Unclassified **ENV/JM/MONO(2004)22**

Organisation de Coopération et de Développement Economiques
Organisation for Economic Co-operation and Development **26-Nov-2004**

English - Or. English

ENVIRONMENT DIRECTORATE
JOINT MEETING OF THE CHEMICALS COMMITTEE AND
THE WORKING PARTY ON CHEMICALS, PESTICIDES AND BIOTECHNOLOGY

ENV/JM/MONO(2004)22
Unclassified

OECD SERIES ON EMISSION SCENARIO DOCUMENTS
Number 11

EMISSION SCENARIO DOCUMENT ON COATING APPLICATION VIA SPRAY-PAINTING IN THE AUTOMOTIVE REFINISHING INDUSTRY

English - Or. English

JT00174705

Document complet disponible sur OLIS dans son format d'origine
Complete document available on OLIS in its original format

OECD Environmental Health and Safety Publications

Series on Emission Scenario Documents No. 11

EMISSION SCENARIO DOCUMENT ON COATING APPLICATION VIA SPRAY-PAINTING IN THE AUTOMOTIVE REFINISHING INDUSTRY

Environment Directorate

Organization for Economic Co-operation and Development

November 2004

About the OECD

The Organisation for Economic Co-operation and Development (OECD) is an intergovernmental organisation in which representatives of 30 industrialised countries in North America, Europe and the Asia and Pacific region, as well as the European Commission, meet to co-ordinate and harmonise policies, discuss issues of mutual concern, and work together to respond to international problems. Most of the OECD's work is carried out by more than 200 specialised committees and working groups composed of member country delegates. Observers from several countries with special status at the OECD, and from interested international organisations, attend many of the OECD's workshops and other meetings. Committees and working groups are served by the OECD Secretariat, located in Paris, France, which is organised into directorates and divisions.

The Environment, Health and Safety Division publishes free-of-charge documents in nine different series: **Testing and Assessment; Good Laboratory Practice and Compliance Monitoring; Pesticides and Biocides; Risk Management; Harmonisation of Regulatory Oversight in Biotechnology; Safety of Novel Foods and Feeds; Chemical Accidents; Pollutant Release and Transfer Registers; and Emission Scenario Documents.** More information about the Environment, Health and Safety Programme and EHS publications is available on the OECD's World Wide Web site (http://www.oecd.org/ehs/).

This publication was produced within the framework of the Inter-Organisation Programme for the Sound Management of Chemicals (IOMC).

The Inter-Organisation Programme for the Sound Management of Chemicals (IOMC) was established in 1995 following recommendations made by the 1992 UN Conference on Environment and Development to strengthen co-operation and increase international co-ordination in the field of chemical safety. The participating organisations are FAO, ILO, OECD, UNEP, UNIDO, UNITAR and WHO. The World Bank and UNDP are observers. The purpose of the IOMC is to promote co-ordination of the policies and activities pursued by the Participating Organisations, jointly or separately, to achieve the sound management of chemicals in relation to human health and the environment.

This publication is available electronically, at no charge.

**For this and many other Environment,
Health and Safety publications, consult the OECD's
World Wide Web site (www.oecd.org/ehs/)**

or contact:

**OECD Environment Directorate,
Environment, Health and Safety Division**

**2 rue André-Pascal
75775 Paris Cedex 16
France**

Fax: (33-1) 45 24 16 75

E-mail: ehscont@oecd.org

Introductory Remarks

Purpose and Background

This OECD Emission Scenario Document (ESD) is intended to provide information on the sources, use patterns and release pathways of chemicals used in automotive refinishing industry. The information can be used to estimate releases of chemicals to the environment.

This ESD should be seen as a 'living' document, which provides the most updated information available. As such, an ESD can be updated to incorporate changes and new information, including those from the industry area in countries other than the lead (United States). Users of the document are encouraged to submit comments, corrections, updates and new information to the OECD Environment, Health and Safety Division (env.riskassessment@oecd.org). The comments received will be forwarded to the OECD Task Force on Environmental Exposure Assessment, which will review the comments every two years so that the lead country can update the document. The submitted information will also be made available to users within the OECD web-site (www.oecd.org/env/riskassessment).

How to use this document

The user of this ESD needs to consider how the information contained in the document covers the situation for which they wish to estimate releases of chemicals. The document could be used as a framework to identify the information needed, or the approaches in the document could be used together with the suggested default values to develop emission estimates. Where specific information is available it should be used in preference to the defaults. At all times, the values inputted and the results should be critically reviewed to assure their validity and appropriateness.

Coverage

This ESD presents a standardized approach to estimate potential occupational exposures and environmental releases of non-volatile chemicals in coating formulations used in automotive refinishing industry. Releases and exposures from other refinishing operations (e.g. sanding and curing) and body shop operations (i.e., welding operations or vehicle exhaust emissions) not directly related to the spray-painting process are not part of the scope of this scenario. The environmental releases resulting from the disposal of empty coating containers, in which the coating was used in spray-painting, are included. The estimation methods in this scenario are applicable to any non-volatile coating component regardless of its function within the coating formulation.

The following releases and exposures to non-volatile coating components used in automotive refinishing shops are discussed in this scenario:

- Release amount from transport container residue
- Release amount from cleanup of coating mixing apparatus and spray gun
- Release amount from overspray (with or without a booth)
- Release amount from overspray captured by filters (with a booth)
- Dermal exposure from transferring paint to the mixing apparatus
- Dermal exposure during manual spray painting
- Inhalation exposure during spray painting operation
- Dermal exposure during cleanup activities

The scope of this scenario is designed to serve the needs of both the U.S. Environmental Protection Agency (EPA) and OECD, so in addition to providing approaches for estimating emissions or releases, this scenario also contains approaches for estimating occupational exposures. Because occupational exposures are not typically included in OECD Emission Scenario Documents (ESDs), the approaches for assessing occupational exposures may not have been included in the review process for most OECD member countries.

How this document was developed

This generic scenario supercedes EPA's 1996 Generic Scenario for Automobile Spray Coating and has been updated using recent data on process descriptions, operating information, chemicals used, wastes generated, worker activities and exposure information for the automotive refinishing industry. Information available as of June 2003, including information from Kirk-Othmer Encyclopedia of Technology, County Business Patterns, Annual Survey of Manufacturers web-site, NIOSHtic database, OSHA web-site for automotive repair and refinishing, and Body Shop Business web-site, is used in the development of this scenario. The information presented in this document is also based on field surveys, site visits and consultations with experts who have experience with automotive refinishing operations.

Release and exposure estimation approaches are based on data readily available to the US EPA. In estimating inhalation exposures, transfer efficiencies for conventional and high volume low pressure (HVLP) spray guns and mist concentration data resulting from spray painting determined from Occupational Safety and Health Administration (OSHA) field survey reports at automotive refinish shops, is used. These surveys provide actual, industry-specific data collected from several automotive refinish shops. The coatings used in these shops are representative of coatings and chemicals covered in the scope of this scenario. This scenario does not provide default concentration ranges for additives typically present in coating formulations because this information is generally available. For example, in EPA's New Chemicals Program, this information is typically provided in the Pre-Manufacturing Notice submission.

The draft document submitted by the US was circulated to the OECD member countries in June 2003 and revised draft in December 2003. Comments were received from Canada, Germany, the Netherlands and the United Kingdom. These comments and additional input from U.S. industry have been incorporated into this document. The approaches used in the main body of this scenario are based on U.S. data. This data indicates that the majority of coatings used in automotive refinishing are solvent-based. Differences in automotive refinishing operations may occur among regions and/or countries; therefore, different assumptions and parameters may need to be used. For example, the U.S. indicates that dry filters are used predominantly to capture overspray whereas European countries sometimes use water backed booths to capture the overspray [based on comments received from the UK]. European countries may want to use this data for estimating emissions in lieu of U.S. data. In other instances, EU data are similar to those in the US. For example, German's industry data on the amount of coatings used per car is supportive of U.S. data and is included in Appendix A.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. Industry Summary and Background

Automotive refinishing operations consist of surface preparation and repainting of motor vehicles subsequent to their initial manufacture. These operations occur in auto-body repair/paint shops, new car dealer repair/paint shops, fleet operator repair/paint shops, production auto-body paint shops, and custom-made car fabrication facilities. Following structural preparation of the automobile, paint and/or coating mixtures are sprayed directly onto the automobile surface using a spray gun. This generic scenario describes methods to estimate the releases of and exposures to non-volatile coating components (pigment, binders, additives) from automotive refinishing spray applications and from the disposal of empty coating containers. As stated in the introductory remarks, releases and exposures resulting from other refinishing and auto-body shop operations such as sanding or curing are not addressed in this scenario.

Refinishing shops typically use three types of coatings to paint an automobile: primer, basecoat, and clearcoat. Each coating type performs a specific task in the refinishing process. The primer coating is specifically designed to adhere to the vehicle metal surfaces to protect it from oxidation, the basecoat provides color for the automobile and the clearcoat adheres to the basecoat and provides protection for the basecoat and a high-gloss finish to the surface. Any of these formulations may contain the chemical of interest.

Automotive refinishing shops fall under the North American Industry Classification System (NAICS) code 811121. They are comprised of businesses primarily engaged in repairing or painting car, truck, or trailer bodies (1). According to the 2001 County Business Patterns data, 34,786 establishments within the United States performed the tasks outlined in this NAICS code with a total of 221,129 workers.

2. Process Description

The following steps are performed at automobile refinish shops (30):

1. Sanding
2. Solvent wipe down
3. Coating mixing
4. Coating application via spraying
5. Curing

A flow diagram is provided in Figure 2-1. While this figure displays all of the processing steps performed during automotive refinishing operations, this generic scenario covers only the releases and exposures associated with step 4 - coating application via spraying and the disposal of the empty coating transport containers. Brief descriptions of the other operations involved in auto refinishing are also included as background information. The dotted line box shown in Figure 2-1 designates the areas from which the release and exposure estimates stem from and which are described within this scenario.

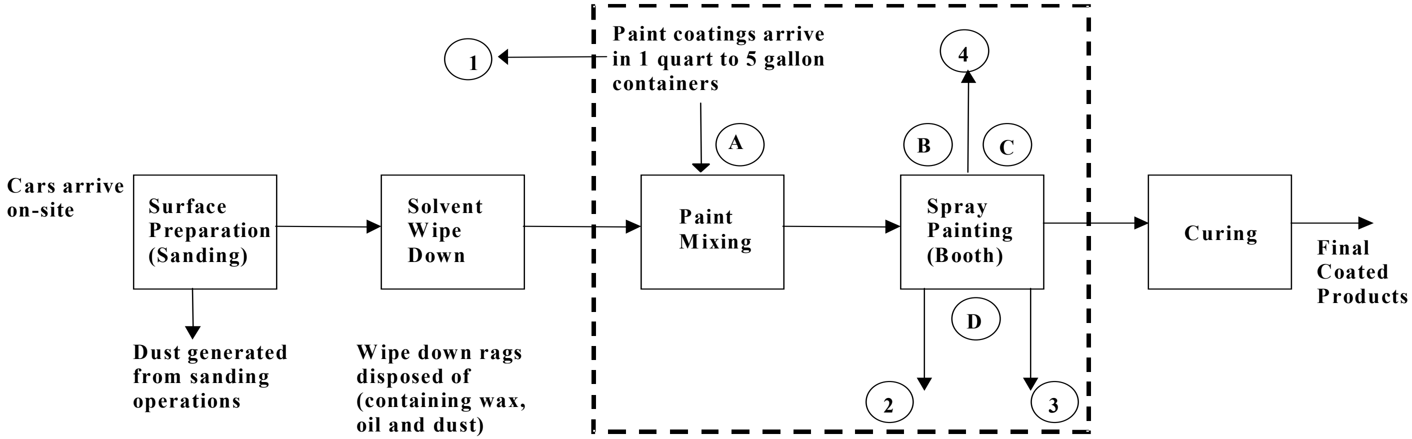
This scenario conservatively assumes that a refinishing facility can perform approximately 30 to 40 jobs per week or approximately seven jobs per day during a five-day work week. The throughput of a shop is highly dependent on its size (i.e., number of painters). Table 2-1 summarizes the available throughput data. Many of the sources reviewed to report throughput rates much lower than 30 to 40 jobs per week; however, the higher throughput is conservatively used as a default.

Table 2-1

Number of Jobs Performed at Automotive Refinishing Shops per Week

Number of Jobs per Week per Shop	Source of Data
16.7	(2)
13.7	(3)
30 to 40	(4)
30 to 40	(5)

Figure 2-1. Process Flow Diagram for Automotive Refinishing Operations



[dashed box] Operation described in this scenario.

EXPOSURES:

- (A) Dermal exposure from transferring paint into mixing apparatus
- (B) Inhalation exposure to mist from spray application
- (C) Dermal exposure from spray application
- (D) Dermal exposure from manual cleanup of equipment

RELEASES:

- (1) Release from container residue (up to 3% Q_{chem_yr})
- (2) Release from cleanup of mixing and spray gun (2% Q_{chem_yr})
- (3) Release from captured overspray (up to 70% Q_{chem_yr})
- (4) Release from overspray (up to 80% Q_{chem_yr} for no booth, 8.0% Q_{chem_yr} for booth)

2.1 Surface Preparation [This section is included for background information only]

The first step in surface preparation is wiping the surface with solvent to remove road tar and other contaminants that may clog the sand paper and compromise the sand paper's effectiveness. The second step is sanding the automotive surface to remove surface abnormalities, to promote proper adhesion of coatings and to foster a high quality finish. Two types of sanding techniques are commonly used:

Wet sanding: Workers manually remove surface irregularities using water and an abrasive material, typically sand paper.

Dry sanding: Workers manually remove surface irregularities using sand paper or a pneumatic disc sander. Pneumatic sanding stations occasionally contain vacuum attachments to remove dust that is created during sanding. Some painters may also use compressed air to remove dusts created during sanding.

Workers may be exposed to the components contained in the original coating during surface preparation. The type of exposure depends upon the sanding method used. During wet sanding operations, workers may experience dermal exposure to the abrasive compounds used to remove surface irregularities, as well as to the original coating particles. During dry sanding operations, workers may inhale the dust generated during sanding (containing original coating particles). A vacuum sanding system (which is present in some pneumatic disc sanders) helps to control particulate inhalation (6).

2.2 Solvent Wipe Down [This section is included for background information only]

After sanding and other surface preparation, the vehicle surface is again manually wiped down with an organic solution and a rag. Chemicals commonly used during this step include methyl ethyl ketone, toluene, xylene, light aliphatic solvent naphtha, and various acetates such as n-Butyl Acetate and Ethylene Glycol Monobutyl Ether Acetate." (5)

Since many of the solvents used to clean the automobile surface are volatile, inhalation of solvent vapors may occur. Because many of these solvents are hazardous if inhaled, their application may take place in a well-ventilated area and/or workers may wear respiratory protection. To prevent dermal exposure to the solvents, which may be irritating to the skin and harmful if absorbed into the body, workers may wear gloves and other skin protection.

2.3 Paint Mixing

Coatings and additives arrive at most facilities in 1-quart to 5-gallon containers (16). The coatings transported in the containers are emptied into the mixing apparatus. In situations where all of the coating in the container is not needed, the containers are resealed with the remaining coating. Empty containers are either crushed for disposal or solvent washed for future use. Their residue is released to landfill or incineration (17). The primer, basecoat, and clearcoat are mixed separately.

Refinishing shops primarily use coatings that contain the following chemicals:

X Pigments - To provide color in the finish;

X Binders - To hold the pigments in suspension in the coating;

X Solvents - To dissolve the binder and reduce its viscosity so that the coating may be applied in an even coat; and

X Additives - To add various properties to the coating (e.g., hardeners)

Most automotive refinishing shops have designated paint mixing rooms where the majority of coating mixing occurs. Primers, clearcoats and basecoats are usually mixed by hand in small containers. Sometimes mixing is followed by mechanical agitation. During basecoat preparation, workers typically use a computerized system to create a color that matches the current color of the automobile. This system provides an electronic recipe list for colors and allows the workers to track the amount of each coating mixed. Workers may also rely on their own experience and information provided by the coating distributor to determine the relative amounts of the individual ingredients needed to achieve the desired basecoat properties (6).

Many engineering control practices exist to mitigate worker exposure during coating mixing. The paint mixing rooms may be ventilated and storage containers should be kept closed to reduce the release of volatile coating components. In order to lower material costs, many shops store and reuse any remaining mixed coating materials. This also minimizes releases resulting from container disposal.

2.4 Coating Application via Spray Painting

In automotive refinishing, almost all spray coating operations involve a worker spraying the vehicle, typically in a ventilated spray booth equipped with a control device to collect oversprayed coating particles (e.g., dry filter). Painters typically apply multiple layers of each type of coating to the vehicle surface (i.e., a primer, a basecoat, and then a clearcoat). The average body shop spends $2,864 per month on paint (3). The prices of primers, basecoats and clearcoats are slightly different. Based on these assumptions, the average amount of each coating type purchased and used by each refinishing site is estimated (see section 3.12). Several control technologies have been developed to lower exposures and releases resulting from the application of these coatings. This section discusses some of the technologies commonly used in the automotive refinishing industry.

The two most common coating application tools are the conventional spray gun and the high volume low pressure (HVLP) spray gun. Both spray guns have a mounted cup to hold the coating formulation and are connected to a pressurized air supply by a hose. The pressurized air atomizes the coating materials into a spray that is transferred to the automobile surface. These spray gun types are described below:

X **Conventional:** Pressurized air, provided by an air compressor, is forced through the gun nozzle at 30 to 90 psig (8); the coating is atomized in the air at the nozzle throat. Due to the high pressures at the gun nozzle, conventional spray guns are characterized by excessive spray mist and overspray fog. High overspray amounts result in lower transfer efficiencies of approximately 20 to 40% (9). As a conservative default value, a transfer efficiency of 20% is used for environmental release estimates in this scenario. As transfer efficiency decreases, material use, air emissions, and solid wastes increase.

X **High Volume Low Pressure (HVLP):** HVLP spray guns use large quantities of low pressure air (typically less than 10 psig at the tip of the spray gun) to atomize the coating. Two types of HVLP guns are primarily used: gravity-fed and siphon cup. Gravity fed spray guns are designed with the paint cup above the atomization nozzle. The coating is released into the spray gun=s air stream to be sprayed on to the automobile. Siphon cup spray guns, also known as suction guns, have paint cups below the gun nozzle. Controlled air pressure meters the flow of coating into the atomization nozzle. Because these spray guns use lower pressures to atomize the coatings, more of the coating is transferred to the surface with less overspray. HVLP spray guns have higher transfer efficiencies than conventional spray guns, averaging 65% (9).

Many automotive refinishing shops continue to use conventional spray guns; however, an increasing number of local and state regulations require the use of HVLP guns to control shop emissions. While 64% of automotive refinishing shops reported owning HVLP spray guns (10), many painters use both spray gun types (e.g., they will use HVLP spray guns to apply primer and basecoat, but will use conventional spray guns for clearcoats). Not all shops use HVLP spray guns because they cost more than conventional spray guns. Shops must also pay training costs for painters to learn proper techniques for applying coatings using lower pressure.

Spraying is often conducted in a spray booth to control dispersion of coating overspray, to provide a closed compartment for forced air drying, and to separate volatile components and coating solids from the workplace. Air entering spray booths is filtered to remove dusts, which is necessary to ensure the quality of coating jobs. Spray application facilities vary in design from designated spray areas to well designed and operated booths. Between 50 and 80% of automobile refinishing shops use minimum engineering controls to protect workers (10). As expected, the larger shops are more likely to have spray booths (10). Spray booths are designed with the following configurations:

X **Crossdraft booths:** Cross-draft booths move overspray along the length of the car through the use of forced air. Make-up air is drawn through filters in the front of the booth, over the automobile, and through filters located in the back of the booth. Approximately 50% of automobile refinishing shops use cross-draft booths (10).

X **Downdraft booths:** Downdraft booths blow air to move overspray from the ceiling to the floor, out of the breathing zone. Clean make-up air enters through filters in the ceiling of the booth, and the contaminated air is drawn from the booth through metal grates in the floor. Approximately 30% of automobile refinishing shops use downdraft booths (10). Downdraft booths are preferred over cross-draft booths because they maintain lower mist and particle concentrations in the workspace. An increasing number of shops are buying downdraft booths instead of cross-draft booths (10). Downdraft booths are the most expensive of the spray booth types.

X **Semi-downdraft booths:** Semi-downdraft spray booths are designed to provide make-up air through filters in the ceiling like downdraft booths; however, exhaust air is drawn through filters in the back of the booth.

These control technologies lower the potential for painter exposures by removing oversprayed coating particles and volatile components from the workspace. They often incorporate dry filters to control the release of the non-volatile coating particles, typically averaging a 90% removal efficiency (11). Very few automotive refinishing shops utilize volatile component controls due to their relatively high costs; therefore, virtually all of the volatile components in the applied coatings are expected to be vented from the spray booth.

Painters may be exposed to chemicals in coating mists through dermal contact and inhalation of contaminated air during spray painting. Companies can likely reduce releases and exposures by performing all spraying activities in a well-maintained and ventilated spray booth using a high transfer efficiency spray gun (e.g., HVLP) with proper spray techniques. The use of proper personal protection equipment such as respiratory protection and skin protection will also reduce occupational exposures.

2.5 **Curing** [This section is included for background information only]

Following application, each coating is cured. The coating may be allowed to dry at atmospheric conditions, or curing may be accelerated through the use of heated paint booth air or portable heat sources (8). Spray booths are typically equipped with air supply fans to provide a flow of heated air to freshly painted vehicle parts. Air from outside of the shop is routed through a heat exchanger and a filter prior to entering the booth. Typical curing temperatures range from 49°C to 60°C (120°F to 140°F) (12). Spray booths with heated air supply capabilities reduce the typical curing time from 12 hours to approximately 20 to 30 minutes. After leaving the heated paint booth, the coating will be dry. The coating film may not be completely cured for days. During this time, coating solvents continue to evaporate.

3. Screening Level Estimation Techniques/Methods

Release and exposure estimates discussed in this section arise from the spray-application of coatings containing the chemical of interest and are only applicable to non-volatile components. This generic scenario does not address the releases and exposures resulting from other refinishing operations, such as surface preparation (e.g., sanding, solvent wipe-down) or the mixing of coatings prior to spraying; however, releases from the disposal of empty coating containers are included in this scenario. The default values cited within this section of the scenario are intended to be used when site-specific information is not available.

In estimating environmental releases, this scenario assumes that both releases to air from handling materials with a vapor pressure less than 0.01 torr and inhalation exposure for materials with a vapor pressure less than 0.001 torr, are negligible (30).

3.1 General Facility Estimates

Default values for the number of operating days and for the number of sites are given in sections 3.1.1 and 3.1.2.

3.1.1 Operating Days ($TIME_{working\ days}$)

Assume up to 180 days of operation per year for the chemical of interest if no information is provided. This is based on conversations conducted during site visits to automotive refinishing shops. These site visits were associated with the Design for the Environment Automotive Refinishing Project in 1995 and 1996. Full-time usage is not assumed because a typical shop uses an estimated 1.39 brands of paint per shop, based on data that show that 65% of shops use one brand of paint, 31.3% use two brands, 1.9% use three brands, and 1.3% use four or more (2). The weighted average of these values yields the default usage of 1.39 brands of paint per shop. Assuming that no more than one brand of paint would contain the chemical of interest due to competitive barriers and that 100% of this one brand will include the chemical of interest, the % of chemical of interest-containing brands per shop is 1/1.39 = 0.72.

3.1.2 Number of Sites (N_{sites})

Automotive refinishing shops are classified under NAICS code 811121. These organizations are involved in repairing or painting car, truck, or trailer bodies. According to the 2001 County Business Patterns, 34,786 establishments operated within the paint or body repair shop sector (1). Table 3-1 provides the distribution of establishments based on the number of workers at each establishment (1).

Table 3-1

Number of U.S. Automotive Refinishing Establishments by Employment-size Class for the Paint or Body Repair Shops (NAICS 811121)

	Number of Employees									Total Establishments
	< 5	**5-9**	**10-19**	**20-49**	**50-99**	**100-249**	**250-499**	**500-999**	**≥ 1000**	
Number of establishments	19,417	8,287	5,222	1,713	121	22	2	0	2	34,786

The following calculation, based on purchasing data from automotive refinishing shops, is used to estimate the amount of coating containing the chemical of interest that is purchased by a typical shop per year. It is based on the monthly cost allowance per site, the fraction of coating that contains chemical of interest, and the quantity and cost of a particular coating (primer, basecoat, clearcoat) used per car in the coating application of the refinishing process.

$$V_{coat\_purchased} = \frac{COST_{coat\_allowance} \times V_{coat\_car} \times \frac{12\ months}{yr} \times F_{coat}}{COST_{coats}} \qquad \textbf{[3-1]}$$

Where:

$COST_{coats}$ = Cost per car based on the quantity in liters (Q_{coat_car}) and cost of each type of coating ($/car).
Default: $450/car
$51/L for basecoats (Default range: $27 to $74/L)[1]
$36/L for clearcoats (Default range: $26 to $46/L)[3]
$30/L for primers (Default range: $20 to $40/L)[3]
[(4 x $51 + 6 x $36 + 1 x $30) = $450]

$COST_{coat\_allowance}$ = Monthly coating allowance per site (shop)
(Default = $2,864/site-month)[2]

F_{coat} = Fraction of coatings that contains chemical of interest 0.72.[3]

---

[1] The price of base coats ranges from $13 to $35/pint ($27 to $74/L), the price of clearcoats ranges from $100 to $175/gallon ($26 to $46/L), and the price of primers ranges from $75 to $150/gallon ($20 to $40/L) (7).

[2] The average body shop spends $2,864 per month on paint. Because averages may be skewed due to the volume of coatings used at larger shops and their volume, the median, $1,500 per month can also be used (3). This information is based on a June 2001 survey analysis conducted through a nationwide mail program to thousands of body shops.

[3] 65% of shops use one brand of paint, 31.3% use two brands, 1.9% use three brands, and 1.3% use four or more (2). The weighted average of these values yields the default usage of 1.39 brands of paint per shop. Assume no more than one brand of paint would contain the chemical of interest due to competitive barriers. Conservatively, this scenario assumes that 100% of this one brand will include the chemical of interest. Therefore, 1 chemical of interest-containing brand / 1.39 brands per shop = 72% are chemical of interest-containing brands per shop. This information is based on a survey executed via a nationwide mail program to thousands of body shops.

V_{coat_car} = Volume of coating used per car in the coating application process (liters/car):
Primer: 1 liter
Basecoat = 4 liters
Clearcoat = 6 liters (33)

$V_{coat\_purchased}$ = Volume of coating containing the chemical of interest purchased per site per year (L coating/site-year)

To estimate the number of automotive refinishing sites using the coating containing the chemical of interest, use the following equation:

$$N_{sites} = \frac{Q_{chem\_yr}}{F_{chem\_coat} \times RHO_{coat} \times V_{coat\_purchased}} \quad \textbf{[3-2]}$$

Where:

RHO_{coat} = Density of the coating (kg coating/L coating). Default: 1 kg coating/L coating (13)

$V_{coat\_purchased}$ = Annual volume of coating containing the chemical of interest purchased per site per year based on default calculation (L coating/site-year)

N_{sites} = Number of sites using coating that contains the chemical of interest

F_{chem_coat} = Mass concentration of the chemical of interest in the coating (kg chemical of interest/kg coating)

Q_{chem_yr} = Annual chemical of interest production volume (kg chemical of interest/yr)

Note: Number of sites should not exceed 33,144 as reported in the 1997 Economic Census. Data provided by the UK indicates that the EU has approximately 75,400 body shops.

3.2 Release Assessments

This section discusses the potential release of the chemical of interest within the coating used in automotive refinishing spray applications. Air releases occur from oversprayed coating that escapes the spray booth. Spray booth dry filters mitigate releases of the coating material to the air. Booths generally have particulate filters at the intake and exhaust to minimize the amount of particulates that pass through the booth with the recirculating air (6). The U.S. predominantly use dry filters whereas the EU countries may use water backed booths for capturing overspray [based on comments from the UK]. Overspray captured from the spray booth by ventilation control device (e.g., dry filter), residue gathered during equipment clean-up, and coating residue left in containers are expected to be disposed by landfill or incineration.

3.2.1 Release to Incineration or Landfill

The total releases from automotive refinishing shops to either incineration or landfill are estimated based on mass balance of the spraying operation. The release of the chemical of interest to either incineration or landfill is expected to result from the following sources:

- Oversprayed coating that is collected within the spray booth or shop area;
- Equipment cleaning or residual coating cleaned from mixing apparatus and spray guns; and
- Disposal or rinsing of coating residuals in empty containers.

The amount of coating that remains in the containers as residue depends on the size of the transport container. Refinish coatings are typically supplied in cans of one gallon or less (16). For this size container, it is estimated that 0.6% of the refinish coating remains as residue (CR%) (17). The estimate for smaller containers is conservative as it represents the high end value of a study regarding container residue for small containers. If the coating is transported in larger containers, assume 3% remains as residue in the empty cans (17). Per Section 261.7 (b) (1) (ii) of the Resource Conservation and Recovery Act (RCRA), a container or an inner liner removed from a container that has held any hazardous wastes, except waste that is a compressed gas or that is identified as an acute hazardous waste listed in §§ 261.31, 261.32, or 261.33(e) of the act is empty if no more than 2.5 centimeters (1 inch) remain on the bottom of the container or liner (31). Section 261.7 (b) (1) (iii) (A) states that no more than 3% by weight of the total capacity of the container remains in the container or inner liner if the container is equal to or less than 110 gallons in size (31). The default for larger containers, 3%, is supported by a pilot scale research project investigating the effect of four parameters on residue quantities in drums (32). The parameters include the design configuration of the container, the viscosity of the chemical, the method of unloading the chemical, and the material of construction or lining of the container. The remaining coating amount is assumed to be loaded into the gun for the spray application process. Not all of the coating that enters the gun is sprayed towards the automobile. In the absence of data, it is typically assumed that releases from equipment cleaning for a multiple pieces of equipment such as the mixing apparatus and spray gun is 2% of the production volume ($F_{equip\_residue}$) (17). This amount remains in the spray gun as residue. Therefore, the total amount of the chemical of interest that is sprayed on cars at automotive refinishing shops is calculated:

$$Q_{chem\_yr\_sprayed} = Q_{chem\_yr} \times \left(1 - F_{container\_residue} - F_{equip\_residue}\right) \qquad \textbf{[3-3]}$$

Where:

$F_{container\_residue}$ = Fraction of coating that remains in the container as residue. (Default = 0.006 if a small container such as a 1-gallon can is used or 0.03 if a larger container is used (17))

$F_{equip\_residue}$ = Percentage of coating that remains in the gun as residue (Default = 0.02 (17))

Q_{chem_yr} = Annual production volume of chemical of interest (kg chemical of interest/yr)

$Q_{chem\_yr\_spray}$ = Annual spray volume of chemical of interest (kg chemical of interest/yr)

The total amount of chemical of interest that is used ($Q_{chem\_yr\_spray}$) is either transferred to the automotive surface or is oversprayed. The amount of coating expected to be transferred to the surface is estimated by the transfer efficiency (F_{eff_gun}) of the spray gun equipment. The transfer efficiency depends on the type of spray gun used. The specifics of each control technology are discussed in detail in Section 2.4. The transfer efficiency also depends on painter technique and other operating parameters (e.g., spray gun operating pressure, viscosity of coating).

Assume that most of the oversprayed coating is collected by the spray booth ventilation control device (e.g., dry filter) and not exhausted to the air. Overspray collected by the filter is disposed of either to incineration or landfill when the used filter is disposed. This amount of collected overspray is estimated based on the removal efficiency of the control device (F_{eff_booth}). In some cases, automotive refinish shop workers may apply coatings outside of a spray booth. In these instances, none of the overspray is captured and is released to air through the stack ($F_{eff\_booth} = 0$).

The release of the chemical of interest to incineration or landfill as a result of overspray, container residue, and equipment cleaning is calculated by equations 3-4 through 3-6 using a mass balance as follows:

$$Elocal_{overspray} = F_{eff\_booth} \times \left(1 - F_{eff\_gun}\right) \times Q_{chem\_yr\_sprayed} \quad \textbf{[3-4]}$$

Where:

F_{eff_booth} = Midpoint paint booth removal efficiency (Default = 0.90 for dry filters; range 0.87 to 0.998 (11); for application outside of booth $F_{eff\_booth} = 0$)

$Elocal_{overspray}$ = Annual release of chemical of interest to either incineration or landfill from captured overspray (kg chemical of interest/year)

F_{eff_gun} = Spray gun transfer efficiency (Default = 0.20 for conventional spray guns (Range: 0.20 to 0.40); 0.65 (Average) for HVLP spray guns (9))

$Q_{chem\_yr\_sprayed}$ = Annual chemical of interest use volume (kg chemical of interest/yr)

This estimate assumes that 100% of the overspray is collected by the spray booth ventilation and is passed through the control device. In reality, a portion of the oversprayed coating will likely settle on the walls and floor of the spray booth and will not pass through the filters; however, these amounts will be routinely cleaned and collected for disposal to the same media as the filters.

A residual amount is expected to remain in the spray gun cup. This residue will be cleaned after each spray operation, and is also expected to be disposed to the same media. It is assumed that 1% of the coating is collected from the equipment and released to incineration or landfill. The estimated release from gun cleaning is calculated as:

$$Elocal_{equip\_cleaning} = F_{equip\_residue} \times Q_{chem\_yr} \times \left(1 - F_{container\_residue}\right) \qquad \textbf{[3-5]}$$

Where:

$Elocal_{equip\_cleaning}$ = Annual release of chemical of interest to either incineration or landfill from gun cleaning (kg chemical of interest/year)

$F_{container\_residue}$ = Fraction of coating that remains in the container as residue. (Default = 0.006 if a small container such as a 1- gallon can is used or 0.03 if a larger container is used (17))

$F_{equip\_residue}$ = Percentage of coating that remains in the mixing apparatus and gun as residue (Default = 0.02 (17))

Q_{chem_yr} = Annual chemical of interest production volume (kg chemical of interest/yr)

The amount of coating that remains in the container as residue depends on the size of the transport container. Refinish coatings are typically supplied in cans of one gallon or less (16). As stated previously, for this size container, assume that 0.6% of the refinish coating remains as residue and if the coating is transported in larger containers, assume 3% remains as residue.

$$Elocal_{container\_residue\_disp} = F_{container\_residue} \times Q_{chem\_yr} \qquad \textbf{[3-6]}$$

Where:

$Elocal_{container\_residue\_disp}$ = Annual release of chemical of interest to either incineration or landfill from container residue (kg chemical of interest/year)

$F_{container\_residue}$ = Percentage of coating that remains in the container as residue (Default = 0.006 if a small container such as 1- gallon can is used, or 0.03 if a larger container is used (17))

Q_{chem_yr} = Annual chemical of interest production volume (kg chemical of interest/yr)

The estimated release of the chemical of interest to incineration or landfill as a result of collected overspray, gun cleaning, and container residue is calculated as:

$$Elocal_{incin\_or\_landfill} = Elocal_{overspray} + Elocal_{equip\_cleaning} + Elocal_{container\_residue\_disp} \qquad \textbf{[3-7]}$$

Where:

$Elocal_{incin\_or\_landfill}$ = Total annual release of chemical of interest to incineration or landfill (kg chemical of interest/yr)

$Elocal_{container\_residue\_disp}$ = Annual release of chemical of interest to incineration or landfill from container residue (kg chemical of interest /yr)

$Elocal_{equip\_cleaning}$ = Annual release of chemical of interest to incineration or landfill from gun cleaning (kg chemical of interest /yr)

$Elocal_{overspray}$ = Annual release of chemical of interest to incineration or landfill from captured overspray (kg chemical of interest /yr)

3.2.2 Release to Air

Chemical of interest release to air is expected to result from the oversprayed coating that escapes the spray booth, as described in Section 3.2.2. The total amount of overspray that is not captured by the spray booth air control device (e.g., dry filter) is assumed to be released to air through the stack. Between 50 and 80% of automobile refinishing shops use minimum engineering controls to protect workers (10). In some cases, automotive refinish shop workers may apply coatings outside of a spray booth. In these instances, all of the overspray is released to air through the stack ($F_{eff\_booth} = 0$). The daily amount of coating released to stack air from overspray is estimated using the following equation:

$$Elocal_{air} = \frac{Q_{chem\_yr\_sprayed}}{N_{sites} \times TIME_{working\_days}} \times \left(1 - F_{eff\_booth}\right) \times \left(1 - F_{eff\_gun}\right) \qquad \textbf{[3-8]}$$

Where:

F_{eff_booth} = Midpoint paint booth removal efficiency (Default = 0.90 for dry filters; range 0.870 to 0.998 (11); for application outside of booth, $F_{eff\_booth} = 0$)

$Elocal_{air}$ = Daily release of chemical of interest to air per site (kg chemical of interest/site-day)

N_{sites} = Number of sites using a chemical of interest containing coating

$TIME_{working\_days}$ = Number of automotive refinishing operating days per year (Default = 180 days/year)

F_{eff_gun} = Spray gun transfer efficiency (Default = 0.020 for conventional spray guns (Range: 0.020 to 0.040); 0.65 (Average) for HVLP spray guns (9))

$Q_{chem\_yr\_sprayed}$ = Annual chemical of interest use volume (kg chemical of interest/yr)

Note that this estimate is conservative for the non-volatile components of the coating, as it assumes that all oversprayed particles are collected in the booth exhaust and are passed through the control device. The amount of overspray depends on the spray gun used and the spray booth configuration. The specifics of each control technology are discussed in detail in Section 2.4. Sample calculations are presented in Section 4.2.

3.2.3 Release to Water

Water releases are not expected for automotive refinish solvent-based coatings. Hygiene surveys in literature and information from a spray booth manufacturer (15) indicates that water controls in refinishing spray booths are seldom, if ever, used. {Some equipment cleaning may be done by water blasting, the spraying of water at high pressures}. In the absence of data, it is typically assumed that releases from equipment cleaning for multiple pieces of equipment is 2% of the production volume ($F_{equip\_residue}$) (17). For water-based coatings, and/or cases where water blasting is expected to be the method of cleaning, it is assumed that releases from cleanup could be released to water. In this case, equation 3-9 below could be used.

$$Elocal_{water} = \frac{F_{equip\_residue} \times Q_{chem\_yr} \times \left(1 - F_{container\_residue}\right)}{N_{sites} \times TIME_{working\_days}} \quad \textbf{[3-9]}$$

Where:

$Elocal_{water}$ = Daily site release of chemical of interest to water from cleanup of mixing apparatus and spray gun (kg chemical of interest/site- day)

$F_{container\_residue}$ = Fraction of coating that remains in the container as residue. (Default = 0.006 if a small container such as a 1- gallon can is used or 0.03 if a larger container is used (17))

$F_{equip\_residue}$ = Percentage of coating that remains in the mixing apparatus and gun as residue (Default = 0.02 (17))

Q_{chem_yr} = Annual chemical of interest production volume (kg chemical of interest/yr)

N_{sites} = Number of sites using a chemical of interest-containing coating

$TIME_{working\_days}$ = Number of automotive refinishing operating days per year (Default = 180 days/year)

In the EU countries, however, there is an additional potential for water releases from use of water back booths. In this case, the following equation may be used.

$$Elocal_{water\_booth} = \frac{Q_{chem\_yr} \times \left(1 - F_{equip\_residue}\right) \times \left(1 - F_{container\_residue}\right) \times F_{eff-booth} \times \left(1 - F_{eff\_gun}\right)}{N_{sites} \times TIME_{working\_days}}$$

Where:

$Elocal_{water\_booth}$ = Daily site release of chemical of interest to water from water back booth (kg chemical of interest/site-day)

$F_{container\_residue}$ = Fraction of coating that remains in the container as residue. (Default = 0.006 if a small container such as a 1-gallon can is used or 0.03 if a larger container is used (17))

$F_{equip\_residue}$ = Percentage of coating that remains in the mixing apparatus and gun as residue (Default = 0.02 (17))

F_{eff_booth}	=	Midpoint paint booth removal efficiency (Default = 0.90 for dry filters; range 0.870 to 0.998 (11); for application outside of booth, F_{eff_booth} = 0). Efficiency for water backed booth is unknown.
F_{eff_gun}	=	Spray gun transfer efficiency (Default = 0.020 for conventional spray guns (Range: 0.020 to 0.040); 0.65 (Average) for HVLP spray guns (9))
Q_{chem_yr}	=	Annual chemical of interest production volume (kg chemical of interest/yr)
N_{sites}	=	Number of sites using a chemical of interest-containing coating
$TIME_{working\_days}$	=	Number of automotive refinishing operating days per year (Default = 180 days/year)

3.3 Occupational Exposure Assessments

Worker activities at automotive refinishing shops include wet sanding, car washing, stripping (coating removal), machine sanding, blowing, buffing, polishing, coating spraying, coating and primer mixing, equipment cleaning and inspection (18). Most refinishing shops typically operate for one, eight-hour shift per day. This may fluctuate depending on the volume of business (29). This scenario provides inhalation and dermal exposure estimates from the manual spraying of coatings containing the chemical of interest. The estimates are based on the non-volatile components of the coatings contained in the overspray mist particles.

Many different personal protective equipment options exist for painters to lower exposure potential. Workers typically wear air-purifying respirators or air-supplied respirators to minimize inhalation exposure to coating mists. Gloves and paint suits are available to painters to limit dermal exposure to coatings. These exposure estimates are conservative since they assume the painters do not wear gloves or respirators.

3.3.1 Number of Workers per Site ($N_{workers}$)

One reference estimates that a typical automotive refinishing shop has an average of 7.8 employees (3). Census data from 2001 for NAICS code 811121 show 221,129 people were paid employees for the 34,786 shops (1) (see Table 3.1), which averages approximately 6.4 workers per site. It is expected that not all of these employees would be painters. In the absence of data, 8 painters per site is assumed as a conservative estimate.

3.3.2 Inhalation Exposure

The inhalation exposure estimates presented in this section are applicable to the non-volatile chemical of interest component of the coating (e.g, a pigment or a resin). The estimates are based on exposure to the non-volatile fraction of the coating when applied through manual spraying with both conventional and HVLP spray guns. This generic scenario does not provide estimates for worker exposures to the volatile components of the coating, nor does it provide estimates for worker exposures to materials encountered while performing other automotive refinishing tasks (e.g., sanding, solvent wipe-down, coating mixing and gun cleaning). Worker inhalation exposures to polyisocyanate components during the application of coatings was presented as an attachment to the *1996 Generic Scenario for Automobile Spray Coating* draft report. The attachment (included as Appendix C in this scenario) for the 1996 generic scenario should be used if the chemical of interest is a polyisocyanate, while the following calculations should be used for all other non-volatile coating components:

The following equation estimates the weight fraction of the chemical of interest in the coating solids:

$$F_{chem\_solids} = \frac{F_{chem\_coat}}{F_{solids\_coat}} \qquad \textbf{[3-10]}$$

Where:

F_{chem_coat}	=	Weight fraction of the chemical of interest in the coating formulation (mg chemical of interest/mg coating)
F_{chem_solids}	=	Weight fraction of chemical of interest in the coating solids (mgchemical of interest/mg solids)
F_{solids_coat}	=	Weight fraction of solid components within the coating formulation (Default = 0.25 mg solids/mg coating, although solids content in coatings vary widely (20))

Inhalation exposure to the chemical of interest during spray pointing operations is estimated using the following equation:

$$EXP_{inhalation} = C_{coat\_mist} \times N_{jobs} \times TIME_{job} \times RATE_{breathing} \times F_{chem\_solids} \qquad \textbf{[3-11]}$$

Where:

$RATE_{breathing}$	= Typical worker breathing rate (Default = 1.25 m^3/hr (19))
C_{coat_mist}	= Coating mist concentration in the air at workers breathing zone (mg/m^3)
$TIME_{job}$	= Job duration (Default = 0.6 hour/job, Range = 0.11 to 3.2 hours per job)
$EXP_{inhalation}$	= Inhalation exposure from the chemical of interest per day (mg chemical of interest/day)
N_{jobs}	= Typical number of jobs per day (Default = jobs/day)
F_{chem_solids}	= Weight fraction of the chemical of interest in the coating solids (mg chemical of interest/mg solids).

Coating mist concentrations (C_{coat_mist}) within the spray booth were obtained through an extensive search of OSHA In-depth Surveys of the Automotive Refinishing Shop Industry. These data are summarized in Table D-1 through Table D-3 (see Appendix D) and are used as the basis for the inhalation exposure assessments. The mist concentration values depend on the spray gun used and the spray booth configuration. The specifics of each control technology are discussed in detail in Section 2.4.

Many of the sources in Table D-1 through Table D-3 reported the spraying time for each job for which coating mist concentrations were monitored. The reported job duration ranged from 7 minutes to 190 minutes. An average of all the times provided in the cited sources, 35.5 min or 0.6 hour per job, is used as the default value for spray painting job times. Job duration depends on the coating characteristics, as well as the size of the area to be coated. Because it is difficult to model time as a function of these two factors, the average is used as the default.

Table 3-3 presents default mist concentrations for five spray painting scenarios. These scenarios are based upon various combinations of engineering controls (i.e., crossdraft, downdraft, or semi-downdraft booths) and spray gun types (i.e., conventional or HVLP). The default coating mist concentrations (C_{coat_mist}) for the following scenarios represent the highest concentrations reported for each configuration found (Appendix D Tables D1-D3) and should be used to calculate inhalation exposure, as presented in Equation 3-10.

Table 3-3

Default Mist Concentrations for Spray Painting Scenarios

Scenario	Scenario Description	Mist Concentration	Notes
1	Crossdraft booth and conventional spray gun	35 mg/m^3	No significant difference was found in the mist concentrations generated from conventional gun and HVLP gun in the crossdraft booth, based on review of available exposure information
2	Crossdraft booth and HVLP spray gun	34 mg/m^3	
3	Downdraft booth and conventional spray gun	9.0 mg/m^3	Higher mist concentration data was found for HVLP guns in the downdraft booth, however the default coating mist concentration has been set equal to the maximum mist concentration from a conventional spray gun in a downdraft booth. This is consistent with industry specific literature surveys citing HVLP guns as creating less overspray than conventional spray guns.
4	Downdraft booth and HVLP spray gun	9.0 mg/m^3	
5	Semi-down draft booth and conventional spray gun	24 mg/m^3	

While many of the measured coating mist concentrations for these configurations are much lower than the default values reported in this scenario, the highest value is used to obtain a conservative estimate.

Table D-1 in Appendix D shows the three studies containing coating mist concentration data for HVLP use in a downdraft booth. Two of these three studies provided each individual data point used to derive an average for each study. The highest individual coating mist concentration data point for the downdraft booth and HVLP spray gun configuration (Scenario 4) is 18 mg/m^3 (5). This data point is twice as large as the highest default value for coating mist concentration estimate for a downdraft booth and conventional spray gun configuration (Scenario 3). Use of a higher default for HVLP versus conventional spray guns in a downdraft booth is not believed to be reasonable based on industry specific literature surveys. Because HVLP spray guns use lower pressures to atomize the coatings, more of the coating is transferred to the surface with less overspray (9). HVLP guns are more efficient, leading to less mist, and lower expected exposures. Despite the concentration values reported in Appendix D, this scenario conservatively assumes that HVLP performance in a downdraft booth is at least equivalent to that of a conventional spray gun in the same environment (9 mg/m^3).

Conservative coating mist concentration data defaults are used in this scenario (Equation 3-10) rather than statistical analysis of each data set. Some of the studies presented in Appendix D provide the geometric mean of all trials taken for a specific study without providing individual data points. The use of the geometric mean in a statistical analysis of coating mist concentration data sets may provide biased results. The geometric mean is a measure of central tendency and does not accurately capture the variability in coating mist concentration data.

The recommended scenario is based on the following statistics (10):

- X 30% of shops use crossdraft booths;
- X 50% of shops use downdraft booths; and
- X 64% of shops use HVLP spray guns.

Scenario 1 and *Scenario 2* are more likely representative of a typical shop than *Scenarios 3, 4 and 5* (29). *Scenario 2* is more likely than *Scenario 1*. *Scenario 1* should be used as a conservative default in the absence of more detailed information on the automotive refinishing shops that use the chemical of interest-containing coatings. Sample calculations are presented in Section 4.2.

3.3.3 Dermal Exposure

There is a potential for dermal exposure to the spray paint chemicals when transferring the paint from the container into a reservoir for mixing; during the spray painting operation itself; and during cleanup. No dermal monitoring data for spray painting was found from investigation of the references cited in this report. In the absence of data, a simplified model is used to estimate potential dermal exposure during industrial activities.

This model is based on experimental data with liquids of varying viscosity. Measurements were made of the amount of exposure to hands for various types of contact. Judgements were then made as to the types of common industrial activities that could be associated with the experimental data. Additionally, available data on pesticide exposures collected by EPA's Office of Pesticide Programs was also used in the development of a Table of Dermal Assessment Factors which are presented in Appendix D (25, 35). Other key assumptions and limitations of the dermal model are that a single contact with a chemical results in an exposure assessment for the entire day. These factors provide an assessment of potential exposure and do not take into account any protection from the use of protective gloves. To calculate dermal exposure to the chemical of interest from these activities use the following equation:

$$EXP_{dermal} = AREA_{surface} \times Q_{liquid\_skin} \times F_{chem\_coat} \times N_{exp\_incident} \quad \textbf{[3-12]}$$

Where:

EXP_{dermal} = Potential dermal exposure to the chemical of interest per day (mg chemical of interest/day)

F_{chem_coat} = Weight fraction of the chemical of interest in the coating formulation (mg chemical of interest/mg coating)

$N_{exp\_incident}$ = Number of exposure incidents per day. Default =1 incident/day

Q_{liquid_skin} = Quantity of liquid remaining on skin
Defaults: Transfer to mixing apparatus: 2.1 mg/cm^2- incident (high-end) and 0.7 mg/cm^2-incident (low-end)
Spray Painting : 10.3 mg/cm^2-incident (high-end) and 1.3 mg/cm^2-incident (low-end)
Cleanup: 2.1 mg/cm^2-incident (high-end) and 0.7 mg/cm^2-incident (low-end) (25)

$AREA_{surface}$ = Surface area of contact: Spray painting and Cleanup: Default = 840 cm^{2,} 2 hands: for transfer to mixing apparatus (small-scale), default = 420 cm^2 (25))Summary of Equations and Sample Calculations Section 4.1 presents a summary of all of the equations introduced in Section 3 of this document. Example calculations are included in Section 4.2 to show how all of these equations are related.

4 SUMMARY OF EQUATIONS AND SAMPLE CALCULATIONS

Section 4.1 presents a summary of all of the equations introduced in Section 3 of this document. Example calculations are included in Section 4.2 to show how all of these equations are related.

4.1 Summary of Release and Exposure Equations

Table 4-1 summarizes the equations introduced in Section 3 of this document. These equations may be used in evaluating releases of and exposures to components of spray coatings used for automotive refinishing. A description of each equation is also presented in the table and supporting nomenclature is provided below the table.

Table 4-1

Summary of Release and Exposures Calculation

General Facility Estimates

Liters of Coating Purchased per Site per Year:

$$V_{coat\_purchased} = \frac{COST_{coat\_allowance} \times V_{coat\_car} \times \frac{12\ months}{yr} \times F_{coat}}{COST_{coats}} \qquad [3\text{-}1]$$

Number of Sites:

$$N_{sites} = \frac{Q_{chem\_yr}}{F_{chem\_coat} \times RHO_{coat} \times V_{coat\_purchased}} \qquad [3\text{-}2]$$

Number of Workers Possibly Exposed per Site:

$N_{workers}$ = 8 per site (Default)

Days of Operation per Year:

$TIME_{working\_days}$ = 180 days/yr (Default)

Use Volume:

$$Q_{chem\_yr\_sprayed} = Q_{chem\_yr} \times \left(1 - F_{container\_residue} - F_{equip\_residue}\right) \qquad [3\text{-}3]$$

Table 4-1(continued)

Release Calculations	
Medium	Calculations
Landfill or Incineration	Releases to Landfill or Incineration from Captured Overspray: $Elocal_{overspray} = F_{eff\_booth} \times (1 - F_{eff\_gun}) \times Q_{chem\_yr\_sprayed}$ [3-4] Releases to Landfill or Incineration from Equipment Cleaning: $Elocal_{equip\_cleaning} = F_{equip\_residue} \times Q_{chem\_yr} \times \left(1 - F_{container\_residue}\right)$ [3-5] Releases to Landfill or Incineration from Container Residue: $Elocal_{container\_residue\_disp} = F_{container\_residue} \times Q_{chem\_yr}$ [3-6] Total Releases to Landfill or Incineration of Chemical of Interest: $Elocal_{incin\_or\_landfill} = Elocal_{overspray} + Elocal_{equip\_cleaning} + Elocal_{container\_residue\_disp}$ [3-7]
Air	$Elocal_{air} = \frac{Q_{chem\_yr\_sprayed}}{N_{sites} \times TIME_{working\_days}} \times \left(1 - F_{eff\_booth}\right) \times \left(1 - F_{eff\_gun}\right)$ [3-8]
Water	$Elocal_{water} = \frac{F_{equip\_residue} \times Q_{chem\_yr} \times \left(1 - F_{container\_residue}\right)}{N_{sites} \times TIME_{working\_days}}$ [3-9]

Table 4-1(continued)

Occupational Exposure
Weight fraction of chemical of interest in coating solids: $$F_{chem\_solids} = \frac{F_{chem\_coat}}{F_{solids\_coat}}$$ [3-10]
Inhalation: $$EXP_{inhalation} = C_{coat\_mist} \times N_{jobs} \times TIME_{job} \times RATE_{breathing} \times F_{chem\_solids}$$ [3-11] C_m: Crossdraft booth and conventional spray gun, C_m = 35 mg/m^3 Crossdraft booth and HVLP spray gun, C_m = 34 mg/m^3 Downdraft booth and conventional spray gun, C_m = 9.0 mg/m^3 Downdraft booth and HVLP spray gun, C_m = 9.0 mg/m^3 Semi-down draft booth and conventional spray gun, C_m = 24 mg/m^3
Dermal: $$EXP_{dermal} = AREA_{surface} \times Q_{liquid\_skin} \times F_{chem\_coat} \times N_{exp\_incident}$$ [3-12]

Where:

$AREA_{surface}$ =Surface area of contact:
Spray painting and Cleanup: Default = 840 cm^{2,} 2 hands:
Transfer to mixing apparatus (small-scale): Default = 420 cm^2 (25))

$COST_{coat\_allowance}$ = Coating allowance per shop per month.
Default: $2,864/site-month (3))

$COST_{coats}$ = Cost per car based on the volume (Q_{coat_car}) and cost of each type of coating ($/car).
Default: $450/car

C_{coat_mist} = Coating mist concentration in the air at workers breathing zone (mg/m^3)

$Elocal_{air}$ = Amount of chemical of interest released to air (kg chemical of interest /site-day)

$Elocal_{container\_residue\_disp}$ = Amount of chemical of interest released to landfill or incineration from container residue (kg chemical of interest /yr)

$Elocal_{equip\_cleaning}$= Amount of chemical of interest released to landfill or incineration from equipment cleaning (kg chemical of interest /yr)

$Elocal_{incin\_or\_landfill}$= Amount of chemical of interest incinerated or landfilled (kg chemical of interest /yr)

$Elocal_{overspray}$= Amount of chemical of interest released to landfill or incineration from captured overspray (kg chemical of interest /yr)

$Elocal_{water}$= Amount of chemical of interest released to water (kg chemical of interest/site-day)

EXP_{dermal} = Dermal exposure to the chemical of interest per day (mg chemical of interest/day)

$EXP_{inhalation}$ = Inhalation exposure from the chemical of interest per day (mg chemical of interest/day

F_{chem_coat} = Fraction of chemical of interest in the coating formulation (kg chemical of interest/ kg coating)

F_{chem_solids} = Weight fraction of chemical of interest in the coating solids (Default = 0.25 mg chemical of interest/mg solids (20))

F_{coat}= Fraction of coating that contains chemical of interest used by a single shop (Default = 72% (2))

$F_{container\_residue}$= Fraction of coating that remains in container as residue (Default = 0.006 (17))

F_{eff_booth} = Midpoint paint booth removal efficiency (Default = 0.90 for dry filters; range 0.87 to 0.998 (11); for application outside of booth, F_{eff_booth} = 0)

F_{eff_gun}= Spray gun transfer efficiency (Default = 20% for conventional spray guns (Range: 20 to 40%), 65% (Average) for HVLP guns (6))

$F_{equip\_residue}$= Percentage of coating that remains in mixing apparatus and gun as residue (Default = 2% (17))

F_{solids_coat}= Weight fraction of solid components within the coating formulation (Default = 0.25 mg solids/mg coating, although solids content in coatings vary widely (20)).

$N_{exp\_incident}$= Number of exposure incidents per day (incident/day). Default: 1 incident/day

N_{jobs}= Typical number of jobs per day(Default = 7 jobs/day)

N_{sites} = Number of sites

$N_{workers}$ = Number of workers potentially exposed

Q_{chem_yr}= Annual production volume of chemical of interest (kg chemical of interest /yr)

$Q_{chem\_yr\_sprayed}$= Annual use volume (amount sprayed) of chemical of interest (kg chemical of interest /yr) Q_{liquid_skin} = *Transfer to mixing apparatus:* 2.1 mg/cm^2-incident (high-end) and 0.7 mg/cm^2-incident (low-end)

Spray Painting: 10.3 mg/cm^2-incident (high-end) and 1.3 mg/cm^2-incident (low-end)

Cleanup: 2.1 mg/cm^2-incident (high-end) and 0.7mg/cm^2-incident (low-end) (25)

Quantity of liquid remaining on skin: 10.3 mg/cm^2 (high end) and 1.3 mg/cm^2 (low end) (25))

$RATE_{breathing}$= Breathing rate (Default = 1.25m^3/hr (19))

RHO_{coat}= Density of the coating (Default = 1 kg/L (13))

$TIME_{job}$ = Job duration (Default = 35.5 minutes, Range 7 to 190 minutes)

$TIME_{working\_days}$ = Days of operation (days/yr)

V_{coat_car} = Liters of coating used per car in the coating application process (liters/car):

Primer: 1 liter
Basecoat = 4 liters
Clearcoat = 6 liters (33)

$Q_{coat\_purchased}$= Liters of coating containing the chemical of interest purchased per site per year (L coating/site-year)

4.2 Individual Chemical Release and Exposure Examples

This section presents an example scenario and displays how the equations in Section 3 might be used to estimate releases of and exposures to non-solvents chemicals found in coating formulations. The default values used in these calculations are presented in Section 3 and should be used only in the absence of site-specific information. The following assumptions are made in this example calculation:

Chemical of interest production volume (Q_{chem_yr}) is 3200 kg/yr
Chemical of interest makes up 5%, by weight, of a clearcoat formulation (F_{chem_coat})
Chemical of interest is used in a crossdraft booth with a conventional spray gun
Chemical of interest is supplied in one-gallon containers

The following values cited in this example calculation are default values used throughout this document. The basis of these values can be found within Section 3:

$AREA_{surface}$ = Surface area of contact = 840 mg/m^3
$COST_{coats}$ = Cost per car based on the number of liters (Q_{coat_car}) and cost of each type of coating ($/car). Default: $450/car
$COST_{coat\_allowance}$ = Monthly coating allowance per site. Default: $2,864/site-month
C_{coat_mist} = Coating mist concentration = 35 mg/m^3 for crossdraft
F_{coat} = Fraction of coating that contains chemical of interest 0.72.[1]
$F_{container\_residue}$ = Fraction of production volume that is released as container residue. Default: 0.006 for small containers
F_{eff_booth} = Midpoint paint booth removal efficiency = 0.90 (Default = 0.90 for dry filters; ange 0.87 to 0.998 (11))
F_{eff_gun} = Spray gun transfer efficiency of spray gun = 0.20
F_{solids_coat} = Weight fraction of solid components in the coating formulation. Default: 0.25 mg solids/mg coating
$N_{exp\_incident}$ = Number of exposure incidents per day. Default: 1 incident/day
N_{jobs} = Typical number of jobs per day (Default = 7 jobs/day)

[1] 65% of shops use one brand of paint, 31.3% use two brands, 1.9% use three brands, and 1.3% use four or more (2). The weighted average of these values yields the default usage of 1.39 brands of paint per shop. Assume no more than one brand of paint would contain the chemical of interest due to competitive barriers. Conservatively, this scenario assumes that 100% of this one brand will include the chemical of interest. Therefore, 1 chemical of interest-containing brand / 1.39 brands per shop = 72% are chemical of interest-containing brands per shop. This information is based on a survey executed via a nationwide mail program to thousands of body shops.

V_{coat_car}	=	Liters of coating used per car in the coating application process Basecoat = 4 liters/car (33)
Q_{liquid_skin}	=	Quantity of liquid remaining on skin = 10.3 mg/cm^2-incident (high end)
$RATE_{breathing}$	=	Worker breathing rate = 1.25 m^3/hr
RHO_{coat}	=	Density of the coating = 1 kg coating/L coating
$TIME_{job}$	=	Job duration (Default = 0.6 hours/job)

Liters of basecoat coating purchased per site per year ($V_{coat\_purchased}$):

$$V_{coat\_purchased} = \frac{COST_{coat\_allowance} \times V_{coat\_car} \times \frac{12\ months}{yr} \times F_{coat}}{COST_{coats}} \qquad [3\text{-}1]$$

$$V_{clearcoat\_purchased} = \frac{\frac{\$2846}{site - month} \times \frac{6\ L\ basecoat}{car} \times \frac{12months}{yr} \times 0.72}{\frac{\$450}{car}} = 330\frac{L\ clearcoat}{site - yr}$$

Number of sites:

$$N_{sites} = \frac{Q_{chem\_yr}}{F_{chem\_coat} \times RHO_{coat} \times V_{coat\_purchased}} \qquad [3\text{-}2]$$

$$N_{sites} = \frac{\frac{3200\ kg\ chem\ of\ interest}{yr}}{\frac{5\ kg\ chem\ of\ interest}{100\ kg\ coating} \times \frac{1\ kg\ coating}{L\ coating} \times \frac{330\ L\ clearcoating}{site - yr}} = 194\ sites$$

Amount sprayed:

$$Q_{chem\_yr\_sprayed} = Q_{chem\_yr} \times \left(1 - F_{container\_residue} - F_{gun\_residue}\right) \qquad [3\text{-}3]$$

$$Q_{chem\_yr\_sprayed} = 3200\frac{kg\ chem\ of\ interest}{yr} \times (1 - 0.006 - 0.01) = 3150\frac{kg\ chem\ of\ interest}{yr}$$

Amount released to incineration or landfill from captured overspray:

$$Elocal_{overspray} = F_{eff\_booth} \times (1 - F_{eff\_gun}) \times Q_{chem\_yr\_sprayed} \qquad [3\text{-}4]$$

$$Elocal_{overspray} = 0.90 \times (1 - 0.2) \times 3150\frac{kg\ chem\ of\ interest}{yr} = 2270\frac{kg\ chem\ of\ interest}{yr}$$

Amount released to incineration or landfill from equipment cleaning:

$$Elocal_{equip\_cleaning} = F_{equip\_residue} \times Q_{chem\_yr} \times \left(1 - F_{container\_residue}\right) \quad [3\text{-}5]$$

$$Elocal_{equip\_cleaning} = 0.02 \times 3200 \frac{\text{kg chem of interest}}{\text{yr}} \times (1 - 0.006) = 63.6 \frac{\text{kg chem of interest}}{\text{yr}}$$

Amount released to incineration or landfill from container residue:

$$Elocal_{container\_residue\_disp} = F_{container\_residue} \times Q_{chem\_yr} \quad [3\text{-}6]$$

$$Elocal_{container\_residue\_disp} = 0.006 \times 3200 \frac{\text{kg chem of interest}}{\text{yr}} = 19.2 \frac{\text{kg chem of interest}}{\text{yr}}$$

Total amount released to incineration or landfill:

$$Elocal_{incin\_or\_landfill} = Elocal_{overspray} + Elocal_{equip\_cleaning} + Elocal_{container\_residue\_disp} \quad [3\text{-}7]$$

$$Elocal_{incin\_or\_landfill} = (2270 + 31.8 + 19.2) \frac{\text{kg chem of interest}}{\text{yr}} = 2320 \frac{\text{kg chem of interest}}{\text{yr}}$$

Amount released to air:

$$Elocal_{air} = \frac{Q_{chem\_yr\_sprayed}}{N_{sites} \times TIME_{working\_days}} \times \left(1 - F_{eff\_booth}\right) \times \left(1 - F_{eff\_gun}\right) \quad [3\text{-}8]$$

$$Elocal_{air} = \frac{3150 \frac{\text{kg}}{\text{yr}}}{194 \text{ sites} \times 180 \frac{\text{days}}{\text{yr}}} \times (1 - 0.90) \times (1 - 0.20) = 0.007 \frac{\text{kg}}{\text{site} - \text{day}}$$

Amount released to water:

$$Elocal_{water} = \frac{F_{equip\_residue} \times Q_{chem\_yr} \times \left(1 - F_{container\_residue}\right)}{N_{sites} \times TIME_{working\_days}} \qquad \textbf{[3-9]}$$

$$Elocal_{water} = \frac{0.02 \times 3200 \frac{\text{kg chemof interest}}{\text{yr}} \times (1 - 0.006)}{194 \text{ sites} \times 180 \frac{\text{days}}{\text{year}}} = 0.002 \frac{\text{kg chem of interest}}{\text{site} - \text{day}}$$

Weight Fraction of Chemical of Interest in Coating Solids:

$$F_{chem\_solids} = \frac{F_{chem\_coat}}{F_{solids\_coat}} \qquad [3\text{-}10]$$

$$F_{chem\_solids} = \frac{0.05 \text{ mg chem of interest} / \text{mg coating}}{0.25 \text{ mg solids} / \text{mg coating}} = 0.2 \frac{\text{mg chem of interest}}{\text{mg solids}}$$

Inhalation exposure:

$$EXP_{inhalation} = C_{coat\_mist} \times N_{jobs} \times TIME_{job} \times RATE_{breathing} \times F_{chem\_solids} \qquad [3\text{-}11]$$

$$EXP_{inhalation} = 35 \frac{\text{mg solids}}{\text{m}^3} \times 7 \frac{\text{jobs}}{\text{day}} \times 0.6 \frac{\text{hrs}}{\text{job}} \times 1.25 \frac{\text{m}^3}{\text{hr}} \times 0.2 \frac{\text{mg chem of interest}}{\text{mg solids}} = 36.2 \frac{\text{mg chem of interest}}{\text{day}}$$

Dermal Exposure:

$$EXP_{dermal} = AREA_{surface} \times Q_{liquid\_skin} \times F_{chem\_coat} \times N_{exp\_incident} \qquad [3\text{-}12]$$

$$EXP_{dermal} = 840\text{cm}^2 \times \frac{10.3 \text{ mg coating}}{\text{cm}^2 - \text{incident}} \times \frac{5 \text{ mg chem of interest}}{100 \text{ mg coating}} \times \frac{1 \text{incident}}{\text{day}} = 430 \frac{\text{mg chem of interest}}{\text{day}}$$

5. DATA GAPS/ UNCERTAINTIES AND FUTURE WORK

- Typical coating formulation percent compositions were not found (i.e. binders, solvents, and other additives).
- Amounts of primer versus basecoat versus clearcoat and their typical densities
- Frequency of dermal exposure
- Accounting for volatile components.
- To calculate the amount of coating purchased per site year (k), the scenario uses a default estimate for the percentage of coating that contains the chemical of interest used by a single shop. A typical shop uses 1.39 brands of coating (2). The scenario assumes that no more than one brand of coating would contain the chemical of interest due to competitive barriers. Also assumed in this scenario is that 100% of a single brand of coating will contain the chemical of interest. Future efforts could analyze the presence of specific chemicals in various coating formulations made by one brand.
- Coating mist concentration data for the use of HVLP guns in semi-down draft booths were not found. Future efforts could search for monitoring data for this configuration.

6. References

The specific information researched in the development of this document included: process description, operating information, chemicals used, wastes generated, worker activities, and exposure information. Categories of sources checked were EPA sources, other government agencies (NIOSH and OSHA), journals, trade associations, and web searches. References listed in the 1996 generic scenario were updated with the information available as of June 2003, including information from: Kirk-Othmer Encyclopedia of Technology, the County Business Patterns web site, the Annual Survey of Manufacturers web site, the NIOSHtic database, the OSHA web site for automatic repair and refinishing, and the Body Shop Business web site. The references specifically cited in this document are listed below:

(1) U.S. Census Bureau. 2001 County Business Patterns, Industry Code Comparison 811121 Automotive body, paint & interior R&M *http://censtats.census.gov/cbpnaic/cbpnaic.shtml* (last confirmed June 2003)

(2) 1997 Body Shop Industry Profile. *http://www.bodyshopbusiness.com* (last confirmed June 2003)

(3) 2000 Body Shop Industry Profile. *http://www.bodyshopbusiness.com* (last confirmed June 2003)

(4) Cooper, et al. In-Depth Survey Report: Control Technology for Autobody Repair and Paint Shops at Jeff Wyler Autobody Shop, Batavia, OH. U.S. Department of Health and Human Services, National Institute for Occupational Safety and Health, ECTB 179-15a, May 1993. *http://www.osha.gov/SLTC/autobody/docs/ectb179-15a/ectb179-15a.html* (last confirmed June 2003)

(5) Heitbrink, et al. In-Depth Survey Report: Control Technology for Autobody Repair and Paint Shops at Valley Paint and Body Shop, Amelia, OH. U.S. Department of Health and Human Services, National Institute for Occupational Safety and Health, ECTB 179-14a, May 1993. *http://www.osha.gov/SLTC/autobody/docs/ectb179-14a/ectb179-14a.html* (last confirmed June 2003)

(6) Memorandum: AReport of Recommended Safe Work Practices;@ from Kevin Sikora, ERG to Mary Cushmac et al., OPPT/DfE; September 28, 1998.

(7) Telecon, Tom Brown, ICI Paints, with Christopher Sweet, SAIC, May 1, 1996. Low VOC Paints.

(8) U.S. EPA, Alternative Control Techniques Document: Automobile Refinishing. April 1994, EPA-453/R-94-031.

(9) W.A. Heitbrink, R.H. Verb, T.J. Fischbach, and M.E. Wallace: A Comparison of Conventional and High Volume-Low Pressure Spray-Painting Guns. Am. Ind. Hyg. Assoc. J. (57)/March, 1996 pp. 304-310.

(10) 1995 Body Shop Industry Profile, prepared by MarketScope for Body Shop Business Magazine.

(11) Vanessa Rodriguez, AGeneric Engineering Assessment: Spray Coating Occupational Exposure and Environmental Releases.@ October 1987.

(12) Office of Pollution Prevention and Toxics (OPPT). New Chemicals Environmental Technology Initiative: Automotive Refinishing Industry Isocyanate Profile, U.S. Environmental Protection Agency, Washington DC, May 1997.

(13) Sikkens, Inc. Material Safety Data Sheets, Akzo Nobel Coatings Inc., Norcross, GA, January 1998.

(14) Site Visit to Chevy Chase Chevrolet-Geo-Oldsmobile by SAIC, April 26, 1996. Paint use data obtained for month of January 1995.

(15) Telecon, Bill Garcia, DeVilbiss Corporation, with John Vierow, SAIC, April 4, 1996. Spray booth design in automobile refinishing industry.

(16) BASF, 1996. Comments received from Mr. Tom Hoermann of BASF in regards to the 1996 Generic Scenario for Automobile Spray Coating Draft.

(17) Memorandum: ARevised Compilation of Guidance Memoranda (1992 - May 1999);@ from Kurt Rindfusz, ERG to Nhan Nguyen, CEB Engineers, ERG PMN Team; December 2, 1999.

(18) John Pfanstiehl, Automotive Paint Handbook, HPBooks, Los Angeles, 1992.

(19) NIOSH 1976. A Guide to Industrial Respiratory Protection. NIOSH, U.S. Department of Health & Human Services Hew Pub 76-189

(20) Kirk-Othmer Encyclopedia of Chemical Technology, Volume 6, ACoatings,@ 1993.

(21) McCammon: CDC NIOSH Health Hazard Evaluation, Matrix CarStar. *http://www.osha.gov/SLTC/autobody/docs/cdc003.html* (last confirmed June 2003)

(22) Rudzinski et al. *Sampling and Analysis of Isocyanates in Spray-Painting Operations*. Am. Ind. Hyg. Assoc. J., Vol 56, March 1995, p. 284-289. (1995)

(23) McCammon. NIOSH Health Hazard Evaluation, Spence=s Carstar, Denver, CO. U.S. Department of Health and Human Services, National Institute for Occupational Safety and Health, HETA 95-0405-2600, September 1996, 1993, *http://www.osha.gov/SLTC/autobody/docs/cdc001.html* (last confirmed June 2003)

(24) Heitbrink et al. *Control of Paint Overspray in Autobody Repair Shops*. Am. Ind. Hyg. Assoc. J., Vol 56, October 1995, pp. 1023-1032

(25) Memorandum: ARevision to CEB=s Method for Screening Level Assessments for Dermal Exposure;@ from Greg Macek, CEB to CEB Staff and Contractors; June 2000.

(26) Heitbrink, William A. et al. In-Depth Survey Report: Control Technology for Autobody Repair and Paint Shops at Cincinnati Collision Autobody Shop., U.S. Department of Health and Human Services, National Institute for Occupational Safety and Health, ECTB 179-16a,

September 21, 1993. *http://www.osha.gov/SLTC/autobody/docs/ectb179-16a/ectb179-16a.html* (last confirmed June 2003)

(27) Heitbrink. In-Depth Survey Report: Control Technology for Autobody Repair and Paint Shops at Team Chevrolet, Colorado Springs, CO., U.S. Department of Health and Human Services, National Institute for Occupational Safety and Health, ECTB 179-18a, December 3, 1993. *http://www.osha.gov/SLTC/autobody/docs/ectb179-18a/ectb179-18a.html* (last confirmed June 2003)

(28) McCammon: CDC NIOSH Health Hazard Evaluation, Martin=s CarStar. *Website: http://www.osha.gov/SLTC/autobody/docs/cdc002.html* (last confirmed June 2003)

(29) Engineering judgment based on experience with the Design for the Environment Automotive Refinishing project and site visits by ERG.

(30) CEB Spread Sheet for Inhalation Exposure and Vapor Generation from Transfer and Open Surface Operations. CEB January 1997.

(31) Resource Conservation and Recovery Act 40 CFR Chapter 1 Part 261, RCRA Online. *http://www.access.gpo.gov/nara/cfr/waisidx_02/40cfr261_02.html* (last confirmed June 2003)

(32) PEI Associates, Inc. 1986. Releases During Cleaning of Equipment. Washington, D.C.: Office of Toxic Substances, U.S. Environmental Protection Agency. Contract 68-02-4248.

(33) Memorandum: "Spray Coating Generic Scenarion – Research Project" from Vanessa E. Rodriguez, Chemical Engineer, to CEB Staff; November 5, 1987.

(34) US EPA, Generic Scenario for Spray Coating, Chemical Engineering Branch, 1996.

(35) CEB, 2000. Options for Revising CEB's Method for Screening-Level Estimates of Dermal Exposure. Final Report. 06/01/00.

APPENDIX A: GERMAN DATA FOR AUTOMOTIVE COATING

Coating in series at car manufacturers

Facility	Capacity	Working time	Area of car body	Process	Amount coating	Coating sludge
Volkswagen p.354	138,000 vehicles/a 600 vehicles/d	4,600 h/a 230 days/a 5-day week 2.5 shifts/d	69 m^2	Base coat	5.47 kg/car body uni- and metallic coating	4 kg/car body
dto				Clear coat	2.3 kg/car body	208 t/a
BMW p. 366	200,000 vehicles/a 905 vehicles/d	3,536 h/a 221 d/a 2 shifts/d	13.5 m^2	Powder coat	1.63 kg/car body	17 t/a 102 g/car body
Daimler-Chrysler p. 370	192,769 vehicles/a	5460 h/a 105 h/week	70 m^2	Base coat	2.7 kg/car body	327 t/a 1.7 kg/car body

Source: DFIU report (2002)

Coating in automotive refinishing (small and medium facilities)

Facility	**Capacity**	**Working time**	**Area of car body**	**Processes**	**Amount coating**	**Coating sludge**
Facility 1 p. 81, 220	3.5 persons/facility 640 repair jobs/a	One day	not relevant	coating repairs	day 1: 1130.9 g/d day 2: 2622.5 g/d	50 g/d about 2 % of used coating/d
Study CORLEY/ TOUSSAINT (1993) p. 61	15 persons/facility 4000 repair jobs/a	One year	not relevant	coating repairs	3816 kg/a 17345 g/d (*)	no data
Study Schläpfer (1998) p. 61	4 persons/facility 1220 repair jobs/a	One year	not relevant	coating repairs	328 L/a 1491 g/d (*)	60 L/a
Facility 1 (1997), p. 81	640 repair jobs/a	One year (1997)	not relevant	coating repairs	1039 kg/a 4722 g/d (*)	200 L/a
Facility 2 (1997), p. 81	500 repair jobs/a	One year (1997)	not relevant	Coating repairs	1116 kg/a 5072 g/d (*)	1300 kg/a

Source: Rentz et al (2000) (*) The daily consumption is calculated with 220 workdays/a (German value).

Mean consumption of coating in these 5 automotive finishing facilities: 2739 g/d. The value of 17345 g/d was excluded from the equation. This value is in good agreement with the default of the US Draft ESD): 2.7 L/d (density of 1 kg/L assumed). If the value of 17345 g/d is included, the mean value would be 5397 g/d

Consumption in Germany for automotive coating

Industry branch	**Consumption [tonne/a] solvent based coating**	**Consumption [tonne/a] Water based coating**	**Consumption [tonne/a] Powder base coating**	**Sum consumptio n [tonnes/a]**
1995				
Car manufacturer	34,000	41,000	0	75.000
Automotive refinishing	30,000	300	0	30.300
Forecast 2007				
Car manufacturer	13,000	18,000	1.000	32.000
Automotive refinishing	16,500	8,500	not known	25,000

Source: BMU (1997)

Varnish production in Germany in 1996: 1.800.000 t/a, of which is consumed

- 89000 t/a for car coating at manufacturers (5%)
- 33700 t/a for automotive refinishing (2%)

Source: DFIU report (2002), p. 8, 9

Germany has 9,500 automotive refinishing facilities that offer coating.
Source: Rentz et al. (2000), p. 45

Average area of a car body, inner and outer parts [m^2]: 70 - 80 m^2

Source: DFIU report (2002), see Table above.

Processing conditions at car series manufacturer and automotive refinishing

Car series manufacturer	Automotive refinishing
Industrial process	Professional process
Automatic coating	Manual coating
High number of pieces with low change of colour	Low number of pieces with high change of colour
High continuous consumption of coating	Low and variable consumption of coating
Continuous air flux loaded with solvents	Low flux of air that is loaded only sometimes with low concentration of solvents
Drying at high temperature (120 – 180 °C)	Drying at low temperatures (20 – 60 °C)

Source: Rentz et al. (2000), p. 42

References

W. Baumann and A. Muth
Farben und Lacke 1 and 2 (in German language)
- Daten und Fakten zum Umweltschutz
Springer Verlag, Berlin1997, ISBN 3-540-62020-6
http://www.oekopro.de

DFIU report (2002). Bericht über Beste Verfügbare Techniken (BVT) im Bereich der Lack- und Klebstoffverarbeitung in Deutschland (*Report on best available technologies (BAT) in processing of varnishes and adhesives in Germany*). Deutsch-Französiches Institut für Umweltforschung (DFIU). Ed. Umweltbundesamt Berlin, UFOPLAN 299 94 326, August 2002.

Rentz O et al. (2000). Stoffstrommanagement für kleine und mittlere Unternehmen aus dem Bereich der Autoreparaturlackierung (*Material flux management for small and medium enterprises in the field of coating in automotive refinishing*). Erich Schmidt Verlag, Berlin 2000. Serie: Initiativen zum Umweltschutz, Vol. 20, ISBN 3-503-05881-9.

BMU (1997). Bundesumweltministerium, Umweltbundesamt, Verband der Lackindustrie, et al. Gemeinsamer Abschlussbericht zum Dialog des BMU und des VCI zu Umweltzielen am Beispiel VOC (*Common report presenting the dialogue between BMU and VCI on environmental goals demonstrated on the example of VOCs*). December 1997.

APPENDIX B: INHALATION EXPOSURE TO POLYISOCYANATE IN PAINT
Excerpts from *1996 Generic Scenenario for Automobile Spray Coating*

A summary of available isocyanate exposure data and other related measured isocyanate concentrations extracted from various documents is presented in Table C-1. Both polyisocyanate and monomer isocyanate data is presented. The data is sorted by type of engineering control (e.g. crossdraft of downdraft paint spray booth) and type of spray gun (e.g. HVLP or conventional).

Note that in some instances results were presented as 8-hr time-weighted averages; preparation and other non-spraying activities were included. In other instances, results were normalized to reflect exposures only while spraying paint. The samples were collected and analyzed according to various methods too numerous to describe. Consequently, a direct comparison of the data may be misleading.

The data in Table C-1 show a lowering of worker exposure to isocyanate in downdraft paint booths compared with crossdraft booths. The data also show a lowering of isocyanate exposure when using HVLP spray guns as compared to conventional spray guns.

The following scenarios present exposure estimates under different combinations of engineering control and spray gun. The concentrations presented represent approximate midpoints in available data. Guidance in selecting a scenario is presented in Section 3.3.2 of this generic scenario.

AWhat if@ Potential Dose Rate (mg/d)= polyisocyanate concentration (mg/m^3) * duration (hr) * 1.25 m^3/hr breathing rate. Note that chemical of interest concentration is not a variable. This is because the polyisocyanate concentration in the paint is unknown for the sampling data in Appendix B. The default duration is 8 hours, although shorter durations can be used as explained in the main body of this report.

Scenario 1. *Crossdraft booth and conventional spray gun*--(Crossdraft hood with paint spray filters or waterfall and air atomization paint-spray gun)
Measured concentration range during spraying operations <0.05-18.4 mg/m^3 (Janko, 1992 and Lesage, 1992)

Scenario 2. *Downdraft booth and conventional spray gun*
Measured concentration range during spraying operations 0.01-3.7 mg/m^3 (Goyer 1995 and Lesage, 1992). Goyer presented only mean values, so the range of actual measurements is unknown.

Scenario 3. *Crossdraft booth and HVLP spray gun*
Measured concentration range during spraying operations 1.0-5.2 mg/m^3 (Rudzinski 1995).

Scenario 4. *Downdraft booth and HVLP spray gun*

Estimated range of polyisocyanate concentration 0.6-1.4 during spraying operations. Based on paint mist data from Table II of Heitbrink (1995), 1.9-4.7 mg/m^3 during spraying operations, and the assumption that approximately 30% of particulate overspray is from a polyisocyanate for a typical HDI based paint system (Rudzinski, 1995).

Table B-1
Isocyanate Concentration

Industry	Isocyanate Sampled	Eng control/gun type	Activity Description	Airborne Concentration (mg/m^3)	Reference
Automobile painting (crash repair workshop)	Active isocyanate	none/NA	Paint mixing & Spray gun washing	0.001 (P) (number of sample not provided)	Pisaniello & Muriale, 1989 (#10)
Automobile painting (crash repair workshop)	Active isocyanate	none/NA	Dry rubbing with mechanical sander (when new coat is few hours old)	0.006-0.02 (P) (2 samples collected) sample periods were approx 18 min duration	Pisaniello & Muriale, 1989 (#10)
USAF Automobile & Miscellaneous parts	HDI	crossdraft/ HVLP	Spray painting of large vehicles and objects	0.017-0.22 (P) (2 samples collected) 0.004-0.14 (A) (4 samples collected) sample period not reported	Rudzinski et. Al., 1995 (#12)
Keesler AFB	N-75 (aliphatic polyisocyantes)	crossdraft/ HVLP	Spray painting trucks	1.0-1.9 (P) (2 samples collected) 1.6-4.1 (A) (4 samples collected) sample period not reported	Rudzinski et. Al., 1995 (#12)
Langley AFB	N-75 (aliphatic polyisocyantes)	crossdraft/ HVLP	Spray painting aircraft ground equipment	4.7-5.2 (P) (2 samples collected) 4.9-13.9 (A) (4 samples collected) sample period not reported	Rudzinski et. al., 1995 (#12)
Car Paint Shops	Oligomer HDI	downdraft/ conventional	Spray paint operations (measured at various heights above floor)	5 in. - 2.6 (A) 32 in. – 2.9 (A) 43 in. – 1.9 (A) 55 in. – 1.4 (A)	Lesage et al, 1992 (#53)

Industry	Isocyanate Sampled	Eng control/gun type	Activity Description	Airborne Concentration (mg/m^3)	Reference
USAF vehicle painting	TDI	crossdraft/ conventional	Spray painting operations	3.0 (P) (3 samples collected) sample period not reported	Dept. of the Army Medical Command, 1996 (#69)
Paint Manufacturing & Application Operations using PUR coatings	HDI and HDI-based polyisocyanates	no information	Transportation After market	0.0006-0.015 (P) (geometric mean = 0.03) (35 samples collected) sample period not reported	H.E. Myer et al, 1993 (#70)
Car Spray painting	HDI polyisocyanate	Downdraft/ no info	Spray painting	0.25 - 3.0 (P) (12 samples collected) sample period not reported	Maitre et al, 1996 (#54)
Paint Manufacturing & Application Operations using PUR Coatings	HDI	no information	Heavy Equipment/Military	0.04 (geom mean) (25 samples collected) (P)	H.E. Myer et al, 1993 (#70)
Paint Manufacturing & Application Operations using PUR coatings	HDI	no information	Maintenance/Construction	0.05 (geom mean) (16 samples collected) (P)	H.E. Myer et al, 1993 (#70)
Paint Manufacturing & Application Operations using PUR coatings	HDI	no information	Wood/Furniture	0.02 (geom mean) (11 samples collected) (P)	H.E. Myer et al, 1993 (#70)
Industrial Spray Operations	HDI monomers & HDI polyisocyanates	crossdraft/ conventional	Spray Painting & Related Operations	HDI monomer 0.007 (P) (geom mean) (24 samples collected) HDI polyisocyanates 0.70-12.2 (P) (geom mean = 3.87) (# = 24)	M. Janko et al, 1992 (#76)

Industry	Isocyanate Sampled	Eng control/gun type	Activity Description	Airborne Concentration (mg/m^3)	Reference
Auto Body Shops	HDI monomers & HDI polyisocyanates	crossdraft/ conventional	Spray Painting & Related Operations	HDI monomer 0.014 (P) (geom mean) (55 samples collected) HDI polyisocyanates ND-18.4 (P) (geom mean = 1.60) (55 samples collected)	M. Janko et al, 1992 (#76)
Spray Finishing of Large Objects	HDI monomers & HDI polyisocyanates	crossdraft/ conventional	Spray Painting & Related Operations	HDI monomer 0.007 - 0.11 (P) (31 samples collected) HDI polyisocyanates 2.09-15.9 (P) (31 samples collected)	M. Janko et al, 1992 (#76)
Auto Refinishing	HDI Oligomer	downdraft/no info		0.1-2.16 mg/m^3 sample period twa	(#91)

P = personal sample
A = area sample

TABLE REFERENCES

D.L. Pisaniello and L. Muriale: The Use of Isocyanate Paints in Auto Refinishing - A Survey of Isocyanate Exposures and Related Work Practices in South Australia. Ann. Occup. Hyg., Vol.33,No. 4, pp. 563-572, (1989).

W. E. Rudzinski, B. Dahlquist, S. A. Svejda, A. Richardson, and T. Thomas: Sampling and Analysis of Isocyanates in Spray-Painting Operations. Am. Ind. Hyg. Assoc. J. , Vol. 56, p. 284-289. (1995).

W. A. Heitbrink, M.E. Wallace, C.J. Bryant, and W.E. Ruch: Control of Paint Overspray in Autobody Repair Shops. Am. Ind. Hyg. Assoc. J., Vol. 56, p. 1023-1032 (1995).

J. Lesage, N. Goyer, F. Desjardins, J. Vincent and G. Perrault: Workers= Exposure to Isocyanates. Am. Ind. Hyg. Assoc. J., Vol. 53, February 1992.

A. Maitre, A. Leplay, A. Perdrix, G. Ohl, P. Boinay, S. Romazini, and J.C. Aubrun: Comparison Between Solid Sampler and Impinger for Evaluation of Occupational Exposure to 1,6-Hexamethylene Diisocyanate Polyisocyanates During Spray Painting. Am. Ind. Hyg. Assoc. J., Vol. 57, February 1996.

Department of the Army Medical Command, U.S. Army Center for Health Promotion and Preventive Medicine. Army Wide Air Sampling Report for Isocyanates, Occupational Health Management Information System, Health Hazard Information Module, Aberdeen Proving Ground, Maryland, February 8, 1996.

H.E. Myer, S.T. O=Block, and V. Dharmarajan: A Survey of Airborne HDI, HDI-Based Polyisocyanate and Solvent Concentrations in the Manufacture and Application of Polyurethane Coatings. Am. Ind. Hyg. Assoc. J. Vol. 54, November 1993.

M. Janko, K. McCarthy, M. Fajer, J. van Raalte: Occupational Exposure to 1,6-Hexamethylene Diisocyanate-Based Polyisocyanates in the State of Oregon, 1980-1990.

W.A. Heitbrink, R.H. Verb, T.J. Fischbach, and M.E. Wallace: A Comparison of Conventional and High Volume-Low Pressure Spray-Painting Guns. Am. Ind. Hyg. Assoc. J. (57)/March 1996 pp. 304-310.

N. Goyer: Performance of Painting Booths Equipped with Down-draft Ventilation. Am. Ind. Hyg. Assoc. J. (56)/March 1995 pp. 258-265.

TEXT REFERENCES

(Brooke, 1994) Lindsay Brooke, "Car Costs Automakers $275 to Paint, Study Says," Automotive Industries, December 1994, page 32.

(Brown, 1996) Telecon, Tom Brown, ICI Paints, with Christopher Sweet, SAIC, May 1, 1996. Low VOC Paints.

(BSB, 1995) 1995 Body Shop Industry Profile, prepared by MarketScope for Body Shop Business Magazine.

(CEB, 1991) Chemical Engineering Branch Manual for the Preparation of Engineering Assessments, U.S. Environmental Protection Agency, February 1991.

(Chan, 1986) T.L. Chan et al., "High-Solids Paint Overspray Aerosols in a Spray Painting Booth: Particle Size and Scrubber Efficiency," *American Industrial Hygiene Association Journal*, 47(7): 441-417 (July 1986).

(CCC, 1996) Site Visit to Chevy Chase Chevrolet-Geo-Oldsmobile by SAIC, April 26, 1996. Paint use data obtained for month of January 1995.

(Donovan, 1986) John Donovan, AProgrammable Process Controllers Boost Quality of Paint Jobs,@ *Plant Engineering*, March 13, 1986.

(Garcia, 1996) Telecon, Bill Garcia, DeVilbiss Corporation, with John Vierow, SAIC, April 4, 1996. Spray booth design in automobile refinishing industry.

(Heitbrink, 1996) W.A. Heitbrink, R.H. Verb, T.J. Fischbach, and M.E. Wallace: A Comparison of Conventional and High Volume-Low Pressure Spray-Painting Guns. Am. Ind. Hyg. Assoc. J. (57)/March 1996 pp. 304-310.

(Heitbrink, 1995) W. A. Heitbrink, M.E. Wallace, C.J. Bryant, and W.E. Ruch: Control of Paint Overspray in Autobody Repair Shops. Am. Ind. Hyg. Assoc. J., Vol. 56, p. 1023-1032 (1995).

(Kia, 1993) Sheila F. Kia et al., "Characterization of Solvents and Solids in Boothwater from Waterborne Paint," *Journal of Coatings Technology*, 65(825): 101-111 (October 1993).

(Kirk-Othmer, Kirk-Othmer Encyclopedia of Chemical Technology, volume 6, (1993) "Coatings," 1993.

(Maitre, 1996) A. Maitre, A. Leplay, A. Perdrix, G. Ohl, P. Boinay, S. Romazini, and J.C. Aubrun, "Comparison Between Solid Sampler and Impinger for Evaluation of Occupational Exposure to 1,6-Hexamethylene Diisocyanate Polyisocyanates During Spray Painting. Am. Ind. Hyg. Assoc. J., Vol. 57, February 1996.

(NIOSH, 1981) National Institute for Occupational Safety and Health, "An Evaluation of Engineering Control Technology for Spray Painting," NIOSH 81-121, June 1981.

(Patterson, 1996) Facsimile, George Patterson, E.I. duPont, to John Vierow, SAIC, June 14, 1996. Paint solids removal in new automobile manufacturing spray booths.

(Pfanstiehl, 1992) John Pfanstiehl, Automotive Paint Handbook, HPBooks, Los Angeles, 1992.

(Rodriguez, 1987) Vanessa Rodriguez, "Generic Engineering Assessment: Spray Coating Occupational Exposure and Environmental Releases. October 1987.

(Sokolovic, 1996) R.S. Sokolovic, ANew Technology for Waste Water from Water-Washed Paint Spray Booths,@ Environmental Technology, 17, pp. 35-43

(USEPA, 1995) U.S. EPA, EPA Office of Compliance Sector Notebook Project: Profile of the Motor Vehicle Assembly Industry. September 1995, EPA/310-R-95-009.

(USEPA, 1994a) U.S. EPA, Alternative Control Techniques Document: Automobile Refinishing. April 1994, EPA-453/R-94-031.

(USEPA, 1994b) U.S. EPA, Automobile Assembly Plant Spray Booth Cleaning Emission Reduction Technology Review. 1994, EPA-453/R-94-029.

(USEPA, 1979) U.S. EPA, "Automobile and Light Duty Truck Surface Coating Operations - Background Information for Proposed Standards," September 1979, EPA-450/3-79-030.

APPENDIX C: PAINT MIST CONCENTRATION DATA

Table C-1
Downdraft Spray Booth Coating Mist Concentration Data

Geometric Mean Coating Mist Concentration (mg/m^3), Sample Type and Number of Samples	Individual Coating Mist Concentration Data Points (mg/m^3)	Sample Duration (min)	Data Source*	Notes
Spray gun type: HVLP				
4.7 Sample type: Personal Number of samples: 7	Individual data points not reported in this document. Geometric average is given.	Not provided	(24)	1) Spray-painting autobody parts that had been set in the booth. 2) Observed concentration divided by fraction of time painting (0.49).
2.3 Range: 0.26 to 18 Sample type: Personal Numbers of samples: 7	0.26	19	(5)	1) "Some concentrations measured on the workers lapel exceeded the OSHA PEL for total dust of 15mg/m3 for an 8-hour day. Because these samples were taken over a fraction of an 8-hour day and the PEL is based upon an 8-hour day, this result does not necessarily indicate that the exposure exceeds the PEL" Page 20. 2) At this shop most of the painting was done for parts hanging from the ceiling at head height.
	0.50	18		
	2.54	19		
	3.0	20		
	5.63	91		
	5.64	38		
	18.0	25		

* Data sources correspond to references presented in Section 6 of this report.

Geometric Mean Coating Mist Concentration (mg/m³), Sample Type and Number of Samples	**Individual Coating Mist Concentration Data Points (mg/m³)**	**Sample Duration (min)**	**Data Source***	**Notes**
0.53 Range: <0.1 to 3.68 Sample type: Personal Number of Samples: 17 (Summary statistics above presented in document. Source does not provide all 17 data points. Available individual points are included)	1.8	12		Appendix D of the data source provides sampling duration and results for every trial. Two covariates were found to significantly affect total dust concentrations: time spent painting and paint type. The statistical analysis also found that spray painting gun used did not significantly affect total dust concentrations. The median concentrations based upon the least squares means were: HVLP: 0.43 mg/m³ and non-HVLP:0.90 mg/m³.
	0.91	19		
	0.78	22		
	0.76	20		
	0.66	20		
	0.56	13		
	0.16	32		
	0.14	9		
	0.12	26		
	0.1	12		
	0.066	19		
	<0.01	21		
	<0.01	14	(26)	

* Data sources correspond to references presented in Section 6 of this report.

Geometric Mean Coating Mist Concentration (mg/m^3), Sample Type and Number of Samples	Individual Coating Mist Concentration Data Points (mg/m^3)	Sample Duration (min)	Data Source*	Notes
Spray gun type: Conventional				
9.0 Sample type: Personal Number of samples: 1	9	15		
	4.6	47		
	3.6	74		
	3.1	21		
	3.0	42		
	1.8	176		Application of primer.
	1.7	47		
	1.1	46		Application of primer.
	0.6	102		Application of primer.
	0.4	64	(23)	Application of primer, color, and clearcoat.
0.68 Range: 0.17 to 1.45 Sample type: Personal Number of samples: 6 (Summary statistics above presented in document. Source does not provide all 6 data points. Available individual points are included)	1.4	12		Appendix D of data source provides sampling duration and results for every trial. Two covariates were found to significantly affect total dust concentrations: time spent painting and paint type. The statistical analysis also found that spray painting gun used did not significantly affect total dust concentrations. The median concentrations based upon the least squares means were: HVLP: 0.43 mg/m^3 and non-HVLP:0.90 mg/m^3.
	1.0	17		
	0.39	44		
	0.16	20	(26)	

* Data sources correspond to references presented in Section 6 of this report.

Geometric Mean Coating Mist Concentration (mg/m^3), Sample Type and Number of Samples	**Individual Coating Mist Concentration Data Points (mg/m^3)**	**Sample Duration (min)**	**Data Source***	**Notes**
Spray gun type: Conventional and HVLP				
2.7 Sample type: Personal Number of samples: 16	Individual data points not reported in this document. Geometric average is given.	Not provided	(24)	1) Experienced spray instructor repeatedly painting an entire car body. 2) Observed concentration was divided by fraction of time painting (0.66). 3.) Gravity-fed conventional spray gun.
1.9 Sample type: Personal Number of samples: 23	Individual data points not reported in this document. Geometric average is given.	Not provided	(24)	1) Spray-painting the side of cars. 2) Observed concentration was divided by fraction of time painting (0.29). 3.) Siphon cup conventional spray gun.

* Data sources correspond to references presented in Section 6 of this report.

Table C-2
Crossdraft Spray Booth Coating Mist Concentration Data

Geometric Mean Coating Mist Concentration (mg/m^3), Sample Type and Number of Samples	Individual Coating Mist Concentration Data Points (mg/m^3)	Sample Duration (min)	Data Source*	Notes
Spray gun type: HVLP				
30 Sample type: Personal Number of samples: 2	28	15 to 60	(22)	Crossdraft booth type was assumed based on description of booth, collected from spray painting half of a generator at Langley AFB. This concentration is on a total particulate basis. Data are derived from Table II: *Comparison of Polyisocyanate Concentrations in Spray Painting Operations of the data source*.
	34	15 to 60		
6 Sample type: Personal Number of samples: 2	4	15 to 60	(22)	Crossdraft booth type was assumed based on description of booth, collected from spray painting wheels, signs, a generator, and aircraft wing parts at Kessler AFB. This concentration is on a total particulate basis. Data are derived from Table II: *Comparison of Polyisocyanate Concentrations in Spray Painting Operations of the data source*.
	8	15 to 60		
Spray gun type: Conventional				
15 Sample type: Personal Number of samples: 8	35	51	(21)	Booth was termed "side-draft". This booth was assumed to be cross-draft based on the booth description provided in the data source.
	30	61		
	12	95		
	12	40		
	9.1	100		
	8.6	66		
	7.0	110		
	4.1	106		

* Data sources correspond to references presented in Section 6 of this report.

Geometric Mean Coating Mist Concentration (mg/m^3), Sample Type and Number of Samples	Individual Coating Mist Concentration Data Points (mg/m^3)	Sample Duration (min)	Data Source*	Notes
23 Sample type: Personal Number of samples: 5	Individual data points not reported in this document. Geometric average is given.	Not provided	(24)	1) Spray-painting parts of the car. 2) Observed concentration was divided by the fraction of time painting (0.26). 3) Siphon cup conventional spray gun.
6.8 Range 3.7 to 11 Sample type: Personal Number of samples: 5	Appendix A provides each individual mist concentration point, but does not designate which are for Trimatic booth.	Time for each run provided in Appendix A of data source Range: 15 to 60	(27)	*Trimatic* crossdraft spray booth; Appendix A of the data source provides sample time and total dust concentrations. The total dust concentration values in this table seem to match up with the values reported in the summary range. These data are taken for under 8 hours and seem to be reported without being time weighted.
4.6 Sample type: Personal Number of samples: 6	6.7	162	(28)	Booth was termed "side-man." This booth was assumed to be cross-draft based on the booth description provided in the data source.
	6.7	141		
	5.1	190		
	4.3	84		
	3.0	33		
	2.0	40		
6.0 Range: 3.1 to 17 Sample type: Personal Number of samples: 6	Appendix A provides each individual mist concentration point, but does not designate which are for DeVilbiss booth.	Time for each run provided in Appendix A of data source Range: 15 to 60	(27)	*DeVilbiss* crossdraft spray booth; Appendix A of the data source provides sample time and total dust concentrations. The total dust concentration values in this table seem to match up with the values reported in the summary range. These data are taken for under 8 hours and seem to be reported.

* Data sources correspond to references presented in Section 6 of this report.

Table C-3
Semi-Downdraft Spray Booth Coating Mist Concentration Data

Geometric Mean Coating Mist Concentration (mg/m^3), Sample Type	Individual Coating Mist Concentration Data Points (mg/m^3)	Sample Duration (min)	Data Source	Notes
Spray gun type: Conventional				
9.7 Sample type: Personal Number of samples: 12	Individual data points not reported in this document. Geometric average is given.	Not provided	(24)	1) Spray-painting parts of the car. 2) Observed concentration was divided by the fraction of time painting (0.30). 3) Siphon cup conventional spray gun.
7.9 Sample type: Personal Number of samples: 7	Individual data points not reported in this document. Geometric average is given.	Not provided	(24)	1) Spray-painting parts of the car. 2) Observed concentration was divided by the fraction of time painting (0.36). 3) Siphon cup conventional spray gun.
5.7 Sample type: Personal Number of samples: 13	24.15	5	(4)	1) Statistical analysis in Appendix E of the data source showed that sampling location and type of paint affected the total dust concentration. 2) Siphon cup conventional spray gun. 3) "Drive-thru" semi-downdraft spray booth.
	15.89	7		
	8.75	21		
	4.69	7		
	3.9	9		
	3.55	14		
	2.69	23		
	2.53	4		
	2.0	3		
	1.5	5		
	1.49	11		
	1.4	11		
	1.13	14		

* Data sources correspond to references presented in Section 6 of this report.

Geometric Mean Coating Mist Concentration (mg/m^3), Sample Type	Individual Coating Mist Concentration Data Points (mg/m^3)	Sample Duration (min)	Data Source	Notes
4.8 Range: 0.29 to 10.52 Sample type: Personal Number of samples: 7	10.52	11	(4)	1) Statistical analysis in Appendix E of the data source showed that sampling location and type of paint affected the total dust concentration. 2) Siphon cup conventional spray gun. 3) “Drive-in” semi-downdraft spray booth.
	8.35	22		
	6	7		
	5.63	13		
	1.78	13		
	1.03	20		
	0.29	18		
2.4 Range: 0.32 to 8.2 Sample type: Personal Number of samples: 5 (The summary statistics presented above were reported in the document. The minimum from these statistics does not correspond to the individual data points)	8.2	8	(26)	Spray painting of automotive parts in semi-downdraft prep station.
	4.7	17		
	3.8	5		
	2.2	30		
	1.8	15		

* Data sources correspond to references presented in Section 6 of this report

APPENDIX D: DERMAL EXPOSURE ASSESSMENT FACTORS

Table D.1: Factors for Screening-Level Assessments of Dermal Exposure to the Hands

Type of Contact[1]	Typical Examples	S2 (cm^2)	Q[3] (mg/cm^2)	Resulting Dermal Contact (mg)
Routine, direct handling of solids - 2 hands	X Filling/dumping containers of powders, flakes, granules X Weighing powder/scooping/ mixing (i.e., dye weighing) X Handling wet or dried material in a filtration and drying process			up to 31004
Routine contact with surfaces - 2 hands - solids	X Handling bags of solid materials (closed or empty)			up to 1100[4]
Routine immersion, 2 hands - liquids	X Handling wet surfaces X Spray painting	840	1.3 - 10.3	up to 8,700
Routine contact, 2 hands - liquids	X Maintenance X Manual cleaning of equipment X Filling drum with liquid	840	0.7 - 2.1	up to 1,800
Incidental contact, 2 hands - liquids	X Connecting transfer line	840	0.7 - 2.1	up to 1,800
Incidental contact, 1 hand - liquids	X Sampling X Ladling liquid/bench scale liquid transfer	420	0.7 - 2.1	up to 900

Notes:

1. The terms "routine" and "incidental" reflect typical CEB judgements on likelihood of contact for the example activities.
2. Values of the skin surface area of the hands taken from: EPA Exposure Factors Handbook, 1997 and are the mean values for men
3. Selected ranges of 'Q' Values for liquid handling activities taken from: EPA, 1992. A Laboratory Method to Determine the Retention of Liquids on the Surface of Hands, Exposure Evaluation Division, Office of Pollution Prevention and Toxic, USEPA, EPA 747-R-92-003, September, 1992.
4. Values for dermal contact for solids handling activities were taken from: Lansink, 1996. Lansink, C.J.M., M.S.C. Breelen, J. Marquart, and J.J. van Hemmen: Skin Exposure to Calcium Carbonate in the Paint Industry. Preliminary Modeling of Skin Exposure Levels to Powders Based on Field Data (TNO Report V 96.064). Rijswijk, The Netherlands: TNO Nutrition and Food Research Institute, 1996.

Further details on derivation of this table can be found in Reference 35