 mg/m³</td>
</tr>
<tr>
<td>COMMENTS:</td>
<td>210 µg, 67 mg/m³, and 28 ppm of Acetone and 94 ug, 30 mg/m³, and 16 ppm of Ethyl Alcohol present in sample #1250490.</td>
<td></td>
</tr>
</tbody>
</table>
Appendix E (Continued)

<table>
<thead>
<tr>
<th>LAB NUMBER</th>
<th>FIELD NUMBER</th>
<th>DESCRIPTION</th>
<th>Analytical Results</th>
<th>University of Wisconsin</th>
</tr>
</thead>
<tbody>
<tr>
<td>1250491</td>
<td></td>
<td>SCT</td>
<td></td>
<td>7.478 liters</td>
</tr>
<tr>
<td>A2</td>
<td></td>
<td>Ethyl Methylacrylate</td>
<td>350 µg/sample 47 mg/m³</td>
<td>10.0 ppm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Methyl Methylacrylate</td>
<td>5.2 µg/sample 0.70 mg/m³</td>
<td>0.27 ppm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>COMMENTS: 610 µg, 85 mg/m³, and 36 ppm of Acetone and 149 µg, 18 mg/m³, and 10 ppm of Ethyl Alcohol present in sample #1250491.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1250492</td>
<td></td>
<td>SCT</td>
<td></td>
<td>17.741 liters</td>
</tr>
<tr>
<td>E1</td>
<td></td>
<td>Ethyl Methylacrylate</td>
<td>620 µg/sample 35 mg/m³</td>
<td>7.6 ppm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Methyl Methylacrylate</td>
<td>67.6 µg/sample 0.56 mg/m³</td>
<td>0.34 ppm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>COMMENTS: 710 µg, 43 mg/m³, and 18 ppm of Acetone and 229 µg, 23 mg/m³, and 5.7 ppm of Ethyl Alcohol present in sample #1250492.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1250493</td>
<td></td>
<td>SCT</td>
<td></td>
<td>0.120 liters</td>
</tr>
<tr>
<td>F1</td>
<td></td>
<td>Ethyl Methylacrylate</td>
<td>ND &lt; 0.80 µg/sample ND &lt; 6.7 mg/m³</td>
<td>ND &lt; 1.4 ppm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Methyl Methylacrylate</td>
<td>ND &lt;2.0 µg/sample ND &lt;17 mg/m³</td>
<td>ND &lt;4.2 ppm</td>
</tr>
<tr>
<td>1250494</td>
<td></td>
<td>SCT</td>
<td></td>
<td>2.990 liters</td>
</tr>
<tr>
<td>G1</td>
<td></td>
<td>Ethyl Methylacrylate</td>
<td>74000 µg/sample 2500 mg/m³</td>
<td>330 ppm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Methyl Methylacrylate</td>
<td>1300 µg/sample 430 mg/m³</td>
<td>100 ppm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>COMMENTS: The Ethyl Methylacrylate reported for sample #1250494 was greater than the upper calibration standard, therefore, these results should be considered to be approximate values. 34% and 33% of the Methyl Methylacrylate and Ethyl Methylacrylate, respectively, reported for sample #1250494 were detected on the back-up section of the tube.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Displayed values on report have been rounded; however all calculations are performed using raw, unwounded intermediate results. Please contact the laboratory if you have any questions regarding our result calculation or rounding. All samples were received by the laboratory in acceptable condition unless otherwise noted.

ND = None Detected  Results are less than the method detection limit

Report ID: 9056284  Page 3 of 5
Appendix E (Continued)

Analytical Methodology

GENERAL SOLVENTS:
These samples are analyzed using WHO method WG006, which is based on the method, OSHA 7.

The collection media is a SMALL (SCT) (SKC 126-01), LARGE (LCT) (SKC 226-09), JUMBO (JCT) (226-16) or JUMBO2 (226-16-02) Activated Charcoal tube.

Front and back sections of the tube are separately desorbed in 1 ml for SMALL tubes, 1 ml for LARGE tubes, 5 ml for JUMBO tubes, or 10 ml for JUMBO2 tubes of Carbon Disulfide for 10 minutes prior to analysis.

The samples are run on a Hewlett-Packard Gas Chromatograph equipped with an FID. The Primary and Confirming columns were chosen from the following:
- Carbopack C /0.1% FF-1000
- VoCol 100M Capillary
- HP-5 Capillary
- Supelcowax-10 Capillary
- SPB-624 capillary

Samples may also have been confirmed on a Model 5972 Hewlett-Packard Gas Chromatograph Mass-Selective Detector containing a Nukol Capillary.

Reporting Limits are specific for each substance.

Results are not blank corrected unless noted in report.

REPORTING LIMITS:

This table contains the WHO determined reporting limits for the compounds specified in this report. These numbers are based on the historical statistical data for a particular analyte or are based on WHO determined values.

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Reporting Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethyl Methacrylate on SCT</td>
<td>1.8 µg/sample</td>
</tr>
<tr>
<td>Methyl Methacrylate on SCT</td>
<td>2 µg/sample</td>
</tr>
</tbody>
</table>
Appendix E (Continued)

Laboratory prepared quality control (QC) samples were analyzed along with the samples included in the analytical report. The analysis results for these QC samples are listed below.

Instrument Used for Analysis: Gas Chromatograph with FID

### Laboratory Control Sample: 120319
QC Sample Media: SCT lot 2000 charcoal

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Target Value</th>
<th>Recovery (%)</th>
<th>Acceptable Recovery (%)</th>
<th>Pass/Fail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methyl methacrylate on Charcoal</td>
<td>936 µg/sample</td>
<td>103.9</td>
<td>82 - 118</td>
<td>PASS</td>
</tr>
</tbody>
</table>

### Laboratory Control Sample: 120320
QC Sample Media: SCT lot 2000 charcoal

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Target Value</th>
<th>Recovery (%)</th>
<th>Acceptable Recovery (%)</th>
<th>Pass/Fail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methyl methacrylate on Charcoal</td>
<td>3744 µg/sample</td>
<td>100.0</td>
<td>82 - 118</td>
<td>PASS</td>
</tr>
</tbody>
</table>

The acceptable range for an analyte is based on the standard deviation of each analyte, which has been determined from statistical evaluation of the historical performance of the assay. The acceptable range includes up to 3 standard deviations, so a result within 3 standard deviations is considered to have passed the QC requirements. A result outside of the acceptable range is considered to have failed QC and may indicate the direction of possible bias for the samples included in the analytical report. The analytes used for QC determination will not always be the same analytes that appear in the samples for the report, however, they are representative of the compounds found in the samples and indicative of overall assay performance.

End of Analytical Report

The results in this report apply only to the samples, specifically listed above, tested at the Wisconsin Occupational Health Laboratory. This report is not to be reproduced except in full.
**WISCONSIN OCCUPATIONAL HEALTH LABORATORY (WOHL) SAMPLE SUBMISSION FORM**

<table>
<thead>
<tr>
<th>WOHL COMP#</th>
<th>Send Results To ATTN: Adam Marty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phone #</td>
<td></td>
</tr>
<tr>
<td>FAX #</td>
<td></td>
</tr>
<tr>
<td>Email Address</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Project</th>
<th>Date Sampled: 02/02/07</th>
</tr>
</thead>
</table>

**SPECIAL INSTRUCTIONS**
Please run OSHA PV2100 for Ethyl methacrylate & Methyl methacrylate

See Steve Strebil for ?

**TURNAROUND:**
- [ ] RUSH
- [ ] PRIORITY
- [x] NORMAL

(The must be rearranged)

**PLEASE GROUP SAMPLES BY MEDIA USED AND ANALYSIS REQUESTED**

<table>
<thead>
<tr>
<th>LAB USE ONLY</th>
<th>CUSTOMER FIELD #</th>
<th>SAMPLE MEDIA</th>
<th>WIPE SAMPLES</th>
<th>FOR AIR SAMPLES ONLY</th>
</tr>
</thead>
<tbody>
<tr>
<td>WOHL SAMPLE #</td>
<td></td>
<td>SIZE OF AREA WIPED</td>
<td>TIME ON</td>
<td>TIME OFF</td>
</tr>
<tr>
<td>1250436</td>
<td></td>
<td>NA</td>
<td>10:24</td>
<td>0:54</td>
</tr>
<tr>
<td>1250437</td>
<td></td>
<td>B1</td>
<td>10:05</td>
<td>0:54</td>
</tr>
<tr>
<td>1250438</td>
<td></td>
<td>C1</td>
<td>10:52</td>
<td>0:54</td>
</tr>
<tr>
<td>1250439</td>
<td></td>
<td>D1</td>
<td>11:52</td>
<td>0:54</td>
</tr>
<tr>
<td>1250440</td>
<td></td>
<td>D2</td>
<td>10:52</td>
<td>0:54</td>
</tr>
<tr>
<td>1250441</td>
<td></td>
<td>E2</td>
<td>10:52</td>
<td>0:54</td>
</tr>
<tr>
<td>1250442</td>
<td></td>
<td></td>
<td>10:52</td>
<td>0:54</td>
</tr>
</tbody>
</table>

**CHAIN OF CUSTODY:**
- Relinquished
- Date:
- Received:
- Date STR-8 PM:

**SAMPLE CONDITION**
- OK
- NOT OK

**UPS, Fed-Ex & Other Shippers**
- Wisconsin Occupational Health Lab
- 2601 Agriculture Drive
- Madison, WI 53718
- Phone: 608-224-6240
- Fax: 608-224-6213

**US Postal Service**
- Wisconsin Occupational Health Lab
- PO Box 7996
- Madison, WI 53707-7996
- Phone: 800-446-0400
- Web Page/Order Media
- http://www.ohl.wisc.edu/wohl

**Sampling Questions**
- WOHL sampling@mail.ohl.wisc.edu

**SAMPLE RECEIPT RECORD**
- Rand 3467
- Date: 02/07/07
**Wisconsin Occupational Health Laboratory (WOHL) Sample Submission Form**

**Bill To:** Adam Marty  
**WOHL Comp#:**  
**Send Results To:** Adam Marty  
**Phone #:**  
**Fax #:**  
**Email Address:**

**Project:**  
**P.O. #:**  
**Date Sampled:** 02/02/07  
**Turnaround:**  
- [ ] Rush  
- [ ] Priority  
- [x] Normal  

(aryl must be prearranged)

**Special Instructions:**  
Please run OSHA PV2100 for ethyl methacrylate and methyl methacrylate.

**See Steve Strebek for ?'s**

---

**+ Please group samples by media used and analysis requested.**

<table>
<thead>
<tr>
<th>Lab Use Only</th>
<th>Customer Field #</th>
<th>Sample Media</th>
<th>Wipe Samples</th>
<th>For Air Samples</th>
<th>Only</th>
<th>Analysis Request</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wohl Sample #</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1250493</td>
<td>F1</td>
<td>Air blank</td>
<td>NA</td>
<td>1840 1841 15</td>
<td>0.031 0.120</td>
<td>OSHA PV2100</td>
</tr>
<tr>
<td>1250494</td>
<td>G1</td>
<td>Air blank</td>
<td>NA</td>
<td>1840 1901 15</td>
<td>0.990 2.990</td>
<td></td>
</tr>
</tbody>
</table>

**Chain of Custody:**  
Relinquished  
Date  
Received  
Date  

---

**UPS, Fed-Ex & Other Shippers:**  
Wisconsin Occupational Health Lab  
2661 Agriculture Drive  
Madison, WI 53718

**US Postal Service:**  
Wisconsin Occupational Health Lab  
PO Box 7996  
Madison, WI 53707-7996

**Phone:** 608-224-6210  
**Fax:** 608-224-6213  
**Sampling Questions:**  
WOHLsampling@mail.wisc.edu  
[Web Page/Order Media]  
http://www.ohl.wisc.edu/ohl

**Sample Condition:**  
[ ] OK  
[ ] NOT OK  
See Sample Receipt Record
Appendix E (Continued)

Analytical Laboratory Report

February 20, 2007

ADAM MARTY

Report ID: 9056585

Company Number: 30672

PROJ

Date Collected: 2/3/2007
Date Received: 2/6/2007
Date of Analysis: 2/13/2007
Date Reported: 2/20/2007

Analyst: PATRICK RILEY, Chemist
rileypk@mail.alb.wisc.edu

Reviewer: STEVE STREBEL, Organic Supervisor
sst@wohl.alb.wisc.edu

WOHL uses only verified, secured electronic signatures on reports. These signatures are as valid as original handwritten signatures.
If you have any questions regarding this report please feel free to contact the laboratory via email (as listed above) or via telephone at 800-446-0403

Report ID: 9056585  Page 1 of 4
### Appendix E (Continued)

<table>
<thead>
<tr>
<th>LAB NUMBER</th>
<th>FIELD NUMBER</th>
<th>DESCRIPTION</th>
<th>AIR VOLUME</th>
</tr>
</thead>
<tbody>
<tr>
<td>1250478</td>
<td></td>
<td>SCT</td>
<td>18.889 liters</td>
</tr>
<tr>
<td></td>
<td>Ethyl Methacrylate</td>
<td>2.3 µg/sample</td>
<td>0.12 µg/m³</td>
</tr>
<tr>
<td></td>
<td>Methyl Methacrylate</td>
<td>68 µg/sample</td>
<td>4.7 µg/m³</td>
</tr>
<tr>
<td></td>
<td><strong>COMMENTS:</strong> 180 µg, 9.4 mg/m³, and 3.9 ppm of Acetone present in sample #1250478. Traces of Ethyl Acetate, Methyl Ethyl Ketone (MEK), Isopropyl Alcohol, Toluene, Butyl Acetate (n-), Butyl Alcohol (n-), Limonene, Dichlorobenzene (p-), and Tetrhydrofuran present in all samples.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1250479</td>
<td></td>
<td>SCT</td>
<td>10.703 liters</td>
</tr>
<tr>
<td></td>
<td>Ethyl Methacrylate</td>
<td>&lt;=2.8 µg/sample</td>
<td>&lt;=0.17 µg/m³</td>
</tr>
<tr>
<td></td>
<td>Methyl Methacrylate</td>
<td>310 µg/sample</td>
<td>12 µg/m³</td>
</tr>
<tr>
<td></td>
<td><strong>COMMENTS:</strong> 110 µg, 11 mg/m³, and 4.6 ppm of Acetone present in sample #1250479.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1250480</td>
<td></td>
<td>SCT</td>
<td>0.64 liters</td>
</tr>
<tr>
<td></td>
<td>Ethyl Methacrylate</td>
<td>ND &lt;0.00 µg/sample</td>
<td>ND &lt;0.15 µg/m³</td>
</tr>
<tr>
<td></td>
<td>Methyl Methacrylate</td>
<td>ND &lt;2.0 µg/sample</td>
<td>ND &lt;34 µg/m³</td>
</tr>
<tr>
<td>1250481</td>
<td></td>
<td>SCT</td>
<td>11.669 liters</td>
</tr>
<tr>
<td></td>
<td>Ethyl Methacrylate</td>
<td>&lt;=2.8 µg/sample</td>
<td>&lt;=0.15 µg/m³</td>
</tr>
<tr>
<td></td>
<td>Methyl Methacrylate</td>
<td>120 µg/sample</td>
<td>11 µg/m³</td>
</tr>
<tr>
<td></td>
<td><strong>COMMENTS:</strong> 110 µg, 13 mg/m³, and 5.6 ppm of Acetone present in sample #1250481.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1250482</td>
<td></td>
<td>SCT</td>
<td>9.508 liters</td>
</tr>
<tr>
<td></td>
<td>Ethyl Methacrylate</td>
<td>&lt;=2.8 µg/sample</td>
<td>&lt;=0.19 µg/m³</td>
</tr>
<tr>
<td></td>
<td>Methyl Methacrylate</td>
<td>330 µg/sample</td>
<td>31 µg/m³</td>
</tr>
<tr>
<td></td>
<td><strong>COMMENTS:</strong> 110 µg, 14 mg/m³, and 5.8 ppm of Acetone present in sample #1250482.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1250483</td>
<td></td>
<td>SCT</td>
<td>8.669 liters</td>
</tr>
<tr>
<td></td>
<td>Ethyl Methacrylate</td>
<td>&lt;=2.8 µg/sample</td>
<td>&lt;=0.22 µg/m³</td>
</tr>
<tr>
<td></td>
<td>Methyl Methacrylate</td>
<td>190 µg/sample</td>
<td>22 µg/m³</td>
</tr>
<tr>
<td></td>
<td><strong>COMMENTS:</strong> 110 µg, 17 mg/m³, and 7.2 ppm of Acetone present in sample #1250483.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix E (Continued)

Wisconsin State Laboratory of Hygiene

Analytical Results

<table>
<thead>
<tr>
<th>LAB NUMBER</th>
<th>FIELD NUMBER</th>
<th>DESCRIPTION</th>
<th>AIR VOLUME</th>
</tr>
</thead>
<tbody>
<tr>
<td>1250484</td>
<td></td>
<td>SCT</td>
<td>3.019 ltr</td>
</tr>
</tbody>
</table>

TTM

Ethyl Methacrylate
66.1 mg/sample

Methyl Methacrylate
67.0 mg/sample

COMMENTS: The Methyl Methacrylate reported for sample #1250484 was greater than the upper calibration standard; therefore, these results should be considered to be approximate values. 36% of both Methyl Methacrylate and Ethyl Methacrylate reported for sample #1250484 were detected on the back-up section of the tube.

Displayed values on report have been rounded; however all calculations are performed using raw, unrounded intermediate results.

Please contact the laboratory if you have any questions regarding our result calculation or rounding. All samples were received by the laboratory in acceptable condition unless otherwise noted.

ND = None Detected. Results are less than the method detection limit

< < Less Than or Equal To. The analyte was detected but at a level too low to be accurately quantitated. The actual amount is less than or equal to the reported value.

Analytical Methodology

GENERAL SOLVENTS:

These samples are analyzed using WOHL method W2804, which is based on the method, OSHA 7.

The collection media is a SMALL (SCT) (SKC 226-01), LARGE (LCT) (SKC 224-09), JUMBO (JCT) (226-16) or JUMBO2 (226-16-02) Activated Charcoal tube.

Front and back sections of the tube are separately desorbed in 1 ml for SMALL tubes, 3 ml for LARGE tubes, 8 ml for JUMBO tubes, or 20 ml for JUMBO2 tubes of Carbon Disulfide for 30 minutes prior to analysis.

The samples are run on a Hewlett-Packard Gas Chromatograph equipped with an FID. The Primary and Confirming columns were chosen from the following:

Carbopack C/0.1% SP-2000
VOCol 10SM Capillary
HP-5 Capillary
Supelcowax-10 Capillary
SPB-624 capillary

Samples may also have been confirmed on a Model 5972 Hewlett-Packard Gas Chromatograph Mass-Selective Detector containing a Nukol Capillary.

Reporting Limits are specific for each substance.

Results are not blank corrected unless noted in report.

Report ID: 9655685

Page 3 of 4
Appendix E (Continued)

**Analytical Quality Control**

Laboratory prepared quality control (QC) samples were analyzed along with the samples included in the analytical report. The analysis results for these QC samples are listed below.

Instrument Used for Analysis: Gas Chromatograph with FID

<table>
<thead>
<tr>
<th>Laboratory Control Sample: 120319</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>QC Sample Media SCT lot 2000 charcoal</td>
<td></td>
</tr>
<tr>
<td><strong>Analyte</strong></td>
<td><strong>Target Value</strong></td>
</tr>
<tr>
<td>Methyl methacrylate on Charcoal</td>
<td>9.6 µg/sample</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Laboratory Control Sample: 120320</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>QC Sample Media SCT lot 2000 charcoal</td>
<td></td>
</tr>
<tr>
<td><strong>Analyte</strong></td>
<td><strong>Target Value</strong></td>
</tr>
<tr>
<td>Methyl methacrylate on Charcoal</td>
<td>2744 µg/sample</td>
</tr>
</tbody>
</table>

The acceptable range for an analyte is based on the standard deviation of each analyte, which has been determined from statistical evaluation of the historical performance of the assay. The acceptable range includes up to 3 standard deviations, so a result within 3 standard deviations is considered to have passed the QC requirements. A result outside of the acceptable range is considered to have failed QC and may indicate the direction of possible bias for the samples included in the analytical report. The analytes used for QC determination will not always be the same analytes that appear in the samples for the report, however they are representative of the compounds found in the samples and indicative of overall assay performance.

**End of Analytical Report**

The results in this report apply only to the samples, specifically listed above, tested at the Wisconsin Occupational Health Laboratory. This report is not to be reproduced except in full.
### WISCONSIN OCCUPATIONAL HEALTH LABORATORY (WOHL) SAMPLE SUBMISSION FORM

**Bill To:** Adam Marty  
**WOHL COMP#** 30672  
**Read Results To** ATTN: Adam Marty  
**Phone #**  
**FAX #**  
**Email Address**  

**Project**  
**P.O. #**  
**Date Sampled:** 02/04/07  

**Turnaround:**  
- [ ] RUSH  
- [X] PRIORITY  
- [ ] NORMAL  

**SPECIAL INSTRUCTIONS**  
Please run OSHA PV100 for ethyl methacrylate + methyl methacrylate.  
* TTN1 has small hairline crack @ inlet  
* See Steve Strebel for 7's

---

**PLEASE GROUP SAMPLES BY MEDIA USED AND ANALYSIS REQUESTED.**

<table>
<thead>
<tr>
<th>LAB USE ONLY</th>
<th>CUSTOMER FIELD #</th>
<th>SAMPLE MEDIA</th>
<th>WIPE SAMPLES</th>
<th>FOR AIR SAMPLES</th>
<th>ONLY</th>
<th>VOLUME (LITERS)</th>
<th>ANALYSIS REQUEST</th>
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<tbody>
<tr>
<td>WOHL SAMPLE #</td>
<td>S</td>
<td></td>
<td>SIZE OF AREA WIPED</td>
<td>TIME ON</td>
<td>TIME OFF</td>
<td>TOTAL TIME (MINS)</td>
<td>FLOW RATE (L/MIN)</td>
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**CHAIN OF CUSTODY:** Relinquished  
**Date**  
**Received**  
**Date**  

**UPS, Fed-Ex & Other Shippers**  
Wisconsin Occupational Health Lab  
2691 Agriculture Drive  
Madison, WI 53718

**US Postal Service**  
Wisconsin Occupational Health Lab  
PO Box 7996  
Madison, WI 53707-7996

**Phone** 608-224-6210  
**Fax** 608-224-6213  
**Sampling Questions**  
WOHLsampling@mail.wisc.edu  
**Web Page/Order Media**  
http://www.slh.wisc.edu/wohl

**SAMPLE CONDITION**  
[ ] OK  
[ ] NOT OK  
See Sample Receipt Record