



Formulation of Waterborne Coatings - Generic Scenario for Estimating Occupational Exposures and Environmental Releases -Draft-

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EXPLANATORY NOTES

Purpose and background

This Generic Scenario is intended to provide information on the sources, use patterns, and potential release pathways of chemicals used in the formulation of waterborne coatings. The document presents approaches for estimating the environmental releases of and occupational exposures to components and additives used in waterborne coatings. These approaches are intended to provide conservative, screening-level estimates resulting in release and exposure amounts that are likely to be higher, or at least higher than average, than amounts that might actually occur in the real world setting.

Under Section 5 of the Toxic Substances Control Act (TSCA), the U.S. Environmental Protection Agency's (EPA's) Office of Pollution Prevention and Toxics (OPPT) evaluates new chemicals (i.e., those chemicals not listed on the TSCA inventory), for potential risks associated with their stated and potential uses. Existing chemicals may also be evaluated under Sections 4 and 6 of TSCA for potential risks associated with their various uses. In these cases, EPA may develop regulatory controls and/or non-regulatory actions to protect human health and the environment from harm resulting from manufacturing, processing, transport, disposal, and current and potential new uses of existing and new chemical substances.

A new chemical, with certain exceptions, is any chemical that is not currently on the TSCA Inventory of Chemicals in commerce. The new chemical review under Section 5 of TSCA requires an identification and mitigation of potential risks with the stated and potential uses of new chemicals. Under Section 5 of TSCA, companies are required to submit a Premanufacture Notification (PMN) at least 90 days prior to commercial production (including importation). The Chemical Engineering Branch (CEB) is responsible for preparing the occupational exposure and release assessments of the new chemicals. These assessments are based on information provided by the PMN submitter, information from readily available databases and literature sources, and standard estimating techniques used by CEB. Frequently, data on the new chemical being assessed are not available. In the event that information is unavailable, CEB relies on other approaches for developing exposure and release assessments. One important tool that CEB uses is generic scenarios.

CEB has developed a number of generic scenarios and modeling approaches for quantifying sources and control efficiencies to use in assessing exposures and releases for various industries and unit operations. These generic scenarios contain a compilation of information from readily available sources and from past CEB assessments. They have helped CEB to standardize its assessments. This generic scenario may be periodically updated to reflect changes in the industry and new information available.

How to use this document

This document may be used to provide conservative, screening-level estimates of environmental releases of and occupational exposures to both volatile and nonvolatile chemical

components used in waterborne coating formulations. Such estimates might result in release and exposure amounts that are likely to be higher, or at least higher than average, than amounts that might actually occur in real world practice.

The users of this Generic Scenario should consider how the information contained in the document applies to the specific scenario being assessed. Where specific information is available, it should be used in lieu of the defaults presented in this document, as appropriate. All input values (default or industry-specific) and the estimated results should be critically reviewed to assure their validity and appropriateness.

Coverage and Methodology

EPA developed this draft generic scenario using recent information on the waterborne coatings industry, including process descriptions, operating information, chemicals used, wastes generated, waste treatment, worker activities, and exposure information. EPA supplemented this information with standard models¹ to develop approaches to estimate environmental release and occupational exposure presented in this generic scenario.

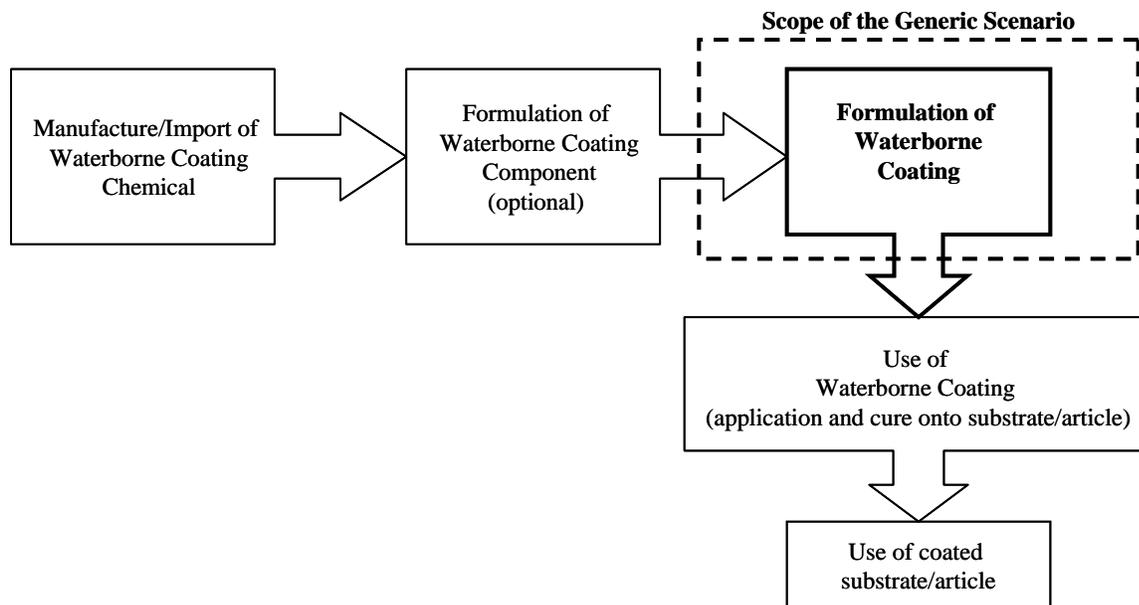
The primary sources of information cited in this document include the American Coatings Association (ACA), formerly known as the National Paint and Coatings Association (NPCA)), a leading trade association for this industry and the Kirk-Othmer Encyclopedia of Technology. NPCA organized two site visits to coating formulation sites and provided additional information on waterborne coatings. Additional information on the sources investigated and the references cited in this document are presented in Section 8.0.

Scope and Content

This Generic Scenario presents a standard approach for estimating the environmental releases and associated occupational exposures to different functional chemical components (both volatile and nonvolatile) used during the formulation of waterborne coatings. Releases and exposures from the manufacture or import of the chemicals and the subsequent blending of the chemicals into components for use in waterborne coating formulations are beyond the scope of this scenario, and therefore not addressed. Additionally, the scenario does not cover the application of the coating onto a substrate or article or the use of the substrate once the coating has been applied and cured.

An illustration of the scope of this scenario within the context of the life cycle of the chemical of interest is provided below.

¹ EPA has developed a series of “standard” models for use in performing conservative release and exposure assessments in the absence of chemical- or industry-specific data. Several of these standard models are described in Appendix B to this ESD.



To estimate environmental releases for the formulation process, this document assumes that volatile chemicals may be released to air at certain points in the process and associated inhalation exposures to the chemical vapors may occur as a result of handling those chemicals. Each user is required to define *volatile* based on the specific objectives of their assessment. For example, EPA often assumes chemicals are nonvolatile if the vapor pressure is less than 0.001 torr. Nonvolatile chemicals result in negligible releases to air from volatilization and negligible associated inhalation exposures (CEB, 1991).

This scenario presents methods that can be used to estimate the following facility operating parameters and the releases from and exposures to chemicals used to formulate waterborne coatings:

- Number of sites in the United States formulating waterborne coatings containing the chemical of interest, and the duration of these activities;
- Releases of volatile chemicals to air during transfer from the transport container into the process (storage or mixing vessel);
- Releases of solid chemicals to air, water, incineration, or landfill during transfer from the transport container (storage bags, supersacks, etc.) into the process (storage or mixing vessel) as a result of dusting;
- Releases to air, water, incineration or landfill from transport container residue (via container cleaning or direct disposal of empty containers);
- Releases to air of volatile chemicals vented from the equipment during the formulation process;
- Releases to air, water, incineration, or landfill during product quality sampling;

- Releases to air, water, incineration, or landfill from equipment cleaning;
- Releases air, incineration, or landfill from the disposal of waste filters containing residual chemicals;
- Releases to water, incineration, or landfill, from the disposal of off-specification waterborne coating;
- Releases to air from volatile chemicals during packaging;
- Number of workers that may come into contact with the waterborne coating components;
- Inhalation and dermal exposures during container unloading;
- Inhalation and dermal exposures during container cleaning and disposal;
- Inhalation and dermal exposures during product quality sampling activities;
- Inhalation and dermal exposures during equipment cleaning;
- Inhalation and dermal exposure during waste filter removal; and
- Inhalation and dermal exposures during packaging.

The estimation methods in this document apply to any volatile or nonvolatile chemical component, regardless of its function within the coating formulation.

How this document was developed

The U.S. Environmental Protection Agency (EPA), with support from Eastern Research Group, Inc. (ERG), has developed this Generic Scenario on the formulation of waterborne coatings to support EPA's chemical review programs. This generic scenario supersedes EPA's 1994 Generic Scenario for the Formulation of Latex/Emulsion Coatings (CEB, 1994). The scenario has been revised and expanded to meet EPA's revised quality standards for generic scenarios (CEB, 2011).

Changes to Previous Generic Scenario

August 2013 Draft

EPA solicited comments from the ACA and updated the generic scenario to reflect comments received from ACA.

December 2012 Draft

EPA updated the December 2012 draft generic scenario based on internal workgroup comments. The following updates were made:

- Revised the U.S. waterborne coating production for architectural coatings in Table 1-6 and average annual facility production rate in Table 3-2. Included a sample calculation under Table 3-2 to clarify how the annual facility production data were calculated from the U.S. waterborne coating production data.
- Updated Figure 2-1 to clarify release and exposure scenario for baghouse dust filter replacement and potential disposal destination for off-spec products.
- Clarified the source data used to calculate general facility parameters.
- Updated parameters table (Table 3-1) to reflect parameters discussed in the section.
- Clarified wastewater treatment assumption in the approach used to estimate potential releases.
- Sample calculation correction.

January 2010 Draft

EPA developed a draft generic scenario in January 2010. The following updates were incorporated into the January 2010 version:

- Per recent CEB guidance, updated language in the Explanatory Notes section and added new subsection describing changes that were made to the previous version;
- Updated market profile (in Section 1) from 2008 and 2002 data using 2010 current industrial reports and 2007 NAICS data from the U.S. Census Bureau, respectively;
- Specified media of releases for each release source throughout the document;
- Updated tables in document containing facility estimates and number of workers;
- Updated ‘data gaps and uncertainty’ discussion;
- Updated references section;
- Updated methodologies in Appendix C and Appendix D based on 2010 current industrial reports and 2007 NAICS data; and
- General formatting corrections throughout the document.

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1.0 INDUSTRY SUMMARY AND BACKGROUND

The following subsections describe the waterborne coatings industry and the market for waterborne coatings in the U.S. The waterborne coatings industry comprises raw material manufacturers, coating formulators, and distributors. This generic scenario focuses on the coating formulators.

1.1 Introduction to Waterborne Coatings

Coatings are manufactured for a variety of applications and may be classified by the end use of the coating. Architectural, OEM product, and special purpose coatings are three major types of uses that are distributed for use in numerous industries. Architectural coatings are used for painting houses and buildings. OEM product coatings are often used to cover metal containers, machinery, metal furniture, coil, and other materials (ORD, 1990). These coatings are often applied as part of the original manufacturing process (OEM). Special purpose coatings are used for high performance maintenance applications, automotive and machinery refinishing, traffic paint, and for other applications (ORD, 1990).

The vast number of end uses for coatings creates a demand for specific properties between coating types. Coatings may be classified as waterborne, organic solvent-based, or powder (IHWRI, 1991). Waterborne coatings have many advantages over solvent-based coatings. The most significant of these advantages are low volatile organic compound (VOC) emissions (well below two pounds per gallon) (PFOnline, 2007). Waterborne coatings use water as their primary solvent; however they do contain some organic solvent, such as glycol ethers to improve their application. While waterborne coatings tend to be more expensive than traditional solvent-based coatings, many applications have found that less waterborne coating is required to complete a given job (Sramcik, 2007). For example, a job that required four to five coats of a traditional solvent-based coating is completed with one or two coats of a waterborne coating (Albright, 2007).

EPA’s Office of Air Quality Planning and Standards (OAQPS) have promulgated or are in the process of promulgating several rules or have issued guidelines that have impacted the volatile organic compound (VOC) and hazardous air pollutant (HAP) content in coatings. These regulations and guidelines have limited the amount of volatiles emitted to air by the coatings industry during formulation. Table 1-1 summarizes the various EPA actions on the coatings industry.

Table 1-1. Summary of Existing EPA Regulations and Guidelines Impacting the Coatings Industry

EPA Regulations / Guidelines	FR Citation	Date
National Emission Standards for Hazardous Air Pollutants (NESHAPs)		
Shipbuilding and Ship Repair (Surface Coating); Wood Furniture Manufacturing Operations – Final	76 FR 72050	November 21, 2011
Paints and Allied Products Manufacturing - Final	74 FR 63504	December 3, 2009

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EPA Regulations / Guidelines	FR Citation	Date
Paint Stripping and Miscellaneous Surface Coating Operations at Area Sources (Auto Body Refinishing) – Final	73 FR 1737	January 9, 2008
Surface Coating of Automobiles and Light-Duty Trucks; Surface Coating of Plastic Parts and Products –Final	72 FR 20227	April 24, 2007
Miscellaneous Coating Manufacturing – Final	71 FR 58499	October 4, 2006
Miscellaneous Organic Chemical Manufacturing and Miscellaneous Coating Manufacturing –Final (amended)	71 FR 40316	July 14, 2006
Miscellaneous Metal Parts and Products Surface Coating Operations - Final	69 FR 129	January 2, 2004
Metal Can Surface Coating Operations- Final	68 FR 64431	November 13, 2003
Wood Building Products Surface Coating Operations	68 FR 31746	May 28, 2003
Metal Furniture Surface Coating Operations – Final	68 FR 28605	May 23, 2003
Surface Coating of Metal Coil – Final	67 FR 39793	June 10, 2002
Other Regulations and Guidelines		
Final National Volatile Organic Compound Emission Standards for Architectural Coatings ^a -	65 FR 7736	February 16, 2000
Consumer and Commercial Products, Group IV: Control Techniques Guidelines in Lieu of Regulations for Miscellaneous Metal Products Coatings, Plastic Parts Coatings, Auto and Light-Duty Truck Assembly Coatings, Fiberglass Boat Manufacturing Materials, and Miscellaneous Industrial Adhesives	73 FR 5848	October 7, 2008
Consumer and Commercial Products: Control Techniques Guidelines in Lieu of Regulations for Paper, Film, and Foil Coatings; Metal Furniture Coatings; and Large Appliance Coatings	72 FR 57215	October 9, 2007

a - More stringent rules have been developed by individual states and localities. These regulations will further reduce emissions from formulation operations.

Other than compliance with newer VOC limitations, waterborne coatings offer many other advantages over traditional solvent-based coatings. Waterborne coatings have a longer shelf life than solvent-based systems. When waterborne coatings are processed or used, equipment may be rinsed and cleaned using water, as opposed to more hazardous and expensive organic solvents (e.g., acetone, methyl acetate) (Sramcik, 2007). Note that, since waterborne coatings may contain some organic solvents and other potentially hazardous compounds, this rinse water may need to be collected and disposed to incineration or landfill.

Disadvantages associated with the use of waterborne coatings include longer drying times where humidity is high (IHWRIC, 1991; PFOnline, 2007). Additional equipment may be needed, which will adversely affect the cost-effectiveness of using waterborne coating systems.

Waterborne coatings are generally composed of a base resin formulated with other functional components. Figure 1-1 depicts three categories of waterborne coatings. Waterborne

coatings contain one of three types of synthetic polymers: water-emulsion, water-reducible, or water-soluble polymers. These types of synthetic polymers make up the categories of waterborne coatings in the industry and are discussed in detail in the following subsections.

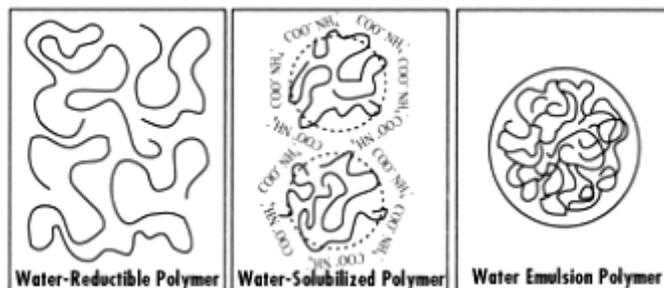


Figure 1-1. Schematic of resin forms in waterborne coatings.

Source: PFOne, 2007

1.1.1 Water-emulsion coatings

Other synonyms used for this type of resin are aqueous dispersion, latex, or emulsion coatings. Coatings containing water-emulsion polymers are characterized by discrete spherical polymeric particles dispersed in water. The molecular weight of the particles is generally high and can be adjusted to improve performance properties, such as hardness, without affecting viscosity. Water-emulsion coatings can be mono-dispersed (i.e., uniform), hetero-dispersed, or poly-dispersed and can be classified by the range in particle sizes, as shown in Table 1-2 (OECD, 2006).

Table 1-2. Classification of Water-Emulsion Coatings

Type of dispersion	Range of particle size (μm)
Fine	0.1-0.3
Middle	0.3-2
Coarse	2-5

Source: OECD, 2006.

Polymeric resins such as styrene-butadiene copolymers, polyvinyl acetate, acrylics, alkyds, and polystyrene can be used in the formulation of water-emulsion coatings. The most important pigment used in this type of coating is titanium dioxide (PFOne, 2007). Table 1-3 summarizes the types and fields of application for water-emulsion coatings. Water-emulsion coatings allow the highest application solids and can be air-dried or go through a thermosetting reaction to further improve the performance of the coating.

Table 1-3. Types and Fields of Application for Water-Emulsion Coatings

Types of water-emulsions	Field of Application	Remarks
Industrial uses	Various industrial applications (e.g. finishing, automotive plastics, and business machines)	Pigment content is 15-20%. Small content of filler but high proportion of titanium dioxide and colored pigments.
Outdoor use	Wood and wall coatings	Pigment content is between 30% (wood) and 55% (concrete).
Indoor use	Wall coatings	Pigment content is 50-80%.
Synthetic resin plaster	Plaster	Binder content is 6-8%. Fillers are sand and other coarse grained matter.
Primer	Indoor and outdoor application	None.
Tint	Tinting of indoor and outdoor coatings	Contains binder, filler, surfactant, titanium dioxide, and coloured pigments.

Source: OECD, 2006; PFOne, 2007.

1.1.2 Water-reducible coatings

Water-reducible coatings contain a miscible organic solvent or a mixture of such solvents and water, which are reduced with water. The organic solvent (i.e., co-solvent) is required to aid in the coalescence of the polymer after the water leaves the coating film. Co-solvents compose approximately 10 percent of the coating formulation but can be as high as 25 percent. Table 1-4 presents typical co-solvents used in water-reducible coatings (OECD, 2006).

Table 1-4. Co-solvents Used in Water-Reducible Coatings

Alcohol:
Propanol
Butanol
iso-Butanol
sec-Butanol
Ethyl Glycol Ether:
Propyl glycol
Butyl glycol
Ethyl diglycol
Butyl diglycol
Propylene Glycol Ether:
Propylene glycol methyl ether
1-Ethoxy-2-propanol
Propylene glycol methyl ether-1,2-acetate
Dipropylene glycol methyl ether

Source: OECD, 2006.

Copolymers formed by polymerization reactions in the water-miscible organic solvent are randomly dispersed in the coating. Polar groups are incorporated into the binder, or resin, to

allow the polymer to be soluble in water (PFOnline, 2007). The resin can be distinguished between non-ionic, anionic, and cationic (OECD, 2006):

- **Non-ionic resins** contain several polar groups that ensure their solubility in water. Their importance is relatively small and they are mainly used as thickener and to modify other types of resins. Some examples of non-ionic resins include cellulose esters and ethers, polyglycol ethers, and polyacrylamides.
- **Cationic binders** contain amino-groups and are neutralized with volatile organic acids. Cationic binders are cured through cross-linking when heated in an oven and are mainly used as primers in the automotive industry. Examples include amine-modified epoxy resins or amine-modified polybutadiene.
- **Anionic binders** are the most important binders for water-reducible coatings. They contain carboxylic acid groups, and are neutralized using volatile amines or ammonia in order to obtain their solubility. These neutralizing agents evaporate during film formation. After physical and chemical drying with atmospheric CO₂, they form an inorganic film. When applied to a mineral substrate, they react chemically and form a very adhesive film. Examples of anionic binders can be found in

Table 1-5.

Unlike water-emulsion polymers, the viscosity and properties of these coatings are largely dependent on molecular weight. Water-reducible coatings impart such properties as high gloss, clarity, depth of image, good pigment wetting and dispersion, and ease of application. These coatings can be used in general industrial and finishing applications (PFOnline, 2007).

Table 1-5. Anionic Binders for Water-Reducible and Water-Soluble Coatings

Type of Binder	Film formation process	Field of application	Remarks
Silicates	Chemical crosslinking via silicate bridges	Mineral substrates, typically on the inside or outside of buildings	Contains a maximum of 5% of organic resins.
Alkyd resins	Oxidation	Industrial appliances like machine and vehicle coatings, corrosion protection primer, wood preservative coatings, surface sealing coatings	High quantities of co-solvents are recommended for neutralization with amines.
Saturated polyesters	Crosslinking with amino-resins or polyisocyanates	Industrial flame drying coatings, coil coatings	Amine and solvent contents <10%.
Epoxy/acrylic resins	Crosslinking amino resins	Can coatings	None.
Phenolic resins	Thermal crosslinking (>160°C)	Flame drying primers	Only in combination with other resins.
Acidic polyacrylates	Physical or thermal crosslinking	Electro-dipping coatings	Can be used in combination with alkyd resins.
Maleinised polybutadiene	Oxidation	Electro-dipping coatings in automotive or metal industry	Solvent content <10%.

Source: OECD, 2006.

1.1.3 Water-soluble coatings

These polymers are also termed colloidal dispersion polymers. Like water-emulsion coatings, water-soluble coatings also contain spherical polymeric particles dispersed in water. The resin particles are smaller than water-emulsion particles and have polar groups (either acidic or basic) that are similar to water-reducible polymers, which impart a degree of solubility. Table 1-5 lists typical anionic binders that are also used in water-soluble coatings.

The number of polar groups in these types of coatings is not sufficient for high water solubility and must be supplemented with hydrophilic groups (e.g., polyglycols). Water-soluble coatings exhibit characteristics of both water-emulsion and water-reducible solutions and offer such properties as good gloss, toughness, water and chemical resistance, durability, and ease of application. Water-soluble coatings are used in industrial finishing applications and can easily be air-dried or oven-dried.

1.2 Market

Waterborne coating formulation facilities are classified under North American Industry Classification System (NAICS) code 325510, Paint and Coatings Manufacturers. The industry is comprised of establishments engaged in mixing pigments, solvents, and binders into paints and other coatings such as stains, varnishes, lacquers, enamels, shellacs, and water repellent coatings for concrete or masonry. These facilities are also involved in the manufacture of allied paint products, such as putties, paint and varnish removers, paint brush cleaners, and allied paint products (ORD, 1990). Facilities that manufacture artist paint, turpentine, and sealants are not covered under NAICS code 325510.

The United States sales and production for the paint and allied products industry totaled over \$19 billion for 1,142 million gallons in 2010 (USCB, 2011). Figure 1-2 shows the distribution of sales in the industry.

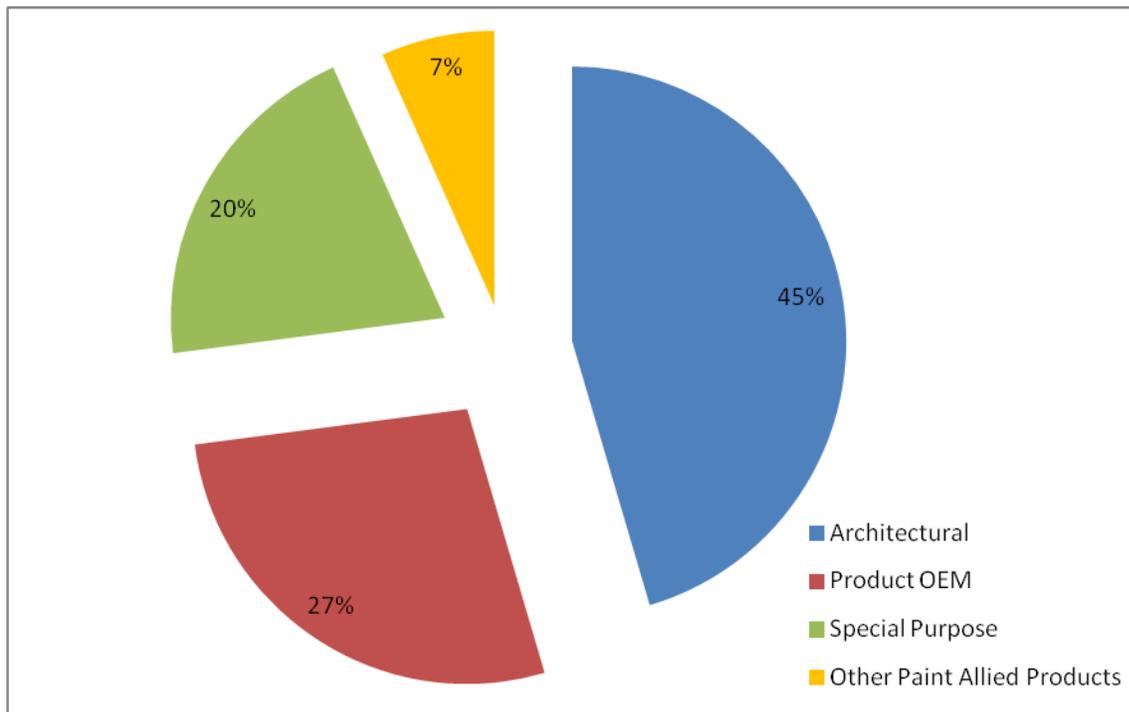


Figure 1-2. 2010 Distribution of Sales for the Paint and Allied Products Industry

The Paint and Allied Products Industry consist of architectural, OEM product, and special purpose coatings. These types of coatings can be further categorized as waterborne, solvent-based, and powder. Waterborne coatings hold over 80 percent of the U.S. architectural coatings market and approximately 35 percent of the OEM product coatings market (BASF, 2004). Special purpose coatings include auto refinishing, traffic marking, and other paints. The penetration of the waterborne coatings market in the special purpose coatings industry is not known. This generic scenario assumes the waterborne coatings market share of special product coatings (35 percent) is similar to the waterborne coatings market share in OEM product

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coatings. Waterborne coatings for automotive refinishing have been limited to primers and basecoats; however, recent developments for waterborne clearcoats indicate the likelihood for waterborne coatings to further penetrate the auto refinishing industry (PPaint2000, 2008).

As outlined in

Table 1-6, out of the 1,142 million gallons of paint produced in the U.S. in 2010, 602.5 million gallons are estimated to be waterborne coatings (or 52.8 percent of the industry's production). Equation 1-1 was used to calculate the estimated production volume shown in Table 1-6 for OEM coatings. Equation 1-1 excludes powder coatings in the estimation of OEM waterborne coatings production. Powder coatings generally do not contain water as a solvent.

Table 1-6. Paint and Allied Products Industry Breakdown, 2010 U.S. Production Data

Type of Coating	Total U.S. Production of Paint (10 ⁶ gal/yr) ^a	Total Number of Sites (sites) ^b	Estimated U.S. Production of Waterborne Coatings (10 ⁶ gal/yr)	Rationale for Waterborne Coatings Production Estimation
Architectural Coatings	643.9	162	515.7	For architectural coatings, the Current Industrial Report (USCB, 2011) provides a breakdown based on the type of solvent. All waterborne coatings were included. Undisclosed volumes were also included as a conservative estimate. Approximately 80 percent of the architectural coatings market is waterborne (BASF, 2004).
Waterborne	515.7			
Solvent-Based	93.6			
Other	NA			
Undisclosed	34.6			
OEM Coatings	329.9	190	103.4	Approximately 35 percent of the North American automotive OEM coatings market is waterborne (BASF, 2004). CEB assumes 35 percent of all OEM coatings (excluding powder coatings) are waterborne.
Automobile Finishes	51.7			
Powder Coatings	34.6			
Wood Flooring Finishes	7.1			
Container/Closure Finishes	40.2			
Other product finishes	23.4			
Other OEM Coatings	113.7			
Undisclosed	59.2			
Special Purpose Coatings	168.3	186	58.9	CEB assumes the waterborne market share for special purpose coatings is similar to OEM coatings; therefore, approximately 35 percent of special purpose coatings are waterborne.
Constructing and Traffic Marking Paint	89.5			
Refinishing Paints	66.8			
Undisclosed	12.0			
Allied Paint Products	145	70	0	Allied paint products consist of paint thinners and removers, brush cleaners, and pigment dispersions. Waterborne paints would not be included in this category.
Total	1,142		602.5	

a - Source: USCB, 2011.

b - Total number of establishments obtained using 2007 Economic Census (USCB, 2007). The 2007 Economic Census does not provide a breakdown of number of establishments by type of coating. EPA used a similar breakdown of number of sites as that provided in the 2002 Economic Census (USCB, 2002)

$$V_{\text{OEM_water}} = (V_{\text{OEM_total}} - V_{\text{OEM_powder}}) \times F_{\text{OEM_water}} \quad (1-1)$$

$$V_{OEM_water} = (329.9 \times 10^6 \text{ gal} - 34.6 \times 10^6 \text{ gal}) \times 0.35 = 103.4 \times 10^6 \text{ gal}$$

Where:

V_{OEM_water}	=	Estimated volume of waterborne OEM coatings manufactured in the United States in 2010
V_{OEM_total}	=	Total volume of OEM coatings manufactured in the United States in 2010 (USCB, 2011)
V_{OEM_powder}	=	Volume of powdered OEM coatings manufactured in the United States in 2010 (USCB, 2011)
F_{OEM_water}	=	Fraction of OEM coatings in the U.S. assumed to be waterborne (BASF, 2004).

2.0 PROCESS DESCRIPTION

The following subsections discuss in detail the formulation of waterborne coatings:

- Section 2.1 presents an overview of the formulation process;
- Section 2.2 presents information on the application process;
- Section 2.3 presents typical formulations of waterborne coatings; and
- Section 2.4 presents physical properties of chemicals used in waterborne coatings.

2.1 Waterborne Coating Formulation

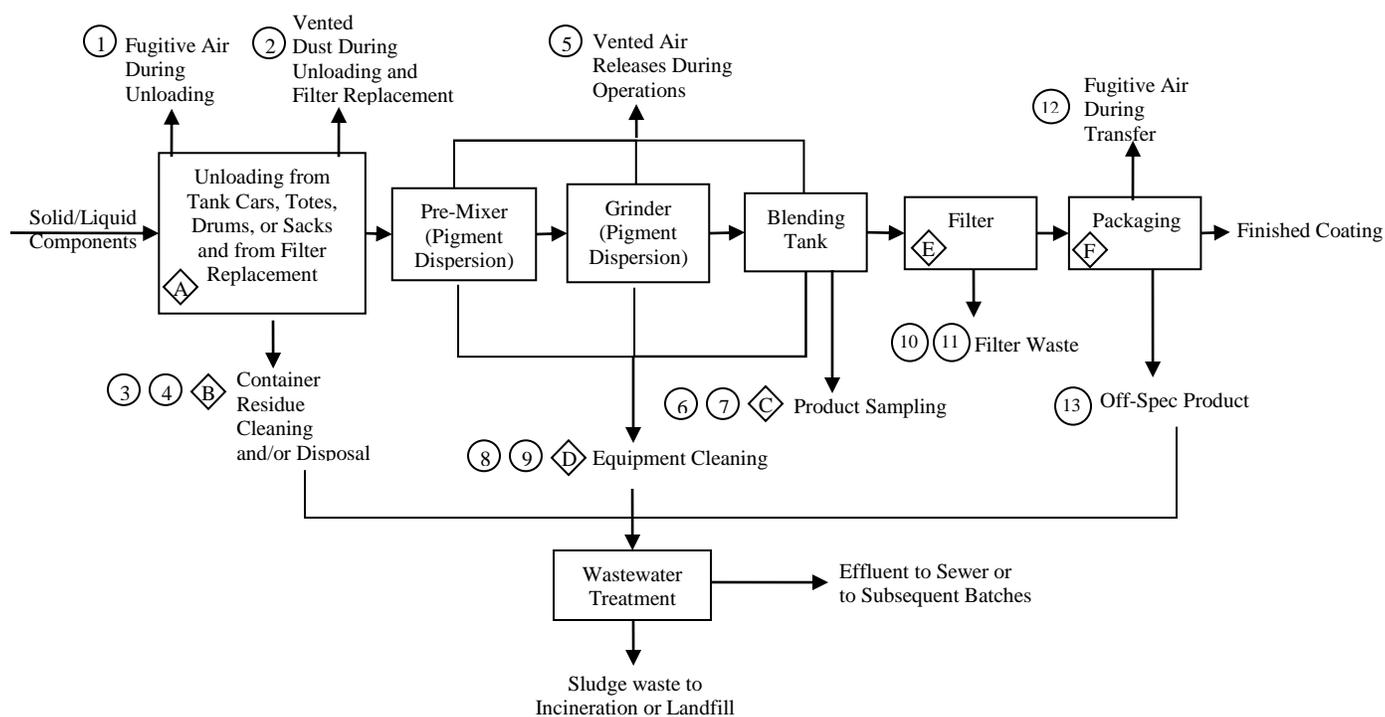
The following process descriptions are based on industry-specific literature and may vary on a site-by-site basis. Figure 2-1 presents a flow diagram of a waterborne coating formulation process, including potential release and exposure points for the chemical of interest.

Traditional paint manufacturing processes consist of the following unit operations (KO, 2005; OECD, 2006):

- Pre-assembly or pre-mixing (of the pigment dispersion);
- Grinding or milling (of the pigment dispersion);
- Blending of the final formulation; and
- Filtration and packaging.

Bulk solvents and resins are normally delivered in road tankers and unloaded by pipes and pipelines into bulk storage tanks. Other liquid materials are delivered in 55-gallon drums or 1 tonne Intermediate Bulk Containers (IBCs). Powder pigments and extenders are delivered in 25 kilogram bags on 1 tonne pallets, in 1 tonne big bags, or occasionally in bulk road tankers from which they are unloaded by compressed air into bulk silos (OECD, 2006).

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○=Environmental Releases:

1. Transfer operation losses of volatile chemicals to air during unloading of the chemical component.
2. Dust losses vented of solid/powder chemical components to air during unloading. Vented dust is captured in bag filters or settles within the workspace, which is subsequently collected and released to water, incineration, or landfill. Dust may also be collected and recycled to subsequent batches.
3. Container residue losses to water, incineration, or landfill from component transport containers. Container residuals may be sent to an on-site wastewater treatment system from which the effluent may be recycled into subsequent batches or sent to a sewer. Waste sludge from the wastewater treatment system is sent to incineration or landfill.
4. Open surface losses of volatile chemicals to air during container cleaning.
5. Vented losses of volatile chemicals to air during pre-mixing, grinding, or blending operations.
6. Product sampling losses to water, incineration, or landfill (not quantified in this ESD).
7. Open surface losses of volatile chemicals to air during product sampling.
8. Equipment cleaning losses to water, incineration or landfill. Equipment washes may be sent to an on-site wastewater treatment system from which the effluent may be recycled into subsequent batches or sent to a sewer. Waste sludge from the wastewater treatment system is sent to incineration or landfill.
9. Open surface losses of volatile chemicals to air during equipment cleaning.
10. Filter waste losses to incineration or landfill during filter media change out.
11. Open surface losses of volatile chemicals to air during filter media change out.
12. Transfer operation losses of volatile chemicals to air during waterborne coating product loading.
13. Off-spec coating released to water, incineration, or landfill. Off-spec coating maybe treated on-site before disposal or may be recycled into subsequent batches.

◇=Occupational Exposures:

- A. Inhalation and dermal exposure to solid or liquid chemical component during unloading and transfer activities.
- B. Inhalation and dermal exposure to solid or liquid chemical component during container cleaning.
- C. Inhalation and dermal exposure to waterborne coating during product sampling.
- D. Inhalation and dermal exposure to waterborne coating during equipment cleaning.
- E. Inhalation and dermal exposure to wet filter wastes during filter media change out.
- F. Inhalation and dermal exposure to waterborne coating during packaging.

Figure 2-1. General Waterborne Coating Formulation Process

2.1.1 Pre-assembly or Pre-mixing of the Pigment Dispersion (Optional)

In the pre-assembly and pre-mix step, liquid raw materials are assembled and then dispersed in containers to form a viscous material to which pigments are added. Raw materials used in the pre-assembly and pre-mix step include water, ammonia, dispersant, pigment, and pigment extenders. This step results in a consistently mixed intermediate product that is referred to as the base or mill base, which has the consistency of a paste. A formulation site may purchase a pigment dispersion containing the chemical of interest (that has already been pre-assembled and pre-mixed) as a raw material; in which case, this step may not be required.

The type of equipment used in the pre-mix process is often dictated by the expected batch size. Due to federal and state regulations restricting air emissions in the paints and coatings industry, vessels are covered during the pigment dispersion. Materials may be mixed in large, high-speed dispersers, disc-type agitators, or variable-speed mixers. Drums equipped with portable mixers may be used for drum-sized batches (NPI, 1998). The most widely used dispersion method is the use of high-speed dispersers equipped with disk type impellers. High-speed disk dispersion may work well for some coatings such as undercoats and primers; however, it is less effective when preparing other coatings such as high-gloss decorative coatings. The use of high-speed disperser can efficiently reduce the need for extensive grinding or milling (Section 2.1.2) (OECD, 2006).

2.1.2 Grinding or Milling of the Pigment Dispersion (Optional)

Pigment grinding or milling is required when the size of the particles in the dispersion needs to be reduced. Solid raw materials loading into the mills may or may not include the use of air pollution control equipment, such as baghouse filters. It is common to dilute the pigment concentrate with resin or solvent prior to milling. Milling also occurs in an enclosed vessel (ACA, 2013). During pigment grinding, the pigment is incorporated into the liquid coating mixture to create a fine particle dispersion (NPI, 1998). Production mills grind the dry pigments and extenders within the liquid mixture (water, ammonia, and dispersants). Each dry pigment particle is actually a cluster of many smaller particles (NSF, 2001). These mills separate pigment clusters into smaller particles and mix them into the liquid vehicle to produce a particle suspension. Mills separate pigment particles so that each particle surface may be wetted with the liquid constituents of the coating formulation (NSF, 2001).

Many different machines are used in grinding operations. The type of equipment used depends on the physical and chemical makeup of the pigments in the coating formulation. The most common types of dispersion equipment used in the coating formulation industry include: ball or pebble mills, disc mills, and sand and bead mills (IHWRI, 1991; NPI, 1998). A brief description of each milling procedure is included below:

Ball mills: Ball mills are cylindrical shaped drums with balls used as grinding media. These balls are often made out of metals, pebbles, or steatite (IHWRI, 1991). During

operation, the cylinder rotates and the pigment particles are dispersed as they move between the balls and the cylinder surface. These mills are outdated technologies in current manufacturing processes (NPI, 1998).

Disc mills: Disc mills provide quick dispersion and are used for many types of latex paints (IHWRIC, 1991). During disc milling, a rotating shaft with a circular saw-toothed blade is immersed into a tank with the coating mixture. When the blade is spun at high speeds in the coating mixture, shearing forces are produced. Disc mills may also provide some pigment particle size reduction while creating a dispersion (IHWRIC, 1991).

Sand mills: These mills use sand particles to shear the pigment particles. Sand is stored in a water-cooled cylinder that contains agitator blades. After the pigment has been adequately dispersed within the coating mixture, the mill is drained and the effluent stream is sent through a screen that retains sand particles (IHWRIC, 1991).

Many operations now use titanium dioxide slurries and other inert pigments to reduce or eliminate pigment dispersion, resulting in reduced production time, labor costs, and waste. Pigment addition and dispersion time can be reduced from 60 minutes to 10 minutes in these operations.

2.1.3 Blending

After the grinding process is complete, the fine particle pigment dispersion is transferred to an agitated mix tank for blending. In the blending process, additional ingredients are added to the mixture to meet final product specifications. Final adjustments to color, viscosity, and other coating characteristics are achieved within a mixing tank (NPI, 1998). First resin and plasticizers are added to the mixture followed by the addition of preservatives, anti-foam agents, and a polyvinyl-acetate emulsion (ORD, 1990). Water is then added to the mixture and acts as a thinner. The batch is thoroughly mixed, checked for quality, adjusted for tint and viscosity, and held for 12 to 16 hours for stabilization. Many facilities use a single high-speed mixer for the grinding and the final blending processes (ORD, 1990).

Batch sizes may widely range between facilities and products. Small plants may produce paint in 10- to 500-gallon (38- to 1900-liter) batches. Larger plants may use batch sizes between 200 and 5,000 gallons (760 and 19,000 liters) (USCB, 2007; USEPA, 2006a,b). While the maximum batch size is similar for OEM and architectural coatings, OEM coatings may be formulated in batches as small as a quart, while architectural coatings may only be formulated in batches larger than 500 gallons (1,900 liters) (IHWRIC, 1991). Two separate sets of site visits indicated batch sizes from 1,000 to 12,000 liters (ECanada, 2003) and from 1 quart to 6,000 gallons (1 to 23,000 liters) (IHWRIC, 1991). Based on site visit reports for five formulation sites, coating formulations are blended in 1,000- to 5,000-gallon (3,785- to 19,000-liter) vessels (USEPA, 2006a,b). The 1994 generic scenario estimated batch sizes between 1,000 and 5,000

gallons and use a batch size of 1,000 gallons for all calculations as a conservative estimate (CEB, 1994). This generic scenario also assumes a typical batch size of 1,000 gallons (3,785 liters).

Generally, a formulation site operates multiple processing lines and can formulate approximately two to three batches of coatings per day (USEPA, 2006a,b). For example, architectural paint formulators often produce two or three product lines of varying quality, comprised of two or three base paints each. One type of base paint is designed to be used alone or tinted to light colors. The second and third are formulated to maintain the correct tinting strength (volume of white pigment) for making medium or deep colors (Wicks, 1992).

2.1.4 Product Sampling

Samples are taken to check the color, viscosity and other characteristics of the mixture. These are normally taken by dipping a small container into the paint through the lid of a pan or hatchway of a tank. Emissions arise through the open hatch during sampling. To avoid such emissions, 'blind' sampling valves have been developed to assist the removal of samples. The samples are collected in a cup and the valve is cleaned from the outside. These devices are however rare, and the collection of representative samples and difficulties of cleaning remain barriers to their use. Alternatively (but not equally efficiently), hatches can be used as long as the length of time during which they remain open is kept to a minimum (OECD, 2006). There is no industry-specific information to show the frequency of collection.

2.1.5 Filtration and Packaging

The filtering step removes undispersed particles or other contaminants that may have been introduced into the batch. The filtration process also removes any grinding media particles that might have exited the mixer along with the coating formulation (NPI, 1998). Removal of these solid impurities is important because they may interfere with the application of the final coating product. Filtration can be achieved through a variety of means. The end use of the product often dictates the type of filtration required (NPI, 1998). Filtration processes range from the use of felt cloth bag filters to the use of strainers or sieves. One commonly used method includes the use of vibrating screens as strainers to separate unwanted material from the paint (NSF, 2001). Filter media are only replaced when they break, sometimes as often as 20 to 30 times a day (Ecanada, 2003). The used media are dried and then disposed to landfill (USEPA, 2006a,b).

After filtration, the coating is transferred to a packaging station. Coatings may be transferred into pails, drums, totes, tank wagons, or other containers for shipment purposes. Transport container filling is highly automated but may occur manually depending on the container size and the facility in question (NPI, 1998).

2.1.6 Equipment Cleaning

In waterborne coating formulation facilities, microorganisms can feed on products both in the can and in the final film. The water, the alkaline pH, and the thickeners are potential food sources that all support bacterial growth. Good material handling and clean plants can minimize formulated paint contamination by microorganisms. Pipes, pumps, tanks, and other equipment

that contact the coatings must also be resistant to water corrosion; therefore, stainless steel, glass-clad metal, or plastic components are often used. To protect aqueous components from contamination, equipment is kept clean and free of lingering paint. Bactericides are often needed to prevent spoilage that would change paint properties in the can. Fungicides are added to control mildew growth on the paint film after it is applied. While some facilities have automated tank washing systems, such as automatic cleaning wands, other facilities may conduct manual equipment cleaning operations.

Each type and color of paint is manufactured in a separate batch and all manufacturing equipment is cleaned between batches of different types or colors to prevent contamination (IHWRIC, 1991). Process equipment is first manually cleaned with a wiper or squeegee, followed by a water/ammonia mixture rinse (WSDE, 2002). The manual cleaning reduces the amount of aqueous waste that must be treated prior to release. A 1,000-gallon tank may be rinsed with as little as 5 to 10 gallons of liquid. Facilities may reuse the wash liquids and rework them into subsequent batches (IHWRIC, 1991).

2.2 Application of Waterborne Coatings

The application of waterborne coatings is outside the scope of this generic scenario. Waterborne coatings may be applied to most substrates, including metal, plastic, wood, glass, and masonry surfaces. Typical application techniques for waterborne coatings include spray, dip, roll, or flow coating.

2.3 Composition of Waterborne Coatings

This section describes typical component formulations of waterborne coatings. Waterborne coatings have four component groups: solvent, polymer base resin, pigments, and various additives. The following sections discuss the role these components play in the final coating formulation.

2.3.1 Solvent

Water is the primary solvent for waterborne coatings. Some categories of waterborne coatings, most notably, water-reducible and water-soluble coatings require a small quantity of organic co-solvent to aid in the binding of the base resin during cure. Some typical co-solvents seen in waterborne coatings are listed in Table 1-4.

2.3.2 Polymer Base Resins

Table 2-1 lists the common base resins used in the formulation of waterborne coatings and the fields of application. These base resins may fall in one or more of the categories of synthetic polymers (i.e., water-emulsion, water-reducible, or water-soluble). The choice of base resin affects pH and pH stability, mechanical properties of the final film, UV stability, color stability and retention, chemical resistance, odor, and water resistance of the final coating. Commercial

polymers include various proprietary components such as surfactants, trace amounts of salts, monomers, and initiator fragments to aid in emulsion polymerization and to stabilize the polymer prior to coating formulation (Wicks, 1992).

Table 2-1. Applications for Various Waterborne Coatings Base Resins

Base Resin	Field of Application
Acrylates	Beverage and food containers Packaging and container exteriors Truck bedliners Sealing of digital imaging products Miscellaneous metal and plastic parts for OEM equipment Industrial wood and hardboard finishing Architectural coatings Traffic marking
Alkyds	Beverage and food containers Miscellaneous metal and plastic parts for OEM equipment Industrial wood and hardboard finishing Architectural coatings Traffic marking
Urethanes	Truck bedliners Sealing of digital imaging products Architectural coatings Traffic marking
Polyurethanes	Miscellaneous metal and plastic parts for OEM equipment Wood flooring industry and graphic arts (signs) coatings.
Polyvinyl Acetate and Acrylate Blends	Industrial wood and hardboard finishing Architectural coatings Traffic marking
Polyvinyl Acetate and Vinyl Chloride Blends	Architectural coatings Traffic marking
Alkyd and Acrylate Blends	Miscellaneous metal and plastic parts for OEM equipment
Two-Part Epoxies	Architectural coatings Traffic marking
Epoxies	Beverage and food containers
Anodic Acrylates, Anodic Alkyds, Cathodic Acrylates, Cathodic Alkyds, Cathodic Epoxies	Electrocoating of OEM miscellaneous metal parts and automotive
Other	Architectural coatings Traffic marking

Source: NPCA, 2006.

2.3.3 Pigments

Pigments are insoluble particles used to provide color, hide substrates, modify application properties, improve final film properties, or reduce costs. Pigments are supplied to the formulator as dry powders, press cakes, or slurries. These materials may be classified in a variety of ways including: white, inert extenders, color, and functional pigments (NPI, 1998). Titanium dioxide is the most common pigment material in waterborne coating formulations.

White pigments such as zinc oxide, zinc sulfide, and lithopone are no longer widely used as pigments, although zinc oxide is still used as a fungicide. Inert extender pigments including calcium and magnesium carbonates, a wide range of clays, magnesium silicates, talc, silicon dioxides, barium sulfate, and a few organic materials such as ground propylene or finely chopped synthetic fibers are added to adjust rheological properties of the liquid coating and to reduce the cost (Wicks, 1992). Inert pigments often reduce or eliminate the need for the pigment dispersion steps, resulting in reduced production time, labor costs, and waste. Functional pigments often modify final coating film properties such as corrosion resistance (NPI, 1998).

2.3.4 Additives

Additives are used to control and modify properties of the coating in its liquid state. Commonly used additives include surfactants (wetting agents, dispersants, defoamers), glycols for freeze-thaw stability, coalescing agents to improve film formation, fungicides and bactericides, pH control agents, thickeners, solution polymers to promote adhesion of chalky substrates, and sequestrants to control undesired ions in water. These additives help create better final film properties and often are sources of additional VOCs and are relatively high in cost. Surfactants include anionic surfactants used primarily to wet and disperse pigments, nonionic surfactants to stabilize total dispersed systems, and defoamers (antifoam agents) used to prevent or control foam formation in paint during manufacture and application. Surfactants comprise only 0.2 to 3.0 percent by weight of coatings but are indispensable to dispersion and system stability.

Based on industry-specific information, waterborne coating formulations may vary according to the end use. Table 2-2 summarizes the composition of several types of waterborne coatings provided during site visits to coating formulation facilities.

Table 2-2. Composition of Selected Types of Waterborne Coatings

General Component	Percent Composition			EPA Default (%)
	Automotive Paints	Wood Coatings	Metal Coatings	
Water	10-50	10-65	10-20	-
Pigments	10-25	15-30	45	45 (Overall Default)
Polymer Resin	20-35	15-25	15-25	35
Co-solvent	10-30	5-10	<10	30
Additives:	NA	<5	1	5
- Dispersant	1-5	NA	NA	
- Thickener	<2	NA	NA	
- Defoamer	<1	NA	NA	
- Surfactant	<1	NA	NA	
- Preservative	<1	NA	NA	
Filler	15-30	NA	NA	30

Source: USEPA, 2006a,b; ECanada, 2003.

NA – Not available.

Table 2-3 shows a more detailed formulation for 1,000 liters (264 gallons) of white latex paint. The density of waterborne coatings is dependent on the components that make up the formulation. Based on this information, white latex paint has a density of 1.33 kg per liter or 5.03 kg per gallon. Waterborne coatings may exhibit the density of water (1.0 kg per liter) if water is a larger fraction of the overall formulation or alternately, may be denser than 1.33 kg per liter if more pigments or additives are used in the formulation (KO, 2005).

Table 2-3. Composition of Latex Coatings

Component	Function	Weight (kg)	Volume (L)	Weight Percent
Latex Emulsion, 53.3%	Binder/Polymer	391	365.8	29.4% (Default)
Water	Solvent	294.5	294.5	22.2%
Titanium Dioxide	Pigment	210.8	52.5	15.9%
Extenders	Reduce cost/amount of pigment required	192.8	80.7	14.5%
Polymeric Opacifier	Make coatings opaque	79.5	76.7	6.0%
Propylene Glycol	Slow the rate of drying	72.3	69.2	5.4%
Zinc Oxide	Pigment, biocide, and UV stabilizer	30.1	5.3	2.3%
Dispersant, 25%	Even particle distribution	14.7	13.3	1.1%
Polyurethane Thickener, 25%	Rheology modifier, increases painted film thickness	12	12.5	0.9%
Texanol	Coalescent, helps paint to properly cure at lower ambient temperatures	11.9	12.4	0.9%
Defoamer	Prevents formation of bubbles when blending and when painting	4.8	5.2	0.4%
Cellulosic Thickener	Rheology modifier, increases painted film thickness	3.6	2.5	0.3%
Aqueous Ammonia, 28%	pH stabilizer	2.7	2.9	0.2%
Surfactant	Helps paint penetrate cracks and groves	2.4	2.2	0.2%
Mildewcide	Prevent mildew grow on painted surfaces	2.4	2.3	0.2%
In-Can Preservative	Antioxidants, biocides, and other chemicals to prevent spoilage	2	2	0.1%
		1,327.5	1,000	100.0%

Source: KO, 2005.

2.4 Physical Properties of Waterborne Coating Chemicals

Table 2-4 presents the physical properties of example chemical compounds that may be used for each of the chemical component categories described in this generic scenario. The specific chemicals within each component category were identified through available references that discuss waterborne coating formulations. These references include:

- OECD Draft Emission Scenario Document on the Coatings Industry;
- *Kirk-Othmer Encyclopedia of Chemical Technology*;
- Chemical properties databases; and
- Web sites of known waterborne coatings companies.

EPA reviewed several sources of physical property data for each of the chemicals identified for the component categories. These sources are cited at the bottom of Table 2-4 and included in the *References* section (Section 8) of this generic scenario. The example chemicals shown in the table were selected based on the following data quality criteria:

- Available data are characterized as either experimental or extrapolated (estimated/modeled data are not included in Table 2-4);
- Physical property data were found to be relatively consistent among multiple sources; and
- A complete “set” of physical property data were found for the chemical.

These compounds represent typical chemical and physical properties for each category; however, they do not cover the entire range of chemicals that may be used in waterborne coatings. The physical properties of these chemicals are presented to provide the reader with a general understanding of potential characteristics of certain waterborne coating components. It should be noted, however, that these chemicals are simply examples of the wide array of chemicals that may be used in specific waterborne coatings.

Table 2-4. Physical Properties of Example Component Chemicals for Waterborne Coatings

Component Category	Example Chemical (CAS, if available)	Neat Physical State	Molecular Weight	Vapor Pressure (torr at 25°C)	Boiling Point (°C)	Melting Point (°C)	Water Solubility (mg/L)	Density, LogK _{ow}
Synthetic Polymer Base Resin	Silicates, Alkyds, Saturated Polyesters, Epoxy/Acrylic Resins	<p>The polymers used in waterborne coatings may be solids or liquids and possess a wide range of molecular weights, vapor pressures, and other physical properties.</p> <p>The base resins in waterborne coatings are generally expected to be of high, variable molecular weight and have a negligible vapor pressure.</p> <p>If the physical state of the polymer is not known, EPA recommends that the polymer be assessed as a solid, which will result in more conservative worker inhalation exposure assessment.</p>						
Co-solvent	Propylene glycol (CAS# 57-55-6)	Liquid (c)	76.1(c)	0.07 @ 21°C (b)	187.6 (c)	-59 (c)	>10g/100mL @ 21°C (c)	1.04 g/cm ³ (c)
Surfactants (wetting agents, dispersants, defoamers)	Alkane Diol (CAS # NA)	Viscous liquid (d)	NA	0.03 @ 21°C (d)	281 (d)	-33 (d)	NA	0.91 g/cm ³ (d)
Pigment / Dye	Titanium Dioxide (CAS# 13463-67-7)	Powder (c)	80.0 (c)	NA	2900 (c)	1855 (c)	Insoluble (c)	4.26 g/cm ³ (c)
pH stabilizer	Aqueous Ammonia (CAS# 7664-41-7)	Liquid (c)	17.0 (c)	NA	-33.3 (c)	-77.7 (c)	89.9 g/100mL @ 0°C (c)	ρ _L : 0.68 g/cm ³ ρ _v : 0.60 g/cm ³ (c)
Coalescent / Adhesion Promoter	Texanol (CAS# 25265-77-4)	Liquid (c)	216.3 (c)	NA	180-182 (b) 244 (c)	-57 (b)	Soluble (b)	0.95 g/cm ³ (c)

NA = No data were found in the references reviewed for this generic scenario.

a – Source: Merck, 1996.

b – Source: Hawley's, 1997.

c – Source: ChemFinder, 2006.

d – Source: Air Products, 2007.

3.0 OVERALL APPROACH AND GENERAL FACILITY ESTIMATES

This document presents a standard approach for estimating environmental releases of and worker exposures to chemicals used in waterborne coating formulations. The estimation methods described in this document utilize available industry-specific information and data to the greatest extent possible; however, EPA acknowledges several areas in which additional chemical information would benefit the scenario. These data needs are summarized in Section 7. EPA intends that the default values cited throughout this scenario only be used when appropriate site-specific or industry-specific information is not available.

Because this scenario presents several alternative default assumptions or values for some estimation parameters, selecting different defaults will affect the final assessment results differently. For example, conservative or high-end daily use rates will result in more conservative release estimates². Alternatively, average or median use rates will result in release estimates that are more “typical” of the industry. This document presents available data that support alternative input values.

This section of the generic scenario presents general facility calculations, which estimates the operating days, concentration of the chemical of interest in the waterborne coating product, throughput of the waterborne coating formulation containing the chemical of interest, number of formulation sites that use the chemical and the number of containers emptied and used per facility.

Section 4 of this document presents the environmental release assessment, which uses the general facility estimates to estimate of the quantity of chemical released from various points in the formulation process and the most likely media of release for each release source.

Section 5 of this document presents the occupational exposure assessment, which uses both the general facility estimates and release estimates to estimate the number of workers potentially exposed while performing various process activities and the corresponding potential level (quantity) of both inhalation and dermal exposure.

3.1 Introduction to the General Facility Calculations

Through the remainder of this section, a method utilizing available waterborne coatings industry data is described to determine the daily use rate of the chemical of interest. The daily use rate can be estimated using several facility parameters, including the annual facility production rate ($Q_{\text{site_yr}}$); the number of formulation sites that may use a particular component containing the chemical of interest (N_{sites}); and the days of operation ($\text{TIME}_{\text{working_days}}$). Based on Census data, production data for waterborne coatings were determined by type of coating (i.e.,

² Note: When evaluating environmental releases, EPA typically assumes the highest daily release is the most conservative, because it will result in the highest aquatic stream concentrations. Therefore, EPA typically uses high-end daily use rates to generate conservative environmental release estimates. Conversely, for conservative occupational exposure assessments, EPA typically utilizes lower daily use rates, which will result in a greater number of use sites, longer use duration, and a greater number of workers exposed.

architectural, OEM coatings, special purpose coatings) (see Table 1-6). Additional information on the number of formulation sites was obtained from the Economic Census data (USCB, 2002).

Combined with available formulation data in Table 2-2 and Table 2-3, market production data and U.S. Census data can be used to calculate the annual facility production rate and daily use rate of the chemical of interest. The number of shipping containers that are transferred into the operation annually and the number of containers that are filled with the waterborne coating annually were also determined.

The general facility estimates described in this section are summarized with their associated inputs/bases and corresponding section number in Table 3-1. In addition, Table A-2 in Appendix A presents a detailed summary of the default values used as inputs to each of the general facility estimates, accompanied by their references.

Table 3-1. Summary of General Facility Parameters for Formulation Sites

Parameter	Description	Generic Scenario Section
$Q_{\text{site_yr}}$	Annual facility waterborne coating production rate containing the chemical of interest (kg product used/site-yr)	3.2
$Q_{\text{site_prod_rate}}$	Total annual facility formulation production rate (kg/site-yr)	3.2
$F_{\text{waterborne}}$	Fraction of the total coating production that contains the chemical of interest (Default: 1 kg waterborne coating containing the chemical/kg total coating formulated)	3.2
$F_{\text{chem_comp}}$	Mass fraction of the chemical of interest in the waterborne coating component (kg chemical/kg component).	3.3
$F_{\text{comp_form}}$	Mass fraction of the component used in the formulated waterborne coating (kg component/kg coating)	3.4
$F_{\text{chem_form}}$	Mass fraction of the chemical of interest in the formulated waterborne coating (kg chemical/kg coating)	3.5
N_{sites}	Number of facilities using the chemical of interest to formulate a waterborne coating (sites).	3.6
$Q_{\text{chem_yr}}$	Annual production volume of the chemical of interest (kg chemical/yr)	3.6
$\text{TIME}_{\text{working_days}}$	Annual number of days the waterborne coating is formulated at each facility (days/yr).	3.7
$N_{\text{bt_site_yr}}$	Annual number of formulation batches for waterborne coatings run at each facility (batches/site-yr).	3.8
$Q_{\text{form_bt}}$	Mass of waterborne coating formulated per batch (kg coating/batch)	3.8
$N_{\text{bt_site_day}}$	Daily number of batches of waterborne coating formulated, per site (batches/site-day)	3.8
$Q_{\text{chem_site_day}}$	Daily use rate for the chemical of interest at each facility (kg of chemical/site-day).	3.9
$N_{\text{cont_empty_site_yr}}$	Annual number of chemical-containing component containers emptied per facility (container/site-yr).	3.10
$Q_{\text{cont_empty}}$	Mass of the waterborne coating component in the container (kg component/container)	3.10
$N_{\text{cont_fill_site_yr}}$	Annual number of chemical-containing waterborne coating containers filled per facility (container/site-yr).	3.11

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Parameter	Description	Generic Scenario Section
$V_{\text{cont_empty}}$	Volume of component per container (liters/container)	3.11
$RHO_{\text{component}}$	Density of the component (kg component/L component)	3.11
$Q_{\text{cont_fill}}$	Mass of the waterborne coating in the filled container (kg coating/container)	3.11
$V_{\text{cont_fill}}$	Volume of waterborne coating per filled container (L product/container)	3.11
$RHO_{\text{waterborne}}$	Density of the formulated waterborne coating (kg component/L component)	3.11

The method described in the remaining sections incorporates certain assumptions in cases where industry-specific data were not found. These key assumptions are presented throughout this section and are accompanied by a discussion of their uncertainties and potential effects on the estimates.

3.2 Annual Facility Waterborne Coating Production Rate ($Q_{\text{site_yr}}$)

The average annual facility production of waterborne coatings may be estimated based on available 2010 U.S. production data and available 2007 U.S. Census Bureau data on the total number of sites that may formulate waterborne coatings. Table 3-2 summarizes the annual facility production rates ($Q_{\text{site_prod_rate}}$) and the annual facility waterborne coatings production rates found in several different sources.

CEB recommends using the total facility production rate ($Q_{\text{site_prod_rate}}$) provided by the U.S. Census Bureau as defaults for each coating type, since these rates represent the overall industry average. The individual facility data points are provided in this table to confirm the validity of the values presented by the U.S. Census, rather than to be used as alternative default rates. Where available, the waterborne coating production rates from the individual facilities were also provided. The default value for the total annual facility production rate ($Q_{\text{site_prod_rate}}$) in Table 3-2 depends on the type of waterborne coating. Figure 3-1 illustrates the logic that can be used to determine the appropriate default for the general facility estimates.

The default value for the waterborne coating production rate ($Q_{\text{site_yr}}$) depends on the fraction of waterborne coatings that contains the chemical of interest produced at the facility. If the fraction is unknown, it is assumed that the chemical of interest is in all coating products at a formulation site ($F_{\text{waterborne}} = 1$ kg product incorporating chemical/kg total product formulated). This assumption would maximize the per-site releases and minimize the number of sites estimated. The following calculation may be used to determine the annual facility production rate for the waterborne coating containing the chemical of interest ($Q_{\text{site_yr}}$):

$$Q_{\text{site_yr}} = Q_{\text{site_prod_rate}} \times F_{\text{waterborne}} \quad (3-1)$$

Where:

$Q_{\text{site_yr}}$	=	Annual facility waterborne coating production rate containing the chemical of interest (kg product used/site-yr)
$Q_{\text{site_prod_rate}}$	=	Total annual facility formulation production rate (kg/site-yr) (See Table 3-2 for default total production rates.)
$F_{\text{waterborne}}$	=	Fraction of the total coating production that contains the chemical of interest (Default: 1 kg waterborne coating containing the chemical/kg total coating formulated)

Note that the 1994 generic scenario (CEB, 1994) estimates the average annual facility production is 500,000 gallons per site, but does not provide a basis for this estimate. A typical formulation plant can produce both waterborne and solvent-based coatings (ORD, 1990). Facilities are also generally categorized by market (i.e., architectural coatings, product coatings, etc.), not by the solvent used in their products (IHWRIC, 1991); therefore, the 1994 generic scenario production rate was not used. Data from several site visits support this assumption (IHWRIC, 1991; ECanada, 2003; USEPA, 2006a,b).

Table 3-2. Summary of Available Waterborne Coating Production Rates

Type of Coating	Average Annual Facility Production Rate of Waterborne Coatings^{a,b} (million kg/site-yr)
Architectural	16.0
Original Equipment Manufacture (OEM)	2.7
Special Purpose	1.6

a – Facility production rates for USCB data were calculated based on the 2010 total U.S. production data for Architectural, OEM, and Special Purpose Coatings divided by the total number of establishments reported for each type of coating (see Table 1-6). For example, facility production rates for architectural waterborne coatings is calculated as (515.7 million gal/yr × 3.785 L/gal × 1.33 kg/L)/(162 sites) = 16.0 million kg/site-yr

b – The facility production rates were provided in gallons. The density of the coating was not given and was assumed 1.33 kg/L (See Section 2.3).

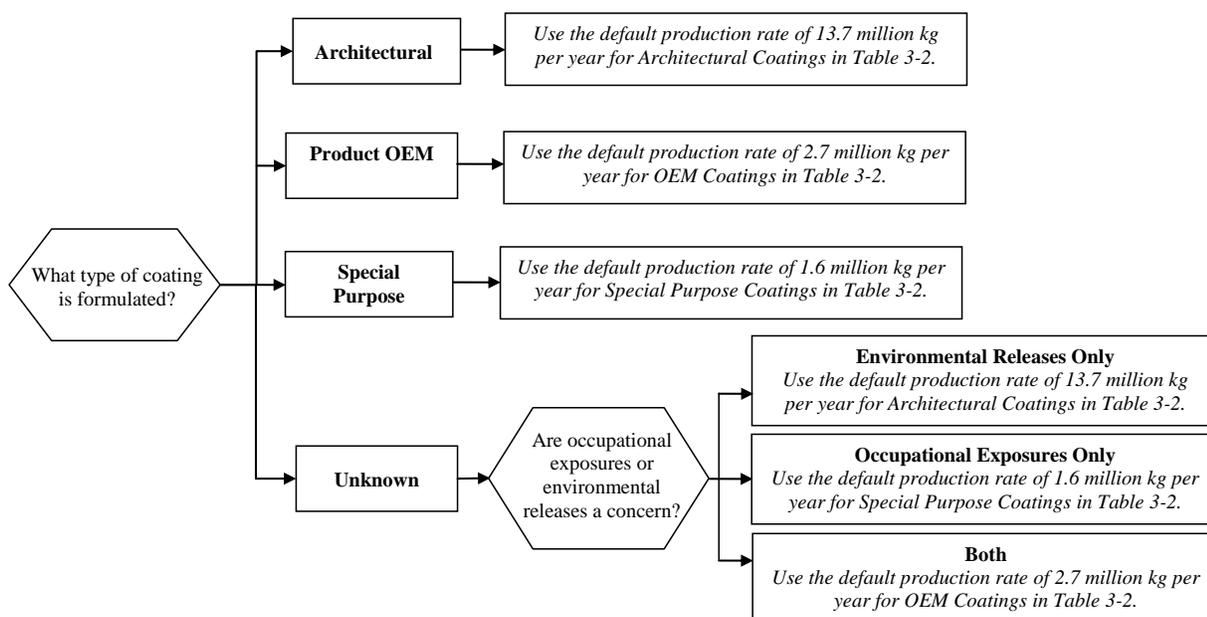


Figure 3-1. Logic Diagram to Determine the Default Average Annual Facility Production Rate for General Facility Estimates

Footnotes to Figure 3-1

- 1) If the specific type of waterborne coating (e.g., architectural, OEM, or special purpose) is known, the appropriate annual facility production rate should be utilized. However, if the specific market is unknown, then the occupational exposure and environmental releases concerns should be considered when selecting the appropriate default for the annual facility production rate.
- 2) When selecting use rates based on potential concerns, EPA typically uses the following methodology to make conservative assessments. For conservative occupational exposure estimates, facilities with the lowest annual use rates are typically selected. This maximizes the number of formulation sites and therefore, maximizes the number of workers. For conservative environmental release assessments, facilities with the highest annual production rates are typically selected. This maximizes the daily use rate and therefore, results in the highest daily release. If both releases and exposures are a concern, average or median values are typically utilized. This methodology was utilized to select the defaults in Figure 3-1.

3.3 Mass Fraction of the Chemical of Interest in the Waterborne Coating Component **(F_{chem_comp})**

The chemical of interest may be shipped to the formulation site for use in a component product, or it may be the waterborne coating component itself. If specific information about the chemical-containing component is not known, EPA assumes 100 percent chemical of interest when performing the calculations in this assessment:

$$F_{\text{chem_comp}} = \text{Mass fraction of the chemical of interest in the component (Default: 1 kg chemical/kg component)}$$

3.4 Mass Fraction of the Component in the Waterborne Coating Formulation **(F_{comp_form})**

Available data for the general composition of a waterborne coating formulation are presented in Table 2-2 and Table 2-3. If the type of industry in which the coating will be used (e.g., architectural, wood, metal) and the general component type are known, EPA suggests using the upper bound concentrations³ in Table 2-2 for the specific industry and component types. If the industry type is not known, but the component type is known for the chemical of interest, use of the EPA default concentrations presented in Table 2-2 is recommended. If no information is available, EPA recommends using the overall default from this table.

Table 2-3 provides more detailed composition information for a water-emulsion or latex formulation. The concentrations shown in the table should be used if the type of coating is architectural and the specific component type is known. If the component type is not known, the default concentration from Table 2-3 can be used.”

$$F_{\text{comp_form}} = \text{Mass fraction of the component used in the formulated waterborne coating (Default: 0.45 kg component/kg coating for a solid chemical or 0.35 kg component/kg coating for a liquid chemical; see Tables 2-2 and 2-3 for alternative fractions, as appropriate.)}$$

3.5 Mass Fraction of the Chemical of Interest in the Waterborne Coating (F_{chem_form})

The fraction of the chemical of interest contained in the waterborne coating can be determined using the following equation.

$$F_{\text{chem_form}} = F_{\text{chem_comp}} \times F_{\text{comp_form}} \quad (3-2)$$

Where:

³Using the upper bound concentration will provide a conservative (worst case) assessment for releases, as well as worst case exposure doses; however, it will not provide a conservative result in the total number of workers potentially exposed to the chemical of interest (i.e., the total number of sites, and thus the number of workers will be minimized).

$F_{\text{chem_form}}$	=	Mass fraction of the chemical of interest in the formulated waterborne coating (kg chemical/kg coating)
$F_{\text{chem_comp}}$	=	Mass fraction of the chemical of interest in the component (See Section 3.3)
$F_{\text{comp_form}}$	=	Mass fraction of the component used in the formulated waterborne coating (See Section 3.4)

3.6 Number of Sites (N_{sites})

The following calculation combines the waterborne coating production rate ($Q_{\text{site_yr}}$), the annual production rate of the chemical of interest ($Q_{\text{chem_yr}}$), and the fraction of the chemical of interest in the waterborne coating ($F_{\text{chem_form}}$) to estimate the number sites expected to utilize the amount of chemical of interest to formulate waterborne coatings:

$$N_{\text{sites}} = \frac{Q_{\text{chem_yr}}}{Q_{\text{site_yr}} \times F_{\text{chem_form}}} \quad (3-3)$$

Where:

N_{sites}^4	=	Number of facilities using the chemical of interest to formulate a waterborne coating (sites)
$Q_{\text{chem_yr}}$	=	Annual production volume of the chemical of interest (kg chemical/yr)
$Q_{\text{site_yr}}$	=	Annual facility waterborne coating production rate (kg coating/site-yr) (See Section 3.2)
$F_{\text{chem_form}}$	=	Mass fraction of the chemical of interest in the formulated waterborne coating (kg chemical/kg coating) (See Section 3.5)

The number of sites that formulate the chemical of interest into waterborne coatings is estimated based on the total amount of the chemical-containing component produced (kg/yr) and the annual facility production rate of the coating (kg/site-yr). The maximum number of sites should not exceed those listed in Table 1-6 for the architectural, OEM, or special purpose coatings, per U.S. Economic Census data (USCB, 2011).

3.7 Days of Operation (TIME_{working days})

Site-specific information indicate the typical days of operation for a formulation site range from 235 days per week to 350 days per week (USEPA, 2006a,b; ECanada, 2003). If the number of days of operation is not known, EPA assumes a maximum of 250 days per year based

⁴The value for N_{sites} , calculated using Equation 3-3 should be rounded up to the nearest integer value. $Q_{\text{site_yr}}$ should then be adjusted for the N_{sites} integer value (to avoid errors due to rounding):

$$Q_{\text{site_yr}} = \frac{Q_{\text{chem_yr}}}{N_{\text{sites}} \times F_{\text{chem_form}}}$$

Note: If the number of formulation sites is known, the previous equation may also be used to estimate the resulting annual production rate for use in subsequent calculations.

on an operating schedule of five days per week over 50 weeks per year, with a two-week annual downtime for maintenance.

3.8 Annual Number of Batches ($N_{bt_site_yr}$)

To estimate the annual number of batches, this scenario uses a default batch size of 1,000 gallons (3,785 liters). Assuming a waterborne coating density of 1.33 kg per liter, the batch size used is 5,030 kilograms. This default value is intended to be only used when site-specific information is not available. The following calculation estimates the annual number of batches for each formulator site based on the annual facility production rate and the batch size:

$$N_{bt_site_yr} = \frac{Q_{site_yr}}{Q_{form_bt}} \quad (3-4)$$

Where:

$N_{bt_site_yr}$	=	Annual number of batches of waterborne coating formulated, per site (batches/site-yr)
Q_{site_yr}	=	Annual facility production rate (kg coating/site-yr) (See Section 3.2)
Q_{form_bt}	=	Mass of waterborne coating formulated per batch (Default: 5,030 kg coating/batch; see Section 2.1.3 for alternative defaults)

Based on site-specific information, a formulation site may have multiple processing lines and produce multiple batches of coating per day. To calculate the number of batches formulated per day, the following equation may be used:

$$N_{bt_site_day} = \frac{N_{bt_site_yr}}{TIME_{working_days}} \quad (3-5)$$

Where:

$N_{bt_site_day}$	=	Daily number of batches of waterborne coating formulated, per site (batches/site-day)
$N_{bt_site_yr}$	=	Annual number of batches of waterborne coating formulated, per site (batches/site-yr) (See Equation 3-4)
$TIME_{working_days}$	=	Annual number of days the waterborne coating is formulated (days/yr) (Section 3.7)

One architectural coating formulation facility indicated that it may take up to seven hours to prepare a batch of coating. An automotive coating formulation facility estimates up to 72 hours per batch (USEPA, 2006a,b). CEB assumes a default of seven hours per batch.

3.9 Daily Use Rate of the Chemical of Interest ($Q_{\text{chem_site_day}}$)

The daily use rate for the chemical of interest in formulating waterborne coatings is estimated using the following equation, based on the formulation production rate, the number of operating days, and the concentration of the chemical of interest in the formulated product:

$$Q_{\text{chem_site_day}} = \frac{Q_{\text{site_yr}} \times F_{\text{chem_form}}}{\text{TIME}_{\text{working_days}}} \quad (3-6)$$

Where:

$Q_{\text{chem_site_day}}$	=	Daily use rate of the chemical of interest used to formulate the waterborne coating (kg chemical/site-day)
$Q_{\text{site_yr}}$	=	Annual production volume of waterborne coatings containing the chemical per site (kg coating/site-yr) (See Section 3.2)
$F_{\text{chem_form}}$	=	Mass fraction of the chemical of interest in the waterborne coating (kg chemical/kg coating) (See Section 3.5)
$\text{TIME}_{\text{working_days}}$	=	Annual number of days the waterborne coating is formulated (days/yr) (See Section 3.7)

Summary of the Relationship of General Facility Parameters

The values for days of operation, daily use rate of the chemical of interest ($Q_{\text{chem_site_day}}$), and number of sites (N_{sites}) are related. This ESD presents one method for estimating $Q_{\text{chem_site_day}}$ using estimated default values for: 1) the total annual U.S. production volume of the waterborne coating per site ($Q_{\text{site_yr}}$); 2) the mass fractions of the chemical and component in formulation; and 3) number of operating days ($\text{TIME}_{\text{working_days}}$).

If $N_{\text{bt_site_day}}$ and $Q_{\text{form_bt}}$ are known, $Q_{\text{chem_site_day}}$ can be calculated alternatively:

$$Q_{\text{chem_site_day}} = Q_{\text{form_bt}} \times N_{\text{bt_site_day}} \times F_{\text{chem_form}}$$

However, it is recommended to calculate the chemical of interest throughput based on the methodology presented in Section 3.9, and compare it to the throughput based on batch size and number of batches per day, as calculated above.

3.10 Annual Number of Chemical-Containing Component Containers Emptied per Facility ($N_{\text{cont_empty_site_yr}}$)

The number of waterborne coating component containers unloaded annually per site can be estimated based on the daily use rate, container size, and concentration of the chemical of interest in the component. Based on site visit data from EPA and Environment Canada, components of waterborne coatings may be shipped to the formulation sites in the following types of containers (USEPA 2006a,b; ECanada, 2003):

- Bags (50 lbs) used for solid additives and some pigments;

- Super sacks (250-1,100 lbs) used for most pigments;
- Pails (~5 gal) used for most liquid additives;
- Drums (~55 gal) used for some liquid additives, solvents, and resins;
- Totes (1,000-1,600 L or 264-423 gal) used for solvents and resins; and
- Tank trucks (~5,000 gal) used for solvents and resins.

EPA suggests that a default transportation container size of a 55-gallon drum be used (CEB, 2002b). This is consistent with industry-specific information on the typical transport containers for waterborne coating components (USEPA, 2006a,b). Engineering judgment should be used to determine if another container type or size is more appropriate (e.g., a 50-pound bag may be more appropriate for a solid component). If the density of a liquid component is not known, the density of water (1 kg/L) can be used as a default.

$$N_{\text{cont_empty_site_yr}} = \frac{Q_{\text{chem_site_day}} \times \text{TIME}_{\text{working_days}}}{F_{\text{chem_comp}} \times Q_{\text{cont_empty}}} \quad (3-7)$$

Where:

$N_{\text{cont_empty_site_yr}}$	=	Annual number of component containers emptied containing chemical of interest per site (containers/site-yr)
$Q_{\text{chem_site_day}}$	=	Daily use rate of the chemical of interest used to formulate the waterborne coating (kg chemical/site-day) (Section 3.9)
$\text{TIME}_{\text{working_days}}$	=	Annual number of days the waterborne coating is formulated (days/yr) (Section 3.7)
$F_{\text{chem_comp}}$	=	Mass fraction of the chemical of interest in the waterborne coating component (kg chemical/kg component) (See Section 3.3)
$Q_{\text{cont_empty}}^5$	=	Mass of the waterborne coating component in the container (kg component/container)

3.11 Annual Number of Waterborne Coating Containers Filled per Facility **($N_{\text{cont fill site yr}}$)**

The number of waterborne coating containers filled annually per site can be estimated similar to the methodology described in Section 3.10 above. The calculation is based on the daily use rate, container size, and concentration of the chemical of interest in the formulated coating. EPA suggests that a default transportation container size of a 55-gallon drum could be used. Engineering judgment should be used to determine if another container type or size is

⁵If the mass of the component in each container is not known, it can be calculated using the volume of the container and the density of the component:

$$Q_{\text{cont_empty}} = V_{\text{cont_empty}} \times \text{RHO}_{\text{component}}$$

Where:

$V_{\text{cont_empty}}$	=	Volume of component per container (Default: 208 L component/container (55-gallon drum); See Table B-3 in Appendix B for alternative default container volumes)
$\text{RHO}_{\text{component}}$	=	Density of the component (Default: 1 kg component/L component)

more appropriate. If the density of a waterborne coating is not known, a density of 1.33 kg/L can be used as a default (see Section 2.3).

$$N_{\text{cont_fill_site_yr}} = \frac{Q_{\text{chem_site_day}} \times \text{TIME}_{\text{working_days}}}{F_{\text{chem_form}} \times Q_{\text{cont_fill}}} \quad (3-8)$$

Where:

$N_{\text{cont_fill_site_yr}}$	=	Annual number of containers filled containing chemical of interest per site (containers/site-yr)
$Q_{\text{chem_site_day}}$	=	Daily use rate of the chemical of interest used to formulate the waterborne coating (kg chemical/site-day) (See Section 3.9)
$\text{TIME}_{\text{working_days}}$	=	Annual number of days the waterborne coating is formulated (days/yr) (See Section 3.7)
$F_{\text{chem_form}}$	=	Mass fraction of the chemical of interest in the waterborne coating (kg chemical/kg coating) (See Section 3.5)
$Q_{\text{cont_fill}}^6$	=	Mass of the waterborne coating in the filled container (kg coating/container)

⁶If the mass of the waterborne coating in each container is not known, it can be calculated using the volume of the container and the density of the product:

$$Q_{\text{cont_fill}} = V_{\text{cont_fill}} \times \text{RHO}_{\text{waterborne}}$$

Where:

$V_{\text{cont_fill}}$	=	Volume of waterborne coating per filled container (Default: 208 L product/container (55-gallon drum); See Table B-3 in Appendix B for alternative default container volumes)
$\text{RHO}_{\text{waterborne}}$	=	Density of the formulated waterborne coating (Default: 1.33 kg product/L product)

4.0 ENVIRONMENTAL RELEASE ASSESSMENTS FOR THE FORMULATION OF WATERBORNE COATINGS

This section presents approaches for estimating the amount of the chemical of interest released from each process source during the formulation of waterborne coatings. The release sources are discussed in the order that they occur in the process (See Figure 2-1), and include the most likely receiving media (i.e., air, water, landfill, or incineration). The primary sources of release are container residue, process equipment cleaning, and filter media waste. The releases are shown on the process flow diagram (Figure 2-1). Note that some additives (mainly pigments) contain heavy metals (e.g., titanium), and may generate elements of concern when incinerated. Key default values used to calculate the release estimates, accompanied by their respective references, are provided in Table A-2 of Appendix A.

Based on available data, emissions of volatile organic compounds (VOCs) and particulate matter (PM) from paint, ink, and other coating manufacturing can be estimated using a number of models, as described in EPA's Methods for Estimating Emissions from Paint, Ink, and Other Coating Manufacturing Facilities (EPA, 2005). In practice, the use of add-on control systems or equipment and process modifications during the formulation of waterborne coatings will reduce the level of VOC and PM emissions and minimize the losses of the chemical. Some pre-process or other upstream releases are likely to occur; however, because losses are assumed to be minimized, the methodology presented in this section for estimating the releases of the chemical of interest from the formulation process does not include adjustments to account for pre-process or other upstream releases of the chemical (e.g., while some material may remain in the transport container, the entire volume received in the container is assumed when estimating equipment cleaning releases). These omissions of mass balance adjustments should not result in a negative throughput of the chemical of interest in these calculations (i.e., the total amount of chemical released from the process should not exceed the amount that enters the process).

All release equations estimate daily rates for a given site. To estimate annual releases for all sites for a given source, the release rates must be multiplied by the number of days of release and by the total number of formulation sites using the chemical of interest (N_{sites}) (See Equation 3-2). Some process releases are expected to be released to the same receiving medium on the same days. Therefore, daily and annual releases to a given medium may be summed to yield total amounts released.

It is uncertain how much waterborne coatings attribute to the overall air, land, and water releases reported in TRI. Based on the 2008 EPA Sector Performance Report Supplement, the paints and coatings industry reported total TRI chemical releases amounting to 5.7 million pounds, of which 4 million pounds were emitted to air, 24,000 pounds to water discharges, and 1.6 million pounds to land or off-site waste disposal. Total air emissions declined by 56 percent between 1997 and 2006 due to the number of regulations limiting the emissions during formulation processes (see Table 1-1). These releases represent the industry as a whole and reflect releases reported during both solvent-borne and waterborne coatings formulation. The top five TRI chemicals reported in the industry as emitting to air are typical solvents used in solvent-borne coatings, although some of these solvents may be used in smaller doses (as co-solvents) in

waterborne coatings. A major component of land disposal quantities reported is metals, likely from coatings additives used in either solvent-borne or waterborne coatings (EPA, 2009).

Many of the environmental release estimates presented in this document are based on standard EPA release models, with the exception of the estimates described in Sections 4.4 and 4.8 for container residuals and equipment cleaning wastes, and Section 4.11 for filter waste containing the chemical during filter media replacement. These release estimates are based on site-specific information obtained from several formulation sites. Additionally, industry specific information is consistent with several of EPA’s standard release models. Table 4-1 summarizes the release estimation methods used in this generic scenario.

Note that the standard model default values cited are current as of the date of this generic scenario; however, EPA may update these models as additional data become available. It is recommended that the most current version of the models be used in these calculations.

EPA has developed a software package (ChemSTEER) containing these models as well as all current EPA defaults. Because of the complexity of the air release models, ChemSTEER is recommended for estimating air releases. Appendix B provides additional information on ChemSTEER, including instructions for obtaining the program, as well as background information, model equations, and default values for several parameters for all standard EPA models.

Table 4-1. Summary of Waterborne Coating Formulation Scenario Release Models

Release Source #	Media of Release	Description	Model Name or Description^a	Standard EPA Model (✓)
1	Air	Transfer operation losses of volatile chemical to air during unloading	EPA/OAQPS AP-42 Loading Model	✓
2	Air, Water, Incineration, or Landfill	Dust losses of solid chemicals to air during unloading	EPA/OPPT Dust Emissions from Transferring Solids Model	✓

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Release Source #	Media of Release	Description	Model Name or Description ^a	Standard EPA Model (✓)
3	Water, Incineration, or Landfill	Container residue losses to non-air media during container cleaning and/or disposal	Specific model used is based on the type and size of the containers, and on the physical state of the waterborne coating component: <ul style="list-style-type: none"> • EPA/OPPT Bulk Transport Residual Model • EPA/OPPT Drum Residual Model • EPA/OPPT Small Container Residual Model • EPA/OPPT Solid Residuals in Transport Containers Model Release estimates to each medium of release can be estimated for site with an on-site wastewater treatment system.	✓
4	Air	Open surface losses of volatile chemical to air during container cleaning	EPA/OPPT Penetration Model	✓
5	Air	Vented losses of volatile chemical to air during dispersion and blending operations	EPA/OPPT Penetration Model	✓
6	Water, Incineration, or Landfill	Product sampling losses to non-air media.	No methodology for quantifying the release from this source has been developed	
7	Air	Open surface losses of volatile chemical to air during product sampling	EPA/OPPT Penetration Model	✓
8	Water, Incineration, or Landfill	Equipment cleaning losses to non-air media	EPA/OPPT Multiple Process Vessel Residual Model Release estimates to each medium of release can be estimated for a site with an on-site wastewater treatment system.	✓
9	Air	Open surface losses of volatile chemical to air during equipment cleaning	EPA/OPPT Penetration Model	✓
10	Incineration, or Landfill	Filter waste losses to non-air media during filter media replacement	Loss rate is based on available industry-specific data.	
11	Air	Open surface losses of volatile chemical to air during filter media replacement	EPA/OPPT Penetration Model	✓
12	Air	Transfer operation losses of volatile chemical to air during container loading	EPA/OAQPS AP-42 Loading Model	✓

OPPT – Office of Pollution Prevention and Toxics.

OAQPS – Office of Air Quality Planning and Standards.

a – Additional detailed descriptions for each of the models presented in this section are provided in Appendix B.

4.1 Control Technologies

The use of automated process control and computer-controlled production during process operations is increasing; although, the prevalence of these automated processes in this industry is unknown. According to ACA, facilities will be required to implement emission controls as part of their air permit requirements. This scenario conservatively assumes that waterborne coating formulation facilities have not implemented these types of technology, which will result in an overestimation of releases at facilities that do implement automated process controls.

Industry-specific information indicates process wastes from the formulation of waterborne coatings may be recycled or released to water, incineration, or landfill. Based on site-specific information from various sources, it is common practice to rework process wastes (e.g., container residuals, equipment cleaning wastes, off-spec products) into subsequent batches of coating (IHWRIC, 1991; ORD, 1990; ECanada, 2003; USEPA, 2006a,b). Paint facilities segregate and store waste only to the degree required by the waste disposal contractor. Since the degree of segregation can affect the amount of material having to be classified as hazardous, and the cost of disposing hazardous materials is increasing, paint facilities are taking a more active role in waste management (ORD, 1990).

The major wastes that the paint industry must manage are empty raw material packages, dust from air pollution control equipment, off-specification paint, spills, and equipment cleaning wastes. Equipment cleaning wastes are a significant portion of the waste stream. These methods come from accounts published in the open literature and through industry contacts. The primary waste streams associated with paint manufacturing are listed in Table 4-2 along with recommended control methods. (ORD, 1990)

Table 4-2. Waste Minimization Methods for the Paint Manufacturing Industry

Waste Stream	Waste Minimization Methods
Equipment cleaning wastes (rinse water, solvent and sludge)	Use mechanical wipers on mix tanks. Use high pressure wash systems. Install Teflon liners on mix tanks. Use foam/plastic pigs to clean lines. Reuse equipment cleaning wastes. Schedule production to minimize need for cleaning. Clean equipment immediately. Use countercurrent rinse methods. Use alternative cleaning agents. Increase spent rinse settling time.* Use de-emulsifiers on spent rinses.*
Spills and off spec paint	Increase use of automation. Use appropriate cleanup methods. Recycle back into process. Implement better operating practices.
Leftover inorganic pigment in bags and packages	Use water soluble bags and liners. Use recyclable/lined/dedicated containers.
Air emissions, including pigment dust	Modify bulk storage tanks. Use paste pigments

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	Install dedicated baghouse systems.
Filter cartridges	Improve pigment dispersion. Use bag or metal mesh filters.
Obsolete products/customer returns	Blend into new products.

*These methods can only be viewed as waste minimization if they allow the continued use of spent cleaning solutions.

Source: ORD, 1987.

Generally for a waterborne coating formulation site, on-site wastewater treatment occurs if liquid wastes are not recycled or reworked. Treatment of process wastes at waterborne coating formulation facilities typically consists of solids removal. The clear effluent from on-site treatment is sent to a publicly owned treatment works (POTW) and the generated residual sludge is sent to incineration or landfill. Facilities may also collect and directly dispose of liquid and solid process wastes by incineration or in landfill (hazardous or municipal, depending on the nature of the wastes). On-site wastewater treatment is site-specific. Data from one formulation site estimates 73 percent of solid components (e.g., pigments and resins) are removed by settling tanks during on-site treatment (ECanada, 2003). Another site used a vacuum drum filter to remove solids from the waste stream; however, a removal efficiency could not be estimated (IHWRIIC, 1991). Several smaller formulators of both solvent-based and waterborne coatings and specialty purpose coatings did not have on-site wastewater treatment, however, the process wastes from these formulation processes were combined into a single waste stream with a heat content high enough for incineration.

Because wastewater treatment is not standard across the industry and because typical wastewater treatment options are only designed to remove solid components, this scenario assumes water is indirectly discharged to water (via POTW) without on-site wastewater treatment. If site-specific information indicates on-site wastewater treatment and removal efficiency data are provided, releases may be partitioned between water and incineration or landfill.

Additionally, baghouse filters are commonly used for dust control of solid raw materials (e.g., pigments) that are used in waterborne coating formulations. The residuals are most likely reworked into subsequent batches, but may also be incinerated or landfilled.

4.2 Transfer Operation Losses to Air from Unloading the Waterborne Coating Component (Release 1)

For nonvolatile chemicals (e.g., the vapor pressure is < 0.001 torr), releases to air are expected to be negligible.

If the chemical is volatile (e.g., the vapor pressure is > 0.001 torr), releases to air may occur from the displacement of saturated air when the chemical is transferred ($E_{\text{local,air,transfers}}$). The standard EPA estimation model for transfer operations may be used to estimate the release to air (*EPA/OAQPS AP-42 Loading Model*). The transfer operations model provides worst and typical case estimates for releases and exposures during transfer operations (e.g., transferring liquids from transport containers into storage tanks or mixers).

Table 4-3 lists the model inputs and default values. The models and all current EPA defaults have been programmed into ChemSTEER; EPA recommends using this software to calculate air releases and exposures during transfer operations. Appendix B provides background information, model equations, and default values for several parameters the model uses to estimate daily releases to air.

Table 4-3. EPA/OAQPS AP-42 Loading Model Parameter Default Values for Air Releases During Unloading

Input Parameter	Default Values
Saturation Factor	EPA defaults 0.5 (typical) and 1 (worst case) for all containers less than 5,000 gallons (CEB, 2002b) (See Appendix B for alternative default saturation factors)
Frequency of Release	Equal to the lesser of TIME _{working_days} or N _{cont_empty_site_yr} (See Sections 3.7 and 3.10)
Molecular Weight	Chemical-specific parameter
Number of Sites	Calculated in Section 3.6
Operating Hours for the Activity	Number of containers emptied per site, per day (See Section 4.4) divided by the unload rate (CEB, 2002b) (default unload rates are found in Appendix B)
Unloading Rate	EPA default 20 containers/hr for volumes between 20 and 1,000 gallons (CEB, 1991) (Alternative default unload rates are found in Appendix B)
Container Volume	Default: 55-gallon drum (208 L), consistent with Section 3.10
Vapor Pressure	Chemical-specific parameter
Vapor Pressure Correction Factor	Standard EPA default = 1

Note: The model also assumes standard temperature and pressure along with ideal gas interactions.

4.3 Dust Generation from Transfer Operations Released to Air, or Collected and Released to Water, Incineration, or Landfill (Release 2)

For liquid components received at the formulation site, this release is negligible.

For solid components, dust generation is expected from transferring operations. Industry-specific data state that baghouse filters are commonly used as a control technology to collect and dispose dust generated from unloading or transferring solid powders; however, not all facilities may have one. The *EPA/OPPT Dust Emissions from Transferring Solids Model* may be used to estimate dust releases. This model assumes that up to 0.5 percent of the transferred quantity may be released to the environment. Note that this default model is based on industry-specific data points. The rationale, defaults, and limitations of these models are further explained in Appendix B.

Most facilities utilize some type of control technology to collect fugitive emissions. Many facilities collect fugitive dust emissions from these operations in filters and dispose of the filters

in landfills or by incineration. Wet scrubbers are not anticipated for this industry. In some cases, uncontrolled/uncollected particulate may be small enough to travel several miles from the facility, resulting in environmental and human exposures to the chemical of interest beyond the boundaries of the site. Some amount of the dust particles may alternately settle on the floor or equipment within the workspace and are disposed of during facility cleaning (water if the floors are rinsed or land or incineration if the floors are swept). Therefore, if additional site specific information is not available, this release is conservatively assumed released to air, water, incineration, or land.

The daily release of fugitive dust emissions can be estimated using the daily use rate ($Q_{\text{chem_site_day}}$).

If the facility-specific information states a control technology is employed, the release may be partitioned to the appropriate media. Table 4-4 provides estimated efficiencies for more common control technologies that may be used in the waterborne coatings industry.

Table 4-4. Estimated Control Technology Efficiencies

Control Technology	Estimated Efficiency (%)	Notes	Default Media of Release for Controlled Release
Filter (such as a baghouse)	>99%	For particles >1 μm	Incineration or Land
Cyclone/Mechanical Collectors:	80-99	For particles >15 μm	Incineration or Land

Source: CEB, 1991.

The portion of release that may be captured by the control technology may be disposed to incineration or land or may be recycled. If the control technology is not known, it can be assumed that none of the dust generated is captured. If the control technology is known, the quantity captured may be estimated using the following equation:

$$E_{\text{local_dust_captured}} = Q_{\text{chem_site_day}} \times F_{\text{dust_generation}} \times F_{\text{dust_control}} \quad (4-1)$$

Where:

- $E_{\text{local_dust_captured}}$ = Daily amount captured by control technology from transfers or unloading (kg/site-day)
- $Q_{\text{chem_site_day}}$ = Daily use rate of the chemical of interest used to formulate the waterborne coating (kg chemical/site-day) (See Section 3.9)
- $F_{\text{dust_generation}}$ = Loss fraction of chemical during transfer/unloading of solid powders (Default: 0.005 kg released/kg handled)
- $F_{\text{dust_control}}$ = Control technology capture efficiency (kg captured/kg processed) (Default: If the control technology is unknown,

assume capture efficiency = 0 kg captured/kg processed, see Table 4-4 for alternative efficiencies).

The portion of the release that will not be captured by the control technology and may be released to air or settle onto the facility floor may be estimated using the following equation:

$$E_{\text{local dust_fugitive}} = Q_{\text{chem_site_day}} \times F_{\text{dust_generation}} \times (1 - F_{\text{dust_control}}) \quad (4-2)$$

Where:

$E_{\text{local dust_fugitive}}$	=	Daily amount not captured by control technology from transfers or unloading (kg/site-day)
$Q_{\text{chem_site_day}}$	=	Daily use rate of the chemical of interest used to formulate the waterborne coating (kg chemical/site-day) (See Section 3.9)
$F_{\text{dust_generation}}$	=	Loss fraction of chemical during transfer/unloading of solid powders (Default: 0.005 kg released/kg handled)
$F_{\text{dust_control}}$	=	Control technology capture efficiency (kg captured/kg processed) (Default: If the control technology is unknown, assume capture efficiency = 0 kg captured/kg processed, see Table 4-4).

This approach is designed for screening-level estimates where appropriate industry-specific or chemical specific information is not available. If the site provided a loss fraction from dust releases, then the site-specific number should be used.

4.4 Waterborne Coating Component Container Residue Released to Water, Incineration, or Landfill (Release 3)

The amount of waterborne coating component remaining in transportation containers will likely depend on the size of the transport container and the physical form of the component product. Therefore, the following standard EPA models may be used to estimate container residue releases:

- *EPA/OPPT Bulk Transport Residual Model* may be used for large containers (e.g., totes, tank trucks, rail cars) containing greater than or equal to 100 gallons of liquid;
- *EPA/OPPT Drum Residual Model* may be used for drums containing between 20 and 100 gallons of liquid;
- *EPA/OPPT Small Container Residual Model* may be used for liquid containers containing less than 20 gallons; and
- *EPA/OPPT Solid Residuals in Transport Containers Model* may be used for containers of all sizes containing solids.

Note that these models estimate between 0.2 percent (bulk containers) and 3 percent (drums) of the received material may be released to the environment. The rationale, defaults, and limitations of these models are further explained in Appendix B.

Waterborne coating components may be received as liquids or solids. If the physical state of the component is not known, EPA suggests reviewing the physical property data summarized in Table 2-4 for some example component chemicals and using engineering judgment to determine if the chemical of interest should be assumed a solid or liquid for the purposes of the assessment.

Industry-specific information on the types of containers used by the waterborne coating formulation industry is summarized in Section 3.10. EPA suggests that a default transportation container size of a 55-gallon drum should be used. Engineering judgment should be used to determine if another container type or size is more appropriate (e.g., a 50-pound bag may be more appropriate for a solid component).

Waterborne coating formulators typically rinse transport containers with water and recycle the rinse water into subsequent coating formulations (USEPA, 2006a,b) or send the wastes to an onsite water treatment system, then to a POTW and landfill. Empty bags and sacks that contained solid raw materials may also be sent to an off-site landfill or incinerator.

The annual number of containers emptied ($N_{\text{cont_empty_site_yr}}$) is estimated based on the daily use rate of the chemical (Section 3.9) and the container size (Section 3.10). EPA recommends assuming 55-gallon (208 L) drums and density of 1.0 kg/L as defaults. If the fraction of the chemical in the component is unknown, assume 100 percent concentration (see Section 3.3).

If the $N_{\text{cont_empty_site_yr}}$ value is fewer than the days of operation ($\text{TIME}_{\text{working_days}}$), the days of release equal $N_{\text{cont_empty_site_yr}}$ (as calculated in Equation 3-10) and the daily release is calculated based on the following equation:

$$E_{\text{local_cont_residue_disp}} = Q_{\text{cont_empty}} \times F_{\text{chem_comp}} \times F_{\text{container_residue}} \times N_{\text{cont_empty_site_day}} \quad (4-3a)$$

This release will occur over [$N_{\text{cont_empty_site_yr}}$] days/year from [N_{sites}] sites

Where:

$E_{\text{local_cont_residue_disp}}$	=	Daily release of chemical of interest from container residue (kg chemical/site-day)
$Q_{\text{cont_empty}}$	=	Mass of the chemical component in the container (kg component/container) (Default: use the same value used to estimate $N_{\text{cont_empty_site_yr}}$ in Section 3.10)
$F_{\text{chem_comp}}$	=	Mass fraction of the chemical of interest in the component (kg chemical/kg component) (See Section 3.3)
$F_{\text{container_residue}}$	=	Fraction of component remaining in the container as residue (Default: 0.03 kg component remaining/kg shipped for drums (CEB, 2002a); See Appendix B for defaults used for other container types)

$N_{\text{cont_empty_site_day}}^7$ = Number of containers unloaded per site, per day (Default: 1 container/site-day)

If $N_{\text{cont_empty_site_yr}}$ is greater than $\text{TIME}_{\text{working_days}}$ (see Section 3.7), more than one container is unloaded per day (i.e., $N_{\text{cont_empty_site_day}} > 1$). The days of release should equal the days of operation, and the average daily release can be estimated based on the following equation:

$$E_{\text{local_cont_residue_disp}} = Q_{\text{chem_site_day}} \times F_{\text{container_residue}} \quad (4-3b)$$

This release will occur over $[\text{TIME}_{\text{working_days}}]$ days/year from $[N_{\text{sites}}]$ sites

Where:

$E_{\text{local_cont_residue_disp}}$ = Daily release of chemical of interest from container residue (kg chemical/site-day)

$Q_{\text{chem_site_day}}$ = Daily use rate of the chemical of interest used to formulate the waterborne coating (kg chemical/site-day) (See Section 3.9)

$F_{\text{container_residue}}$ = Fraction of coating remaining in the container as residue (Default: 0.03 kg component remaining/kg shipped for drums (CEB, 2002a); See Appendix B for defaults used for other container types)

Note: This equation may also be used if a container size is not assumed in Equations 3-6 and 4-4a, and $N_{\text{cont_empty_site_yr}}$ is unknown.

If site-specific information indicates on-site wastewater treatment of liquid wastes from container cleaning and the site provides a wastewater treatment efficiency solids removal rate, then releases may be partitioned between water and incineration or landfill (see Section 4.1). If there is no on-site wastewater treatment, a wastewater treatment efficiency of 0 can be assumed, which indicates no removal of solids from the waste stream. Equations 4-4a and 4-4b show the partition of container residual wastes between water and incineration or landfill, respectively.

$$E_{\text{local_water_WWT}} = E_{\text{local_cont_residue_disp}} \times (1 - F_{\text{eff_WWT}}) \quad (4-4a)$$

⁷ The daily number of containers unloaded per site may be estimated as (consistent with Section 3.10):

$$N_{\text{cont_empty_site_day}} = \frac{N_{\text{cont_empty_site_yr}}}{\text{TIME}_{\text{working_days}}}$$

($N_{\text{cont_empty_site_day}}$ should be rounded up to the nearest integer.)

Where:

$N_{\text{cont_empty_site_yr}}$ = Annual number of containers emptied containing chemical of interest per site (containers/site-yr) (See Section 3.10)

$\text{TIME}_{\text{working_days}}$ = Annual number of days the waterborne coating is formulated (days/yr) (See Section 3.7)

Where:

$E_{\text{local}}_{\text{water_WWT}}$	=	Daily release of chemical of interest to POTW after wastewater treatment (kg chemical of interest/site-day)
$E_{\text{local}}_{\text{cont_residue_disp}}$	=	Daily release of chemical of interest from container residual cleaning (kg chemical of interest/site-day) (see Equation 4-3a or Equation 4-3b, as appropriate)
$F_{\text{eff_WWT}}$	=	Wastewater treatment efficiency (Default: If there is no on-site treatment, site-specific information is not available, or for liquid chemical removal efficiency, assume a value of 0)

$$E_{\text{local}}_{\text{sludge_WWT}} = E_{\text{local}}_{\text{cont_residue_disp}} \times F_{\text{eff_WWT}} \quad (4-4b)$$

Where:

$E_{\text{local}}_{\text{sludge_WWT}}$	=	Daily release of chemical of interest as sludge waste from wastewater treatment (kg chemical of interest/site-day)
$E_{\text{local}}_{\text{cont_residue_disp}}$	=	Daily release of chemical of interest from equipment cleaning (kg chemical of interest/site-day) (see Equation 4-3a or Equation 4-3b, as appropriate)
$F_{\text{eff_WWT}}$	=	Wastewater treatment efficiency (Default: If there is no on-site treatment or site-specific information is not available, assume the efficiency = 0.)

4.5 Open Surface Losses to Air During Container Cleaning (Release 4)

For nonvolatile chemicals (e.g., the vapor pressure is < 0.001 torr), releases to air are expected to be negligible.

If the chemical is volatile (e.g., the vapor pressure is > 0.001 torr), it may volatilize and be emitted from the process while empty containers are being rinsed and cleaned ($E_{\text{local}}_{\text{air_cleaning}}$). To estimate this release, the EPA standard model for estimating releases to air from containers cleaned indoors may be used (*EPA/OPPT Penetration Model*).

Table 4-5 lists the model inputs and default values. The models and all current EPA defaults have been programmed into ChemSTEER; EPA recommends using this software to calculate open surface losses to air during container cleaning. Appendix B provides background information, model equations, and default values for several parameters the model uses to estimate daily releases to air.

Table 4-5. EPA/OPPT Penetration Model Parameter Default Values During Container Cleaning

Input Parameter	Default Values
Diameter of Opening	EPA default 2 in. (5.08 cm) for all containers less than 5,000 gallons (CEB, 2002b) (See Appendix B for alternative default diameters)
Frequency of Release	Equal to the lesser of $N_{\text{cont_empty_site_yr}}$ or $\text{TIME}_{\text{working_days}}$, consistent with Section 4.4
Molecular Weight	Chemical-specific parameter
Number of Sites	Calculated in Section 3.6
Operating Hours for the Activity	Number of containers per site, per day ($N_{\text{cont_empty_site_day}}$, consistent with Release 3) divided by the unload rate (CEB, 2002b) (Default: 20 containers/hr for volumes between 20 and 1,000 gallons (CEB, 1991); Alternative default unload rates are found in Appendix B)
Vapor Pressure	Chemical-specific parameter
Air Speed	EPA default 100 feet/min for indoor conditions (CEB, 1991)
Vapor Pressure Correction Factor	Standard EPA default = 1

Note: The model also assumes standard temperature and pressure along with ideal gas interactions.

4.6 Vented Losses to Air During Dispersion and Blending (Release 5)

The vapor pressure of the chemical of interest should be estimated to determine whether it should be considered volatile for the purposes of this assessment (e.g., has a vapor pressure > 0.001 torr).

For nonvolatile chemicals (e.g., the vapor pressure is < 0.001 torr), releases to air are expected to be negligible from volatilization.

If the chemical is volatile (e.g., the vapor pressure is > 0.001 torr), chemicals may volatilize and be emitted from the process during pigment dispersion and blending ($E_{\text{local_air_process_vent}}$). In an operation where the waterborne coating is generally nonvolatile or that incorporates relatively stable, non-reactive components, the mixing vessel and other operations may be open. In this case, volatile chemicals may be emitted into the workspace and subsequently vented to the air outside of the facility.

The EPA standard model for estimating releases to air from open vessels or process vents may be used (*EPA/OPPT Penetration Model*). The model inputs and default values are listed in Table 4-6. The models and all current EPA defaults have been programmed into ChemSTEER; EPA recommends using this software to calculate open surface losses to air during process operations. Appendix B provides background information, model equations, and default values for several parameters the model uses to estimate daily releases to air.

Table 4-6. EPA/OPPT Penetration Model Parameter Default Values During Dispersion and Blending

Input Parameter	Default Values
Diameter of Opening	EPA default 4-in vent (10 cm) (engineering judgment) If the dispersion or blending vessels are open, see Equation 4-5
Frequency of Release	Equal to TIME _{working_days} (See Section 3.7)
Molecular Weight	Chemical-specific parameter
Number of Sites	Calculated in Section 3.6
Operating Hours for the Activity	24 hrs/day or 7 hrs/batch × N _{bt_site_day} (See Section 3.8), whichever is less (CEB, 2002b) and consistent with calculations described in Section 3.8
Temperature	Default 25°C (CEB, 1991)
Vapor Pressure	Chemical-specific parameter
Air Speed	EPA default 100 feet/min for indoor conditions (CEB, 1991)
Vapor Pressure Correction Factor	Standard EPA default = 1

Note: The model generally assumes standard temperature and pressure along with ideal gas interactions.

Two parameters required for using the model are release time and diameter of the opening. Mixing vessels will likely be closed; therefore, EPA also suggests assuming the vent has an opening diameter of four inches (engineering judgment⁸). These defaults should be used in absence of site-specific data for the *EPA/OPPT Penetration Model*.

If it is known that the process utilizes an open mixing vessel, the opening diameter should be the diameter of the vessel and not of the vent. EPA recommends assuming that the mixing vessel is cylindrical and capable of holding the known or estimated batch size (Q_{form_bt}; See Section 3.8). The following equation can be used to calculate the opening diameter to use in the *EPA/OPPT Penetration Model* based on batch size:

$$D_{\text{opening}} = \left[\frac{4 \times V_{\text{form_bt}} \times 3785.44 \text{ (cm}^3 \text{ / gal)}}{\pi} \right]^{1/3} \quad (4-5)$$

Where:

D_{opening} = Diameter of the mixing vessel opening (cm/vessel)
V_{form_bt} = Volume of coating formulated per batch (gallons) (See Section 3.8)

⁸ Note: The 4-inch vent diameter default is based on professional experience in the radiation-curable adhesives formulation, fermentation, and petroleum processing industries. Based on these industries, a 4-inch vent is assumed to provide conservative estimates for potential air releases during operations. Similar vent sizes are anticipated throughout the adhesive formulation industry; however, the applicability of this default to the entire industry is uncertain. Additionally, the vessel may be vented through control technologies (e.g., scrubber, condenser, thermal oxidizer); however, industry-specific information on vent sizes or control technologies for volatile components was not identified.

Note that this equation assumes an aspect ratio (height/diameter) of one, per McCabe, Smith, and Harriott, Unit Operations of Chemical Engineering, 5th Edition to relate mixing time for various types of impellers and Reynolds Number.

Batch times for the formulation of waterborne coatings may vary. Site-specific data states that a batch can take seven hours or can be as high as 72 hours (USEPA, 2006). A default of seven hours per batch may be assumed.

4.7 Waterborne Coating Product Sampling Wastes Disposed to Water, Incineration, or Landfill (Release 6)

EPA generally assumes that formulation processes incorporate product sampling activities for quality assurance/quality control (QA/QC) and that some amount of waste from this sampling will be generated and disposed to either water, incineration, or landfill (engineering judgment). No industry-specific data were found in the references reviewed for this generic scenario (refer to Section 8), nor does EPA currently have data on QA/QC sampling waste amounts that can be used to generally quantify the release of these process wastes to non-air media.

It should be noted that EPA expects releases of the chemical from product sampling activities to be relatively low in comparison to the other sources of release in the formulation process.

4.8 Open Surface Losses to Air During Product Sampling (Release 7)

For nonvolatile chemicals (e.g., the vapor pressure is < 0.001 torr), releases to air are expected to be negligible.

If the chemical is volatile (e.g., the vapor pressure is > 0.001 torr), it may volatilize and be emitted from the process during product QA/QC sampling activities ($E_{\text{local air sample}}$). The EPA standard model for estimating releases to air from sampling activities performed indoors may be used (*EPA/OPPT Penetration Model*). It should be noted that EPA expects releases of the chemical from product sampling activities to be relatively low in comparison to the other sources of release in the formulation process.

The model inputs and default values are listed in Table 4-7. The models and all current EPA defaults have been programmed into ChemSTEER; EPA recommends using this software to calculate open surface losses to air during container cleaning. Appendix B provides background information, model equations, and default values for several parameters the model uses to estimate daily releases to air.

Table 4-7. EPA/OPPT Penetration Model Parameter Default Values During Product Sampling

Input Parameter	Default Values
Diameter of Opening	EPA defaults are 1 in. (2.5 cm) typical; and 4 in. (10 cm) worst case (CEB, 2002b)
Frequency of Release	Equal to TIME _{working_days} (See Section 3.7)
Molecular Weight	Chemical-specific parameter
Number of Sites	Calculated in Section 3.6
Operating Hours for the Activity	1 hour/day (CEB, 1991)
Temperature	Default 25°C (CEB, 1991)
Vapor Pressure	Chemical-specific parameter
Air Speed	EPA default 100 feet/min for indoor conditions (CEB, 1991)
Vapor Pressure Correction Factor	Standard EPA default = 1

Note: The model also assumes standard temperature and pressure along with ideal gas interactions.

4.9 Equipment Cleaning Releases to Water, Incineration, or Landfill (Release 8)

Equipment cleaning wastes make up 80 percent of the waste generated in paint manufacturing (IHWRIC, 1991). Process equipment is typically first manually cleaned with a wiper or squeegee, followed by a water/ammonia mixture rinse (WSDE, 2002). The manual cleaning reduces the amount of aqueous waste that must be treated prior to release. A 1,000-gallon tank may be rinsed with as little as 5 to 10 gallons of liquid. Facilities may reuse the wash liquids and rework them into subsequent batches; however, rinse water must be incorporated into the next batch in less than a day to prevent bacterial contamination (IHWRIC, 1991). Also if the pigment or colorant concentration is too high, the cleaning waste cannot be recycled or they will tint subsequent batches. Equipment cleaning frequently occurred after every batch at several coating formulation sites (ECanada, 2003; IHWRIC, 1991, USEPA, 2006a,b). As a conservative estimate, assume equipment is cleaned after every batch unless site-specific information is available.

Data from site visits conducted by Environment Canada show losses between 1.3 percent and 3.0 percent of the total annual production from equipment cleaning (ECanada, 2003). The amount of residual chemical remaining in the process equipment may be estimated using the *EPA/OPPT Multiple Process Vessels Residual Model*. The model assumes that no more than two percent of the batch size or capacity of the process remains in the equipment as residue that is released as equipment cleaning waste. While equipment may not be cleaned after every batch, assuming a 2 percent loss of the daily use rate is consistent with site visit data. Note that equipment cleaning wastes may be recycled into subsequent batches or sent to an on-site wastewater treatment system to be treated prior to disposal to a POTW.

If $N_{bt_site_yr}$ or the known number of cleanings is fewer than the days of operation ($TIME_{working_days}$), the days of release equal $N_{bt_site_yr}$ (as calculated in Section 3.8) and the daily release of chemical residue in the process equipment can be calculated using Equation 4-6a. If $N_{bt_site_yr}$ is greater than $TIME_{working_days}$, the days of release equal the days of operation, then Equation 4-6b can be used.

$$E_{local_equipment_cleaning} = Q_{form_bt} \times F_{chem_form} \times N_{bt_site_day} \times F_{equipment_cleaning} \quad (4-6a)$$

This release will occur over $[N_{bt_site_yr}]$ days/year from $[N_{sites}]$ sites.

$$E_{local_equipment_cleaning} = Q_{chem_site_day} \times F_{equipment_cleaning} \quad (4-6b)$$

This release will occur over $[TIME_{working_days}]$ days/year from $[N_{sites}]$ sites

Where:

$E_{local_equipment_cleaning}$	=	Daily release of chemical of interest from equipment cleaning (kg chemical/site-day)
Q_{form_bt}	=	Mass of waterborne coating formulated per batch (kg coating/batch) (See Section 3.8)
F_{chem_form}	=	Mass fraction of the chemical of interest in the waterborne coating (kg chemical/kg coating) (See Section 3.5)
$N_{bt_site_day}$	=	Daily number of batches formulated at each site (batches/site-day) (See Section 3.8)
$F_{equipment_cleaning}$	=	Fraction of waterborne coating released as residual in process equipment (Default: 0.02 kg coating released/kg batch holding capacity (CEB, 1992a))
$Q_{chem_site_day}$	=	Daily use rate of the chemical of interest used to formulate the waterborne coating (kg chemical/site-day) (See Section 3.9)

If site-specific information indicates on-site wastewater treatment and a site-specific treatment efficiency removal rate is provided, releases may be partitioned between water and incineration or landfill (see Section 4.1). If there is no on-site wastewater treatment or site-specific information is unknown, a wastewater treatment efficiency of 0 can be assumed, which indicates no removal of solids from the waste stream. Equations 4-7a and 4-7b show the partition of equipment cleaning wastes between water and incineration or landfill, respectively.

$$E_{local_water_WWT} = E_{local_equipment_cleaning} \times (1 - F_{eff_WWT}) \quad (4-7a)$$

Where:

$E_{local_water_WWT}$	=	Daily release of chemical of interest to POTW after wastewater treatment (kg chemical of interest/site-day)
$E_{local_equipment_cleaning}$	=	Daily release of chemical of interest from equipment cleaning (kg chemical of interest/site-day)
F_{eff_WWT}	=	Wastewater treatment efficiency (Default (consistent with Section 4.4): If there is no on-site treatment, site-specific

information is not available, or for liquid removal efficiency, assume a value of 0 kg removed/kg processed)

$$E_{\text{local}}_{\text{sludge_WWT}} = E_{\text{local}}_{\text{equipment_cleaning}} \times F_{\text{eff_WWT}} \quad (4-7b)$$

Where:

$E_{\text{local}}_{\text{sludge_WWT}}$	=	Daily release of chemical of interest as sludge waste from wastewater treatment (kg chemical of interest/site-day)
$E_{\text{local}}_{\text{equipment_cleaning}}$	=	Daily release of chemical of interest from equipment cleaning (kg chemical of interest/site-day)
$F_{\text{eff_WWT}}$	=	Wastewater treatment efficiency (Default (consistent with Section 4.4): If there is no on-site treatment or site-specific information is not available, the efficiency = 0 kg removed/kg processed.)

4.10 Open Surface Losses to Air During Equipment Cleaning (Release 9)

For nonvolatile chemicals (e.g., the vapor pressure is < 0.001 torr), releases to air are expected to be negligible.

If the chemical is volatile (e.g., the vapor pressure is > 0.001 torr) it may evaporate and be released to the air during equipment cleaning ($E_{\text{local}}_{\text{air_eqpt_cleaning}}$). This operation is likely to occur indoors; therefore, the *EPA/OPPT Penetration Model* (EPA default for indoor operations) may be used to estimate the release of volatile chemicals during equipment cleaning. Model inputs and default values are listed in Table 4-8. The models and all current EPA defaults have been programmed into ChemSTEER; EPA recommends using this software to calculate open surface losses to air during equipment cleaning. Appendix B provides background information, model equations, and default values for several parameters the model uses to estimate daily releases to air.

Table 4-8. EPA/OPPT Penetration Model Parameter Default Values During Equipment Cleaning

Input Parameter	Default Values
Diameter of Opening	EPA default 3-ft manhole (92 cm) (CEB, 2002b)
Frequency of Release	Equal to the number of cleanings per year, as determined in Section 4.9.
Molecular Weight	Chemical-specific parameter
Number of Sites	Calculated in Section 3.6
Operating Hours for the Activity	The lesser of EPA default 7 hr/batch $\times N_{bt_site_day}$ (See Section 3.8) or 24 hrs/day (CEB, 2002b) and consistent with calculations described in Section 3.8
Temperature	Default 25°C (CEB, 1991)
Vapor Pressure	Chemical-specific parameter
Air Speed	EPA default 100 feet/min for indoor conditions (CEB, 1991)
Vapor Pressure Correction Factor	Standard EPA default = 1

Note: The model also assumes standard temperature and pressure along with ideal gas interactions.

The default assumption for the diameter of the opening and the operating hours for this activity are based on the EPA defaults of 3 feet diameter and four hours for cleaning a multiple vessels (CEB 2002b).

4.11 Filter Waste Releases to Incineration or Landfill during Filter Media Changeout (Release 10)

After premix, pigment dispersion, and blending, the coating is filtered to remove large particles and other contaminants. Based on site visit information, the spent filters may be incinerated or landfilled (IHWRIC, 1991; ECanada, 2003; USEPA, 2006a,b). The quantity of filter waste is minimal in comparison to the quantity of coating manufactured and the quantity of other wastes (IHWRIC, 1991), and is only included in this document for completeness. Less than 0.02 percent of the total facility production was lost due to filter wastes at the sites visited. As a conservative estimate, a loss fraction of 0.02 percent released to incineration or landfill should be assumed. Note that filter wastes may contain titanium and/or other heavy metals that may generate elements of concern when incinerated.

$$E_{local_filter_residue} = Q_{chem_site_day} \times F_{filter_residue} \quad (4-8)$$

This release will occur over [TIME_{working_days}] days/year from [N_{sites}] sites

Where:

- $E_{local_filter_residue}$ = Daily release of chemical of interest from filter media change out (kg chemical of interest/site-day)
- $Q_{chem_site_day}$ = Daily use rate of chemical of interest (kg chemical of interest/site-day)

$F_{\text{filter_residue}}$ = Fraction of chemical remaining on the filter as residue
 (Default: 0.0002 kg filter waste/kg used)

4.12 Open Surface Losses to Air During Filter Media Change Out (Release 11)

For nonvolatile chemicals (e.g., the vapor pressure is < 0.001 torr), releases to air are expected to be negligible.

If the chemical is volatile (e.g., the vapor pressure is > 0.001 torr) it may be released to the air ($E_{\text{local_air_filter_change}}$). This operation is likely to occur indoors; therefore, the *EPA/OPPT Penetration Model* (EPA default for indoor operations) may be used to estimate the release of volatile chemicals during filter media change out. Model inputs and default values are listed in Table 4-9. The models and all current EPA defaults have been programmed into ChemSTEER; EPA recommends using this software to calculate open surface losses to air during equipment cleaning. Appendix B provides background information, model equations, and default values for several parameters the model uses to estimate daily releases to air.

Table 4-9. EPA/OPPT Penetration Model Parameter Default Values During Filter Media Change Out

Input Parameter	Default Values
Diameter of Opening	6-inch filter (15 cm) (engineering judgment)
Frequency of Release	TIME _{working_days}
Molecular Weight	Chemical-specific parameter
Number of Sites	Calculated in Section 3.6
Operating Hours for the Activity	0.25 hours (engineering judgment)
Temperature	Default 25°C (CEB, 1991)
Vapor Pressure	Chemical-specific parameter
Air Speed	EPA default 100 feet/min for indoor conditions (CEB, 1991)
Vapor Pressure Correction Factor	Standard EPA default = 1

Note: The model also assumes standard temperature and pressure along with ideal gas interactions.

4.13 Transfer Operation Losses to Air from Packaging Waterborne Coatings into Transport Containers (Release 12)

For nonvolatile chemicals (e.g., the vapor pressure is < 0.001 torr) at the operating temperature, releases to air are expected to be negligible.

If the chemical is volatile (e.g., the vapor pressure is > 0.001 torr) at the operating temperature, the chemical may evaporate and be emitted during transfer (e.g., filling drums) operations ($E_{\text{local_air_packaging}}$). In an operation where the waterborne coating is generally nonvolatile and the components are relatively stable, non-reactive components, the transfer

operations may be open. In this case, volatile chemicals may be emitted into the workspace and subsequently vented to the air outside of the facility.

For volatile chemicals (e.g., the vapor pressure is > 0.001 torr), the *EPA/OAQPS AP-42 Loading Model* may be used. Model parameter defaults are based on the type and size of the containers. A default transportation container size of a 55-gallon drum should be used in the absence of site-specific information and consistent with the values used in Section 3.11. Model inputs and default values are listed in Table 4-10. The model and all current EPA defaults have been programmed into ChemSTEER; EPA recommends using this software to calculate open surface losses to air during container loading. Appendix B provides background information, model equations, and default values for several parameters the model uses to estimate daily releases to air.

Table 4-10. EPA/OAQPS AP-42 Loading Model Parameter Default Values During Product Packaging

Input Parameter	Default Values
Saturation Factor	EPA defaults 0.5 (typical) and 1 (worst case) for all containers less than 5,000 gallons (CEB, 1991) (See Appendix B for alternative default diameters)
Frequency of Release	Equal to the lesser of $N_{\text{cont_fill_site_yr}}$ (Section 3.11) or $\text{TIME}_{\text{working_days}}$ (Section 3.7)
Molecular Weight	Chemical-specific parameter
Number of Sites	Calculated in Section 3.6
Operating Hours for the Activity	Number of containers per site, per day ⁹ divided by the fill rate (CEB, 2002b) (Default: 20 containers/hr for volumes between 20 and 1,000 gallons (CEB, 1991); Alternative default fill rates are found in Appendix B)
Temperature	Default 25°C (CEB, 1991)
Vapor Pressure	Chemical-specific chemical parameter (for heated processes, EPA recommends using the vapor pressure of the chemical at the operating temperature)
Container Volume	Default: 55-gallon drum (208 L) (See Appendix B for alternative default container volumes)
Vapor Pressure Correction Factor	Standard EPA default = 1

Note: The model also assumes standard temperature and pressure along with ideal gas interactions.

4.14 Off-Specification and Other Waste Coatings to Water, Incineration, or Landfill (Release 13)

Most off-specification coating is produced by specialty coating manufacturers, although other coating types may also produce off-specification products (ORD, 1990). Over-production, customer returns, and inventory spoilage also generate waste coatings (IHWRIC, 1991). Off-specification batches are typically re-worked into a marketable product. Data from site visits conducted by Environment Canada and IHWRIC found loss fractions from off-specification and other waste paint ranged from 0.85 to 1.2 percent of total production (ECanada, 2003; IHWRIC,

⁹The daily number of containers filled per site may be estimated as:

$$N_{\text{cont_fill_site_day}} = \frac{N_{\text{cont_fill_site_yr}}}{\text{TIME}_{\text{working_days}}}$$

($N_{\text{cont_fill_day}}$ should be rounded up to the nearest integer.)

Where:

$N_{\text{cont_fill_site_yr}}$ = Annual number of containers filled containing chemical of interest per site (containers/site-yr) (See Section 3.11)

$\text{TIME}_{\text{working_days}}$ = Annual number of days the waterborne coating is formulated (days/yr) (See Section 3.7)

1991). However, many facilities generated no off-specification product waste, since the off-specification products were re-worked or sold at a reduced cost. When off-spec products are not re-worked, the waste coatings are typically combined with other wastes on-site for treatment and sent to water, incineration, or landfill (ECanada, 2003; IHWRIC, 1991). As a conservative estimate, assume 1.2 percent of the production volume is released to water, incineration, or landfill from off-specification and other waste coatings. This percentage may also be used to calculate the amount of chemical in the off-specification waste that is disposed of. Note that off-specification coatings may contain titanium and/or other heavy metals that may generate elements of concern when incinerated.

It is assumed that off-spec product waste does not generally result in a small daily release, but a large, infrequent release (e.g., when an entire batch is contaminated). EPA suggests that the days of release should be estimated using the following equation and the result rounded up to the nearest integer:

$$N_{\text{off-spec_days_site_yr}} = \frac{N_{\text{bt_site_yr}} \times F_{\text{off_spec}}}{N_{\text{off-spec_bt_day}}} \quad (4-9)$$

Where:

$N_{\text{off-spec_days_site_yr}}$	=	Number of days per year off-spec waste product is disposed/released (days/site-yr)
$N_{\text{bt_site_yr}}$	=	Annual number of batches of coating formulated per site (batches/site-yr) (See Equation 3-3)
$F_{\text{off-spec}}$	=	Fraction of the annual number of batches that are disposed as off-specification and other waste coatings (Default = 0.012 off-spec batch/annual number of batches) (ECanada, 2003; IHWRIC, 1991)
$N_{\text{off-spec_bt_day}}$	=	Number of off-spec batches per day (Default: 1 off-spec batch/day)

The release of off-spec may then be estimated by the following equation:

$$E_{\text{local_off-spec_day}} = Q_{\text{form_bt}} \times F_{\text{chem_form}} \quad (4-10)$$

This release will occur over $[N_{\text{off-spec_days_site_yr}}]$ days/year from $[N_{\text{sites}}]$ sites

Where:

$E_{\text{local_off-spec_day}}$	=	Release of chemical of interest on each occurrence of offspec batch discharge (kg chemical/site-day)
$Q_{\text{form_bt}}$	=	Average batch size (kg coating/batch) (See Section 3.8)
$F_{\text{chem_form}}$	=	Mass fraction of the chemical in the waterborne coating (kg chem./kg coating) (See Section 3.5).

5.0 OCCUPATIONAL EXPOSURE ASSESSMENTS FOR THE FORMULATION OF WATERBORNE COATINGS

The following section presents estimation methods for worker exposures to the chemical of interest. Figure 2-1 illustrates the occupational activities performed during the formulation process that have the greatest potential for worker exposure to the chemical.

Industry-specific occupational exposure information was found in the references reviewed for this ESD (refer to Section 8 for a description of the sources reviewed and full citations for those specifically used in these calculations). The occupational exposure estimates presented in this document are based on standard EPA exposure models. Table 5-1 summarizes the exposure estimation methods used in this ESD.

Note that the standard model default values cited are current as of the date of this generic scenario; however, EPA may update these models as additional data become available. It is recommended that the most current version of the models be used in these calculations.

EPA has developed a software package (ChemSTEER) containing these models as well as all current EPA defaults. Because of the complexity of the inhalation exposure to vapor models, ChemSTEER is recommended for estimating these exposures. Appendix B provides additional information on ChemSTEER, including information on obtaining the program, as well as background information, model equations, and default values for several parameters for all standard EPA models.

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Table 5-1. Summary of Waterborne Coating Formulation Scenario Exposure Models

Exposure Activity	Description	Route of Exposure / Physical Form	Model Name or Description ^a	Standard EPA Model (✓)
A	Unloading solid or liquid coating components	Inhalation of volatile liquid chemical vapors	EPA/OPPT Mass Balance Model	✓
		Inhalation of solid chemical particles	Specific model used is based on daily amount of waterborne coating component handled: <ul style="list-style-type: none"> • For amounts > 54 kg/day: OSHA PNOR PEL-Limiting Model • For amounts ≤ 54 kg/day: EPA/OPPT Small Volume Solids Handling Model 	✓
		Dermal exposure to liquid chemical	EPA/OPPT 2-Hand Dermal Contact with Liquid Model	✓
		Dermal exposure to solid chemical	EPA/OPPT 2-Hand Dermal Contact with Solids Model	✓
B	Exposure to solid or liquid coating components during container cleaning	Inhalation of volatile liquid chemical vapors	EPA/OPPT Mass Balance Model	✓
		Inhalation of solid chemical particles	Specific model used is based on daily amount of waterborne coating component handled: <ul style="list-style-type: none"> • For amounts > 54 kg/day: OSHA PNOR PEL-Limiting Model • For amounts ≤ 54 kg/day: EPA/OPPT Small Volume Solids Handling Model 	✓
		Dermal exposure to liquid chemical	EPA/OPPT 2-Hand Dermal Contact with Liquid Model	✓
		Dermal exposure to solid chemical	EPA/OPPT 2-Hand Dermal Contact with Solids Model	✓
C	Exposure to liquid waterborne coating during sampling	Inhalation of volatile liquid chemical vapors	EPA/OPPT Mass Balance Model	✓
		Dermal exposure to liquid chemical	EPA/OPPT 1-Hand Dermal Contact with Liquid Model	✓
D	Exposure to waterborne coating during equipment cleaning	Inhalation of volatile liquid chemical vapors	EPA/OPPT Mass Balance Model	✓
		Dermal exposure to liquid chemical	EPA/OPPT 2-Hand Dermal Contact with Liquid Model	✓

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Exposure Activity	Description	Route of Exposure / Physical Form	Model Name or Description ^a	Standard EPA Model (✓)
E	Exposure to waterborne coating during filter media change out	Inhalation of volatile liquid chemical vapors	EPA/OPPT Mass Balance Model	✓
		Dermal exposure to liquid chemical	EPA/OPPT 2-Hand Dermal Contact with Liquid Model	✓
F	Exposure to waterborne coating during packaging	Inhalation of volatile liquid chemical vapors	EPA/OPPT Mass Balance Model	✓
		Dermal exposure to liquid chemical	EPA/OPPT 2-Hand Dermal Contact with Liquid Model	✓

a – Additional detailed descriptions for each of the models presented in this section are provided in Appendix B to this generic scenario.

5.1 Personal Protective Equipment

Based on information provided by industry, current practices may have an effect on worker exposures during normal handling and processing operations. Workers who handle raw materials and formulations use personal protective equipment (PPE) when there is a possibility of contact. The type of PPE depends on the type of potential exposure. Typically, PPE used in the workplace include safety glasses and gloves. Face shields and a particulate respirator may also be required in cases where there is a potential for dust exposure (USEPA, 2006a,b).

Please note that EPA does not assess the effectiveness of PPE at mitigating occupational exposures in this document. The exposure mitigation by PPE is affected by many factors including availability, cost, worker compliance, impact on job performance, chemical and physical properties of the substance and protective clothing, and the use, decontamination, maintenance, storage, and disposal practices applicable to the industrial operation (CEB, 1997). Therefore, the conservative, screening-level occupational exposure estimates presented in this generic scenario do not account for PPE. Actual occupational exposure may be significantly less than the estimates presented in this generic scenario.

5.2 Number of Workers Exposed Per Site

Table 5-2 summarizes the estimated number of production workers per site based on the 2007 Economic Census. The 2007 Economic Census does not provide a breakdown of number or workers by type of coating (as did the 2002 Economic Census). EPA assumed a similar breakdown of the number of workers based on the 2002 Economic Census (USCB, 2002). Appendix D provides additional information on EPA’s approach for estimating the number of production workers per facility. Based on the Economic Census, architectural coating formulators average 65 workers employed at each facility (USCB, 2007); however, not all are expected to work in the production areas. The 2002 Economic Census estimates approximately 62 percent of these workers are *production* workers (USCB, 2007), which are defined by the U.S. Census Bureau to include...

...workers (up through the line-supervisor level) engaged in fabricating, processing, assembling, inspecting, receiving, storing, handling, packing, warehousing, shipping (but not delivering), maintenance, repair, janitorial and guard services, product development, auxiliary production for plant's own use (e.g., power plant), record keeping, and other services closely associated with these production operations at the establishment (USCB, 2007).

All other “non-production” employees include...

...those engaged in supervision above the line-supervisor level, sales (including driver-salespersons), sales delivery (highway truck drivers and their helpers), advertising, credit, collection, installation and servicing of own products, clerical and routine office functions, executive, purchasing, financing, legal, personnel (including cafeteria, medical, etc.), professional, technical employees, and employees on the payroll of the manufacturing establishment engaged in the construction of major additions or alterations utilized as a separate work force (USCB, 2007).

OEM product and special-purpose coating formulators employ an average of 38 and 25 production workers per facility (approximately 53 and 54 percent of the total number of employees, respectively). EPA also collected information on the number of workers from several site visits and case studies, which is presented in Appendix D. CEB recommends using the total number of workers provided by the U.S. Census Bureau as defaults for each coating type and consistent with type of coating chosen for the default production volume (see Section 3.2). The individual facility data points are provided in this table show the range of workers that may be exposed. It is uncertain whether these workers are directly involved in the handling of the chemical of interest or in the waterborne coating formulations that contain the chemical of interest. Due to uncertainty, CEB does not recommend using the individual facility data points as alternative defaults.

The EPA default number of workers exposed during each of the activities specified in this section can be used and is dependent on the type of coating formulated (see Table 5-3) and should be consistent with the type of coating chosen for the default facility production rate in Section 3.2. Site-specific data from two formulation facilities estimated the number of production workers that perform some of the exposure activities discussed in this section (EPA, 2006a,b) (see Appendix D). Although the breakdown of the number of workers does not cover all the activities discussed in this section, it may be used, in conjunction with engineering judgment, to determine the EPA default number of workers exposed for each activity (Table 5-3). It can be assumed that special purpose coatings have a similar breakdown in production workers as OEM product coating formulators. The methodology for determining the EPA default number of workers for each activity and each type of coating is presented in Appendix D.

Coating formulators may have one to four shifts to supporting operations at coating formulation facilities. No information was found on the typical hours of operation per day;

however, an estimate for the duration of exposure for each worker activity is presented in the remainder of this section (based on standard EPA defaults and methodology).

Table 5-2. EPA Default Number of Workers Potentially Exposed During the Formulation Process

Type of Coating	Default Number of Production Workers per Facility
Architectural	40
Original Equipment Manufacture (OEM)	38
Special Purpose	25

Source: USCB, 2007. EPA obtained the total number of workers using 2007 Economic Census (USCB, 2007). The 2007 Economic Census does not provide a breakdown of number of workers by type of coating. EPA used a similar breakdown of number of workers as that provided in the 2002 Economic Census (USCB, 2002)

Table 5-3. EPA Defaults for Breakdown of Production Workers by Activity

Activity	Number of Production Workers Observed per Activity ^a
Architectural	40
Unloading solid/liquid chemicals (Exposure A)	11
Cleaning of transport containers (Exposure B)	2
Sampling product (Exposure C)	6
Cleaning of process equipment (Exposure D)	2
Replacing spent filter media (Exposure E)	1
Loading liquid coating (Exposure F)	18
Product OEM	38
Unloading solid/liquid chemicals (Exposure A)	3
Cleaning of transport containers (Exposure B)	6
Sampling product (Exposure C)	8
Cleaning of process equipment (Exposure D)	6
Replacing spent filter media (Exposure E)	5
Loading liquid coating (Exposure F)	10
Special Purpose	25
Unloading solid/liquid chemicals (Exposure A)	2
Cleaning of transport containers (Exposure B)	4
Sampling product (Exposure C)	5
Cleaning of process equipment (Exposure D)	4
Replacing spent filter media (Exposure E)	3
Loading liquid coating (Exposure F)	7

a – EPA’s methodology for determining default number of workers for each worker activity is detailed in Appendix D.

5.3 **Exposure from Unloading Solid or Liquid Chemicals (Exposure A)**

Workers may connect transfer lines, manually unload chemicals from transport containers into the mixing tanks, and replace filters from air pollution equipment. If the concentration of the chemical in the component ($F_{\text{chem_comp}}$) is unknown, 100 percent concentration may be assumed as a conservative default, as previously discussed in Section 3.3. The default number of workers exposed during this activity is dependent on the type of coating used as a default in Section 5.2. See Table 5-4 for the breakdown of workers by activity for each type of coating.

Inhalation Exposure:

Liquids:

The method used to calculate inhalation exposure ($EXP_{\text{inhalation}}$) depends on the volatility and the physical state of the chemical of interest. Inhalation exposure to liquids is assumed negligible for nonvolatile liquids (e.g., the vapor pressure is < 0.001 torr).

The vapor generation rate calculated in Release 1 and the EPA standard model for estimating inhalation exposure due to evaporation of volatile chemicals (*EPA/OPPT Mass Balance Model*) may be used to estimate the associated worker inhalation exposure to the chemical of interest during transfer operations. The model and all current EPA defaults have been programmed into ChemSTEER; EPA recommends using this software to calculate inhalation exposure to volatile chemicals during transfer operations. Appendix B explains the background and derivation of the model and provides EPA default values for several model parameters.

Table 5-5 lists the model inputs and default values. Note that the exposure hours per day is equivalent to the operating hours per day for this activity (consistent with Section 4.4 calculations), but EPA assumes an exposure duration of eight hours per day. Similarly, the exposure days per site, per year should be consistent with the release days, but EPA assumes a maximum of 250 days per year. These exposure duration maximum defaults are based on full-time employment and considers an individual worker's vacation, sick, and weekend time (i.e., a 40-hour work week over 50 weeks per year).

Table 5-4. EPA/OPPT Mass Balance Model Parameter Default Values During Transfers

Input Parameter	Default Values
Inhalation Rate	Default = 1.25 m ³ /hr (CEB, 1991)
Exposure Days	Consistent with the Frequency of Release determined in Section 4.2, up to 250 days per year
Vapor Generation Rate	Calculated by the <i>EPA/OPPT Penetration Model</i> (Section 4.2)
Exposure Duration	Consistent with the Operating Hours determined in Section 4.2, up to 8 hours per day
Mixing Factor	EPA defaults 0.5 (typical) and 0.1 (worst case) (CEB, 1991)
Molecular Weight	Chemical-specific parameter
Number of Sites	Calculated in Section 3.6
Ventilation Rate	EPA defaults 3,000 ft ³ /min (typical) and 500 ft ³ /min (worst case) for indoor conditions (default for containers less than 1,000 gallons (CEB, 1991) (See Appendix B for alternative default ventilation rates)
Vapor Pressure	Chemical-specific parameter
Vapor Pressure Correction Factor	Standard EPA default = 1

Note: The model also assumes standard temperature and pressure along with ideal gas interactions.

Solids:

The transfer of nonvolatile solid coating components from containers to storage or mixing vessels generates particulates. Nonvolatile solid coating components that are generated from these transfer activities can be captured on filters that will require replacement. Potential exposures of these particulates from filter replacement may also occur. The degree of inhalation exposure to particulates depends on the concentration of the chemical of interest in the component (F_{chem_comp}), the potential concentration of the component in the worker's breathing zone ($C_{particulate}$), and the total amount of component the worker is exposed to per day in performing this activity ($Q_{comp_site_day}$).

The daily transfer rate of the component may be estimated using the following equation:

$$Q_{comp_site_day} = \frac{Q_{chem_site_day}}{F_{chem_comp}} \quad (5-1)$$

Where:

- $Q_{comp_site_day}$ = Daily amount of component transferred into the process (kg component/site-day)
- $Q_{chem_site_day}$ = Daily use rate of the chemical of interest used to formulate the waterborne coating (kg chemical/site-day) (See Section 3.9)

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$$F_{\text{chem_comp}} = \text{Mass fraction of the chemical of interest in the component (kg chemical/kg component) (See Section 3.3)}$$

Two equations can be used to determine worker exposure. Selection of the appropriate equation should be based on the amount of component the worker is exposed to per day ($Q_{\text{comp_site_day}}$), not the amount of chemical of interest the worker is exposed to ($Q_{\text{chem_site_day}}$). Additional explanation of the two standard EPA models used to estimate inhalation exposure to solid powder is presented in Appendix B.

If the transfer rate of the solid component containing the chemical of interest ($Q_{\text{comp_site_day}}$) is *greater than* 54 kg/site-day, EPA recommends using the OSHA Total Particulates Not Otherwise Regulated (PNOR) PEL-Limiting Model:

$$EXP_{\text{inhalation}} = C_{\text{particulate}} \times RATE_{\text{breathing}} \times TIME_{\text{exposure}} \times F_{\text{chem_comp}} \quad (5-2a)$$

This exposure will occur over [the lesser of $N_{\text{bt_site_yr}}$ or $TIME_{\text{working_days}}$, up to 250] days/year

Where:

$EXP_{\text{inhalation}}$	=	Inhalation exposure to the chemical of interest per day (mg chemical of interest/day)
$C_{\text{particulate}}$	=	Concentration of particulate component in the workers breathing zone (Default: 15 mg component/m ³ ; based on OSHA Total PNOR PEL (8-hr TWA*) (29 CFR 1910.1000))
$RATE_{\text{breathing}}$	=	Typical worker breathing rate (Default: 1.25 m ³ /hr (CEB, 1991))
$TIME_{\text{exposure}}$	=	Duration of exposure (Default: 8 hrs/day; Note: because the default value for $C_{\text{particulate}}$ is an 8-hr TWA*, the 8 hrs/day value <u>must</u> be used)
$F_{\text{chem_comp}}$	=	Mass fraction of the chemical of interest in the component (mg chemical/mg component) (See Section 3.3)

*TWA = Time-weighted average

The accuracy of solid component inhalation estimates are limited by the estimated airborne concentration of the chemical of interest and the assumed breathing rate.

If the transfer rate of the solid component containing the chemical of interest ($Q_{\text{comp_site_day}}$) is *less than or equal to* 54 kg/site-day, EPA recommends using the EPA/OPPT Small Volume Solids Handling Inhalation Model:

$$EXP_{\text{inhalation}} = Q_{\text{comp_site_day}} \times F_{\text{chem_comp}} \times F_{\text{exposure}} \quad (5-2b)$$

This exposure will occur over [the lesser of $N_{\text{bt_site_yr}}$ or $TIME_{\text{working_days}}$, up to 250] days/year

Where:

$EXP_{inhalation}$	=	Inhalation exposure to the chemical of interest per day (mg chemical of interest/day)
$Q_{comp_site_day}$	=	Daily amount of component transferred into the process (kg component/site-day) (See Equation 5-1)
F_{chem_comp}	=	Mass fraction of the chemical of interest in the component (mg chemical/mg component) (See Section 3.3)
$F_{exposure}$	=	Weight fraction of the total particulate component in the workers breathing zone (Default: 0.0477 (typical) to 0.161 (worst) mg component exposure/kg of component handled (CEB, 1992b))

Dermal Exposure:

Dermal exposure is expected for both automated and manual unloading activities. Automated systems may limit the extent of dermal exposure more than manual unloading; however, workers may still be exposed when connecting transfer lines or transferring the liquid chemicals from the transport container to mixing vessels. Workers may manually scoop or pour solid or liquid waterborne coating components into the process equipment.

The *EPA/OPPT 2-Hand Dermal Contact with Liquid Model* may be used to estimate dermal exposure to the chemical of interest in a liquid formulation during these activities, and the *EPA/OPPT Direct 2-Hand Dermal Contact with Solids Model* may be used to estimate dermal exposure to the chemical of interest in a solid powder formulation. The rationale, defaults, and limitations of these models are further explained in Appendix B.

Liquids:

To estimate the potential worker exposure to the chemical of interest in a liquid component for this activity, EPA recommends using the following equation:

$$EXP_{dermal} = Q_{liquid_ski} \times AREA_{surface} \times N_{exp_incident} \times F_{chem_comp} \quad (5-3a)$$

This exposure will occur over [the lesser of $N_{bt_site_yr}$ or $TIME_{working_days}$ (consistent with Section 4.2), up to 250] days per year

Where:

EXP_{dermal}	=	Potential dermal exposure to the chemical of interest per day (mg chemical/day)
Q_{liquid_skin}	=	Quantity of liquid component remaining on skin (Defaults: 2.1 mg component/cm ² -incident (high-end) and 0.7 mg component/cm ² -incident (low-end) for routine or incidental contact (CEB, 2000a))

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$AREA_{\text{surface}}$	=	Surface area of contact (Default: 840 cm ² for 2 hands (CEB, 2000a))
$N_{\text{exp_incident}}^{10}$	=	Number of exposure incidents per day (Default: 1 incident/day)
$F_{\text{chem_comp}}$	=	Mass fraction of the chemical of interest in the component (mg chemical/mg component) (See Section 3.3)

Solids:

To estimate the potential worker exposure to the chemical of interest in a solid component for this activity, EPA recommends using the following equation (CEB, 2000a):

$$EXP_{\text{dermal}} = \text{up to 3,100 mg component/incident} \times N_{\text{exp_incident}} \times F_{\text{chem_comp}} \quad (5-3b)$$

This exposure will occur over [the lesser of $N_{\text{bt_site_yr}}$ or $TIME_{\text{working_days}}$ (consistent with Section 4.2, up to 250] days per year

Where:

EXP_{dermal}	=	Potential dermal exposure to the chemical of interest per day (mg chemical/day)
$N_{\text{exp_incident}}$	=	Number of exposure incidents per day (Default: 1 incident/day) (see Equation 5-3a)
$F_{\text{chem_comp}}$	=	Mass fraction of the chemical of interest in the component (mg chemical/mg component) (See Section 3.3)

5.4 Exposure to Solids or Liquids During Container Cleaning (Exposure B)

Workers may be exposed while rinsing containers used to transport the coating component. If the concentration of the chemical in the component ($F_{\text{chem_comp}}$) is unknown, 100 percent concentration may be assumed as a conservative default, as previously discussed in Section 3.3. The default number of workers exposed during this activity is dependent on the type of coating used as a default in Section 3.2. See Table 5-4 for the breakdown of workers by activity for each type of coating.

¹⁰Only one contact per day ($N_{\text{exp_incident}} = 1$ event/worker-day) is assumed because $Q_{\text{liquid_skin}}$, with few exceptions, is not expected to be significantly affected either by wiping excess chemical material from skin or by repeated contacts with additional chemical material (i.e., wiping excess from the skin does not remove a significant fraction of the small layer of chemical material adhering to the skin and additional contacts with the chemical material do not add a significant fraction to the layer). Exceptions to this assumption may be considered for chemicals with high volatility and/or with very high rates of absorption into the skin.

Inhalation Exposure:

Liquids:

The method used to calculate inhalation exposure ($EXP_{\text{inhalation}}$) depends on the volatility and the physical state of the chemical of interest. Inhalation exposure to liquids is assumed negligible for nonvolatile liquids (e.g., the vapor pressure is < 0.001 torr).

Using the vapor generation rate calculated in Release 3, the *EPA/OPPT Mass Balance Model* can be used to calculate worker inhalation exposure due to volatilization during cleaning operations. The default ventilation rates and mixing factors provide a typical and worst case estimate of exposure. Table 5-6 lists the model inputs and default values. Note that the exposure hours per day are equivalent to the operating hours per day for this activity (consistent with Section 4.4 calculations), but EPA assumes a maximum exposure duration of eight hours per day. Similarly, the exposure days per site, per year, should be consistent with the release days, but EPA assumes a maximum of 250 days per year, as previously discussed in Section 5.3.

Table 5-5. EPA/OPPT Mass Balance Model Parameter Default Values During Container Cleaning

Input Parameter	Default Values
Inhalation Rate	Default = 1.25 m ³ /hr (CEB, 1991)
Exposure Days	Consistent with the Frequency of Release determined in Section 4.4, up to 250 days per year
Vapor Generation Rate	Calculated by the <i>EPA/OPPT Penetration Model</i> (Section 4.4)
Exposure Duration	Consistent with the Operating Hours determined in Section 4.4, up to 8 hours per day
Mixing Factor	EPA defaults 0.5 (typical) and 0.1 (worst case) (CEB, 1991)
Molecular Weight	Chemical-specific parameter
Number of Sites	Calculated in Section 3.6
Ventilation Rate	EPA defaults 3,000 ft ³ /min (typical) and 500 ft ³ /min (worst case) for indoor conditions (default for containers less than 1,000 gallons (CEB, 1991) (See Appendix B for alternative default ventilation rates)
Vapor Pressure	Chemical-specific parameter
Vapor Pressure Correction Factor	Standard EPA default = 1

Note: The model also assumes standard temperature and pressure along with ideal gas interactions.

The models and all current EPA defaults have been programmed into ChemSTEER; EPA recommends this software to calculate inhalation exposure to volatile chemicals during container cleaning. Appendix B explains the background and derivation of the model and provides EPA default values for several model parameters.

Solids:

The cleaning of solid powders from transport containers may generate dust particulate. The degree of inhalation exposure to particulates depends on the concentration of the chemical of interest in the formulation (F_{chem_comp}), the potential concentration of the chemical in the worker's breathing zone ($C_{particulate}$), and the total amount of component residual removed from the containers ($Q_{comp_residue_site_day}$). EPA recommends using the following equation to estimate the amount of component residual handled by a worker during container cleaning:

$$Q_{comp_residue_site_day} = \frac{E_{local_cont_residue_disp}}{F_{chem_comp}} \quad (5-4)$$

Where:

$Q_{comp_residue_site_day}$	=	Quantity of component handled during container cleaning (kg component/site-day)
$E_{local_cont_residue_disp}$	=	Daily release of chemical of interest from container residue (kg chemical/site-day) (See Equation 4-3a or 4-3b, consistent with Section 4.4 calculations)
F_{chem_comp}	=	Mass fraction of the chemical of interest in the component (kg chemical/kg component) (See Section 3.3)

Two equations can be used to determine worker exposure. Selection of the appropriate equation should be based on the amount of solid component the worker is exposed to per day ($Q_{residue_site_day}$), not the amount of chemical of interest the worker is exposed to per day ($E_{local_cont_residue_disp}$). A further explanation, including the background and model defaults, of the two standard EPA models used to estimate inhalation exposure to solid powder is presented in Appendix B.

If the daily amount of the solid powder component containing the chemical of interest ($Q_{comp_residue_site_day}$) is *greater than* 54 kg/site-day, EPA recommends using the OSHA Total PNOR PEL-Limiting Model:

$$EXP_{inhalation} = C_{particulate} \times RATE_{breathing} \times TIME_{exposure} \times F_{chem_comp} \quad (5-5a)$$

This exposure will occur over [the lesser of $N_{cont_empty_site_yr}$ or $TIME_{working_days}$ (consistent with Section 4.4), up to 250] days per year

Where:

$EXP_{inhalation}$	=	Inhalation exposure to the chemical of interest per day (mg chemical/day)
$C_{particulate}$	=	Concentration of particulate component in the workers breathing zone (Default: 15 mg component/m ³ ; based on OSHA Total PNOR PEL (8-hr TWA*) (29 CFR 1910.1000))
$RATE_{breathing}$	=	Typical worker breathing rate (Default: 1.25 m ³ /hr (CEB, 1991))

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$TIME_{\text{exposure}}$	=	Duration of exposure (Default: 8 hrs/day; Note: because the default value for $C_{\text{particulate}}$ is an 8-hr TWA*, the 8 hrs/day value <u>must</u> be used)
$F_{\text{chem_comp}}$	=	Mass fraction of the chemical of interest in the component (mg chemical/mg component) (See Section 3.3)
*TWA = Time-weighted average		

The accuracy of solid component inhalation estimates are limited by the estimated airborne concentration of the chemical of interest and the assumed breathing rate.

If the daily amount of the solid powder waterborne coating component containing the chemical of interest ($Q_{\text{comp_residue_site_day}}$) is *less than or equal to* 54 kg/site-day, EPA recommends using the EPA/OPPT Small Volume Solids Handling Inhalation Model:

$$EXP_{\text{inhalation}} = Q_{\text{comp_residue_site_day}} \times F_{\text{chem_comp}} \times F_{\text{exposure}} \quad (5-5b)$$

This exposure will occur over [the lesser of $N_{\text{cont_empty_site_yr}}$ or $TIME_{\text{working_days}}$ (consistent with Section 4.4, up to 250] days per year

Where:

$EXP_{\text{inhalation}}$	=	Inhalation exposure to the chemical of interest per day (mg chemical/day)
$Q_{\text{comp_residue_site_day}}$	=	Quantity of component handled during container cleaning (kg component/site-day) (See Equation 5-4)
$F_{\text{chem_comp}}$	=	Mass fraction of the chemical of interest in the component (mg chemical/mg component) (See Section 3.3)
F_{exposure}	=	Weight fraction of the total particulate component in the workers breathing zone (Default: 0.0477 (typical) to 0.161 (worst) mg component exposure/kg of component handled (CEB, 1992b))

Dermal Exposure:

Dermal exposure is expected during the cleaning of transport containers. The *EPA/OPPT 2-Hand Dermal Contact with Liquid Model* may be used to estimate dermal exposure to the chemical of interest in a liquid formulation during these activities, and the *EPA/OPPT Direct 2-Hand Dermal Contact with Solids Model* may be used to estimate dermal exposure to the chemical of interest in a solid powder formulation. The rationale, defaults, and limitations of these models are explained in Appendix B.

Liquids:

To estimate the potential worker exposure to the chemical of interest in a liquid component for this activity, EPA recommends using the following equation:

$$EXP_{\text{dermal}} = Q_{\text{liquid_skin}} \times AREA_{\text{surface}} \times N_{\text{exp_incident}} \times F_{\text{chem_comp}} \quad (5-6a)$$

This exposure will occur over [the lesser of $N_{\text{cont_empty_site_yr}}$ or $TIME_{\text{working_days}}$ (consistent with Section 4.4), up to 250] days per year

Where:

EXP_{dermal}	=	Potential dermal exposure to the chemical of interest per day (mg chemical/day)
$Q_{\text{liquid_skin}}$	=	Quantity of liquid component remaining on skin (Defaults: 2.1 mg component/cm ² -incident (high-end) and 0.7 mg component/cm ² -incident (low-end) for routine or incidental contact (CEB, 2000a))
$AREA_{\text{surface}}$	=	Surface area of contact (Default: 840 cm ² for 2 hands (CEB, 2000a))
$N_{\text{exp_incident}}$	=	Number of exposure incidents per day (Default: 1 incident/day) (See Equation 5-3a)
$F_{\text{chem_comp}}$	=	Mass fraction of the chemical of interest in the component (mg chemical/mg component) (See Section 3.3)

Solids:

To estimate the potential worker exposure to the chemical of interest in a solid component for this activity, EPA recommends using the following equation (CEB, 2000a):

$$EXP_{\text{dermal}} = \text{up to 3,100 mg component/incident} \times N_{\text{exp_incident}} \times F_{\text{chem_comp}} \quad (5-6b)$$

This exposure will occur over [the lesser of $N_{\text{cont_empty_site_yr}}$ or $TIME_{\text{working_days}}$ (consistent with Section 4.4), up to 250] days per year

Where:

EXP_{dermal}	=	Potential dermal exposure to the chemical of interest per day (mg chemical/day)
$N_{\text{exp_incident}}$	=	Number of exposure incidents per day (Default: 1 incident/day) (see Equation 5-3a)
$F_{\text{chem_comp}}$	=	Weight fraction of the chemical of interest in the component (mg chemical/mg component) (See Section 3.3)

5.5 Exposure from Sampling Waterborne Coatings (Exposure C)

Workers may collect samples of the waterborne product for quality analysis/quality control (QA/QC). The default number of workers exposed during this activity is dependent on the type of coating used as a default in Section 3.2. See Table 5-4 for the breakdown of workers by activity for each type of coating.

Inhalation Exposure:

The method used to calculate inhalation exposure ($EXP_{inhalation}$) depends on the volatility and the physical state of the chemical of interest at the operating temperature. Inhalation exposure to liquids is assumed negligible for nonvolatile liquids (e.g., the vapor pressure is < 0.001 torr).

Using the vapor generation rate calculated in Release 7, the *EPA/OPPT Mass Balance Model* can be used to calculate worker inhalation exposure due to volatilization during sampling activities. The default ventilation rates and mixing factors provide a typical and worst case estimate of exposure. Table 5-7 lists the model inputs and default values. Note that the exposure days per site, per year should be consistent with the release days, but EPA assumes a maximum of 250 days per year, as discussed in Section 5.3.

The models and all current EPA defaults have been programmed into ChemSTEER; EPA recommends using this software to calculate inhalation exposure to volatile chemicals during sampling activities. Appendix B explains the background and derivation of the model and provides EPA default values for several model parameters.

Table 5-6. EPA/OPPT Mass Balance Model Parameter Default Values During Sampling

Input Parameter	Default Values
Inhalation Rate	Default = 1.25 m ³ /hr (CEB, 1991)
Exposure Days	Consistent with the Frequency of Release determined in Section 4.8, up to 250 days per year
Vapor Generation Rate	Calculated by the <i>EPA/OPPT Penetration Model</i> (Section 4.8)
Exposure Duration	Consistent with the Operating Hours determined in Section 4.8, up to 8 hours per day (default: 1 hour/day (CEB, 1991))
Mixing Factor	EPA defaults 0.5 (typical) and 0.1 (worst case) (CEB, 1991)
Molecular Weight	Chemical-specific parameter
Number of Sites	Calculated in Section 3.6
Ventilation Rate	EPA defaults 3,000 ft ³ /min (typical) and 500 ft ³ /min (worst case) for indoor conditions (default for containers less than 1,000 gallons (CEB, 1991) (See Appendix B for alternative default ventilation rates)
Temperature	Consistent with the Temperature used in Section 4.8
Vapor Pressure	Consistent with the Vapor Pressure used in Section 4.8
Vapor Pressure Correction Factor	Standard EPA default = 1

Note: The model also assumes standard temperature and pressure along with ideal gas interactions.

Dermal Exposure:

Dermal exposure to waterborne coatings is expected during sampling activities. The *EPA/OPPT 1-Hand Dermal Contact with Liquid Model* may be used to estimate dermal

exposure to the chemical of interest in a liquid formulation during product sampling. The rationale, defaults, and limitations of this model are explained in Appendix B.

If the product is sampled/analyzed at temperatures above 60°C, EPA recommends that the dermal exposure to these materials be assumed negligible. EPA typically assumes that dermal exposures to materials above 60°C are mitigated through the use of PPE (CEB, 2002b).

To estimate the potential worker exposure to the chemical of interest in a waterborne coating sampled at temperatures less than 60°C, EPA recommends using the following equation:

$$EXP_{\text{dermal}} = Q_{\text{liquid_skin}} \times AREA_{\text{surface}} \times N_{\text{exp_incident}} \times F_{\text{chem_form}} \quad (5-7)$$

This exposure will occur over [the lesser of $N_{\text{bt_site_yr}}$ or $TIME_{\text{working_days}}$ (consistent with Section 4.8), up to 250] days per year

Where:

EXP_{dermal}	=	Potential dermal exposure to the chemical of interest per day (mg chemical/day)
$Q_{\text{liquid_skin}}$	=	Quantity of waterborne remaining on skin (Defaults: 2.1 mg coating/cm ² -incident (high-end) and 0.7 mg coating/cm ² -incident (low-end) for routine or incidental contact (CEB, 2000a))
$AREA_{\text{surface}}$	=	Surface area of contact (Default: 420 cm ² for 1 hand (CEB, 2000a))
$N_{\text{exp_incident}}$	=	Number of exposure incidents per day (Default: 1 incident/day) (See Equation 5-3a)
$F_{\text{chem_form}}$	=	Mass fraction of the chemical of interest in the waterborne coating (mg chemical/mg coating) (See Section 3.5)

5.6 Exposure to Liquids During the Equipment Cleaning of Mixers and Other Process Equipment (Exposure D)

Workers may be exposed while cleaning the mixing tanks or other process equipment with water or organic solvents. Because some equipment cleaning may be performed manually, exposures during equipment cleaning should be assessed. The default number of workers exposed during this activity is dependent on the type of coating used as a default in Section 3.2. See Table 5-4 for the breakdown of workers by activity for each type of coating.

Inhalation Exposure:

The method used to calculate inhalation exposure ($EXP_{\text{inhalation}}$) depends on the volatility and the physical state of the chemical of interest. Inhalation exposure to liquids is assumed negligible for nonvolatile liquids (e.g., the vapor pressure is < 0.001 torr).

Using the vapor generation rate calculated in Release 9, the *EPA/OPPT Mass Balance Model* can be used to calculate worker inhalation exposure due to volatilization during

equipment cleaning activities. The default ventilation rates and mixing factors provide a typical and worst case estimate of exposure. Table 5-8 lists the model inputs and default values. Note that the exposure hours per day are equivalent to the operating hours per day for this activity (consistent with Section 4.10 calculations), but EPA assumes an exposure duration of eight hours per day. Similarly, the exposure days per site, per year should be consistent with the release days, but EPA assumes a maximum of 250 days per year, as discussed in Section 5.3.

The model and all current EPA defaults have been programmed into ChemSTEER; EPA recommends using this software to calculate inhalation exposure to volatile chemicals during equipment cleaning. Appendix B explains the background and derivation of the model and provides EPA default values for several model parameters.

Table 5-7. EPA/OPPT Mass Balance Model Parameter Default Values During Equipment Cleaning

Input Parameter	Default Values
Inhalation Rate	Default = 1.25 m ³ /hr (CEB, 1991)
Exposure Days	Consistent with the Frequency of Release determined in Section 4.10, up to 250 days per year
Vapor Generation Rate	Calculated by the <i>EPA/OPPT Penetration Model</i> (Section 4.10)
Exposure Duration	Consistent with the Operating Hours determined in Section 4.10, up to 8 hours per day
Mixing Factor	EPA defaults 0.5 (typical) and 0.1 (worst case) (CEB, 1991)
Molecular Weight	Chemical-specific parameter
Number of Sites	Calculated in Section 3.6
Ventilation Rate	EPA defaults 3,000 ft ³ /min (typical) and 500 ft ³ /min (worst case) for indoor conditions (CEB, 1991) (See Appendix B for alternative default ventilation rates)
Temperature	Default 25°C (see Section 4.6)
Vapor Pressure	Chemical-specific parameter
Vapor Pressure Correction Factor	Standard EPA default = 1

Note: The model also assumes standard temperature and pressure along with ideal gas interactions.

Dermal Exposure:

Dermal exposure to liquids is expected during the cleaning of process equipment. The *EPA/OPPT 2-Hand Dermal Contact with Liquid Model* may be used to estimate dermal exposure to the chemical of interest in a liquid formulation during these activities. The rationale, defaults, and limitations of this model are explained in Appendix B.

To estimate the potential worker exposure to the chemical of interest in the waterborne coating for this activity, use the following equation:

$$EXP_{\text{dermal}} = Q_{\text{liquid_skin}} \times AREA_{\text{surface}} \times N_{\text{exp_incident}} \times F_{\text{chem_form}} \quad (5-8)$$

This exposure will occur over [$N_{\text{bt_site_yr}}$ or $TIME_{\text{working_days}}$, up to 250] days per year

Where:

EXP_{dermal}	=	Potential dermal exposure to the chemical of interest per day (mg chemical/day)
$Q_{\text{liquid_skin}}$	=	Quantity of waterborne coating remaining on skin (Defaults: 2.1 mg coating/cm ² -incident (high-end) and 0.7 mg coating/cm ² -incident (low-end) for routine or incidental contact (CEB, 2000a))
$AREA_{\text{surface}}$	=	Surface area of contact (Default: 840 cm ² for 2 hands (CEB, 2000a))
$N_{\text{exp_incident}}$	=	Number of exposure incidents per day (Default: 1 incident/day) (See Equation 5-3a)
$F_{\text{chem_form}}$	=	Mass fraction of the chemical of interest in the waterborne coating (mg chemical/mg coating) (See Section 3.5)

5.7 Exposure from Changing Spent Filter Media (Exposure E)

Workers may remove spent filters plugged with residual wastes that contain the chemical of interest. Spent filter media may be regenerated and reused, further minimizing exposure and frequency of exposure during change outs. The default number of workers exposed during this activity is dependent on the type of coating used as a default in Section 3.2. See Table 5-4 for the breakdown of workers by activity for each type of coating.

Inhalation Exposure:

The method used to calculate inhalation exposure ($EXP_{\text{inhalation}}$) depends on the volatility and the physical state of the chemical of interest. Inhalation exposure to liquids is assumed negligible for nonvolatile liquids (e.g., the vapor pressure is < 0.001 torr).

Unless site-specific information is available, EPA recommends assuming that fugitive emission of volatile chemicals may occur and estimating the associated worker inhalation exposure as conservative.

Using the vapor generation rate calculated in Release 11, the *EPA/OPPT Mass Balance Model* can be used to calculate worker inhalation exposure due to volatilization during filter change out activities. The default ventilation rates and mixing factors provide a typical and worst case estimate of exposure. Table 5-9 lists the model inputs and default values. Note that the exposure hours per day are equivalent to the operating hours per day for this activity (consistent with Section 4.11 calculations), but EPA assumes a maximum exposure duration of eight hours per day. Similarly, the exposure days per site, per year, should be consistent with the release days, but EPA assumes a maximum of 250 days per year, as discussed in Section 5.3.

Table 5-8. EPA/OPPT Mass Balance Model Parameter Default Values During Filter Media Change Out

Input Parameter	Default Values
Inhalation Rate	Default = 1.25 m ³ /hr (CEB, 1991)
Exposure Days	Consistent with the Frequency of Release determined in Section 4.12, up to 250 days per year
Vapor Generation Rate	Calculated by the <i>EPA/OAQPS AP-42 Loading Model</i> (Section 4.12)
Exposure Duration	Consistent with the Operating Hours determined in Section 4.12, up to 8 hours per day
Mixing Factor	EPA defaults 0.5 (typical) and 0.1 (worst case) (CEB, 1991)
Molecular Weight	Chemical-specific parameter
Number of Sites	Calculated in Section 3.6
Ventilation Rate	EPA defaults 3,000 ft ³ /min (typical) and 500 ft ³ /min (worst case) for indoor conditions (default for containers less than 1,000 gallons (CEB, 1991) (See Appendix B for alternative default ventilation rates)
Temperature	Default 25°C (see Section 4.6)
Vapor Pressure	Chemical-specific parameter (at operating temperature)
Vapor Pressure Correction Factor	Standard EPA default = 1

Note: The model also assumes standard temperature and pressure along with ideal gas interactions.

The models and all current EPA defaults have been programmed into ChemSTEER; EPA recommends using this software to calculate inhalation exposure to volatile chemicals during packaging/loading activities. Appendix B explains the background and derivation of the model and provides EPA default values for several model parameters.

Dermal Exposure:

Dermal exposure to the waterborne coating is expected during spent filter media change out. The *EPA/OPPT 2-Hand Dermal Contact with Solid Model* may be used to estimate dermal exposure to the chemical of interest in solid form during these activities. The rationale, defaults, and limitations of this model are explained in Appendix B.

To estimate the potential worker exposure to the chemical of interest in a solid component for this activity, EPA recommends using the following equation (CEB, 2000a):

$$EXP_{\text{dermal}} = \text{up to } 3,100 \text{ mg product/incident} \times N_{\text{exp_incident}} \times F_{\text{chem_comp}} \quad (5-9)$$

This exposure will occur over [the lesser of $N_{\text{bt_site_yr}}$ or $TIME_{\text{working_days}}$ (consistent with Section 4.12, up to 250] days per year

Where:

EXP_{dermal}	=	Potential dermal exposure to the chemical of interest per day (mg chemical/day)
$N_{\text{exp_incident}}$	=	Number of exposure incidents per day (Default: 1 incident/day) (see Equation 5-3a)
$F_{\text{chem_comp}}$	=	Mass fraction of the chemical of interest in the component (mg chemical/mg component) (See Section 3.3)

5.8 Exposure from Packaging Waterborne Coatings (Exposure F)

Workers may connect transfer lines to load the waterborne containing the chemical into transport containers or handle transport containers during filling. Based on industry-specific information, loading processes may be automated or enclosed; thus, minimizing exposure. The default number of workers exposed during this activity is dependent on the type of coating used as a default in Section 3.2. See Table 5-4 for the breakdown of workers by activity for each type of coating.

Inhalation Exposure:

The method used to calculate inhalation exposure ($EXP_{\text{inhalation}}$) depends on the volatility and the physical state of the chemical of interest. Inhalation exposure to liquids is assumed negligible for nonvolatile liquids (e.g., the vapor pressure is < 0.001 torr).

Using the vapor generation rate calculated in Release 12, the *EPA/OPPT Mass Balance Model* can be used to calculate worker inhalation exposure due to volatilization during packaging activities. The default ventilation rates and mixing factors provide a typical and worst case estimate of exposure. Table 5-10 lists the model inputs and default values. Note that the exposure hours per day are equivalent to the operating hours per day for this activity (consistent with Section 4.13 calculations), but EPA assumes a maximum exposure duration of eight hours per day. Similarly, the exposure days per site, per year, should be consistent with the release days, but EPA assumes a maximum of 250 days per year, as discussed in Section 5.3.

Table 5-9. EPA/OPPT Mass Balance Model Parameter Default Values During Loading

Input Parameter	Default Values
Inhalation Rate	Default = 1.25 m ³ /hr (CEB, 1991)
Exposure Days	Consistent with the Frequency of Release determined in Section 4.13, up to 250 days per year
Vapor Generation Rate	Calculated by the <i>EPA/OAQPS AP-42 Loading Model</i> (Section 4.13)
Exposure Duration	Consistent with the Operating Hours determined in Section 4.13, up to 8 hours per day
Mixing Factor	EPA defaults 0.5 (typical) and 0.1 (worst case) (CEB, 1991)
Molecular Weight	Chemical-specific parameter
Number of Sites	Calculated in Section 3.6
Ventilation Rate	EPA defaults 3,000 ft ³ /min (typical) and 500 ft ³ /min (worst case) for indoor conditions (default for containers less than 1,000 gallons (CEB, 1991) (See Appendix B for alternative default ventilation rates)
Temperature	Consistent with the Temperature used in Section 4.13
Vapor Pressure	Consistent with the Vapor Pressure used in Section 4.13
Vapor Pressure Correction Factor	Standard EPA default = 1

Note: The model also assumes standard temperature and pressure along with ideal gas interactions.

The models and all current EPA defaults have been programmed into ChemSTEER; EPA recommends using this software to calculate inhalation exposure to volatile chemicals during packaging/loading activities. Appendix B explains the background and derivation of the model and provides EPA default values for several model parameters.

Dermal Exposure:

Dermal exposure to waterborne coatings is expected during packaging activities. The *EPA/OPPT 2-Hand Dermal Contact with Liquid Model* may be used to estimate dermal exposure to the chemical of interest in a liquid formulation during these activities. The rationale, defaults, and limitations of this model are explained in Appendix B.

If the coating is packaged at temperatures above 60°C, EPA recommends that the dermal exposure to these materials be assumed negligible. EPA typically assumes that dermal exposures to materials above 60°C are mitigated through the use of PPE (CEB, 2002b).

To estimate the potential worker exposure to the chemical of interest in a waterborne coating packaged at temperatures less than 60°C, EPA recommends using the following equation:

$$EXP_{\text{dermal}} = Q_{\text{liquid_ski}} \times AREA_{\text{surface}} \times N_{\text{exp_incident}} \times F_{\text{chem_form}} \quad (5-10)$$

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This exposure will occur over [the lesser of $N_{\text{cont_fill_site_yr}}$ or $\text{TIME}_{\text{working_days}}$ (consistent with Section 4.13), up to 250] days per year

Where:

$\text{EXP}_{\text{dermal}}$	=	Potential dermal exposure to the chemical of interest per day (mg chemical/day)
$Q_{\text{liquid_skin}}$	=	Quantity of waterborne coating remaining on skin (Defaults: 2.1 mg coating/cm ² -incident (high-end) and 0.7 mg coating/cm ² -incident (low-end) for routine or incidental contact (CEB, 2000a))
$\text{AREA}_{\text{surface}}$	=	Surface area of contact (Default: 840 cm ² for 2 hands (CEB, 2000a))
$N_{\text{exp_incident}}$	=	Number of exposure incidents per day (Default: 1 incident/day) (See Equation 5-3a)
$F_{\text{chem_form}}$	=	Mass fraction of the chemical of interest in the waterborne coating (mg chemical/mg coating) (See Section 3.5)

6.0 SAMPLE CALCULATIONS

This section presents an example of how the equations introduced in Sections 3, 4, and 5 might be used to estimate releases of and exposures to a volatile chemical present in a liquid component used to formulate a waterborne coating. The default values used in these calculations are presented in Sections 3 through 5 and should be used only in the absence of site-specific information. The following data are used in the example calculations:

1. Chemical of interest production volume ($Q_{\text{chem_yr}}$ is 100,000 kg *chemical/yr* and is used as defoamer added to the waterborne coating formulation.
2. Chemical of interest has a molecular weight ($MW_{\text{chem.}}$) of 100 g/mol and a vapor pressure ($VP_{\text{chem.}}$) of 0.1 torr @ 25°C (i.e., the chemical is volatile for the purposes of the assessment).
3. Chemical of interest is distributed to the formulators in *liquid* form to be incorporated into an *unknown type of waterborne coating*.
4. Both environmental releases and occupational exposures are a concern for the chemical of interest.

6.1 General Facility Estimates for the Formulation of Waterborne Coatings

6.1.1 Annual Waterborne Coating Production Rate ($Q_{\text{site_yr}}$)

Aside from the annual production volume and physical state of the chemical of interest, no other site-specific information or data are known for the Equation 3-3 parameters (i.e., $Q_{\text{site_yr}}$, $F_{\text{chem_comp}}$, and $F_{\text{comp_form}}$) used to estimate the number of formulation sites using the chemical (N_{sites}). Therefore, use of the default assumptions is appropriate. Using Figure 3-1, for an unknown waterborne coating with release and exposure concerns, the default total annual facility production rate for *OEM Coatings* was used. The following default assumptions about the type of coating formulator are made from Table 3-2:

Type of Waterborne Coating: *OEM Coatings*

The total annual facility production rate of OEM coatings ($Q_{\text{site_prod_rate}}$) from Table 3-2 is 2,700,000 kg *coating/site-yr*. Since the fraction of total coating production that contains the chemical of interest is not known, assume that the facility makes only waterborne coatings ($F_{\text{waterborne}}=1$ kg waterborne coating/kg total coating formulated)

$$Q_{\text{site_yr}} = Q_{\text{site_prod_rate}} \times F_{\text{waterborne}} \quad [\text{Eqn. 3-1}]$$

$$Q_{\text{site_yr}} = 2,700,000 \text{ kg coating/site - yr} \times 1 \text{ kg waterborne coating/kg total coating formulated}$$

$$Q_{\text{site_yr}} = 2,700,000 \text{ kg waterborne coating/site - yr}$$

6.1.2 Concentration (Mass Fraction) of the Chemical of Interest in the Coating Component ($F_{\text{chem_comp}}$)

If the concentration of the chemical of interest in the coating component ($F_{\text{chem_comp}}$) is not known, assume 100 percent (or *1 kg chemical/kg component*).

6.1.3 Concentration (Mass Fraction) of the Coating Component in the Product ($F_{\text{comp_form}}$)

Since the component is used as a defoamer within the waterborne coating, and since the concentration of the component in the final product is not known, the high-end concentration (weight fraction) for a defoamer presented in Table 2-2 is assumed. The high-end concentration for defoamer used in waterborne coatings ($F_{\text{comp_form}}$) is *0.01 kg component/kg coating*.

6.1.4 Concentration (Mass Fraction) of the Chemical of Interest in the Waterborne Coating ($F_{\text{chem_form}}$)

The concentration of the chemical of interest in the waterborne coating can be calculated using the concentrations that were determined for the chemical in component and the component in formulation.

$$F_{\text{chem_form}} = F_{\text{chem_comp}} \times F_{\text{comp_form}} \quad [\text{Eqn. 3-2}]$$

$$F_{\text{chem_form}} = 1 \text{ kg chemical} / 1 \text{ kg component} \times 0.01 \text{ kg component} / 1 \text{ kg coating product}$$

$$F_{\text{chem_form}} = 0.01 \text{ kg chemical} / 1 \text{ kg coating product}$$

6.1.5 Number of Sites (N_{sites})

$$N_{\text{sites}} = \frac{Q_{\text{chem_yr}}}{Q_{\text{site_yr}} \times F_{\text{chem_form}}} \quad [\text{Eqn. 3-3}]$$

$$N_{\text{sites}} = \frac{100,000 \text{ kg chem./yr}}{2,700,000 \text{ kg coating/site - yr} \times 0.01 \text{ kg chem./kg product}}$$

$$N_{\text{sites}} = 3.7 \text{ sites}$$

Round N_{sites} up to next integer (*4 formulation sites*) and recalculate $Q_{\text{site_yr}}$:

$$Q_{\text{site_yr}} = \frac{100,000 \text{ kg chem./yr}}{4 \text{ sites} \times 0.01 \text{ kg chem./kg product}}$$

$$Q_{\text{site_yr}} = 2,500,000 \text{ kg product/site - yr}$$

6.1.6 Days of Operation ($\text{TIME}_{\text{working_days}}$, days/year)

The number of operating days is assumed 250 days per year.

6.1.7 Number of Batches ($N_{bt_site_yr}$, batches/site-year)

If the batch size (Q_{form_bt}) is not known, the default batch size of 1,000 gallons (5,030 kilograms) can be assumed. Equation 3-4 can be estimated using the default batch size:

$$N_{bt_site_yr} = \frac{Q_{site_yr}}{Q_{form_bt}} \quad [\text{Eqn. 3-4}]$$

$$N_{bt_site_yr} = \frac{2,500,000 \text{ kg prod./site - yr}}{5,030 \text{ kg prod./bt}}$$

$$N_{bt_site_yr} = 497 \text{ bts/site - yr}$$

The number of batches per day is calculated using Equation 3-5:

$$N_{bt_site_day} = \frac{N_{bt_site_yr}}{\text{TIME}_{\text{working_days}}} \quad [\text{Eqn. 3-5}]$$

$$N_{bt_site_day} = \frac{497 \text{ bts/site - yr}}{250 \text{ days/yr}}$$

$$N_{bt_site_day} = 2 \text{ bts/site - day}$$

6.1.8 Daily Use Rate of the Chemical of Interest ($Q_{chem_site_day}$, kg chemical/site-day)

$$Q_{chem_site_day} = \frac{Q_{site_yr} \times F_{chem_form}}{\text{TIME}_{\text{working_days}}} \quad [\text{Eqn. 3-6}]$$

$$Q_{chem_site_day} = \frac{\frac{2,500,000 \text{ kg prod.}}{\text{site - yr}} \times \frac{0.01 \text{ kg chem.}}{\text{kg prod.}}}{250 \text{ days/yr}}$$

$$Q_{chem_site_day} = \frac{100 \text{ kg chem.}}{\text{site - day}}$$

6.1.9 Annual Number of Component Containers Emptied per Site ($N_{cont_empty_site_yr}$, container/site-year)

It is assumed that the coating component (which is 100 percent chemical of interest, by default) is shipped to the formulators in 55-gallon drums, as a default. A density of 1 kg/L is also assumed for the component. The mass capacity for each of the drums is calculated as:

$$Q_{cont_empty} = V_{cont_empty} \times \text{RHO}_{\text{component}} = \frac{208 \text{ L comp.}}{\text{container}} \times \frac{1 \text{ kg comp.}}{\text{L}} = \frac{208 \text{ kg comp.}}{\text{container}}$$

The number of shipping containers that are emptied per site, per year is calculated as:

$$N_{\text{cont_empty_site_yr}} = \frac{Q_{\text{chem_site_day}} \times \text{TIME}_{\text{working_days}}}{F_{\text{chem_comp}} \times Q_{\text{cont_empty}}} \quad [\text{Eqn. 3-7}]$$

$$N_{\text{cont_empty_site_yr}} = \frac{100 \text{ kg chem./site - day} \times 250 \text{ days/yr}}{1 \text{ kg chem./kg comp.} \times 208 \text{ kg comp./container}}$$

$$N_{\text{comp_cont_empty_site_yr}} = 120 \text{ containers/site - yr}$$

6.1.10 Annual Number of Waterborne Coating Containers Filled per Site ($N_{\text{cont_fill_site_yr}}$, container/site-year)

It is assumed that the waterborne coating (which is 35 percent chemical of interest, by default) is packaged in 55-gallon drums, as a default. Also, a density of 1.33 kg/L is assumed for the waterborne coating. The mass capacity for each of the drums is calculated as:

$$Q_{\text{cont_fill}} = V_{\text{cont_fill}} \times \text{RHO}_{\text{waterborne}} = \frac{208 \text{ L prod.}}{\text{container}} \times \frac{1.33 \text{ kg prod.}}{\text{L}} = \frac{276.9 \text{ kg prod.}}{\text{container}}$$

The number of shipping containers that are filled per site, per year is calculated as:

$$N_{\text{cont_fill_site_yr}} = \frac{Q_{\text{chem_site_day}} \times \text{TIME}_{\text{working_days}}}{F_{\text{chem_form}} \times Q_{\text{cont_fill}}} \quad [\text{Eqn 3-8}]$$

$$N_{\text{form_cont_fill_site_yr}} = \frac{\left(\frac{100 \text{ kg chem.}}{\text{site - day}} \times \frac{250 \text{ days}}{\text{yr}} \right)}{\left(\frac{0.01 \text{ kg chem.}}{\text{kg prod.}} \times \frac{276.9 \text{ kg prod.}}{\text{container}} \right)}$$

$$N_{\text{form_cont_fill_site_yr}} = 9,029 \text{ containers/site - yr}$$

6.2 Release Assessments for the Formulation of Waterborne Coatings

6.2.1 Transfer Operation Losses to Air from Unloading the Waterborne Coating Component (Release 1)

Since the chemical of interest is volatile, it will be emitted from the process from the displacement of saturated air when the chemical is transferred. The *EPA/OAQPS AP-42 Loading Model* is used to estimate the rate at which the chemical is emitted during this activity:

$$Q_{\text{vapor_generation}} = \frac{F_{\text{saturation_factor}} \times MW_{\text{chem}} \times \left(V_{\text{cont_empty}} \times \frac{3785.4 \text{ cm}^3}{\text{gal}} \right) \times \left(\frac{\text{RATE}_{\text{fill}}}{3600 \text{ sec/hour}} \right) \times F_{\text{correction_factor}} \times \left(\frac{VP_{\text{chem}}}{760 \text{ torr/atm}} \right)}{R \times \text{TEMP}_{\text{ambient}}} \quad [\text{Eqn. B-5}]$$

Table 6-1. Summary of ChemSTEER Inputs for Release 1

Parameter	Units	ChemSTEER Input
MW _{chem}	g/mol	100
F _{saturation_factor}	Dimensionless	Typical = 0.5 Worst Case = 1
VP _{chem}	Torr	0.1
V _{cont_empty}	Gal	55
RATE _{fill}	containers/hour	20
TEMP _{ambient}	K	298
F _{correction_factor}	Dimensionless	1
R	L-atm/mol-K	82.05

Therefore:

$$Q_{\text{vapor_generation}} = 3.1 \times 10^{-4} \text{ g/s for typical and } Q_{\text{vapor_generation}} = 6.2 \times 10^{-4} \text{ g/s for worst case}$$

Using $Q_{\text{vapor_generation}}$ calculated in Equation B-5 and the other standard default values presented in Table 4-3 for container unloading, the model then estimates the daily release to air using the following equation:

$$E_{\text{local_air_transfers}} = Q_{\text{vapor_generation}} \times \text{TIME}_{\text{activity_durs}} \times \frac{3600 \text{ sec/hour}}{1000 \text{ g/kg}} \quad [\text{Eqn. B-7}]$$

$$E_{\text{local_air_transfers}} = (3.1 \times 10^{-4} \text{ to } 6.2 \times 10^{-4}) \text{ g chem./sec} \times \left(\frac{120 \text{ containers/site - yr}}{250 \text{ days/yr} \times 20 \text{ containers/hr}} \right) \times \frac{3600 \text{ sec/hr}}{1000 \text{ g/kg}}$$

$$E_{\text{local_air_transfers}} = 2.6 \times 10^{-5} - 5.3 \times 10^{-6} \text{ kg chem. emitted/site-day}$$

...over 250 days/year from 4 sites.

6.2.2 Dust Generation from Transfer Operations Released to Air, or Collected and Released to Water, Incineration, or Landfill (Release 2)

The chemical is received as a liquid component; therefore, dust generation is not expected.

6.2.3 Waterborne Coating Component Container Residue Released to Water, Incineration, or Landfill (Release 3)

If the use of a wastewater treatment system is unknown, assume that wastes may be directly discharged to water, incineration, or landfill without treatment. Since $N_{\text{cont_empty_site_yr}}$ is greater

than TIME_{working_days}, it is assumed that more than one container is emptied on each operating day. The following equation is used to estimate the daily release:

$$E_{\text{local}}_{\text{cont_reside_disp}} = Q_{\text{chem_site_day}} \times F_{\text{container_residue}} \quad [\text{Eqn. 4-3b}]$$

Since it is known that the component is in a liquid form when shipped to the formulation site, and the container is assumed to be a 55-gallon drum by default, the *EPA/OPPT Drum Residual Model* is used to estimate this release. The default fraction of liquid chemical that remains in the empty container ($F_{\text{container_residue}}$) is 0.03 kg chemical remaining/kg chemical in full container (see Table B-3 in Appendix B):

$$E_{\text{local}}_{\text{cont_reside_disp}} = \frac{100 \text{ kg chem.}}{\text{site} - \text{day}} \times \frac{0.03 \text{ kg chem. remain}}{\text{kg chem. full}}$$

$$E_{\text{local}}_{\text{container_residue_disp}} = \frac{3 \text{ kg chem. released}}{\text{site} - \text{day}}$$

...over 250 days/year from 4 sites.

6.2.4 Open Surface Losses to Air During Container Cleaning (Release 4)

Since the chemical of interest is volatile, it will be emitted from the process while the emptied containers are cleaned. The *EPA/OPPT Penetration Model* is used to estimate the rate at which the chemical is emitted during this activity:

$$Q_{\text{vapor_generation}} = \frac{(8.24 \times 10^{-8}) \times MW_{\text{chem}}^{0.835} \times F_{\text{correction_factor}} \times VP_{\text{chem}} \times \left(\frac{1}{29} + \frac{1}{MW_{\text{chem}}} \right)^{0.25} \times \text{RATE}_{\text{air_speed}}^{0.5} \times \text{AREA}_{\text{opening}}}{\text{TEMP}_{\text{ambient}}^{0.05} \times D_{\text{opening}}^{0.5} \times P_{\text{ambient}}^{0.5}} \quad [\text{Eqn. B-1}]$$

Table 6-2. Summary of ChemSTEER Inputs for Release 4

Parameter	Units	ChemSTEER Input
MW _{chem}	g/mol	100
F _{correction_factor}	Dimensionless	1
VP _{chem}	Torr	0.1
RATE _{air_speed}	ft/min	100
AREA _{opening}	cm ²	20.3
TEMP _{ambient}	K	298
D _{opening}	cm	5.08
P _{ambient}	Atm	1

Therefore:

$$Q_{\text{vapor_generation}} = 1.2 \times 10^{-5} \text{ g/s}$$

Using $Q_{\text{vapor_generation}}$ calculated in Equation B-1 and the other standard default values presented in Table 4-2 for container cleaning, the model then estimates the daily release to air using the following equation:

$$E_{\text{local_air_cleaning}} = Q_{\text{vapor_generation}} \times \text{TIME}_{\text{activity_hrs}} \times \frac{3600 \text{ sec/hour}}{1000 \text{ g/kg}} \quad [\text{Eqn. B-2}]$$

$$E_{\text{local_air_cleaning}} = 1.2 \times 10^{-5} \text{ g chem./sec} \times \left(\frac{120 \text{ containers/site - yr}}{250 \text{ days/yr} \times 20 \text{ containers/hr}} \right) \times \frac{3600 \text{ sec/hour}}{1000 \text{ g/kg}}$$

$$E_{\text{local_air_cleaning}} = 1.0 \times 10^{-6} \text{ kg chem. emitted/site - day}$$

...over 250 days/year from 4 sites.

6.2.5 Vented Losses to Air During Dispersion and Blending (Release 5)

Since the chemical of interest is volatile, it will be emitted from the process during product mixing and formulation. Because of the volatility of the chemical, it is also assumed that the vessel is closed with a 4-inch (10 cm) diameter vent. The *EPA/OPPT Penetration Model* is used to estimate the rate at which the chemical is emitted during this activity:

$$Q_{\text{vapor_generation}} = \frac{(8.24 \times 10^{-8}) \times \text{MW}_{\text{chem}}^{0.835} \times F_{\text{correction_factor}} \times \text{VP}_{\text{chem}} \times \left(\frac{1}{29} + \frac{1}{\text{MW}_{\text{chem}}} \right)^{0.25} \times \text{RATE}_{\text{air_speed}}^{0.5} \times \text{AREA}_{\text{opening}}}{\text{TEMP}_{\text{ambient}}^{0.05} \times D_{\text{opening}}^{0.5} \times P_{\text{ambient}}^{0.5}} \quad [\text{Eqn. B-1}]$$

Table 6-3. Summary of ChemSTEER Inputs for Release 5

Parameter	Units	ChemSTEER Input
MW_{chem}	g/mol	100
$F_{\text{correction_factor}}$	Dimensionless	1
VP_{chem}	Torr	0.1
$\text{RATE}_{\text{air_speed}}$	ft/min	100
$\text{AREA}_{\text{opening}}$	cm ²	79
$\text{TEMP}_{\text{ambient}}$	K	298
D_{opening}	cm	10
P_{ambient}	Atm	1

Therefore:

$$Q_{\text{vapor_generation}} = 3.3 \times 10^{-5} \text{ g/s}$$

Using $Q_{\text{vapor_generation}}$ calculated in Equation B-1 and the other standard default values presented in Table 4-4 for product mixing, the model then estimates the daily release to air using the following equation:

$$E_{\text{local}}_{\text{air_proces_vent}} = Q_{\text{vapor_generation}} \times \text{TIME}_{\text{activity_hurs}} \times \frac{3600 \text{ sec/hour}}{1000 \text{ g/kg}} \quad [\text{Eqn. B-2}]$$

$$E_{\text{local}}_{\text{air_proces_vent}} = 3.3 \times 10^{-5} \text{ g chem./sec} \times (24 \text{ hrs/day}) \times \frac{3600 \text{ sec/hour}}{1000 \text{ g/kg}}$$

$$E_{\text{local}}_{\text{air_proces_vent}} = 2.9 \times 10^{-3} \text{ kg chem. emitted/day}$$

...over 250 days/year from 4 sites.

6.2.6 Waterborne Coating Product Sampling Wastes Disposed to Water, Incineration or Landfill (Release 6)

While a release from this source is likely to occur, EPA does not currently have data to support quantifying the release.

6.2.7 Open Surface Losses to Air During Product Sampling (Release 7)

Since the chemical of interest is volatile, it will be emitted from the process during QA/QC sampling. The *EPA/OPPT Penetration Model* is used to estimate the rate at which the chemical is emitted during this activity:

$$Q_{\text{vapor_generation}} = \frac{(8.24 \times 10^{-8}) \times MW_{\text{chem}}^{0.835} \times F_{\text{correction_factor}} \times VP_{\text{chem}} \times \left(\frac{1}{29} + \frac{1}{MW_{\text{chem}}} \right)^{0.25} \times \text{RATE}_{\text{air_speed}}^{0.5} \times \text{AREA}_{\text{opening}}}{\text{TEMP}_{\text{ambient}}^{0.05} \times D_{\text{opening}}^{0.5} \times P_{\text{ambient}}^{0.5}} \quad [\text{Eqn. B-1}]$$

Table 6-4. Summary of ChemSTEER Inputs for Release 7

Parameter	Units	ChemSTEER Input
MW _{chem}	g/mol	100
F _{correction_factor}	Dimensionless	1
VP _{chem}	Torr	0.1
RATE _{air_speed}	ft/min	100
AREA _{opening}	cm ²	4.9-78.5
TEMP _{ambient}	K	298
D _{opening}	Cm	2.5-10
P _{ambient}	Atm	1

Therefore:

$$Q_{\text{vapor_generation}} = 4.1 \times 10^{-6} - 3.3 \times 10^{-5} \text{ g/s}$$

Using $Q_{\text{vapor_generation}}$ calculated in Equation B-1 and the other standard default values presented in Table 4-5 for product sampling, the model then estimates the daily release to air using the following equation:

$$E_{\text{local_air_sample}} = Q_{\text{vapor_generation}} \times \text{TIME}_{\text{activity_hurs}} \times \frac{3600 \text{ sec/hour}}{1000 \text{ g/kg}} \quad [\text{Eqn. B-2}]$$

$$E_{\text{local_air_sample}} = (4.1 \times 10^{-6} \text{ to } 3.3 \times 10^{-5}) \text{ g chem./sec} \times 1 \text{ hr/site - day} \times \frac{3600 \text{ sec/hour}}{1000 \text{ g/kg}}$$

$$E_{\text{local_air_sample}} = 1.5 \times 10^{-5} - 1.2 \times 10^{-4} \text{ kg chem. emitted /site - day}$$

...over 250 days/year from 4 sites.

6.2.8 Equipment Cleaning Releases to Water, Incineration or Landfill (Release 8)

If the use of a wastewater treatment system is unknown, assume that wastes may be directly discharged to water, incineration, or landfill without treatment. Since $N_{\text{bt_site_yr}}$ is greater than $\text{TIME}_{\text{working_days}}$, the following equation is used to estimate the daily release:

$$E_{\text{local_equipment_cleaning}} = Q_{\text{chem_site_day}} \times F_{\text{equipment_cleaning}} \quad [\text{Eqn. 4-6b}]$$

$$E_{\text{local_equipment_cleaning}} = \frac{100 \text{ kg chem.}}{\text{site - day}} \times \frac{0.02 \text{ kg chem released}}{\text{kg chem used}}$$

$$E_{\text{local_equipment_cleaning}} = \frac{2 \text{ kg chem. released}}{\text{site - day}}$$

...over 250 days/year from 4 sites

6.2.9 Open Surface Losses to Air During Equipment Cleaning (Release 9)

Since the chemical of interest is volatile, it will be emitted from the process during process equipment cleaning. The *EPA/OPPT Penetration Model* is used to estimate the rate at which the chemical is emitted during this activity:

$$Q_{\text{vapor_generation}} = \frac{(8.24 \times 10^{-8}) \times MW_{\text{chem}}^{0.835} \times F_{\text{correction_factor}} \times VP_{\text{chem}} \times \left(\frac{1}{29} + \frac{1}{MW_{\text{chem}}} \right)^{0.25} \times \text{RATE}_{\text{air_speed}}^{0.5} \times \text{AREA}_{\text{opening}}}{\text{TEMP}_{\text{ambient}}^{0.05} \times D_{\text{opening}}^{0.5} \times P_{\text{ambient}}^{0.5}} \quad [\text{Eqn. B-1}]$$

Table 6-5. Summary of ChemSTEER Inputs for Release 9

Parameter	Units	ChemSTEER Input
MW _{chem}	g/mol	100
F _{correction_factor}	Dimensionless	1
VP _{chem}	Torr	0.1
RATE _{air_speed}	ft/min	100
AREA _{opening}	cm ²	6,648
TEMP _{ambient}	K	298
D _{opening}	cm	92
P _{ambient}	Atm	1

Therefore:

$$Q_{\text{vapor_generation}} = 9.2 \times 10^{-4} \text{ g/s}$$

Using $Q_{\text{vapor_generation}}$ calculated in Equation B-1 and the other standard default values presented in Table 4-6 for process equipment cleaning, the model then estimates the daily release to air using the following equation:

$$E_{\text{local_air_eqpt_cleaning}} = Q_{\text{vapor_generation}} \times \text{TIME}_{\text{activity_hurs}} \times \frac{3600 \text{ sec/hour}}{1000 \text{ g/kg}} \quad [\text{Eqn. B-2}]$$

$$E_{\text{local_air_eqpt_cleaning}} = 9.2 \times 10^{-4} \text{ g chem./sec} \times (24 \text{ hrs/day}) \times \frac{3600 \text{ sec/hour}}{1000 \text{ g/kg}}$$

$$E_{\text{local_air_sample}} = 0.08 \text{ kg chem. emitted /day}$$

...over 250 days/year from 4 sites

6.2.10 Filter Waste Releases to Incineration or Landfill during Filter Media Changeout (Release 10)

By default, 0.02 percent of each batch is disposed as filter waste.

$$E_{\text{local_filter_waste}} = Q_{\text{chem_yr}} \times F_{\text{filter_residue}} \quad [\text{Eqn. 4-8}]$$

$$E_{\text{local_filter_waste}} = 100 \text{ kg chem./site - day} \times 0.0002 \text{ kg filter waste/kg used}$$

$$E_{\text{local_filter_waste}} = 0.02 \text{ kg chem. released / site - day}$$

...over 250 days/yr for 4 sites

6.2.11 Open Surface Losses to Air During Filter Media Changeout (Release 11)

Since the chemical of interest is volatile, it will be emitted from the process during filter media replacement. The *EPA/OPPT Penetration Model* is used to estimate the rate at which the chemical is emitted during this activity:

$$Q_{\text{vapor_generation}} = \frac{(8.24 \times 10^{-8}) \times MW_{\text{chem}}^{0.835} \times F_{\text{correction_factor}} \times VP_{\text{chem}} \times \left(\frac{1}{29} + \frac{1}{MW_{\text{chem}}} \right)^{0.25} \times RATE_{\text{air_speed}}^{0.5} \times AREA_{\text{opening}}}{TEMP_{\text{ambient}}^{0.05} \times D_{\text{opening}}^{0.5} \times P_{\text{ambient}}^{0.5}} \quad [\text{B-1}]$$

Table 6-6. Summary of ChemSTEER Inputs for Release 11

Parameter	Units	ChemSTEER Input
MW _{chem}	g/mol	100
F _{correction_factor}	Dimensionless	1
VP _{chem}	Torr	0.1
RATE _{air_speed}	ft/min	100
AREA _{opening}	cm ²	182.4
TEMP _{ambient}	K	298
D _{opening}	cm	15.24
P _{ambient}	Atm	1

Therefore:

$$Q_{\text{vapor_generation}} = 6.2 \times 10^{-5} \text{ g/s}$$

Using Q_{vapor_generation} calculated in Equation B-1 and the other standard default values presented in Table 4-6 for filter media change out, the model then estimates the daily release to air using the following equation:

$$E_{\text{local_air_filter_residue}} = Q_{\text{vapor_generation}} \times \text{TIME}_{\text{activity_hours}} \times \frac{3600 \text{ sec/hour}}{1000 \text{ g/kg}} \quad [\text{Eqn. B-2}]$$

$$E_{\text{local_air_filter_residue}} = 6.2 \times 10^{-5} \text{ g chem./sec} \times (0.25 \text{ hrs/bt} \times 2 \text{ bt/site} - \text{day}) \times \frac{3600 \text{ sec/hour}}{1000 \text{ g/kg}}$$

$$E_{\text{local_air_sample}} = 1.1 \times 10^{-4} \text{ kg chem. emitted /site} - \text{day}$$

...over 250 days/year from 4 sites.

6.2.12 Transfer Operation Losses to Air from Loading Product into Transport Containers (Release 12)

Since the chemical of interest is volatile, it will be emitted from the process from the displacement of saturated air when the chemical is transferred. The *EPA/OAQPS AP-42 Loading Model* is used to estimate the rate at which the chemical is emitted during this activity:

$$Q_{\text{vapor_generation}} = \frac{F_{\text{saturation_factor}} \times MW_{\text{chem}} \times \left(V_{\text{cont_empty}} \times \frac{3785.4 \text{ cm}^3}{\text{gal}} \right) \times \left(\frac{\text{RATE}_{\text{fill}}}{3600 \text{ sec/hour}} \right) \times F_{\text{correction_factor}} \times \left(\frac{VP_{\text{chem}}}{760 \text{ torr/atm}} \right)}{R \times \text{TEMP}_{\text{ambient}}} \quad [\text{Eqn. B-5}]$$

Table 6-7. Summary of ChemSTEER Inputs for Release 12

Parameter	Units	ChemSTEER Input
MW _{chem}	g/mol	100
F _{saturation_factor}	dimensionless	Typical = 0.5 Worst Case = 1
VP _{chem}	torr	0.1
V _{cont_empty}	gal	55
RATE _{fill}	containers/hour	20
TEMP _{ambient}	K	298
F _{correction_factor}	dimensionless	1
R	L-atm/mol-K	82.05

Therefore:

$$Q_{\text{vapor_generation}} = 3.1 \times 10^{-4} \text{ g/s for typical and } Q_{\text{vapor_generation}} = 6.2 \times 10^{-4} \text{ g/s for worst case}$$

Using $Q_{\text{vapor_generation}}$ calculated in Equation B-5 and the other standard default values presented in Table 4-7 for packaging, the model then estimates the daily release to air using the following equation:

$$\text{Elocal}_{\text{air_packaging}} = Q_{\text{vapor_generation}} \times \text{TIME}_{\text{activity_hours}} \times \frac{3600 \text{ sec/hour}}{1000 \text{ g/kg}} \quad [\text{Eqn. B-7}]$$

$$\text{Elocal}_{\text{air_packaging}} = (3.1 \times 10^{-4} \text{ to } 6.2 \times 10^{-4}) \text{ g chem./sec} \times \left(\frac{9,029 \text{ containers/site - yr}}{250 \text{ days/yr} \times 20 \text{ containers/hr}} \right) \times \frac{3600 \text{ sec/hr}}{1000 \text{ g/kg}}$$

$$\text{Elocal}_{\text{air_packaging}} = 2.0 \times 10^{-3} - 4.0 \times 10^{-2} \text{ kg chem. emitted/site-day}$$

...over 250 days/year from 4 sites.

6.2.13 Off-Specification and Other Waste Coatings to Water, Incineration, or Landfill (Release 13)

Since information is not available on the amount of off-specification wastes produced, it is appropriate to assume a default loss fraction of 0.012, released to water, incineration, or landfill. The number of off-spec days per site can be calculated as follows:

$$N_{\text{off-spec_days_site_yr}} = \frac{N_{\text{bt_site_yr}} \times F_{\text{off_spec}}}{N_{\text{off-spec_bt_day}}} \quad [\text{Eqn. 4-9}]$$

$$N_{\text{off-spec_days_site_yr}} = \frac{497 \text{ batches/site-yr} \times 0.012 \text{ off-spec bt/batches}}{1 \text{ off-spec bt/day}}$$

$$N_{\text{off-spec_days_site_yr}} = 6.0 \text{ days/site-yr}$$

The daily release from off-specification product can then be estimated using the following equation. Note that the number of days of release is assumed to be equal to the number of off-spec days per year for each site.

$$E_{\text{local_off-spec_day}} = Q_{\text{form_bt}} \times F_{\text{chem_form}} \quad [\text{Eqn. 4-10}]$$

$$E_{\text{local_off-spec_day}} = 5,030 \text{ kg coating/bt} \times 0.01 \text{ kg chemical/kg coating}$$

$$E_{\text{local_off-spec_yr}} = 50.3 \text{ kg chemical/site-day}$$

...over 6 days/yr from 4 sites.

6.3 Occupational Exposure Assessments for the Formulation of Waterborne Coatings

6.3.1 Total Number of Workers Potentially Exposed to the Chemical

It is assumed that the chemical is used in a coating formulation for OEM product coatings. 39 OEM product coating formulation workers are potentially exposed to the chemical at each site; therefore, the total number of workers is calculated as:

$$38 \frac{\text{workers}}{\text{site}} \times N_{\text{sites}} = 38 \frac{\text{workers}}{\text{site}} \times 4 \text{ site} = 152 \text{ total waterborne coating formulation workers}$$

Note that a breakdown of workers for each activity is summarized in Table 5-3. Based on the chosen default coating type as OEM product coatings, the breakdown of workers for this type of coating is used.

OEM Activity	Number of Production
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	Workers per Activity
Unloading solid/liquid chemicals (Exposure A)	3
Cleaning of transport containers (Exposure B)	6
Sampling product (Exposure C)	8
Cleaning of process equipment (Exposure D)	6
Replacing spent filter media (Exposure E)	5
Loading liquid coating (Exposure F)	10

6.3.2 Exposure from Unloading Solid or Liquid Chemicals (Exposure A)

Three workers are exposed during this activity.

Inhalation Exposure:

The density of the liquid component is assumed 1 kg/L, which is not typical of a viscous component. The liquid component will likely be unloaded at ambient temperatures. Four workers are exposed during this activity.

Using the vapor generation rate calculated in Release 1 and the CEB standard model for estimating inhalation exposure due to evaporation of volatile chemicals (*EPA/OPPT Mass Balance Model*), ChemSTEER calculates the worker exposure using the following equations:

Table 6-8. Summary of ChemSTEER Inputs for Exposure A

Parameter	Units	ChemSTEER Input
$F_{\text{mixing_factor}}$	Dimensionless	Typical = 0.5 Worst Case = 0.1
$TEMP_{\text{ambient}}$	K	298
MW_{chem}	g/mol	100
$RATE_{\text{ventilation}}$	ft ³ /min	Typical = 3000 Worst Case = 500
$Q_{\text{vapor_generation}}$	g/s	Typical = 3.1×10^{-4} Worst Case = 6.2×10^{-4}
$RATE_{\text{breathing}}$	m ³ /hour	1.25
V_{molar}	L/mol	24.45
$RATE_{\text{fill}}$	containers/hr	20
$TIME_{\text{exposure}}$	hours/day	0.24

$$C_{\text{chem_volumetric}} = \frac{(1.7 \times 10^5) \times TEMP_{\text{ambient}} \times Q_{\text{vapor_generation}}}{MW_{\text{chem}} \times RATE_{\text{ventilation}} \times F_{\text{mixing_factor}}} \quad [\text{Eqn. B-7}]$$

$C_{\text{chem_volumetric}} = 0.1$ ppm for typical and 6.3 ppm for worst case

Next, the volumetric concentration is converted to a mass concentration ($C_{\text{chem_mass}}$) by the following equation:

$$C_{\text{chem_mass}} = \frac{C_{\text{chem_volumetric}} \times MW_{\text{chem}}}{V_{\text{molar}}} \quad [\text{Eqn. B-9}]$$

$$C_{\text{chem_mass}} = 0.4 \text{ mg/m}^3 \text{ for typical and } C_{\text{chem_mass}} = 25.8 \text{ mg/m}^3 \text{ for worst case}$$

Finally, the mass concentration of the chemical and the standard default values presented in Table 5-2 for the container unloading activity are used to estimate the amount of inhalation exposure per worker using the following calculation:

$$EXP_{\text{inhalation}} = C_{\text{chem_mass}} \times RATE_{\text{breathing}} \times TIME_{\text{exposure}} \quad [\text{Eqn. B-10}]$$

$$EXP_{\text{inhalation}} = (0.41 \text{ to } 25) \text{ mg/m}^3 \times 1.25 \text{ m}^3/\text{hr} \times \left(\frac{481 \text{ containers/site - yr}}{250 \text{ days/yr} \times 20 \text{ containers/hr}} \right)$$

$$EXP_{\text{inhalation}} = 0.05 - 3.1 \text{ mg chem./day}$$

...over 250 days/year.

Dermal Exposure:

The potential worker exposure to the chemical within the liquid waterborne coating component is calculated using the *EPA/OPPT 2-Hand Dermal Contact with Liquid Model*:

$$EXP_{\text{dermal}} = Q_{\text{liquid_ski}} \times AREA_{\text{surface}} \times N_{\text{exp_incident}} \times F_{\text{chem_comp}} \quad [\text{Eqn. 5-3a}]$$

$$= \left[\frac{0.7 \text{ to } 2.1 \text{ mg comp.}}{\text{cm}^2 \text{ - incident}} \right] \times 840 \text{ cm}^2 \times \frac{1 \text{ incident}}{\text{day}} \times \frac{1 \text{ mg chem.}}{\text{mg comp.}}$$

$$EXP_{\text{dermal}} = \frac{588 - 1,764 \text{ mg chem.}}{\text{day}}$$

...over 250 days/year.

6.3.3 Exposure to Liquids During Container Cleaning (Exposure B)

Six workers are exposed during this activity.

Inhalation Exposure:

Using the vapor generation rate calculated in Release 2 and the CEB standard model for estimating inhalation exposure due to evaporation of volatile chemicals (*EPA/OPPT Mass Balance Model*), ChemSTEER calculates the worker exposure using the following equations:

Table 6-9. Summary of ChemSTEER Inputs for Exposure B

Parameter	Units	ChemSTEER Input
$F_{\text{mixing_factor}}$	dimensionless	Typical = 0.5 Worst Case = 0.1
$TEMP_{\text{ambient}}$	K	298
MW_{chem}	g/mol	100
$RATE_{\text{ventilation}}$	ft ³ /min	Typical = 3000 Worst Case = 500
$Q_{\text{vapor_generation}}$	g/s	Typical = 1.2×10^{-5}
$RATE_{\text{breathing}}$	m ³ /hour	1.25
V_{molar}	L/mol	24.45
$RATE_{\text{fill}}$	containers/hr	20
$TIME_{\text{exposure}}$	hours/day	0.72

$$C_{\text{chem_volumetric}} = \frac{(1.7 \times 10^5) \times TEMP_{\text{ambient}} \times Q_{\text{vapor_generation}}}{MW_{\text{chem}} \times RATE_{\text{ventilation}} \times F_{\text{mixing_factor}}} \quad [\text{Eqn. B-7}]$$

$C_{\text{chem_volumetric}} = 4.0 \times 10^{-3}$ ppm for typical and $C_{\text{chem_volumetric}} = 0.12$ ppm for worst case

Next, the volumetric concentration is converted to a mass concentration ($C_{\text{chem_mass}}$) by the following equation:

$$C_{\text{chem_mass}} = \frac{C_{\text{chem_volumetric}} \times MW_{\text{chem}}}{V_{\text{molar}}} \quad [\text{Eqn. B-9}]$$

$C_{\text{chem_mass}} = 1.7 \times 10^{-2}$ mg/m³ for typical and $C_{\text{chem_mass}} = 0.5$ mg/m³ for worst case

Finally, the mass concentration of the chemical and the standard default values presented in Table 5-3 for the container cleaning activity are used to estimate the amount of inhalation exposure per worker using the following calculation:

$$EXP_{\text{inhalation}} = C_{\text{chem_mass}} \times RATE_{\text{breathing}} \times TIME_{\text{exposure}} \quad [\text{Eqn. B-10}]$$

$$EXP_{\text{inhalation}} = (0.017 \text{ to } 0.49) \text{ mg/m}^3 \times 1.25 \text{ m}^3/\text{hr} \times \left(\frac{481 \text{ containers/site - yr}}{250 \text{ days/yr} \times 20 \text{ containers/hr}} \right)$$

$$EXP_{\text{inhalation}} = 2.0 \times 10^{-3} - 0.06 \text{ mg chem./day}$$

...over 250 days/year.

Dermal Exposure:

The potential worker exposure to the chemical within the liquid waterborne coating component is calculated using the *EPA/OPPT 2-Hand Dermal Contact with Liquid Model*:

$$\begin{aligned}
 EXP_{\text{dermal}} &= Q_{\text{liquid_ski}} \times \text{AREA}_{\text{surface}} \times N_{\text{exp_incident}} \times F_{\text{chem_comp}} && \text{[Eqn. 5-6a]} \\
 &= \left[\frac{0.7 \text{ to } 2.1 \text{ mg comp.}}{\text{cm}^2 \text{ - incident}} \right] \times 840 \text{ cm}^2 \times \frac{1 \text{ incident}}{\text{day}} \times \frac{1 \text{ mg chem.}}{\text{mg comp.}} \\
 EXP_{\text{dermal}} &= \frac{588 - 1,764 \text{ mg chem.}}{\text{day}} \\
 &\dots \text{over 250 days/year.}
 \end{aligned}$$

6.3.4 Exposure from Sampling Waterborne Coatings (Exposure C)

Eight workers are exposed during this activity.

Inhalation Exposure:

Using the vapor generation rate calculated in Release 7 and the CEB standard model for estimating inhalation exposure due to evaporation of volatile chemicals (*EPA/OPPT Mass Balance Model*), ChemSTEER calculates the worker exposure using the following equations:

Table 6-10. Summary of ChemSTEER Inputs for Exposure C

Parameter	Units	ChemSTEER Input
F _{mixing_factor}	dimensionless	Typical = 0.5 Worst Case = 0.1
TEMP _{ambient}	K	298
MW _{chem}	g/mol	100
RATE _{ventilation}	ft ³ /min	Typical = 3000 Worst Case = 500
Q _{vapor_generation}	g/s	Typical = 4.1 × 10 ⁻⁶ Worst Case = 3.3 × 10 ⁻⁵
RATE _{breathing}	m ³ /hour	1.25
V _{molar}	L/mol	24.45
TIME _{exposure}	hours/day	1

$$C_{\text{chem_volumetric}} = \frac{(1.7 \times 10^5) \times \text{TEMP}_{\text{ambient}} \times Q_{\text{vapor_generation}}}{\text{MW}_{\text{chem}} \times \text{RATE}_{\text{ventilation}} \times F_{\text{mixing_factor}}} \quad \text{[Eqn. B-7]}$$

C_{chem_volumetric} = 1.4 × 10⁻³ ppm for typical and C_{chem_volumetric} = 0.3 ppm for worst case

Next, the volumetric concentration is converted to a mass concentration ($C_{\text{chem_mass}}$) by the following equation:

$$C_{\text{chem_mass}} = \frac{C_{\text{chem_volumetric}} \times MW_{\text{chem}}}{V_{\text{molar}}} \quad [\text{Eqn. B-9}]$$

$$C_{\text{chem_mass}} = 5.7 \times 10^{-3} \text{ mg/m}^3 \text{ for typical and } C_{\text{chem_mass}} = 1.4 \text{ mg/m}^3 \text{ for worst case}$$

Finally, the mass concentration of the chemical and the standard default values presented in Table 5-5 for the product sampling activity are used to estimate the amount of inhalation exposure per worker using the following calculation:

$$EXP_{\text{inhalation}} = C_{\text{chem_mass}} \times RATE_{\text{breathing}} \times TIME_{\text{exposure}} \quad [\text{Eqn. B-10}]$$

$$EXP_{\text{inhalation}} = (5.7 \times 10^{-3} \text{ to } 1.4) \text{ mg/m}^3 \times 1.25 \text{ m}^3/\text{hr} \times 1 \text{ hr/site} - \text{day}$$

$$EXP_{\text{inhalation}} = 7.1 \times 10^{-3} - 1.7 \text{ mg chem./day}$$

...over 250 days/year.

Dermal Exposure:

The potential worker exposure to the chemical within the waterborne coating is calculated using the *EPA/OPPT 1-Hand Dermal Contact with Liquid Model*:

$$EXP_{\text{dermal}} = Q_{\text{liquid_skn}} \times AREA_{\text{surface}} \times N_{\text{exp_incident}} \times F_{\text{chem_form}} \quad [\text{Eqn. 5-7}]$$

$$= \left[\frac{0.7 \text{ to } 2.1 \text{ mg prod.}}{\text{cm}^2 - \text{incident}} \right] \times 420 \text{ cm}^2 \times \frac{1 \text{ incident}}{\text{day}} \times \frac{0.01 \text{ mg chem.}}{\text{mg prod.}}$$

$$EXP_{\text{dermal}} = \frac{2.9 - 8.8 \text{ mg chem.}}{\text{day}}$$

...over 250 days/year.

6.3.5 Exposure to Liquids During the Equipment Cleaning of Mixers and Other Process Equipment (Exposure D)

Six workers are exposed during this activity.

Inhalation Exposure:

Using the vapor generation rate calculated in Release 9 and the CEB standard model for estimating inhalation exposure due to evaporation of volatile chemicals (*EPA/OPPT Mass Balance Model*), ChemSTEER calculates the worker exposure using the following equations:

Table 6-11. Summary of ChemSTEER Inputs for Exposure D

Parameter	Units	ChemSTEER Input
$F_{\text{mixing_factor}}$	dimensionless	Typical = 0.5 Worst Case = 0.1
$TEMP_{\text{ambient}}$	K	298
MW_{chem}	g/mol	100
$RATE_{\text{ventilation}}$	ft ³ /min	Typical = 3000 Worst Case = 500
$Q_{\text{vapor_generation}}$	g/s	9.2×10^{-4}
$RATE_{\text{breathing}}$	m ³ /hour	1.25
V_{molar}	L/mol	24.45
$TIME_{\text{exposure}}$	hours/day	4 - 8

$$C_{\text{chem_volumetric}} = \frac{(1.7 \times 10^5) \times TEMP_{\text{ambient}} \times Q_{\text{vapor_generation}}}{MW_{\text{chem}} \times RATE_{\text{ventilation}} \times F_{\text{mixing_factor}}} \quad [\text{Eqn. B-7}]$$

$$C_{\text{chem_volumetric}} = 0.3 - 9.3 \text{ ppm}$$

Next, the volumetric concentration is converted to a mass concentration ($C_{\text{chem_mass}}$) by the following equation:

$$C_{\text{chem_mass}} = \frac{C_{\text{chem_volumetric}} \times MW_{\text{chem}}}{V_{\text{molar}}} \quad [\text{Eqn. B-9}]$$

$$C_{\text{chem_mass}} = \frac{(0.3 \text{ to } 9.3) \text{ ppm} \times 100 \text{ g/mol}}{24.45 \text{ L/mol}}$$

$$C_{\text{chem_mass}} = 1.3 - 38.2 \text{ mg/m}^3$$

Finally, the mass concentration of the chemical and the standard default values presented in Table 5-6 for the process equipment cleaning activity are used to estimate the amount of inhalation exposure per worker using the following calculation:

$$EXP_{\text{inhalation}} = C_{\text{chem_mass}} \times RATE_{\text{breathing}} \times TIME_{\text{exposure}} \quad [\text{Eqn. B-10}]$$

$$EXP_{\text{inhalation}} = (1.3 \text{ to } 38.2) \text{ mg/m}^3 \times 1.25 \text{ m}^3/\text{hr} \times 4 - 8 \text{ hrs/site - day}$$

$$EXP_{\text{inhalation}} = 16.4 - 382.3 \text{ mg chem./day}$$

...over 250 days/year.

Dermal Exposure:

$$\begin{aligned}
 EXP_{\text{dermal}} &= Q_{\text{liquid_sli}} \times AREA_{\text{surface}} \times N_{\text{exp_incident}} \times F_{\text{chem_form}} && \text{[Eqn. 5-8]} \\
 &= \left[\frac{0.7 \text{ to } 2.1 \text{ mg prod.}}{\text{cm}^2 \text{ - incident}} \right] \times 840 \text{ cm}^2 \times \frac{1 \text{ incident}}{\text{day}} \times \frac{0.01 \text{ mg chem.}}{\text{mg prod.}} \\
 EXP_{\text{dermal}} &= \frac{5.9 - 17.6 \text{ mg chem.}}{\text{day}} \\
 &\dots \text{over 250 days/year.}
 \end{aligned}$$

6.3.6 Exposure from Changing Spent Filter Media (Exposure E)

Five workers are exposed during this activity.

Inhalation Exposure:

Using the vapor generation rate calculated in Release 11 and the CEB standard model for estimating inhalation exposure due to evaporation of volatile chemicals (*EPA/OPPT Mass Balance Model*), ChemSTEER calculates the worker exposure using the following equations:

Table 6-12. Summary of ChemSTEER Inputs for Exposure E

Parameter	Units	ChemSTEER Input
$F_{\text{mixing_factor}}$	dimensionless	Typical = 0.5 Worst Case = 0.1
$TEMP_{\text{ambient}}$	K	298
MW_{chem}	g/mol	100
$RATE_{\text{ventilation}}$	ft ³ /min	Typical = 3000 Worst Case = 500
$Q_{\text{vapor_generation}}$	g/s	6.2×10^{-5}
$RATE_{\text{breathing}}$	m ³ /hour	1.25
V_{molar}	L/mol	24.45
$TIME_{\text{exposure}}$	hours/day	0.25

$$C_{\text{chem_volumetric}} = \frac{(1.7 \times 10^5) \times TEMP_{\text{ambient}} \times Q_{\text{vapor_generation}}}{MW_{\text{chem}} \times RATE_{\text{ventilation}} \times F_{\text{mixing_factor}}} \quad \text{[Eqn. B-7]}$$

$C_{\text{chem_volumetric}} = 0.02 \text{ ppm}$ for typical and $C_{\text{chem_volumetric}} = 0.63 \text{ ppm}$ for worst case

Next, the volumetric concentration is converted to a mass concentration ($C_{\text{chem_mass}}$) by the following equation:

$$C_{\text{chem_mass}} = \frac{C_{\text{chem_volumetric}} \times MW_{\text{chem}}}{V_{\text{molar}}} \text{ [Eqn. B-9]}$$

$C_{\text{chem_mass}} = 0.08 \text{ mg/m}^3$ for typical and $C_{\text{chem_mass}} = 2.58 \text{ mg/m}^3$ for worst case

Finally, the mass concentration of the chemical and the standard default values presented in Table 5-7 for the filter media replacement activity are used to estimate the amount of inhalation exposure per worker using the following calculation:

$$EXP_{\text{inhalation}} = C_{\text{chem_mass}} \times RATE_{\text{breathing}} \times TIME_{\text{exposure}} \text{ [Eqn. B-10]}$$

$$EXP_{\text{inhalation}} = (0.08 \text{ to } 2.58) \text{ mg/m}^3 \times 1.25 \text{ m}^3/\text{hr} \times .25 \text{ hrs/site} - \text{day}$$

$$EXP_{\text{inhalation}} = 0.06 - 0.81 \text{ mg chem./day}$$

...over 250 days/year.

Dermal Exposure:

$$EXP_{\text{dermal}} = \text{up to } 3,100 \text{ mg product/incident} \times N_{\text{exp_incident}} \times F_{\text{chem_comp}} \text{ [Eqn. 5-9]}$$

$$= 3,100 \text{ mg/incident} \times \frac{1 \text{ incident}}{\text{day}} \times \frac{0.01 \text{ mg chem.}}{\text{mg prod.}}$$

$$EXP_{\text{dermal}} = \frac{31.0 \text{ mg chem.}}{\text{day}}$$

...over 250 days/year.

6.3.7 Exposure from Packaging Waterborne Coatings (Exposure F)

Ten workers are exposed during this activity.

Inhalation Exposure:

Using the vapor generation rate calculated in Release 12 and the CEB standard model for estimating inhalation exposure due to evaporation of volatile chemicals (*EPA/OPPT Mass Balance Model*), ChemSTEER calculates the worker exposure using the following equations:

Table 6-13. Summary of ChemSTEER Inputs for Exposure F

Parameter	Units	ChemSTEER Input
$F_{\text{mixing_factor}}$	dimensionless	Typical = 0.5 Worst Case = 0.1
$TEMP_{\text{ambient}}$	K	298
MW_{chem}	g/mol	100
$RATE_{\text{ventilation}}$	ft ³ /min	Typical = 3000 Worst Case = 500
$Q_{\text{vapor_generation}}$	g/s	Typical = 3.1×10^{-4} Worst Case = 6.2×10^{-4}
$RATE_{\text{breathing}}$	m ³ /hour	1.25
V_{molar}	L/mol	24.45
$TIME_{\text{exposure}}$	hours/day	8

$$C_{\text{chem_volumetric}} = \frac{(1.7 \times 10^5) \times TEMP_{\text{ambient}} \times Q_{\text{vapor_generation}}}{MW_{\text{chem}} \times RATE_{\text{ventilation}} \times F_{\text{mixing_factor}}} \quad [\text{Eqn. B-7}]$$

$$C_{\text{chem_volumetric}} = 0.10 \text{ ppm for typical and } C_{\text{chem_volumetric}} = 6.3 \text{ ppm for worst case}$$

Next, the volumetric concentration is converted to a mass concentration ($C_{\text{chem_mass}}$) by the following equation:

$$C_{\text{chem_mass}} = \frac{C_{\text{chem_volumetric}} \times MW_{\text{chem}}}{V_{\text{molar}}} \quad [\text{Eqn. B-9}]$$

$$C_{\text{chem_mass}} = 0.43 \text{ mg/m}^3 \text{ for typical and } C_{\text{chem_mass}} = 26 \text{ mg/m}^3 \text{ for worst case}$$

Finally, the mass concentration of the chemical and the standard default values presented in Table 5-7 for the waterborne product packaging activity are used to estimate the amount of inhalation exposure per worker using the following calculation:

$$EXP_{\text{inhalation}} = C_{\text{chem_mass}} \times RATE_{\text{breathing}} \times TIME_{\text{exposure}} \quad [\text{Eqn. B-10}]$$

$$EXP_{\text{inhalation}} = (0.43 \text{ to } 26) \text{ mg/m}^3 \times 1.25 \text{ m}^3/\text{hr} \times \left(\frac{36,114 \text{ containers/site - yr}}{250 \text{ days/yr} \times 20 \text{ containers/hr}} \right)$$

$$EXP_{\text{inhalation}} = 3.9 - 232.9 \text{ mg chem./worker - day}$$

...over 250 days/year.

Dermal Exposure:

$$EXP_{\text{dermal}} = Q_{\text{liquid_ski}} \times AREA_{\text{surface}} \times N_{\text{exp_incident}} \times F_{\text{chem_form}} \quad [\text{Eqn. 5-10}]$$

$$= \left[\frac{0.7 \text{ to } 2.1 \text{ mg prod.}}{\text{cm}^2 \text{ - incident}} \right] \times 840 \text{ cm}^2 \times \frac{1 \text{ incident}}{\text{day}} \times \frac{0.01 \text{ mg chem.}}{\text{mg prod.}}$$
$$\text{EXP}_{\text{dermal}} = \frac{5.9 - 17.6 \text{ mg chem.}}{\text{day}}$$

...over 250 days/year.

7.0 DATA GAPS/UNCERTAINTIES AND FUTURE WORK

This generic scenario relies on anecdotal data, industry data and information gathered from various sources to generate general facility estimates, release estimates, and exposure estimates. EPA wishes to make this generic scenario as detailed and up-to-date as possible, such that the risk-screening assessments reflect current industrial practices. This generic scenario could be improved by collecting measured data and associated information to verify or supersede the anecdotal data and information.

EPA is most interested in obtaining information about the waterborne coatings industry that is characterized as “typical” or “conservative” (i.e., worse case), and is applicable to a generic formulation site. While EPA welcomes site-specific information as valuable to this generic scenario, additional qualifiers of how reflective it is to the industry are needed to ensure its transparency if used in the scenario. Reviewers should also feel free to recommend additional resources that may be useful to the development of this generic scenario.

The key data gaps are summarized below. Note that the data gaps are listed in order of importance (the first being most important):

1. EPA obtained the number of formulation sites and the number of production workers using the 2007 Economic Census. The 2007 Economic Census no longer provides a breakdown of the number of sites and workers by subsector. The latest data set with this breakdown was the 2002 Economic Census. To be able to use the latest data from the Economic Census, EPA made the assumption that a similar breakdown of the number of sites and workers between each type of coating in 2002 also occurred in 2007. Using this assumption, EPA was able to break down the number of sites and workers by subsector using the 2007 Economic Census data. Obtaining the actual breakdown of sites and workers from the Census Bureau can confirm whether this approach is acceptable.
2. The document assumes the facility production rate estimated from U.S. Census data for the number of U.S. formulation sites. The quality of these production rates could be improved with additional data on typical formulation site component use rates or production rates for the various types of waterborne coatings (e.g., kg/batch, kg/site-day).
3. The scenario assumes that formulators use a single component product (containing the chemical of interest) for all waterborne coatings of the same type. Additional information on the validity of these assumptions would improve the quality of the estimates. In other words, might formulators alternately use one of several available types of stabilizers when formulating a waterborne coating?

4. Additional data on the numbers of workers performing the various exposure activities in the formulation processes were limited. Additional information on the numbers workers performing each exposure activity would further enhance the calculations.
5. Specific input on the reasonableness of the default values used in the general facility estimates (e.g., batch duration, number of operating days per year) would enhance the quality of the calculations.
6. Specific data on the amount of sampling losses encountered during product quality sampling would enhance the quality of this scenario.
7. Industry-specific monitoring data for operations involving volatile liquids would enhance the estimates for vented or fugitive releases and associated worker inhalation exposures.
8. Industry-specific dermal monitoring data for all operations involving workers manually handling the components or formulated products would enhance the estimates.

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Appendix A

ESTIMATION EQUATION SUMMARY AND DEFAULT PARAMETER VALUES

Summary of Release and Exposure Estimation Equations for Formulation Sites

Table A-1 summarizes the equations introduced in Sections 3, 4, and 5 of this document. These equations may be used in evaluating releases of and exposures to chemicals used in the formulation of waterborne coatings. A description of each input variable and associated default is provided in Table A-2.

Table A-1. Waterborne Coating Formulation Release and Exposure Calculation Summary

General Facility Estimates
<p>Annual Facility Waterborne Coating Production Rate (Q_{site_yr}):</p> $Q_{site_yr} = Q_{site_prodrate} \times F_{waterborne} \quad \text{(Eqn. 3-1)}$
<p>Mass Fraction of Chemical in Waterborne Coating Formulation (F_{chem_form}):</p> $F_{chem_form} = F_{chem_comp} \times F_{comp_form} \quad \text{(Eqn. 3-2)}$
<p>Number of Formulation Sites (N_{sites}):</p> $N_{sites} = \frac{Q_{chem_yr}}{Q_{site_yr} \times F_{chem_form}} \quad \text{(Eqn. 3-3)}$ <p>The value for N_{sites}, calculated using Equation 3-3 should be rounded up to the nearest integer value. Q_{site_yr} should then be adjusted for the N_{sites} integer value (to avoid errors due to rounding):</p> $Q_{site_yr} = \frac{Q_{chem_yr}}{N_{sites} \times F_{chem_form}}$ <p>*Note: If the number of formulation sites is known, the previous equation may also be used to estimate the resulting average annual production rate for use in subsequent calculations.</p>
<p>Annual Number of Batches (batch/site-year) ($N_{bt_site_yr}$): Given the default batch size of 1,000 gallons, the annual number of batches can be calculated:</p> $N_{bt_site_yr} = \frac{Q_{site_yr}}{Q_{form_bt}} \quad \text{(Eqn. 3-4)}$ <p>To calculate the number of batches formulated per day, the following equation may be used:</p> $N_{bt_site_day} = \frac{N_{bt_site_yr}}{TIME_{working_days}} \quad \text{(Eqn. 3-5)}$

Table A-1 (Continued)

<p>Daily Use Rate of the Chemical of Interest (kg chemical/site-day) ($Q_{chem_site_day}$):</p> $Q_{chem_site_day} = \frac{Q_{site_yr} \times F_{chem_form}}{TIME_{working_days}} \quad (Eqn. 3-6)$ <p>The daily use rate can be alternatively estimated using this equation:</p> $Q_{chem_site_day} = Q_{form_bt} \times N_{bt_site_day} \times F_{chem_form}$	
<p>Annual Number of Waterborne coating component Containers Emptied per Facility (containers/site-year) ($N_{cont_empty_ite_yr}$):</p> $N_{cont_empty_site_yr} = \frac{Q_{chem_site_day} \times TIME_{working_days}}{F_{chem_comp} \times Q_{cont_empty}} \quad (Eqn. 3-7)$	
<p>Annual Number of Waterborne Product Containers Filled per Facility (containers/site-year) ($N_{cont_fill_site_yr}$):</p> $N_{cont_fill_site_yr} = \frac{Q_{chem_site_day} \times TIME_{working_days}}{F_{chem_form} \times Q_{cont_fill}} \quad (Eqn. 3-8)$	

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Table A-1 (continued)

Release Calculations		
Source	Possible Medium	Daily Release Rates (kg/site-day), Elocal (for Given Sources)
Transfer Operations (Volatile Releases)	Air	EPA/OAQPS AP-42 Loading Model (See Section 4.2)
Transfer Operations (Dust Releases)	Air Water Landfill Incineration	EPA/OPPT Generic Model to Estimate Dust Releases from Transfer/Unloading Operations of Solid Powders (See Section 4.3)
Container Residue	Water Landfill Incineration	<p>If $N_{\text{cont_empty_site_yr}}$ is fewer than $\text{TIME}_{\text{working_days}}$:</p> $\text{Elocal}_{\text{cont_reside_disp}} = Q_{\text{cont_empty}} \times F_{\text{chem_comp}} \times F_{\text{containerresidue}} \times N_{\text{cont_empty_site_day}}$ <p>... released over $[N_{\text{cont_empty_site_yr}}]$ days/year from $[N_{\text{sites}}]$ sites (Eqn. 4-3a)</p> <p>If $N_{\text{cont_empty_site_yr}}$ is greater than $\text{TIME}_{\text{working_days}}$:</p> $\text{Elocal}_{\text{cont_reside_disp}} = Q_{\text{chem_site_day}} \times F_{\text{containerresidue}}$ <p>... released over $[\text{TIME}_{\text{working_days}}]$ days/year from $[N_{\text{sites}}]$ sites (Eqn. 4-3b)</p> <p>Partition of residual wastes from on-site wastewater treatment:</p> $\text{Elocal}_{\text{water_WWT}} = \text{Elocal}_{\text{cont_reside_disp}} \times (1 - F_{\text{eff_WWT}})$ (Eqn. 4-4a) $\text{Elocal}_{\text{sludge_WWT}} = \text{Elocal}_{\text{cont_reside_disp}} \times F_{\text{eff_WWT}}$ (Eqn. 4-4b)
Container Cleaning (Volatile Releases)	Air	EPA/OPPT Penetration Model (See Section 4.5)
Process Vents (Volatile Releases)	Air	<p>EPA/OPPT Penetration Model (See Section 4.6)</p> <p>If operation occurs in an open vessel:</p> $D_{\text{opening}} = \left[\frac{4 \times V_{\text{form_bt}} \times 3785.44 \text{ (cm}^3 \text{ / gal)}}{\pi} \right]^{1/3}$ (Eqn. 4-5)
Product Sampling Wastes	Water Landfill Incineration	EPA does not currently have a model for quantifying this release.
Product Sampling (Volatile Releases)	Air	EPA/OPPT Penetration Model (See Section 4.8)

Table A-1 (Continued)

Release Calculations		
Source	Possible Medium	Daily Release Rates (kg/site-day), Elocal (for Given Sources)
Process Equipment Residue	Water Landfill Incineration	If $N_{bt_site_yr}$ or known number of cleanings is fewer than $TIME_{form_working_days}$: $E_{local_equipment_cleaning} = Q_{form_bt} \times F_{chem_form} \times N_{bt_site_day} \times F_{equipment_cleaning}$... released over $[N_{bt_site_yr}]$ days/year from $[N_{sites}]$ sites (Eqn. 4-6a)
		If $N_{bt_site_yr}$ is greater than $TIME_{working_days}$: $E_{local_equipment_cleaning} = Q_{form_chem_site_day} \times F_{equipment_cleaning}$... released over $[TIME_{working_days}]$ days/year from $[N_{sites}]$ sites (Eqn. 4-6b)
		Partition of residual wastes from on-site wastewater treatment: $E_{local_water_WWT} = E_{local_equipment_cleaning} \times (1 - F_{eff_WWT})$ (Eqn. 4-7a)
		$E_{local_sludge_WWT} = E_{local_equipment_cleaning} \times F_{eff_WWT}$ (Eqn. 4-7b)
Equipment Cleaning (Volatile Releases)	Air	EPA/OPPT Penetration Model (See Section 4.10)
Filter Media Wastes	Landfill Incineration	$E_{local_filter_residue} = Q_{chem_site_day} \times F_{filter_residue}$... released over $[TIME_{working_days}]$ days/year from $[N_{sites}]$ sites (Eqn. 4-8)
Filter Media Wastes (Volatile Releases)	Air	EPA/OPPT Penetration Model (See Section 4.12)
Packaging Operations (Volatile Releases)	Air	EPA/OAQPS AP-42 Loading Model (See Section 4.13)
Off-spec Product Wastes	Water Incineration Landfill	$N_{off-spec_days_site_yr} = \frac{N_{bt_site_yr} \times F_{off_spec}}{N_{off-spec_bt_day}}$ (Eqn. 4-9)
		$E_{local_off-spec_day} = Q_{form_bt} \times F_{chem_form}$ (Eqn. 4-10) ... released over $[N_{off-spec_days_site_yr}]$ days/year from $[N_{sites}]$ sites

Table A-1 (Continued)

Occupational Exposure Calculations
<p>Number of Workers Exposed Per Site: See Section 5.2.</p>
<p>Inhalation Exposure from Unloading Solid or Liquid Chemicals:</p> <p><i>Liquid Chemicals:</i></p> <p>EPA/OPPT Mass Balance Inhalation Model (See Section 5.3)</p> <p><i>Solid Chemicals:</i></p> $Q_{\text{comp_site_day}} = \frac{Q_{\text{chem_site_day}}}{F_{\text{chem_comp}}} \quad (\text{Eqn. 5-1})$ <p>If $Q_{\text{comp_site_day}}$ is greater than 54 kg/site-day:</p> $\text{EXP}_{\text{inhalation}} = C_{\text{particulate}} \times \text{RATE}_{\text{breathing}} \times \text{TIME}_{\text{exposure}} \times F_{\text{chem_comp}} \quad (\text{Eqn. 5-2a})$ <p style="text-align: center;">...over [the lesser of $N_{\text{bt_site_yr}}$ or $\text{TIME}_{\text{working_days}}$, up to 250] days/year</p> <p>If $Q_{\text{comp_site_day}}$ is less than or equal to 54 kg/site-day:</p> $\text{EXP}_{\text{inhalation}} = Q_{\text{comp_site_day}} \times F_{\text{chem_comp}} \times F_{\text{exposure}} \quad (\text{Eqn. 5-2b})$ <p style="text-align: center;">.....over [the lesser of $N_{\text{bt_site_yr}}$ or $\text{TIME}_{\text{working_days}}$, up to 250] days/year</p>
<p>Dermal Exposure from Unloading Solid or Liquid Chemicals:</p> <p><i>Liquid Chemicals:</i></p> $\text{EXP}_{\text{dermal}} = Q_{\text{liquid_skin}} \times \text{AREA}_{\text{surface}} \times N_{\text{exp_incident}} \times F_{\text{chem_comp}} \quad (\text{Eqn. 5-3a})$ <p style="text-align: center;">... over [the lesser of $N_{\text{bt_site_yr}}$ or $\text{TIME}_{\text{working_days}}$ (consistent with Section 4.2), up to 250] days per year</p> <p><i>Solid Chemicals:</i></p> $\text{EXP}_{\text{dermal}} = \text{up to 3,100 mg component/ incident} \times N_{\text{exp_incident}} \times F_{\text{chem_comp}} \quad (\text{Eqn. 5-3b})$ <p style="text-align: center;">... over [the lesser of $N_{\text{bt_site_yr}}$ or $\text{TIME}_{\text{working_days}}$, up to 250] days per year</p>

Table A-1 (Continued)

Occupational Exposure Calculations	
Inhalation Exposure to Solids or Liquids During Container Cleaning:	
<i>Liquid Chemicals:</i>	
EPA/OPPT Mass Balance Inhalation Model (See Section 5.4)	
<i>Solid Chemicals:</i>	
$Q_{\text{comp_residue_site_dy}} = \frac{E_{\text{local}} \text{container_residue_dtp}}{F_{\text{chem_comp}}} \quad (\text{Eqn. 5-4})$	
If $Q_{\text{comp_residue_site_day}}$ is <i>greater than</i> 54 kg/site-day:	
$\text{EXP}_{\text{inhalation}} = C_{\text{particulate}} \times \text{RATE}_{\text{breathing}} \times \text{TIME}_{\text{exposure}} \times F_{\text{chem_comp}} \quad (\text{Eqn. 5-5a})$	
... over [the lesser of $N_{\text{cont_empty_site_yr}}$ or $\text{TIME}_{\text{working_days}}$ (consistent with Section 4.4), up to 250] days per year	
If $Q_{\text{comp_residue_site_day}}$ is <i>less than or equal to</i> 54 kg/site-day:	
$\text{EXP}_{\text{inhalation}} = Q_{\text{comp_residue_site_dy}} \times F_{\text{chem_comp}} \times F_{\text{exposure}} \quad (\text{Eqn. 5-5b})$	
... over [the lesser of $N_{\text{cont_empty_site_yr}}$ or $\text{TIME}_{\text{working_days}}$ (consistent with Section 4.4), up to 250] days per year	
Dermal Exposure to Solids or Liquids During Container Cleaning:	
<i>Liquid Chemicals:</i>	
$\text{EXP}_{\text{dermal}} = Q_{\text{liquid_ski}} \times \text{AREA}_{\text{surface}} \times N_{\text{exp_incident}} \times F_{\text{chem_comp}} \quad (\text{Eqn. 5-6a})$	
... over [the lesser of $N_{\text{bt_site_yr}}$ or $\text{TIME}_{\text{working_days}}$ (consistent with Section 4.4), up to 250] days per year	
<i>Solid Chemicals:</i>	
$\text{EXP}_{\text{dermal}} = \text{up to 3,100 mg component/incident} \times N_{\text{exp_incident}} \times F_{\text{chem_comp}} \quad (\text{Eqn. 5-6b})$	
... over [the lesser of $N_{\text{cont_empty_site_yr}}$ or $\text{TIME}_{\text{working_days}}$ (consistent with Section 4.4), up to 250] days per year	
Exposure from Sampling Liquid Product:	
<i>Inhalation Exposure:</i>	
EPA/OPPT Mass Balance Inhalation Model (See Section 5.5)	
<i>Dermal Exposure:</i>	
$\text{EXP}_{\text{dermal}} = Q_{\text{liquid_ski}} \times \text{AREA}_{\text{surface}} \times N_{\text{exp_incident}} \times F_{\text{chem_form}} \quad (\text{Eqn. 5-7})$	
... over [the lesser of $N_{\text{bt_site_yr}}$ or $\text{TIME}_{\text{working_days}}$ (consistent with Section 4.8), up to 250] days per year.	
Exposure to Liquids During the Equipment Cleaning of Mixers and Other Process Equipment:	
<i>Inhalation Exposure:</i>	
EPA/OPPT Mass Balance Inhalation Model (See Section 5.8)	
<i>Dermal Exposure:</i>	
$\text{EXP}_{\text{dermal}} = Q_{\text{liquid_ski}} \times \text{AREA}_{\text{surface}} \times N_{\text{exp_incident}} \times F_{\text{chem_form}} \quad (\text{Eqn. 5-8})$	
... over [$N_{\text{bt_site_yr}}$ (consistent with Section 4.9) or $\text{TIME}_{\text{working_days}}$, up to 250] days per year.	

Table A-1 (Continued)

Occupational Exposure Calculations
<p>Exposure to Liquids During Filter Media Changeout:</p> <p><i>Inhalation Exposure:</i></p> <p>EPA/OPPT Mass Balance Inhalation Model (See Section 5.7)</p> <p><i>Dermal Exposure:</i></p> $EXP_{\text{dermal}} = \text{up to 3,100 mg product/incident} \times N_{\text{exp_incident}} \times F_{\text{chem_comp}} \quad (\text{Eqn. 5-9})$ <p>... over [the lesser of $N_{\text{bt_site_yr}}$ or $\text{TIME}_{\text{working_days}}$ (consistent with Section 4.12), up to 250] days per year.</p>
<p>Exposure from Packaging Liquid Product:</p> <p><i>Inhalation Exposure:</i></p> <p>EPA/OPPT Mass Balance Inhalation Model (See Section 5.8)</p> <p><i>Dermal Exposure:</i></p> $EXP_{\text{dermal}} = Q_{\text{liquid_stri}} \times \text{AREA}_{\text{surface}} \times N_{\text{exp_incident}} \times F_{\text{chem_form}} \quad (\text{Eqn. 5-10})$ <p>... over [the lesser of $N_{\text{cont_fill_site_yr}}$ or $\text{TIME}_{\text{working_days}}$ (consistent with Section 4.13), up to 250] days per year.</p>

Table A-2. Summary of Equation Parameter Default Values Used in the Generic Scenario

Variable	Variable Description	Default Value	Data Source
AREA _{surface}	Surface area of contact (cm ²)	840 cm ² (2 hands) 420 cm ² (1 hand)	CEB, 2000
C _{particulate}	Concentration of particulate in workers breathing zone (OSHA Total PNOR PEL (8-hr TWA) (mg/m ³))	15	29 CFR 1910.1000
F _{chem_comp}	Mass fraction of the chemical of interest in the component (kg chemical/kg component)	1	EPA assumption
F _{comp_form}	Mass fraction of the component in the formulated product (kg component/kg product)	0.45 For pigment used in a waterborne coating	See Table 2-3
F _{chem_form}	Mass fraction of the chemical in the formulated product (kg chemical/kg product)	0.45	See Table 2-3
F _{container_residue}	Fraction of component remaining in the container as residue (kg component remaining/kg component in full container)	0.03	CEB, 2002a
F _{equipment_cleaning}	Fraction of waterborne product released as residual in process equipment (kg waterborne released/kg batch capacity)	0.01	CEB, 1992a
F _{exposure}	Weight fraction of total particulate waterborne coating component or product in the workers' breathing zone (mg chemical/kg handled)	0.0477 (typical) 0.161 (worst case)	CEB, 1992b
F _{filter_residue}	Fraction of the chemical adhered to the filter and disposed as waste (kg adhered/kg processed)	0.0002	ECanada, 2003 IHWRIC, 1991 USEPA, 2006a,b
F _{off-spec}	Fraction of the annual number of batches disposed as off-spec waste (off-spec bt/annual number of batches)	0.012	ECanada 2003 IHWRIC, 1991
F _{waterborne}	Fraction of the total annual coating production rate that contains the chemical of interest.	1	EPA assumption
N _{exp_incident}	Number of exposure incidents per day (incidents/day)	1	CEB, 2000
N _{off-spec_bt_day}	Number of off-spec batches per day (off-spec bt/day)	1	EPA Assumption
Q _{form_bt}	Mass of waterborne coating formulated per batch (kg/bt)	5,030	CEB, 1994
Q _{site_yr}	Annual facility production rate (kg product/site-yr)	3,100,000 kg/yr For OEM product coating	See Table 3-2
Q _{liquid_skin}	Quantity of liquid component or product remaining on skin (mg/cm ² -incident)	0.7 (low end) 2.1 (high end)	CEB, 2000
Q _{liquid_skin} × AREA _{surface} (for solids)	Quantity of dermal exposure to solids	3,100 mg/incident	CEB, 2000
RATE _{breathing}	Typical worker breathing rate (m ³ /hr)	1.25	CEB, 1991

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Table A-2 (Continued)

Variable	Variable Description	Default Value	Data Source
RHO_{form}	Density of the waterborne coating (kg/L)	1.33	KO, 2000
$RHO_{component}$	Density of the waterborne coating component (kg/L)	1	EPA assumption
$TIME_{working\ days}$	Days of operation for formulation sites	250	CEB, 1992a
V_{cont_fill}	Volume of waterborne coating per filled container (L/container)	276.9 (55-gallon drum)	See Section 3.10
V_{cont_empty}	Volume of waterborne coating component per container (L/container)	208 (55-gallon drum)	EPA assumption

Appendix B

**BACKGROUND INFORMATION AND EQUATIONS/DEFAULTS FOR THE
STANDARD EPA ENVIRONMENTAL RELEASE AND WORKER EXPOSURE
MODELS**

B.1. INTRODUCTION

This appendix provides background information and a discussion of the equations, variables, and default assumptions for each of the standard release and exposure models used by EPA in estimating environmental releases and worker exposures. The models described in this appendix are organized into the following five sections:

- Section B.2: Chemical Vapor Releases & Associated Inhalation Exposures;
- Section B.3: Container Residue Release Models (non-air);
- Section B.4: Process Equipment Residue Release Models (non-air);
- Section B.5: Dust Emissions from Transferring Solids Model;
- Section B.6: Chemical Particle Inhalation Exposure Models; and
- Section B.7: Dermal Exposure Models.

Please refer to the guidance provided in the scenario for estimating environmental releases and worker exposures using these standard models, as it may suggest the use of certain overriding default assumptions to be used in place of those described for each model within this appendix.

This appendix includes a list of the key reference documents that provide the background and rationale for each of the models discussed. These references may be viewed in their entirety through the ChemSTEER Help System. To download and install the latest version of the ChemSTEER software and Help System, please visit the following EPA web site:

<http://www.epa.gov/opptintr/exposure/docs/chemsteer.htm>

B.2. CHEMICAL VAPOR RELEASES & ASSOCIATED INHALATION EXPOSURES

This section discusses the models used by EPA to estimate chemical vapor generation rates and the resulting volatile releases to air and worker inhalation exposures to that chemical vapor. The volatile air release models (discussed in B.2.1) calculate both a vapor generation rate ($Q_{\text{vapor_generation}}$; g/sec) and the resulting daily release rate of the chemical vapors to air. The *EPA/OPPT Mass Balance Inhalation Model* (discussed in Section B.2.2) uses the value of $Q_{\text{vapor_generation}}$, calculated by the appropriate release model, to estimate the resulting inhalation exposure to that released vapor.

B.2.1 Vapor Generation Rate and Volatile Air Release Models

The following models utilize a series of equations and default values to calculate a chemical vapor generation rate ($Q_{\text{vapor_generation}}$; g/sec) and the resulting daily volatile air release rate ($E_{\text{local_air}}$; kg/site-day):

- *EPA/OPPT Penetration Model* – evaporative releases from an exposed liquid surface located indoors;
- *EPA/OPPT Mass Transfer Coefficient Model* – evaporative releases from an exposed liquid surface located outdoors; and
- *EPA/OAQPS AP-42 Loading Model* – releases of volatile chemical contained in air that is displaced from a container being filled.

Each of these models is described in greater detail in the following sections:

B.2.1.1 EPA/OPPT Penetration Model

Model Description and Rationale:

The *EPA/OPPT Penetration Model* estimates releases to air from evaporation of a chemical from an open, exposed liquid surface. This model is appropriate for determining volatile releases from activities that are performed *indoors*¹¹ or when air velocities are expected to be *less than or equal to 100 feet per minute*.

A draft paper (Arnold and Engel, 1999) evaluating the relative performance of this model and the *Mass Transfer Coefficient Model* against experimentally measured evaporation rates described laminar airflow conditions existing up to 100 feet per minute. The paper compared the *Penetration Model* to experimental evaporation rate data measured under laminar (less than 100 feet per minute) and turbulent (above 100 feet per minute) airflow conditions. While the *Penetration Model* did not provide accurate estimates of evaporation rates under turbulent air flow conditions (relative to the *Mass Transfer Coefficient Model*), the results modeled under laminar flow conditions were found to more closely approximate the experimental data (usually within 20 percent). It is assumed that the conditions of an indoor work area most closely approximate laminar airflow conditions.

The model was originally developed using Fick's second law of diffusion. Model results were tested against experimental results of a study on evaporation rates for 15 compounds studied at different air velocities and temperatures in a test chamber. The experimental data confirmed the utility and accuracy of the model equation. Sample activities in which the *Penetration Model* may be used to estimate volatile releases to air are sampling liquids and cleaning liquid residuals from smaller transport containers (e.g., drums, bottles, pails).

¹¹Similar air releases from surfaces located at *outdoor* locations (air speeds > 100 ft/min) are calculated using the *Mass Transfer Coefficient Model* (see the description provided in this section of Appendix B).

Model Equations:

The model first calculates the average vapor generation rate of the chemical from the exposed liquid surface using the following equation:

$$Q_{\text{vapor_generation}} = \frac{(8.24 \times 10^{-8}) \times MW_{\text{chem}}^{0.835} \times F_{\text{correction_factor}} \times VP_{\text{chem}} \times \left(\frac{1}{29} + \frac{1}{MW_{\text{chem}}} \right)^{0.25} \times RATE_{\text{air_speed}}^{0.5} \times AREA_{\text{opening}}}{TEMP_{\text{ambient}}^{0.05} \times D_{\text{opening}}^{0.5} \times P_{\text{ambient}}^{0.5}} \quad [\text{B-1}]$$

Where:

- $Q_{\text{vapor_generation}}$ = Average vapor generation rate (g of chemical/sec)
 - MW_{chem} = Molecular weight of the chemical of interest (g/mol)
 - $F_{\text{correction_factor}}$ = Vapor pressure correction factor (EPA default = 1)¹²
 - VP_{chem} = Vapor pressure of the chemical of interest (torr)
 - $RATE_{\text{air_speed}}$ = Air speed (EPA default = 100 feet/min; value must be \leq 100 feet/min for this model)
 - $AREA_{\text{opening}}$ = Surface area of the static pool or opening (cm²;
 $B \times D_{\text{opening}}^2 / 4$)
 - $TEMP_{\text{ambient}}$ = Ambient temperature (EPA default = 298 K)
 - D_{opening} = Diameter of the static pool or opening (cm; See Table B-1 for appropriate EPA default values)
 - P_{ambient} = Ambient pressure (EPA default = 1 atm)
- Note: The factor 8.24×10^{-8} in Equation B-1 accounts for various unit conversions. See Arnold and Engel, 1999, for the derivation of this constant.

Using the vapor generation rate ($Q_{\text{vapor_generation}}$) calculated in Equation B-1, the model then estimates the daily release to air for the activity using the following equation:

$$E_{\text{local_air}} = Q_{\text{vapor_generation}} \times TIME_{\text{activity_hours}} \times \frac{3600 \text{ sec/hour}}{1000 \text{ g/kg}} \quad [\text{B-2}]$$

Where:

- $E_{\text{local_air}}$ = Daily release of the chemical vapor to air from the activity (kg/site-day)
- $Q_{\text{vapor_generation}}$ = Average vapor generation rate (g of chemical/sec; see Equation B-1)
- $TIME_{\text{activity_hours}}$ = Operating hours for the release activity per day (hours/site-day; See Table B-1 for appropriate EPA default values)

¹²The default vapor pressure correction factor, $F_{\text{correction_factor}}$, assumes that the chemical-containing material in the evaporating pool exhibits the vapor pressure of the chemical of interest, as a worst case (i.e., effective VP of the evaporating material = $F_{\text{correction_factor}} \times VP_{\text{chem}}$). Alternatively, Raoult's Law may be assumed (i.e., effective VP = mole fraction of the chemical in the material $\times VP_{\text{chem}}$), thus the $F_{\text{correction_factor}}$ may be set equivalent to the chemical's mole fraction in the material, if known. Note: in the absence of more detailed data, the chemical's weight fraction within the material formulation may be used to approximate its mole fraction.

References:

Arnold, F.C. and Engel, A.J. Pre-publication draft article entitled, *Evaporation of Pure Liquids from Open Surfaces*. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, Washington DC. October 1999.

U.S. EPA. Chemical Engineering Branch. *CEB Manual for the Preparation of Engineering Assessment*, Volume 1 (Equation 4-24 and Appendix K). U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, Washington DC. Contract No. 68-D8-0112. February 1991.

B.2.1.2 EPA/OPPT Mass Transfer Coefficient Model

Model Description and Rationale:

The *EPA/OPPT Mass Transfer Model* estimates releases to air from the evaporation of a chemical from an open, exposed liquid surface. This model is appropriate for determining this type of volatile release from activities that are performed *outdoors*¹³ or when air velocities are expected to be *greater than 100 feet per minute*. A draft paper (Arnold and Engel, 1999) evaluating the relative performance of this and the *Penetration Model* against experimentally measured evaporation rates, described laminar airflow conditions existing up to 100 feet per minute. It is assumed that the conditions of an indoor process area most closely approximate laminar air flow conditions, while outdoor conditions approximate turbulent airflow conditions above 100 feet per minute.

As discussed in the draft paper, the model is predicated on the solution of the classical mass transfer coefficient model with the gas-phase mass transfer coefficient estimated by the correlation of Mackay and Matsugu. Results were tested against experimental results on 19 compounds generated by four different experimenters over a wide range of experimental conditions. While the *Mass Transfer Coefficient Model* matched the data well (usually within 20 percent), it was found that the *Penetration Model* (see description in previous section) outperformed the *Mass Transfer Coefficient Model* under laminar flow (i.e., “indoor”) conditions. Therefore, the *Penetration Model* is used as a default for estimating indoor evaporation rates, while the *Mass Transfer Coefficient Model* is used for outdoor rates. Sample activities in which the *Mass Transfer Coefficient Model* may be used to estimate volatile releases to air are cleaning liquid residuals from process equipment and bulk transport containers (e.g., tank trucks, rail cars).

¹³Similar air releases from surfaces located at *indoor* locations (air speeds \leq 100 ft/min) are calculated using the *Penetration Model* (see the description provided in this section of Appendix B).

Model Equations:

The model first calculates the average vapor generation rate of the chemical from the shallow pool using the following equation:

$$Q_{\text{vapor_generation}} = \frac{(1.93 \times 10^{-7}) \times MW_{\text{chem}}^{0.78} \times F_{\text{correction_factor}} \times VP_{\text{chem}} \times \left(\frac{1}{29} + \frac{1}{MW_{\text{chem}}} \right)^{0.33} \times RATE_{\text{air_speed}}^{0.78} \times AREA_{\text{opening}}}{TEMP_{\text{ambient}}^{0.4} \times D_{\text{opening}}^{0.11} \times (TEMP_{\text{ambient}}^{0.5} - 5.87)^{2/3}} \quad \text{[B-3]}$$

Where:

$Q_{\text{vapor_generation}}$	=	Average vapor generation rate (g of chemical of interest/sec)
MW_{chem}	=	Molecular weight of the chemical of interest (g/mol)
$F_{\text{correction_factor}}$	=	Vapor pressure correction factor (EPA default = 1) ¹⁴
VP_{chem}	=	Vapor pressure of the chemical of interest (torr)
$RATE_{\text{air_speed}}$	=	Air speed (EPA default = 440 feet/min; value must be > 100 feet/min for this model)
$AREA_{\text{opening}}$	=	Surface area of the static pool or opening (cm ² ; $B \times D_{\text{opening}}^2 / 4$)
$TEMP_{\text{ambient}}$	=	Ambient temperature (EPA default = 298 K)
D_{opening}	=	Diameter of the static pool or opening (cm; See Table B-1 for appropriate EPA default values)

Note: The factor 1.93×10^{-7} in Equation B-3 accounts for various unit conversions. See Arnold and Engel, 1999, for the derivation of this constant.

Using the vapor generation rate ($Q_{\text{vapor_generation}}$) calculated in Equation B-3, the model then estimates the daily release to air for the activity using the following equation:

$$E_{\text{local_air}} = Q_{\text{vapor_generation}} \times TIME_{\text{activity_hours}} \times \frac{3600 \text{ sec/hour}}{1000 \text{ g/kg}} \quad \text{[B-4]}$$

Where:

$E_{\text{local_air}}$	=	Daily release of the chemical vapor to air from the activity (kg/site-day)
$Q_{\text{vapor_generation}}$	=	Average vapor generation rate (g of chemical/sec; see Equation B-3)
$TIME_{\text{activity_hours}}$	=	Operating hours for the release activity per day (hours/site-day; See Table B-1 for appropriate EPA default values)

¹⁴The default vapor pressure correction factor, $F_{\text{correction_factor}}$, assumes that the chemical-containing material in the evaporating pool exhibits the vapor pressure of the chemical of interest, as a worst case (i.e., effective VP of the evaporating material = $F_{\text{correction_factor}} \times VP_{\text{chem}}$). Alternatively, Raoult's Law may be assumed (i.e., effective VP = mole fraction of the chemical in the material $\times VP_{\text{chem}}$), thus the $F_{\text{correction_factor}}$ may be set equivalent to the chemical's mole fraction in the material, if known. Note: in the absence of more detailed data, the chemical's weight fraction within the material formulation may be used to approximate its mole fraction.

References:

Arnold, F.C. and Engel, A.J. Pre-publication draft article entitled, *Evaporation of Pure Liquids from Open Surfaces*. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, Washington DC. October 1999.

U.S. EPA. Chemical Engineering Branch. *CEB Manual for the Preparation of Engineering Assessment*, Volume 1. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, Washington DC. Contract No. 68-D8-0112. February 1991.

B.2.1.3 EPA/OAQPS AP-42 Loading Model

Model Description and Rationale:

The EPA’s Office of Air Quality Planning and Standards (OAQPS) *AP-42 Loading Model* estimates releases to air from the displacement of air containing chemical vapor as a container/vessel is filled with a liquid. This model assumes that the rate of evaporation is negligible compared to the vapor loss from the displacement.

This model is used as the default for estimating volatile air releases during both loading activities and unloading activities. This model is used for unloading activities because it is assumed while one vessel is being unloaded another is assumed to be loaded. The *EPA/OAQPS AP-42 Loading Model* is used because it provides a more conservative estimate than either the *EPA/OPPT Penetration Model* or the *Mass Transfer Coefficient Model* for unloading activities.

Model Equations:

The model first calculates the average vapor generation rate of the chemical from the displacement during loading/filling operation using the following equation:

$$Q_{\text{vapor_generation}} = \frac{F_{\text{saturation_factor}} \times MW_{\text{chem}} \times \left(V_{\text{cont_empty}} \times \frac{3785.4 \text{ cm}^3}{\text{gal}} \right) \times \left(\frac{\text{RATE}_{\text{fill}}}{3600 \text{ sec/hour}} \right) \times F_{\text{correction_factor}} \times \left(\frac{VP_{\text{chem}}}{760 \text{ torr/atm}} \right)}{R \times \text{TEMP}_{\text{ambient}}} \quad [\text{B-5}]$$

Where:

- | | | |
|---------------------------------|---|-------------------------------------------------------------------------------------|
| $Q_{\text{vapor_generation}}$ | = | Average vapor generation rate (g of chemical/sec) |
| $F_{\text{saturation_factor}}$ | = | Saturation factor (See Table B-1 for appropriate EPA default values) |
| MW_{chem} | = | Molecular weight of the chemical of interest (g/mol) |
| $V_{\text{cont_empty}}$ | = | Volume of the container (gallons; see Table B-1 for appropriate EPA default values) |
| $\text{RATE}_{\text{fill}}$ | = | Fill rate (containers/hour; see Table B-1 for appropriate EPA default values) |

$F_{\text{correction_factor}}$	=	Vapor pressure correction factor (EPA default =1) ¹⁵
VP_{chem}	=	Vapor pressure of the chemical of interest (torr)
R	=	Universal Gas Constant (82.05 atm-cm ³ /mol-K)
$TEMP_{\text{ambient}}$	=	Ambient temperature (EPA default = 298 K)

Using the vapor generation rate ($Q_{\text{vapor_generation}}$) calculated in Equation B-5, the model then estimates the daily release to air for the activity using the following equation:

$$E_{\text{local_air}} = Q_{\text{vapor_generation}} \times \text{TIME}_{\text{activity_hours}} \times \frac{3600 \text{ sec/hour}}{1000 \text{ g/kg}} \quad [\text{B-6}]$$

Where:

$E_{\text{local_air}}$	=	Daily release of the chemical vapor to air from the activity (kg/site-day)
$Q_{\text{vapor_generation}}$	=	Average vapor generation rate (g of chemical/sec; see Equation B-5)
$\text{TIME}_{\text{activity_hours}}$	=	Operating hours for the release activity per day (hours/site-day; see Table B-1 for appropriate EPA default values)

Reference:

U.S. EPA. Chemical Engineering Branch. *CEB Manual for the Preparation of Engineering Assessment*, Volume 1 (Equation 4-21). U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, Washington DC. Contract No. 68-D8-0112. February 1991.

¹⁵The default vapor pressure correction factor, $F_{\text{correction_factor}}$, assumes that the chemical-containing material in the evaporating pool exhibits the vapor pressure of the chemical of interest, as a worst case (i.e., effective VP of the evaporating material = $F_{\text{correction_factor}} \times VP_{\text{chem}}$). Alternatively, Raoult's Law may be assumed (i.e., effective VP = mole fraction of the chemical in the material $\times VP_{\text{chem}}$), thus the $F_{\text{correction_factor}}$ may be set equivalent to the chemical's mole fraction in the material, if known. Note: in the absence of more detailed data, the chemical's weight fraction within the material formulation may be used to approximate its mole fraction.

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Table B-1. Standard EPA Default Values Used in Vapor Generation Rate/Volatile Air Release Models

Activity Type (Location)	V _{cont_empty} (gallons)	D _{opening} (cm)	RATE _{fill} (containers/hour)	F _{saturation_factor}	TIME _{activity_hours} (hours/site-day)
Container-Related Activities (e.g., filling, unloading, cleaning, open surface/evaporative losses):					
Bottles (Indoors)	1 (Range: <5)	5.08 (<5,000 gals)	60	Typical: 0.5 Worst Case: 1	Number of containers handled per site-day.) RATE _{fill}
Small Containers (Indoors)	5 (Range: 5 to <20)		20		
Drums (Indoors)	55 (Range: 20 to <100)				
Totes (Indoors)	550 (Range: 100 to <1,000)				
Tank Trucks (Outdoors)	5,000 (Range: 1,000 to <10,000)	7.6 (≥5,000 gals)	2	1	
Rail Car (Outdoors)	20,000 (Range: 10,000 and up)		1		
Equipment Cleaning Activities:					
Multiple Vessels (Outdoors)	Not applicable	92	Not applicable	1	4
Single, Large Vessel (Outdoors)					1
Single, Small Vessel (Outdoors)					0.5
Sampling Activities:					
Sampling Liquids (Indoors)	Not applicable	Typical: 2.5 ^a Worst Case: 10	Not applicable	1	1

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Table B-1 (Continued)

Activity Type (Location)	V_{cont_empty} (gallons)	$D_{opening}$ (cm)	$RATE_{fill}$ (containers/hour)	$F_{saturation_factor}$	$TIME_{activity_hours}$ (hours/site-day)
Other Activities:					
Continuous Operation	If other scenario-specific activities are identified that use one of the vapor generation rate/air release models described in this section, the scenario will describe the model and provide appropriate default values for the model parameters.			1	24
Batch Operation					Lesser of: (Hours/batch × Batches/site-day) or 24

a - The "typical" diameter default value of 2.5 cm was adopted as a policy decision in 2002, which supersedes the previous default value of 7 cm shown in the 1991 U.S. EPA reference document.

B.2.2 Chemical Vapor Inhalation Model

The following sections describe the EPA standard model for estimating worker inhalation exposures to a chemical vapor, utilizing a vapor generation rate ($Q_{\text{vapor_generation}}$).

B.2.2.1 EPA/OPPT Mass Balance Model

Model Description and Rationale:

The *EPA/OPPT Mass Balance Model* estimates a worker inhalation exposure to an estimated concentration of chemical vapors within the worker's breathing zone. The model estimates the amount of chemical inhaled by a worker during an activity in which the chemical has volatilized and the airborne concentration of the chemical vapor is estimated as a function of the source vapor generation rate ($Q_{\text{vapor_generation}}$). This generation rate may be calculated using an appropriate standard EPA vapor generation model (see Equation B-1, Equation B-3, or Equation B-5) or may be an otherwise known value.

The *EPA/OPPT Mass Balance Model* also utilizes the volumetric ventilation rate within a given space and includes simplifying assumptions of steady state (i.e., a constant vapor generation rate and a constant ventilation rate) and an assumed mixing factor for non-ideal mixing of air. The default ventilation rates and mixing factors provide a typical and worst case estimate for each exposure. The airborne concentration of the chemical cannot exceed the level of saturation for the chemical.

An evaluation of the model was performed against collected monitoring data for various activities (see the 1996 AIHA article). This evaluation confirmed that the Mass Balance Model is able to conservatively predict worker inhalation exposures within one order of magnitude of actual monitoring data and is an appropriate model for screening-level estimates.

Model Equations:

The model first calculates the volumetric concentration of the chemical vapor in air using the following equation:

$$C_{\text{chem_volumetric}} = \frac{(1.7 \times 10^5) \times \text{TEMP}_{\text{ambient}} \times Q_{\text{vapor_generation}}}{\text{MW}_{\text{chem}} \times \text{RATE}_{\text{ventilatin}} \times F_{\text{mixing_factor}}} \quad [\text{B-7}]$$

Where:

$C_{\text{chem_volumetric}}$	=	Volumetric concentration of the chemical vapor in air (ppm)
$Q_{\text{vapor_generation}}$	=	Average vapor generation rate (g of chemical/sec; see Equation B-1, Equation B-3, or Equation B-5, as appropriate)
$\text{TEMP}_{\text{ambient}}$	=	Ambient temperature (EPA default = 298 K)
MW_{chem}	=	Molecular weight of the chemical of interest (g/mol)
$\text{RATE}_{\text{ventilatin}}$	=	Ventilation rate (ft ³ /min; see Table B-2 for appropriate EPA default values)

$F_{\text{mixing_factor}}$ = Mixing factor (dimensionless; see Table B-2 for appropriate EPA default values)

Note: The factor 1.7×10^5 in Equation B-7 accounts for various unit conversions. See Fehrenbacher and Hummel, 1996, for the derivation of this constant.

Note that the airborne concentration of the chemical vapor cannot exceed the saturation level of the chemical in air. Equation B-8 calculates the volumetric concentration at the saturation level based on Raoult's Law. Use the lesser value for the volumetric concentration of the chemical vapor ($C_{\text{chem_volumetric}}$) calculated in either Equation B-7 or Equation B-8 in calculating the mass concentration of the chemical of interest in the air (see Equation B-9).

$$C_{\text{chem_volumetric}} = F_{\text{correction_factor}} \times VP_{\text{chem}} \times \frac{10^6 \text{ ppm}}{P_{\text{ambient}}} \quad [\text{B-8}]$$

Where:

$C_{\text{chem_volumetric}}$ = Volumetric concentration of the chemical of interest in air (ppm)

$F_{\text{correction_factor}}$ = Vapor pressure correction factor (EPA default = 1)¹⁶

VP_{chem} = Vapor pressure of the chemical of interest (torr)

P_{ambient} = Ambient pressure (Default = 760 torr)

Note: Raoult's law calculates the airborne concentration as a mole fraction. The factor 10^6 in Equation B-8 accounts for the unit conversion from mole fraction to ppm.

The volumetric concentration of the chemical of interest in air (calculated in either Equation B-7 or Equation B-8) is converted to a mass concentration by the following equation:

$$C_{\text{chem_mass}} = \frac{C_{\text{chem_volumetric}} \times MW_{\text{chem}}}{V_{\text{molar}}} \quad [\text{B-9}]$$

Where:

$C_{\text{chem_mass}}$ = Mass concentration of the chemical vapor in air (mg/m^3)

$C_{\text{chem_volumetric}}$ = Volumetric concentration of the chemical vapor in air (ppm, see Equation B-7 or B-8, as appropriate)

MW_{chem} = Molecular weight of the chemical of interest (g/mol)

V_{molar} = Molar volume (Default = 24.45 L/mol at 25°C and 1 atm)

Assuming a constant breathing rate for each worker and an exposure duration for the activity, the inhalation exposure to the chemical vapor during that activity can be estimated using the following equation:

¹⁶The default vapor pressure correction factor, $F_{\text{correction_factor}}$, assumes that the chemical-containing material in the evaporating pool exhibits the vapor pressure of the chemical of interest, as a worst case (i.e., effective VP of the evaporating material = $F_{\text{correction_factor}} \times VP_{\text{chem}}$). Alternatively, Raoult's Law may be assumed (i.e., effective VP = mole fraction of the chemical in the material $\times VP_{\text{chem}}$), thus the $F_{\text{correction_factor}}$ may be set equivalent to the chemical's mole fraction in the material, if known. Note: in the absence of more detailed data, the chemical's weight fraction within the material formulation may be used to approximate its mole fraction.

$$EXP_{\text{inhalation}} = C_{\text{chem_mass}} \times RATE_{\text{breathing}} \times TIME_{\text{exposure}} \quad [\text{B-10}]$$

Where:

$EXP_{\text{inhalation}}$	=	Inhalation exposure to the chemical vapor per day (mg chemical/worker-day)
$C_{\text{chem_mass}}$	=	Mass concentration of the chemical vapor in air (mg/m ³ ; see Equation B-9]
$RATE_{\text{breathing}}$	=	Typical worker breathing rate (EPA default = 1.25 m ³ /hr)
$TIME_{\text{exposure}}$	=	Duration of exposure for the activity (hours/worker-day; see Table B-2 for appropriate EPA default values (≤ 8 hours/worker-day))

References:

Fehrenbacher, M.C. and Hummel, A.A.¹⁷. “Evaluation of the Mass Balance Model Used by the EPA for Estimating Inhalation Exposure to New Chemical Substances”. *American Industrial Hygiene Association Journal*. June 1996. 57: 526-536.

U.S. EPA. Chemical Engineering Branch. *CEB Manual for the Preparation of Engineering Assessment*, Volume 1 (Equation 4-21). U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, Washington DC. Contract No. 68-D8-0112. February 1991.

¹⁷Note: This reference is currently not available for viewing in the ChemSTEER Help System.

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Table B-2. Standard EPA Default Values Used in the *EPA/OPPT Mass Balance Inhalation Model*

Activity Type (Location)	V _{cont_empty} (gallons)	RATE _{fill} (containers/hour)	RATE _{air_speed} (feet/min)	RATE _{ventilation} ^a	F _{mixing_factor}	TIME _{exposure} (hours/day)
Container-Related Activities (e.g., filling, unloading, cleaning, open surface/evaporative losses):						
Bottles (Indoors)	1 Range: <5	60	100 (Indoors)	Typical: 3,000 Worst Case: 500 (Indoors)	Typical: 0.5 Worst Case: 0.1	Lesser of: (Number of containers handled per site-day)) RATE _{fill} or 8
Small Containers (Indoors)	5 Range: 5 to <20					
Drums (Indoors)	55 Range: 20 to <100					
Totes (Indoors)	550 Range: 100 to <1,000					
Tank Trucks (Outdoors)	5,000 Range: 1,000 to <10,000	2	440 (Outdoors)	Average: 237,600 Worst Case: 26,400 × (60 × RATE _{air_speed}) 5,280) ³ (Outdoors)		
Rail Car (Outdoors)	20,000 Range: 10,000 and up	1				
Equipment Cleaning Activities:						
Multiple Vessels (Outdoors)	Not applicable		440 (Outdoors)	Average: 237,600 Worst Case: 26,400 × (60 × RATE _{air_speed}) 5,280) ³ (Outdoors)	Typical: 0.5 Worst Case: 0.1	4
Single, Large Vessel (Outdoors)						1
Single, Small Vessel (Outdoors)						0.5

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Table B-2 (Continued)

Activity Type (Location)	$V_{\text{cont_empty}}$ (gallons)	$\text{RATE}_{\text{fill}}$ (containers/hour)	$\text{RATE}_{\text{air_speed}}$ (feet/min)	$\text{RATE}_{\text{ventilation}}^a$	$F_{\text{mixing_factor}}$	$\text{TIME}_{\text{exposure}}$ (hours/day)
Sampling Activities:						
Sampling Liquids (Indoors)	Not applicable		100 (Indoors)	Typical: 3,000 Worst Case: 500 (Indoors)	Typical: 0.5 Worst Case: 0.1	1
Other Activities:						
Continuous Operation	If other scenario-specific activities are identified that use one of the vapor generation rate models with the <i>Mass Balance Inhalation Model</i> described in this section, the scenario will describe the models and provide appropriate default values for the model parameters.				Typical: 0.5 Worst Case: 0.1	≤ 8
Batch Operation						

a - If the appropriate vapor generation rate model is the *EPA/OAQPS AP-42 Loading Model* (see Equation B-5) for an outdoor activity, the $\text{RATE}_{\text{air_speed}}$ should be set to 440 feet/min, as a default in determining the worst case $\text{RATE}_{\text{ventilation}}$.

B.3. CONTAINER RESIDUE RELEASE MODELS (NON-AIR)

Model Description and Rationale:

EPA has developed a series of standard models for estimating the quantity of residual chemical remaining in emptied shipping containers that is released to non-air media (e.g., water, incineration, or landfill) when the container is either rinsed or disposed. All of the residue models assume a certain portion or fraction of the chemical remains in the emptied container to be later rinsed or discarded with the empty container.

The default parameters of model are defined based upon the particular size/type of container (e.g., small containers, drums, or large bulk), as well as the physical form of the chemical residue (e.g., liquid or solid). These defaults are based upon data collected during a 1988 EPA-sponsored study of residuals in containers from which materials have been poured or pumped.

Model Equation:

All of the models discussed in this section utilize the following common equation for calculating the amount of chemical residue:

$$E_{\text{local}_{\text{container_residue_disp}}} = F_{\text{container_residue}} \times Q_{\text{total_daily_container}} \quad [\text{B-11}]$$

Where:

$E_{\text{local}_{\text{container_residue_disp}}}$	=	Daily release of the chemical residue to water, incineration, or landfill from the cleaning or disposal of empty shipping containers (kg/site-day)
$F_{\text{container_residue}}$	=	Fraction of the amount of the total chemical in the shipping container remaining in the emptied container (dimensionless; see Table B-3 for appropriate EPA default values)
$Q_{\text{total_daily_container}}$	=	Total (daily) quantity of the chemical contained in the shipping containers prior to emptying (kg of chemical/site-day; see Table B-4 for appropriate EPA default values)

Each model, however, utilizes unique default values within that equation based upon the relative size of the container and the physical form of the chemical residue. These default values are summarized in Table B-3 and Table B-4. The following models are the standard EPA models for estimating container residues:

- *EPA/OPPT Small Container Residual Model;*
- *EPA/OPPT Drum Residual Model;*
- *EPA/OPPT Bulk Transport Residual Model;* and
- *EPA/OPPT Solid Residuals in Transport Containers Model.*

The default frequency with which the container residues are released ($\text{TIME}_{\text{days_container_residue}}$, days/site-year) must be appropriately “paired” with the total daily

quantity of chemical contained in the containers ($Q_{\text{total_daily_container}}$) used in calculating the daily release. Thus, Table B-4 also contains the appropriate EPA default values for $\text{TIME}_{\text{days_container_residue}}$.

References:

U.S. EPA. Chemical Engineering Branch. Memorandum: *Standard Assumptions for PMN Assessments*. From the CEB Quality Panel to CEB Staff and Management. October 1992.

U.S. EPA. Office of Pesticides and Toxic Substances. *Releases During Cleaning of Equipment*. July 1988.

Table B-3. Standard EPA Default Values for Use in the Container Residual Release Models

Chemical Form	Container Type	V _{cont_empty} (gallons)	Model Title	F _{container_residue} ^a
Liquid	Bottle	1 Range: <5	<i>EPA/OPPT Small Container Residual Model</i>	Central Tendency: 0.003 High End: 0.006
	Small Container	5 Range: 5 to <20		
	Drum	55 Range: 20 to <100	<i>EPA/OPPT Drum Residual Model</i>	Central Tendency: 0.025 High End ^b : 0.03 (for <u>pumping</u> liquid out of the drum) Alternative defaults: Central Tendency: 0.003 High End: 0.006 (for <u>pouring</u> liquid out of the drum)
	Tote	550 Range: 100 to <1,000	<i>EPA/OPPT Bulk Transport Residual Model</i>	Central Tendency: 0.0007 High End: 0.002
	Tank Truck	5,000 Range: 1,000 to <10,000		
	Rail Car	20,000 Range: 10,000 and up		
Solid	Any	Any	<i>EPA/OPPT Solid Residuals in Transport Containers Model</i>	0.01

a - These defaults are based on the 1988 EPA study investigating container residue and summarized in the 1992 internal EPA memorandum (see *References* in this section for the citations of these sources).

b - The 1992 EPA memorandum reference document contains the previous default of 0.04 for the high-end loss fraction (F_{container_residue}) for the *Drum Residual Model*; however, this value was superseded by an internal policy decision in 2002. Per 40 CFR 261.7(b)(1) 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...is empty if...(ii) no more than 2.5 centimeters (1 inch) remain on the bottom of the container or liner or (iii)(A) no more than 3 percent 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...”. The 3 percent high-end default is consistent with the range of experimental results documented in the 1988 EPA study (see *References* in this section for a citation of this study).

Table B-4. Standard EPA Methodology for Calculating Default $Q_{\text{total_daily_container}}$ and $\text{TIME}_{\text{days_container_residue}}$ Values for Use in the Container Residual Models

Number of Containers Emptied per Day	$Q_{\text{total_daily_container}}$ (kg/site-day)	$\text{TIME}_{\text{days_container_residue}}$ (days/year)
1 or more	(Mass quantity of chemical in each container (kg/container)) × (Number of containers emptied per day)	Total number of operating days for the facility/operation
Less than 1	Mass quantity of chemical in each container (kg/container)	Total number of containers emptied per site-year

B.4. PROCESS EQUIPMENT RESIDUE RELEASE MODELS (NON-AIR)

Model Description and Rationale:

EPA has developed two standard models for estimating the quantity of residual chemical remaining in emptied process equipment that is released to non-air media (e.g., water, incineration, or landfill) when the equipment is periodically cleaned and rinsed. The residue models assume a certain portion or fraction of the chemical remains in the emptied vessels, transfer lines, and/or other equipment and is later rinsed from the equipment during cleaning operations and discharged with the waste cleaning materials to an environmental medium.

The default parameters of the model are defined based upon whether the residues are being cleaned from a *single* vessel or from *multiple* pieces of equipment. These defaults are based upon data collected during an EPA-sponsored study of residuals in process equipment from which materials have pumped or gravity-drained.

Model Equation:

The models discussed in this section utilize the following common equation for calculating the amount of chemical residue:

$$E_{\text{local}_{\text{equip_cleaning}}} = F_{\text{equip_residue}} \times Q_{\text{total_chem_capacity}} \quad [\text{B-12}]$$

Where:

$E_{\text{local}_{\text{equip_cleaning}}}$	=	Daily release of the chemical residue to water, incineration, or landfill from cleaning of empty process equipment (kg/site-day)
$F_{\text{equip_residue}}$	=	Fraction of the amount of the total chemical in the process equipment remaining in the emptied vessels, transfer lines, and/or other pieces (dimensionless; see Table B-5 for appropriate EPA default values)
$Q_{\text{equip_chem_capacity}}$	=	Total capacity of the process equipment to contain the chemical in question, prior to emptying (kg of chemical/site-day; see Table B-6 for appropriate EPA default values)

Each model, however, utilizes unique default values within that equation based upon whether the residues are cleaned from a single vessel or from multiple equipment pieces. These default values are summarized in Table B-5 and Table B-6. The following models are the standard EPA models for estimating process equipment residues:

- *EPA/OPPT Single Process Vessel Residual Model; and*
- *EPA/OPPT Multiple Process Vessel Residual Model.*

The default frequency with which the equipment residues are released ($\text{TIME}_{\text{days_equip_residue}}$, days/site-year) must be appropriately “paired” with the total capacity of the equipment to contain the chemical of interest ($Q_{\text{equip_chem_capacity}}$) used in calculating the daily

release. Thus, Table B-6 also contains the appropriate EPA default values for $TIME_{days_equip_residue}$.

References:

U.S. EPA. Chemical Engineering Branch. Memorandum: *Standard Assumptions for PMN Assessments*. From the CEB Quality Panel to CEB Staff and Management. October 1992.

U.S. EPA. Office of Pesticides and Toxic Substances. *Releases During Cleaning of Equipment*. July 1988.

Table B-5. Standard EPA Default Values for Use in the Process Equipment Residual Release Models

Model Title	$F_{\text{equip_residue}}^a$
<i>EPA/OPPT Single Process Vessel Residual Model</i>	Conservative: 0.01 (for <u>pumping</u> process materials from the vessel) *Alternative defaults: Central Tendency: 0.0007 High End to Bounding: 0.002 (alternative defaults for <u>gravity-draining</u> materials from the vessel)
<i>EPA/OPPT Multiple Process Vessel Residual Model</i>	Conservative: 0.02

a - These defaults are based on the 1988 EPA study investigating container residue and summarized in the 1992 internal EPA memorandum (see *References* in this section for the citations of these sources).

Table B-6. Standard EPA Methodology for Calculating Default $Q_{\text{equip_chem_capacity}}$ and $\text{TIME}_{\text{days_equip_residue}}$ Values for Use in the Process Equipment Residual Models

Process Type	Number of Batches per Day	$Q_{\text{equip_chem_capacity}}$ (kg/site-day)	$\text{TIME}_{\text{days_equip_residue}}$ (days/year)
Batch	1 or more	(Mass quantity of chemical in each batch (kg/batch)) × (Number of batches run per day)	Total number of operating days for the facility/operation
	Less than 1	Mass quantity of chemical in each batch (kg/batch)	Total number of batches run per site-year
Continuous	Not applicable	Daily quantity of the chemical processed in the equipment (kg/site-day)	Total number of operating days for the facility/operation

Note: Please refer to the scenario for any overriding default assumptions to those summarized above. Equipment cleaning may be performed periodically throughout the year, as opposed to the default daily or batch-wise cleaning frequencies shown above. For example, facilities may run dedicated equipment for several weeks, months, etc within a single campaign before performing equipment-cleaning activities, such that residuals remaining in the emptied are released less frequently than the standard default $\text{TIME}_{\text{days_equip_residue}}$ summarized above in Table B-6. Care should be given in defining the appropriate $Q_{\text{total_daily_container}}$ and $\text{TIME}_{\text{days_container_residue}}$ to be used in either of the standard EPA process equipment residue models.

B.5. DUST EMISSIONS FROM TRANSFERRING SOLIDS MODEL

EPA has developed the *EPA/OPPT Dust Emissions from Transferring Solids Model* to estimate the releases from dust generation during the unloading/transferring of solid powders. While there are multiple potential industrial sources of dust (e.g., grinding, crushing), the scope of this model is limited to transferring/unloading of solids. Specifically, this can be defined as activities where packaging/transport materials are opened and contents are emptied either into a feed system and conveyed or directly added into a process tank (e.g., reactor, mixing tank).

Model Description and Rationale:

The EPA/OPPT Dust Emissions from Transferring Solids Model estimates that 0.5percent of the solid powder transferred may be released from dust generation. This model is based on 13 sources, including site visit reports, Organisation for Economic Co-operation and Development (OECD) Emission Scenario Documents (ESD), EPA's AP-42 Emission Factors, and Premanufacture Notice submissions (EPA's new chemicals review program). Each source contained estimates of the quantity of solid powder that may be lost during transfers for a specific industry. The different sources contained dust loss data or loss fraction estimates from a variety of industries including paint and varnish formulation, plastic manufacturing, printing ink formulation, rubber manufacturing, and chemical manufacturing. These estimates ranged from negligible to 3percent of the transferred volume. The mean of the upper bound from each data set was 0.5percent.

Additionally, dust generation test data were reviewed. A study by Plinke, et al. investigated key parameters for developing a theoretical approach for estimating dust losses based on moisture content, particle size, drop height, and material flow (Plinke, 1995). Dust generation rates during unloading and transfers were measured for four materials. The highest measured dust generation rate was 0.5percent. These data further justified the adoption of a 0.5percent loss fraction as a conservative estimate.

For the media of release of the dust generated, most facilities utilize some type of control device(s) to collect fugitive emissions. Many facilities collect fugitive dust emissions from these operations in filters and dispose of the filters in landfills or by incineration. Wet scrubbers may also be utilized by industry. However, in some cases, uncontrolled/uncollected particulates may be small enough to travel several miles from the facility, resulting in environmental and human exposures to the chemical of interest beyond the boundaries of the site. Fugitive dust emissions may also settle to facility floors and are disposed of when floors are cleaned (water if the floors are rinsed or land or incineration if the floors are swept). Therefore, as a conservative assumption the model assumes an uncontrolled release to air, water, incineration, or landfill.

If facility-specific information states a control technology is employed, the release may be partitioned to the appropriate media. If the control technology efficiency information is not available, the *CEB Engineering Manual* may be utilized for control technology efficiencies. Table B-7 provides estimated efficiencies for common control technologies.

Table B-7. Default Control Technology Efficiencies

Control Technology	Default Control Technology Capture Efficiency (%)	Notes/Source	Default Media of Release for Controlled Release
None (default)	0	No control technology should be assumed as conservative.	N/A
Filter (such as a baghouse)	99	For particles > 1 um. CEB Engineering Manual.	Incineration or Land
Cyclone/Mechanical Collectors	80	For particles > 15 um CEB Engineering Manual.	Incineration or Land
Scrubber	Varies 95 may be assumed	Consult Table 7-1 of the CEB Engineering Manual.	Water

Model Equation:

Based on these data, the model estimates the portion of the release that is not captured or the uncontrolled release using the following equation. As a default this material is assumed released to air, water, incineration, or land.

$$E_{\text{local dust_fugitive}} = Q_{\text{transferred}} \times F_{\text{dust_generation}} \times (1 - F_{\text{dust_control}}) \quad [\text{B-13}]$$

Where:

- $E_{\text{local dust_fugitive}}$ = Daily amount not captured by control technology from transfers or unloading (kg/site-day)
- $Q_{\text{transferred}}$ = Quantity of chemical transferred per day (kg chemical/site-day)
- $F_{\text{dust_generation}}$ = Loss fraction of chemical during transfer/unloading of solid powders (Default: 0.005 kg released/kg handled)
- $F_{\text{dust_control}}$ = Control technology capture efficiency (kg captured/kg processed) (Default: If the control technology is unknown, assume capture efficiency = 0 kg captured/kg processed, see Table B-7).

The following equation estimates the portion of dust release captured by the control technology. The default media of release for this material should be selected based on the information presented in Table B-7.

$$E_{\text{local dust_captured}} = Q_{\text{transferred}} \times F_{\text{dust_generation}} \times F_{\text{dust_control}} \quad [\text{B-14}]$$

Where:

$E_{local_{dust_captured}}$	=	Daily amount captured by control technology from transfers or unloading (kg/site-day)
$Q_{transferred}$	=	Quantity of chemical transferred per day (kg chemical/site-day)
$F_{dust_generation}$	=	Loss fraction of chemical during transfer/unloading of solid powders (Default: 0.005 kg released/kg handled)
$F_{dust_control}$	=	Control technology capture efficiency (kg captured/kg processed) (Default: If the control technology is unknown, assume capture efficiency = 0 kg captured/kg processed, see Table B-7).

References:

U.S. EPA. Chemical Engineering Branch. “Generic Model to Estimate Dust Releases from Transfer/Unloading Operations of Solid Powders”. November 2006.

U.S. EPA. Chemical Engineering Branch. *CEB Manual for the Preparation of Engineering Assessment*, Volume 1 (page 4-11). U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, Washington DC. Contract No. 68-D8-0112. February 1991.

Plinke, Marc A.E., et al. “Dust Generation from Handling Powders in Industry.” *American Industrial Hygiene Association Journal*. Vol. 56: 251-257, March 1995.

B.6. CHEMICAL PARTICLE INHALATION EXPOSURE MODELS

The following EPA standard models may be used to estimate worker inhalation exposures to particles containing the chemical of interest:

- *EPA/OPPT Small Volume Solids Handling Inhalation Model*; and
- *OSHA Total Particulates Not Otherwise Regulated (PNOR) Permissible Exposure Limit (PEL)-Limiting Model*.

Each of these models is an alternative default for calculating worker inhalation exposures during the following particulate-handling activities, based upon the relative daily amount of particulate material being handled:

- Unloading and cleaning solid residuals from transport containers/vessels;
- Loading solids into transport containers/vessels; and
- Cleaning solid residuals from process equipment.

For amounts up to (and including) 54 kg/worker-shift, the *EPA/OPPT Small Volume Solids Handling Inhalation Model* is used, as it more accurately predicts worker exposures to particulates within this range than the *OSHA Total PNOR PEL-Limiting Model*. The *Small Volume Solids Handling Inhalation Model* is based on exposure monitoring data obtained for workers handling up to 54 kg of powdered material. Beyond this data-supported limit, EPA assumes that exposures within occupational work areas are maintained below the regulation-based exposure limit for “particulates, not otherwise regulated”.

The *EPA/OPPT Small Volume Solids Handling Model* is also the exclusive model used for any solids sampling activity. Each of these models is described in detail in the following sections.

B.6.1 EPA/OPPT Small Volume Solids Handling Inhalation Model

Model Description and Rationale:

The *EPA/OPPT Small Volume Solids Handling Inhalation Model* utilizes worst case and typical exposure factors to estimate the amount of chemical inhaled by a worker during handling of *small volumes*¹⁸ (i.e., ≤54 kg/worker-shift) of solid/powdered materials containing the chemical of interest. The handling of these small volumes is presumed to include scooping, weighing, and pouring of the solid materials.

The worst case and typical exposure factor data were derived from a study of dye weighing and adapted for use in situations where workers are presumed to handle small volumes of solids in a manner similar to the handling in the study. The maximum amount of dye handled in the study was 54 kg/worker-shift, so the *Small Volume Solids Handling Inhalation Model* is presumed to be valid for quantities up to and including this amount. In the absence of more specific exposure data for the particular activity, EPA uses these data to estimate inhalation exposures to solids transferred at a rate up to and including 54 kg/worker-shift. This model assumes that the exposure concentration is the same as the concentration of the chemical of interest in the airborne particulate mixture.

Note that the amount handled per worker per shift is typically unknown, because while the throughput may be known, the number of workers and the breakdown of their activities are typically unknown. For example, while two workers may together handle 100 kg of material/day, one worker may handle 90 kg of material/day and the other may only handle 10 kg of material/day. Therefore, as a conservative estimate EPA assumes that the total throughput ($Q_{\text{facility_day}}$; kg/site-day) is equal to the amount handled per worker ($Q_{\text{shift_handled}}$; kg/worker-shift), if site-specific information is not available.

Model Equation:

The model calculates the inhalation exposure to the airborne particulate chemical using the following equation:

¹⁸Worker inhalation exposures to particulates handled in amounts *greater than 54 kg/worker-shift* are calculated using the *OSHA Total PNOR PEL-Limiting Model* (see the description provided in this section of Appendix B).

$$EXP_{\text{inhalation}} = (Q_{\text{shift_handled}} \times N_{\text{shifts}}) \times F_{\text{chem}} \times F_{\text{exposure}} \quad [\text{B-15}]$$

Where:

$EXP_{\text{inhalation}}$	=	Inhalation exposure to the particulate chemical per day (mg chemical/worker-day)
$Q_{\text{shift_handled}}$	=	Quantity of the solid/particulate material containing the chemical of interest that is handled by workers each shift (kg/worker-shift; see Table B-8 for appropriate EPA default values; must be ≤ 54 kg/worker-shift for this model to be valid)
N_{shifts}^{19}	=	Number of shifts worked by each worker per day (EPA default = 1 shift/day)
F_{chem}	=	Weight fraction of the chemical of interest in the particulate material being handled in the activity (dimensionless; refer to the scenario discussion for guidance on appropriate default value)
F_{exposure}	=	Exposure factor; amount of total particulate handled that is expected to be inhaled (EPA defaults: 0.0477 mg/kg (typical) and 0.161 mg/kg (worst case))

Table B-8. Standard EPA Default Values for $Q_{\text{daily_handled}}$ in the EPA/OPPT Small Volume Solids Handling Inhalation Model

Activity Type	Default $Q_{\text{shift_handled}}^{20}$ (kg/worker-day)
Loading and Unloading Containers	Quantity of material in each container (kg/container) \times Number of containers/worker-shift
Container Cleaning	Quantity of residue in each container (kg/container) \times Number of container/worker-shift
Process-Related Activity (equipment cleaning, sampling):	
Continuous process:	Daily throughput of material / Number of shifts per day
Batch process (<1 batch per day):	Quantity of material per batch
Batch process (>1 batch per day):	Quantity of material per batch \times Number of batches per shift

References:

U.S. EPA. Chemical Engineering Branch. Generic Scenario: *Textile Dyeing*. October 15, 1992.

¹⁹Note that this value is the number of shifts worked by *each worker* per day. This value would only be greater than one if a worker worked for over eight hours in a given day.

²⁰The appropriate quantity of material handled by each worker on each day may vary from these standard CEB defaults, per the particular scenario. Be sure to consult the discussion presented in the ESD activity description in determining the most appropriate default value for $Q_{\text{daily_handled}}$.

U.S. EPA. Chemical Engineering Branch. *CEB Manual for the Preparation of Engineering Assessment*, Volume 1 (page 4-11). U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, Washington DC. Contract No. 68-D8-0112. February 1991.

U.S. EPA Economics, Exposure and Technology Division²¹. *Textile Dye Weighing Monitoring Study*. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, Washington D.C., EPA 560/5-90-009. April 1990.

B.6.2 OSHA Total PNOR PEL-Limiting Model

Model Description and Rationale:

The *OSHA Total Particulates Not Otherwise Regulated (PNOR) Permissible Exposure Limit (PEL)-Limiting Model* estimates the amount of chemical inhaled by a worker during handling of solid/powdered materials containing the chemical of interest. The estimate assumes that the worker is exposed at a level no greater than the OSHA PEL for *Particulate, Not Otherwise Regulated*, total particulate. Operations are generally expected to comply with OSHA's federal regulation regarding total particulate exposures. This model assumes that the exposure concentration is the same as the concentration of the chemical of interest in the airborne particulate mixture.

The *OSHA Total PNOR PEL-Limiting Model* is used in cases where workers are handling quantities of solid/powdered materials *in excess of 54 kg/worker-shift*²². As stated in Section B.6.1, the *Small Volume Solids Handling Model*, based on monitoring data, provides a more realistic estimate of worker inhalation exposures to smaller quantities particulate material. The data used by the *Small Volume Solids Handling Model* are supported up to and including 54 kg solid material handled per worker-shift. Beyond this amount, EPA assumes the occupational exposures are maintained below the regulatory exposure limit contained in the *OSHA Total PNOR PEL-Limiting Model*, although the exposures provided by this model are considered to be worst-case, upper-bounding estimates.

Refer to Table B-8 for the standard EPA assumptions used in determining the appropriate quantity of particulate material handled to determine the applicability of this model to a given activity.

NOTE: The OSHA Total PNOR PEL (used as the basis for the model calculations) is an 8-hour time-weighted average (TWA); therefore, *worker exposures must be assumed to occur over an 8-hour period* for the *OSHA Total PNOR PEL-Limiting Model* estimate to be valid basis for the calculated inhalation exposure estimate.

²¹Note: This reference is currently available for viewing in the ChemSTEER Help System.

²²Worker inhalation exposures to particulates handled in amounts *up to and including 54 kg/worker-shift* are calculated using the *EPA/OPPT Small Volume Handling Inhalation Model* (see the description provided in this section of Appendix B).

Model Equations:

The model first calculates the mass concentration of the airborne particulate chemical using the following equation:

$$C_{\text{chem_mass}} = C_{\text{total_mass}} \times F_{\text{chem}} \quad [\text{B-16}]$$

Where:

$C_{\text{chem_mass}}$	=	Mass concentration of the chemical in air (mg/m ³)
$C_{\text{total_mass}}$	=	Mass concentration of total particulate (containing the chemical) in air (EPA default = 15 mg/m ³ , based on the OSHA Total PNOR PEL, 8-hr TWA)
F_{chem}	=	Weight fraction of the chemical of interest in the particulate material being handled in the activity (dimensionless; refer to the scenario discussion for guidance on appropriate default value)

Similar to Equation B-10 in the *EPA/OPPT Mass Balance Inhalation Model*, the *OSHA Total PNOR PEL-Limiting Model* then uses the mass airborne concentration of the chemical ($C_{\text{mass_chem}}$) in Equation B-16, to calculate the inhalation exposure to the particulate chemical using the following equation:

$$\text{EXP}_{\text{inhalation}} = C_{\text{chem_mass}} \times \text{RATE}_{\text{breathing}} \times \text{TIME}_{\text{exposure}} \quad [\text{B-17}]$$

Where:

$\text{EXP}_{\text{inhalation}}$	=	Inhalation exposure to the airborne particulate chemical per day (mg chemical/worker-day)
$C_{\text{chem_mass}}$	=	Mass concentration of the particulate chemical in air (mg/m ³ ; see Equation B-17)
$\text{RATE}_{\text{breathing}}$	=	Typical worker breathing rate (EPA default = 1.25 m ³ /hr)
$\text{TIME}_{\text{exposure}}$	=	Duration of exposure for the activity (EPA default = 8 hours/worker-day ²³)

References:

U.S. EPA. Chemical Engineering Branch. *CEB Manual for the Preparation of Engineering Assessment*, Volume 1 (Equations 4-1 and 4-11). U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, Washington DC. Contract No. 68-D8-0112. February 1991.

²³Since the OSHA Total PNOR PEL is an 8-hr TWA, the exposure duration must be assumed as 8 hours/worker-day for the model defaults to apply.

B.7. DERMAL EXPOSURE MODELS

Model Description and Rationale:

EPA has developed a series of standard models for estimating worker dermal exposures to liquid and solid chemicals during various types of activities. All of these dermal exposure models assume a specific surface area of the skin that is contacted by a material containing the chemical of interest, as well as a specific surface density of that material in estimating the dermal exposure. The models also assume *no use of controls or gloves* to reduce the exposure. These assumptions and default parameters are defined based on the nature of the exposure (e.g., one hand or two hand, immersion in material, contact with surfaces) and are documented in the references listed in this section.

In the absence of data, the EPA/OPPT standard models for estimating dermal exposures from industrial activities described in this section can be used. The models for exposures to liquid materials are based on experimental data with liquids of varying viscosity and the amount of exposure to hands was measured for various types of contact. Similar assessments were made based on experimental data from exposure to solids.

Model Equation:

All of the standard EPA models utilize the following common equation for calculating worker dermal exposures:

$$EXP_{\text{dermal}} = AREA_{\text{surface}} \times Q_{\text{remain_skin}} \times F_{\text{chem}} \times N_{\text{event}} \quad [\text{B-18}]$$

Where:

EXP_{dermal}	=	Dermal exposure to the liquid or solid chemical per day (mg chemical/worker-day)
$AREA_{\text{surface}}$	=	Surface area of the skin that is in contact with liquid or solid material containing the chemical (cm ² ; see Table B-9 for appropriate EPA default values)
$Q_{\text{remain_skin}}$	=	Quantity of the liquid or solid material containing the chemical that remains on the skin after contact (mg/cm ² -event; see Table B-9 for appropriate EPA default values)
F_{chem}	=	Weight fraction of the chemical of interest in the material being handled in the activity (dimensionless; refer to the scenario discussion for guidance on appropriate default value)
N_{event}^{24}	=	Frequency of events for the activity (EPA default = 1 event/worker-day)

²⁴Only one contact per day ($N_{\text{event}} = 1$ event/worker-day) is assumed because $Q_{\text{remain_skin}}$, with few exceptions, is not expected to be significantly affected either by wiping excess chemical material from skin or by repeated contacts with additional chemical material (i.e., wiping excess from the skin does not remove a significant fraction of the small layer of chemical material adhering to the skin and additional contacts with the chemical material do not add a significant fraction to the layer). Exceptions to this assumption may be considered for chemicals with high volatility and/or with very high rates of absorption into the skin.

Each model, however, utilizes unique default values within that equation based upon the nature of the contact and the physical form of the chemical material. These default values are summarized in Table B-9. The following models are the standard EPA models for estimating worker dermal exposures:

- *EPA/OPPT 1-Hand Dermal Contact with Liquid Model;*
- *EPA/OPPT 2-Hand Dermal Contact with Liquid Model;*
- *EPA/OPPT 2-Hand Dermal Immersion in Liquid Model;*
- *EPA/OPPT 2-Hand Dermal Contact with Container Surfaces Model;* and
- *EPA/OPPT 2-Hand Dermal Contact with Solids Model.*

For several categories of exposure, EPA uses qualitative assessments to estimate dermal exposure. Table B-10 summarizes these categories and the resulting qualitative dermal exposure assessments.

References:

U.S. EPA. Chemical Engineering Branch. *Options for Revising CEB's Method for Screening-Level Estimates of Dermal Exposure – Final Report*. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, Washington DC. June 2000.

U.S. EPA. Chemical Engineering Branch. *CEB Manual for the Preparation of Engineering Assessment*, Volume 1. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, Washington DC. Contract No. 68-D8-0112. February 1991.

Table B-9. Standard EPA Default Values for Use in the Worker Dermal Exposure Models

Default Model	Example Activities	AREA _{surface} ^a (cm ²)	Q _{remain_skin} ^b (mg/cm ² - event)	Resulting Contact AREA _{surface} × Q _{remain_skin} (mg/event)
Physical Form: Liquids				
<i>EPA/OPPT 1-Hand Dermal Contact with Liquid Model</i>	<ul style="list-style-type: none"> Liquid sampling activities Ladling liquid/bench-scale liquid transfer 	420 (1 hand mean)	Low: 0.7 High: 2.1	Low: 290 High: 880
<i>EPA/OPPT 2-Hand Dermal Contact with Liquid Model</i>	<ul style="list-style-type: none"> Maintenance Manual cleaning of equipment and containers Filling drum with liquid Connecting transfer line 	840 (2 hand mean)	Low: 0.7 High: 2.1	Low: 590 High: 1,800
<i>EPA/OPPT 2-Hand Dermal Immersion in Liquid Model</i>	<ul style="list-style-type: none"> Handling wet surfaces Spray painting 	840 (2 hand mean)	Low: 1.3 High: 10.3	Low: 1,100 High: 8,650
Physical Form: Solids				
<i>EPA/OPPT 2-Hand Dermal Contact with Container Surfaces Model</i>	<ul style="list-style-type: none"> Handling bags of solid materials (closed or empty) 	No defaults	No defaults	< 1,100 ^c
<i>EPA/OPPT 2-Hand Dermal Contact with Solids Model</i>	<ul style="list-style-type: none"> Solid sampling activities Filling/dumping containers of powders, flakes, granules Weighing powder/scooping/mixing (i.e., dye weighing) Cleaning solid residues from process equipment Handling wet or dried material in a filtration and drying process 	No defaults	No defaults	< 3,100 ²³

a - These default values were adopted in the 2000 EPA report on screening-level dermal exposure estimates (see *References* in this section for the citations of this sources) and are the mean values for men taken from the EPA Exposure Factors Handbook, 1997.

b - These default values were adopted in the 2000 EPA report on screening-level dermal exposure estimates (see *References* in this section for the citation of this source). The report derived the selected ranges of values for liquid handling activities from: U.S. EPA. A Laboratory Method to Determine the Retention of Liquids on the Surface of Hands. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, Exposure Evaluation Division. EPA 747-R-92-003. September 1992.

c - These default values were adopted in the 2000 EPA report on screening-level dermal exposure estimates (see *References* in this section for the citation of this source). The report derived values for dermal contact for solids handling activities from: 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.

Table B-10. EPA Default Qualitative Assessments for Screening-Level Estimates of Dermal Exposure

Category	Dermal Assessment
Corrosive substances (pH>12, pH<2)	Negligible
Materials at temperatures >140°F (60°C)	Negligible
Cast Solids (e.g., molded plastic parts, extruded pellets)	Non-Quantifiable (Some surface contact may occur if manually transferred)
“Dry” surface coatings (e.g., fiber spin finishes, dried paint)	Non-Quantifiable (If manual handling is necessary and there is an indication that the material may abrade from the surface, quantify contact with fingers/palms as appropriate)
Gases/Vapors	Non-Quantifiable (Some contact may occur in the absence of protective clothing)

Source: U.S. EPA. Chemical Engineering Branch. *CEB Manual for the Preparation of Engineering Assessment*, Volume 1. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, Washington DC. Contract No. 68-D8-0112. February 1991.

Appendix C

**RATIONALE FOR THE SELECTION OF THE DEFAULT FACILITY PRODUCTION
RATE FOR EACH TYPE OF COATING IN TABLE 3-2**

This appendix provides the rationale that was used in selecting the annual facility use rate presented in Table 3-2. Facility production data were collected from the following sources:

- U.S. EPA, January 2006 Site Visits (EPA, 2006) - EPA conducted a site visit to a latex formulation plant in Frederick, MD and to an automobile refinishing coating formulation site in Front Royal, VA.
- U.S. Census Bureau, 2002 Manufacturing Industry Series (MIS) (USCB, 2002) - The 2002 MIS reports contained a breakdown of the number of establishments for the primary types of coating in the paint and coating manufacturing industry.
- U.S. Census Bureau, 2007 Manufacturing Industry Series (MIS) (USCB, 2007) - The 2007 MIS reports contained information on the total number of establishments for the paint and coating manufacturing industry.
- U.S. Census Bureau, 2010 Current Industrial Reports (CIR) (USCB, 2011) - The 2010 CIR contained the most recent information related to the production of the primary types of coating in the paint and coating manufacturing industry.
- Office of Research and Development, 1987 case studies (ORD, 1987)– This is a guidance document on waste minimization options, which was developed through assessments of two Los Angeles area paint manufacturing firms commissioned by the California Department of Health Services. The two firms’ operations, manufacturing processes, and waste generation and management practices were surveyed, and their existing and potential waste minimization options were characterized.
- Illinois Hazardous Waste Research and Information Center, 1991 site visits (IHWIC, 1991) - This report presents case studies which document site visits conducted to characterize paint related waste activities of Illinois paint manufacturers, users, and waste processing facilities. Case studies are presented for eight paint users, four paint manufacturers, and one paint related waste processing facility within Illinois. In addition, two case studies document visits to waste processing facilities outside Illinois which process significant quantities of Illinois paint related waste.
- Environment Canada, 2000-2001 site visits (ECanada, 2003) – Site visit data from five facilities, including four coatings formulators and one automobile spray coating operation, were included in this draft report outlining several release scenarios.. The products produced from the four formulators ranged from water and solvent-based coatings to ultraviolet (UV) curable coatings for wood, metal and architecture applications.

The 2007 Economic Census data did not provide a detailed breakdown of the number of establishments manufacture each type of coating (as did the 2002 Economic Census). EPA used a similar breakdown to the 2002 Economic Census to estimate the number of sites for each type of coating. The 2007 estimated number of sites for each type of coating formulation is provided in Table C-1.

Table C-2 presents an industry average of the facility production rate from the U.S. Census data for the three primary types of coatings: architectural, original equipment manufacture (OEM), and special purpose. As shown, U.S. Census data represent industry averages of total coatings production, which is calculated as the total production of coatings divided by the total number of establishments.

For example, the total facility production rate for architectural coatings was estimated using the following equation:

Total Facility Production of Architectural Coatings:
 $= 440.2 \times 10^6 \text{ gal/yr (Table 1-6)} \times 3.785 \text{ L/gal (conv.)} \times 1.33 \text{ kg/L } (\rho_L) \div 162 \text{ sites (Table 1-6)}$
 $= 13.7 \times 10^6 \text{ kg/site-yr.}$

There is uncertainty in the breakdown of waterborne versus solvent-based coatings manufactured at a facility; therefore, CEB estimated waterborne coatings production based on the overall market share for each type of coating. According to BASF, 2004, 80 percent and 35 percent of the market are waterborne for architectural and OEM coatings, respectively. CEB assumed a similar market share to OEM coatings for special purpose coatings.

Table C-1. 2007 Estimated Number of Sites by Type of Coating

Type of Coating	Total Establishments (USCB, 2002)	% of 2002 Total Establishments	Total Establishments (USCB, 2007)
Total	1,409	100%	1,369
Architectural	166	12%	162 (est.)
OEM	195	14%	190 (est.)
Special Purpose	191	14%	186 (est.)
Allied Paint Products	72	5%	70 (est.)

Table C-2. Industry Average Coating Production Rates

Type of Coating	Total Facility Production Rate of Coatings ^{a,b} ($Q_{\text{site_prod_rate}}$ in million kg/site-yr)	Total Facility Production Rate of Waterborne Coatings (million kg/site-yr)
Architectural	20.0	13.7
OEM	8.7	2.7
Special Purpose	4.6	1.6
Allied Paint Products	10.4	0

a – Facility production rates for USCB data were calculated based on the 2010 total U.S. production data for Architectural, OEM, Special Purpose Coatings, and Allied Paint Products divided by the total number of establishments reported for each type of coating (see Table 1-6).

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b – The facility production rates were provided in gallons. The density of the coating was not given and was assumed 1.33 kg/L (See Section 2.3).

Table C-2 shows individual site visit or case study data. In this table, the total facility production rate and the facility production rate of waterborne coatings were provided as part of the source data collection activities and are site-specific values. All of the data fall into the architectural and OEM coatings categories. Latex coatings are a type of architectural coating. The remaining types of coatings are considered OEM coatings.

Table C-2. Site-Specific Coatings Production Data

Type of Coating	Total Facility Production Rate of Coatings ^a , $Q_{\text{site_prod_rate}}$ (million kg/site-yr)	Total Facility Production Rate of Waterborne Coatings (million kg/site-yr)	Source
Latex	12.1 ^b	12.1	January 2006 site visit USEPA, 2006
Latex	42.8 ^b	34.2	1987 case study ORD, 1990
Latex (interior and exterior)	12.6 ^b	12.6	1991 site visit IHWRIC, 1991
Latex (interior and exterior)	35.2 ^b	35.2	October 1991 site visit IHWRIC, 1991
Range for Architectural Coatings	Range: 12.1 – 42.8 Median: 23.9 Mean: 25.7	Range: 12.1 – 35.2 Median: 23.4 Mean: 23.5	
Automotive	29.6 ^c	14.8	August 2000 site visit ECanada, 2003
Wood	12.5 ^c	0.6	January 2001 site visit ECanada, 2003
Wood and Metal	4.7 ^c	3.0	February 2001 site visit ECanada, 2003
Metal	8.4 ^c	0.8	May 1991 site visit IHWRIC, 1991
Industrial (pigmented emulsions)	1.8 ^b	0.2	1987 case study ORD, 1990
Industrial (clear emulsions)	6.1 ^b	0.6	1987 case study ORD, 1990
Industrial (general)	8.8 ^b	0.9	May 1991 site visit IHWRIC, 1991
Industrial (general)	1.2 ^c	NA	March 1991 site visit IHWRIC, 1991
Range for OEM coatings	Range: 1.2 – 29.6 Median: 7.4 Mean: 9.1	Range: 0.2 – 14.8 Median: 0.8 Mean: 3.0	

a – Production rate (in kg-site/year) = Production rate (in gallons/yr) x 3.785 L/gallon x Density (kg/L).

b – The facility production rates were provided in gallons. The density of the coating was not given and was assumed 1.33 kg/L (See Section 2.3).

c – The facility production rates were provided in gallons. The density of the coating was given by the facility and used to convert to kilograms per year.

Averages for the total facility production rate of coatings from Table C-2 are comparable to the industry averages shown in Table C-1. Industry averages are not available for waterborne coating production data; however, based on the market shares for waterborne coatings presented in literature, the estimated waterborne facility production rate can be calculated. Site-specific production data for waterborne coatings are comparable to the estimated waterborne production using Census data.

Table 3-2 presents the EPA defaults for waterborne coating production based on Census data that should be used in the exposure assessment if site-specific information is not available. Census

data are most representative of the overall industry (rather than a select number of sites) and would limit the amount of bias in the estimated facility production rates for waterborne coatings.

Table 3-2. EPA Defaults for Waterborne Coating Production Rates

Type of Coating	Facility Production Rate of Waterborne Coatings^{a,b} (million kg/yr)
Architectural	13.7
Original Equipment Manufacture (OEM)	2.7
Special Purpose	1.6

a – Facility production rates for USCB data were calculated based on the 2010 total U.S. production data for Architectural, OEM, and Special Purpose Coatings divided by the total number of establishments reported for each type of coating (see Table 1-6).

b – The facility production rates were provided in gallons. The density of the coating was not given and was assumed 1.33 kg/L (See Section 2.3).

APPENDIX D

RATIONALE FOR THE SELECTION OF THE EPA DEFAULT NUMBER OF WORKERS FOR EACH TYPE OF COATING IN TABLE 5-2 AND THE METHODOLOGY FOR THE DETERMINATION OF THE DEFAULT NUMBER OF WORKERS FOR EACH WORKER ACTIVITY IN TABLE 5-4

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This appendix details the rationale that was used in selecting the default number of workers in Table 5-2. Number of workers data was collected from the same sources as presented in Appendix C. The 2007 Economic Census data did not provide a detailed breakdown of the number of production workers involved in the formulation of each type of coating (as did the 2002 Economic Census). EPA used a similar breakdown to the 2002 Economic Census to estimate the number of production workers involved with each type of coating formulation. The 2007 estimated number of workers for each type of coating formulation is provided in Table D-1.

Table D-1 presents an industry average of the number of workers from the 2002 U.S. Census data for the three primary types of coatings. As shown, U.S. Census data represent industry averages of the number of workers per facility, which is calculated as the total number of production workers divided by the total number of establishments. Table D-2 shows individual site visit or case study data. In this table, the number of workers is site-specific values. Due to the variability of the data collected, it is uncertain whether the site-specific data are representative of the industry as a whole. Therefore, industry averages based on Census data should be used if information is not available.

Table D-1. 2007 Estimated Industry Average Number of Workers

Type of Coating	Total Number of Production Workers (USCB, 2002)	% of 2002 Total Production Workers	Total Number of Product Workers (USCB, 2007)	Total Establishments (USCB, 2007) (see Table C-1)	Average Number of Production Workers per Facility
Total	25,176	100%	23,874	1,369	
Architectural	6,825	27%	6,473 (est.)	162 (est.)	40e
OEM	7,538	30%	7,149 (est.)	190 (est.)	38
Special Purpose	4,856	19%	4,605 (est.)	186 (est.)	25
Allied Paint Products	1,641	7%	1,557 (est.)	70 (est.)	23

Table D-2. Site-Specific Number of Workers Data

Type of Coating	Number of Production Workers per Facility	Source
Latex	7	January 2006 site visit USEPA, 2006
Latex	20 ^a	1991 site visit IHWRIC, 1991
Latex (interior and exterior)	50 ^a	October 1991 site visit IHWRIC, 1991
Latex (interior and exterior)	6 ^{a,b}	January 2001 site visit ECanada, 2003
<i>Range for architectural coatings</i>	<i>Range: 6 – 50 Median: 14 Mean: 27</i>	
Automotive	45	January 2006 site visit EPA, 2006
Wood	150 ^{a,b}	January 2001 site visit ECanada, 2003
Wood and Metal	75 ^{a,b}	February 2001 site visit ECanada, 2003

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Metal	25 ^{a,b}	May 1991 site visit IHWRIC, 1991
Industrial (general)	56 ^{a,b}	May 1991 site visit IHWRIC, 1991
Industrial (general)	19 ^{a,b}	March 1991 site visit IHWRIC, 1991
Range for OEM coatings	Range: 19 – 150 Median: 51 Mean: 59	

a – The total number of workers employed at the plant may include workers that do not directly handle the waterborne coating containing the chemical of interest.

b – The total number of workers employed includes workers that operate non-waterborne formulation processes.

The methodology for determining the distribution of the number of workers for each worker activity is based on data collected during two 2006 EPA site visits. A breakdown of workers for each activity was provided for an architectural coating and an OEM coating facility. Table D-3 presents the breakdown of workers for each of these coating facilities. The breakdown for each facility only represents 7 workers and 45 workers for each site.

Table D-3. Site-Specific Breakdown of Production Workers by Activity

Activity	Number of Production Workers Observed per Activity	% of Total Number of Production Workers per Activity
Architectural	7	100
Raw material handling	2	28.6
Monitoring and sampling	1	14.3
Product loading	3	42.9
Warehousing	1	14.3
Product OEM	45	100
Raw material handling	4	8.9
Pigment Dispersion	3	6.7
Blending and product loading	12	26.7
Sampling	10	22.2
Maintenance	4	8.9
Warehousing	12	26.7

Source: EPA, 2006

Based on the percentages of the overall number of workers for each coating type and each activity, a similar breakdown was calculated for the default number of workers presented in Table D-1. Table D-4 presents the EPA defaults for the number of workers for each activity. Where possible, the percentages calculated in Table D-3 were used to determine the number of workers for each activity identified in Section 5 of the generic scenario. For exposure activities that were not explicitly identified during the site visits, the remaining percentage of workers were evenly distributed among those exposure activities in Table D-4. Because site-specific data were not provided for facilities manufacturing special purpose coatings, EPA assumed that the distribution of workers for each activity was equivalent to OEM coating facilities.

Table D-8-1. EPA Defaults for Breakdown of Production Workers by Activity

Activity	Number of Production Workers Observed per Activity	% of Total Number of Production Workers per Activity
Architectural	40	100
Unloading solid/liquid chemicals (Exposure A)	11	28.6
Cleaning of transport containers (Exposure B) ^a	2	-
Sampling product (Exposure C)	6	14.3
Cleaning of process equipment (Exposure D) ^a	2	-
Replacing spent filter media (Exposure E) ^a	1	-
Loading liquid coating (Exposure F)	18	42.9
Product OEM	38	100
Unloading solid/liquid chemicals (Exposure A)	3	8.9
Cleaning of transport containers (Exposure B) ^a	6	-
Sampling product (Exposure C)	8	22.2
Cleaning of process equipment (Exposure D) ^a	6	-
Replacing spent filter media (Exposure E) ^a	5e	-
Loading liquid coating (Exposure F)	10	26.7
Special Purpose	25	100
Unloading solid/liquid chemicals (Exposure A)	2	8.9
Cleaning of transport containers (Exposure B) ^a	4	-
Sampling product (Exposure C)	5	22.2
Cleaning of process equipment (Exposure D) ^a	4	-
Replacing spent filter media (Exposure E) ^a	3	-
Loading liquid coating (Exposure F)	7	26.7

a – Site-specific data on the percentage of production workers involved with these activities were not found. The calculated percentages for the other known activities were applied (i.e., unloading, sampling, loading) and the remaining number of workers were divided among the three unknown activities (i.e. container cleaning, equipment cleaning, and filter media change out).