



Use of Additives in the Thermoplastic
Converting Industry-
Generic Scenario for Estimating Occupational
Exposures and Environmental Releases
-Draft-

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Explanatory Notes

Purpose and background

This Generic Scenario (GS) is intended to provide information on the sources, use patterns, and potential environmental release and occupational exposure pathways of additives used in the conversion of compounded plastic resins into finished products. The reader should note that this document does not cover the compounding of additives into plastic resins. Compounding is covered separately in the *Generic Scenario on the Use of Additives in the Thermoplastics Compounding Industry*. The document presents standard approaches for estimating environmental releases of and occupational exposures to chemicals used in plastics additives. 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 and occupational exposures to non-volatile chemical additives (solid or liquid) present in compounded thermoplastics during their conversion into finished products. 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.

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 plastics 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 the environmental releases and occupational exposures presented in this Generic Scenario.

The primary sources of information cited in this scenario include information published by the U.S. Census Bureau, various EPA and other government sources (e.g., CEB, OECD, and regional/state pollution prevention organizations), and the Kirk-Othmer Encyclopedia of Chemical Technology. Additional information on the sources investigated and the references cited in this document are presented in Section 8.

This Generic Scenario presents methods for estimating environmental releases of and occupational exposures to non-volatile chemical additives (solid or liquid) that are present during the conversion of compounded thermoplastics into finished products. For EPA new chemical assessments, volatile chemicals are considered to be those whose vapor pressures are above 0.001 torr (CEB, 2008). The volatilization of chemicals with vapor pressures below 0.001 torr, for the purposes of estimating screening-level inhalation exposures and air releases, is considered negligible (CEB, 2008).

A review of Premanufacture Notices (PMNs) submitted to EPA under section 5 of the Toxic Substances Control Act (TSCA) for chemicals used as plastics additives indicates that vapor pressures typically are below 0.001 torr. Based on a sample of 71 PMNs, 98% had vapor pressures below 0.001 torr. Only one of the reviewed PMNs was for a chemical with a vapor pressure greater than 0.001 torr.

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 GS.

PMN submissions submitted to EPA generally represent a distinct chemical substance that may be entering commerce in the United States. EPA maintains a database of the functions and uses of chemicals reviewed under the PMN program (i.e., EPA's new chemicals review program).

The scope of the Generic Scenario covers any non-volatile plastics additive chemical (solid or liquid) that is present in compounded thermoplastics resins during their conversion into finished products. These chemicals can be classified into one of several types of plastics additives such as fillers, flame retardants, plasticizers, and slip promoters. Table 1-1 provides additional examples of the types of plastics additives applicable to the scenario. These plastics additives may be present in various types of polymers (e.g., polyethylene and poly(vinyl chloride)). Table 1-2 provides additional examples of the types of polymers associated with plastics additives.

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

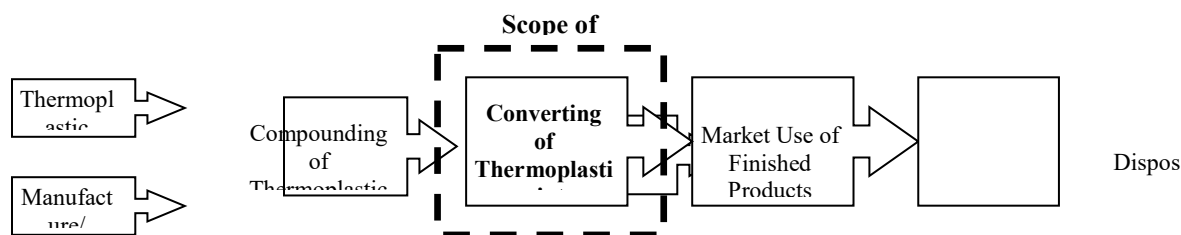


Figure 1. Scope of the GS on the Use of Additives in the Thermoplastics Converting Industry

Although plastics additives serve similar functions in both thermoplastic and thermoset polymers, the processes by which they are incorporated into finished products are not similar. For thermoplastics, additives are compounded into polymer resins, which are then converted into plastic articles in a separate process. Thermosets, on the other hand, incorporate additives during the production of the finished articles, without any preceding compounding operations. Since this GS assumes that converting sites use compounded thermoplastic resins that contain chemical additives as their process inputs, applications that do not use resins, such as thermoset plastics and foams, are outside of the GS scope.

When considering the polymer applications applicable to this GS, it is important to note that there are multiple methods for classifying polymers. One method is to classify polymers based on their chemistry of polymerization. In this method, polymers are generally classified as a step-growth polymer or a chain-growth polymer. Another method is to classify polymers based on their applications. When classifying polymers based on application method,

polymers are generally classified as shown in Figure 2 (Stevens, 1999). EPA develops Generic Scenarios with a particular application focus. Therefore, for the purposes of this GS, EPA follows the application categorization of polymers in defining the scope of this document. Since the scope of this GS only focuses on thermoplastics converting, the other polymer applications shown in Figure 2 are outside the scope of this GS.

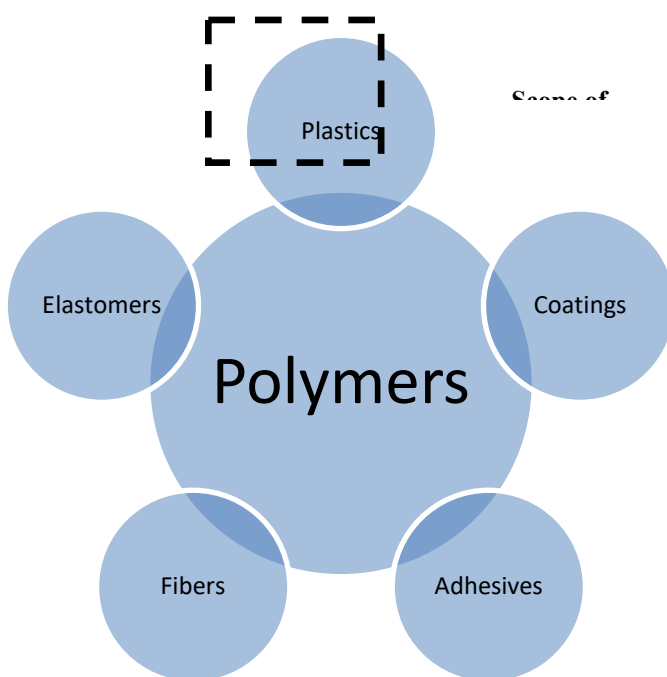


Figure 2. Polymer Applications Applicable to the Scope of the GS

This Generic Scenario presents methods that can be used to estimate the following facility operating parameters and the environmental releases from and occupational exposures to non-volatile plastics additive chemicals (solid or liquid) that are present in compounded thermoplastic resins, as used during thermoplastics converting:

- Number of sites in the United States that convert thermoplastic resins containing the chemical of interest;
- Releases to incineration or landfill from transport container residue (via container cleaning or direct disposal of empty containers);
- Releases from spillage to water, incineration, or landfill during handling of compounded resins;

- Releases of solids to air, water, incineration, or landfill during container transfers (e.g., storage bags, supersacks);
- Releases during forming and molding processes, including changing or cleaning of emission control filters (from dust and fugitive air emissions);
- Releases to water, incineration, or landfill from equipment cleaning residue and cooling water from forming and molding processes; and
- Releases to incineration or landfill from the disposal of wastes generated during trimming operations.
- Number of workers that may come into contact with the chemical of interest during converting operations;
- Inhalation exposures during container unloading;
- Inhalation exposures from dusts generated during converting processes; and
- Inhalation exposures during trimming activities.

The estimation methods in this document apply to any non-volatile plastics additive chemical (solid or liquid) that is present in compounded thermoplastic resins, regardless of its function within the compounded thermoplastic resin.

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 use of additives in the thermoplastics converting industry to support EPA's chemical review programs.

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1.0 PLASTICS CONVERTING INDUSTRY SUMMARY AND BACKGROUND

The plastics manufacturing industry can be divided into three distinct phases: manufacturing of polymers and chemical additives, compounding of polymer resins and chemical additives, and converting of the compounded plastic into finished products. Polymer manufacturers synthesize polymers. Compounders receive the polymer resins from these manufacturers and produce master batches of plastics with specific properties by blending the polymer with plastics additives (e.g., fillers, reinforcements). Converters receive the master batch of plastics from compounders and convert it into the finished plastic product. Compounding and converting can take place at the same facility (i.e., “in-house” manufacturing) or at separate facilities.

The facility throughput of plastics additives associated with converting operations will vary according to both the type of additive and the type of plastic resin blended together by compounders. Additives typically are blended with polymers to achieve desired properties of the blended plastic, and can be added during polymer production, compounding, or converting. However, it is most common for additives to be added during the compounding process in order to produce a custom “masterbatch” of compounded resin.

The following section provides an overview of the terminology used in this document, as well as background on the plastics additive industry and market. A glossary of these terms is also provided in Appendix C.

1.1 Terminology

Plastics are produced through chemical reactions in which monomers, the fundamental building blocks, react to form oligomers and polymers, as shown in Figure 1-1. Monomers covalently bond (i.e., polymerize) to form oligomers, which are a subset of polymer molecules comprising relatively few monomers. The oligomers shown in Figure 1-1 comprise two, three, or four monomers, and can be referred to as dimers, trimers, and tetramers, respectively.

It is important to note that some terms, while ubiquitous in industry, have meanings that are rather ambiguous. For example, there is no concrete definition setting oligomers and polymers apart. In fact, the International Union of Pure and Applied Chemistry (IUPAC) simply defines an oligomer as a molecule having “a small plurality of units derived...from molecules of lower relative molecular mass.” IUPAC provides an explanatory note indicating that the addition or removal of one or more units would affect the physical properties of the oligomer significantly, while it would have a negligible effect on a polymer molecule (IUPAC, 1996).

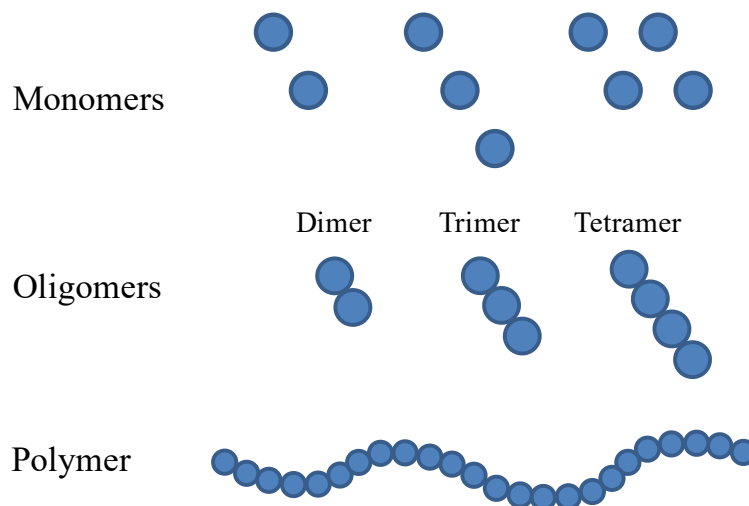


Figure 1-1. Visualizing Monomer Polymerization at the Molecular Level

1.2 Polymer Classifications

There are multiple methods for classifying polymers. One method is to classify polymers based on their chemistry of polymerization. In this method, polymers are generally classified as a step-growth polymer or a chain-growth polymer. Another method is to classify polymers based on their applications. In this application method, polymers are generally classified as one of the following (Stevens, 1999):

- *Plastics* – Polymeric formulations, including both commodity and engineering plastics, which exhibit a range of modulus (stiffness).
- *Elastomers* – Synthetic and naturally occurring rubbers, which exhibit low modulus and good resilience (ability to return to their original shape after being stretched).
- *Fibers* – Synthetic and naturally occurring fibers, which exhibit high strength and modulus, good stretchability and thermal stability.
- *Adhesives* – Polymeric substances that can bind surfaces or objects together.
- *Coatings* – Polymeric formulations that form protective or decorative films on surfaces.

A given polymer may fall into more than one category. Some examples include:

- Styrene-butadiene copolymer is an elastomer, but when formulated into an aqueous emulsion (or latex) it is used as a coating.

- Poly(ethylene terephthalate) (PET) and polyamides (such as nylon-6) are both used as both a plastic and a fiber.

EPA develops Generic Scenarios with a particular application focus. Therefore, for the purposes of this GS, EPA follows the application categorization of polymers in defining the scope of this document. The scope of this GS is focused on plastics only; the other polymer applications are not included. More specifically, the scope of this GS focuses on *thermoplastics*, which is further discussed below.

Polymer resins can be classified into the two following polymer types:

- *Thermoplastics* are melted and become fluid when heat and pressure are applied. The molten polymers are formed into finished products via pressure. Thermoplastics solidify when cooled, and the heating and cooling process can be repeated many times with little loss in properties.
- *Thermosetting plastics* (e.g., polyurethane foam, epoxy) are formed into finished products during a chemical reaction under pressure and heat. This process creates permanent cross-linking, and the product retains its shape during subsequent cooling and heating. Thermosetting polymers are not within the scope of this generic scenario and are not discussed further.

1.3 **Additives Used in Plastics Processing**

Additive components include, but are not limited to, antioxidants, antistatics, colorants, coupling agents, fillers, flame retardants, heat stabilizers, impact modifiers, lubricants, plasticizers, preservatives, slip promoters, and ultraviolet stabilizers. Table 1-1 presents an overview of several types of additives used in thermoplastics, including their function, the types of chemicals used, and the weight fraction of that additive that could be compounded into plastic resins.

The types and quantities of plastics additives present in polymer resins will depend on the desired properties for the finished article. Table 1-2 summarizes typical weight fractions of various plastics additives for several thermoplastic resins. Table 1-3 provides examples of the types of plastic articles produced from the resins in Table 1-2. For each of the listed articles, EPA also has included product categories associated with the EPA Chemical Data Reporting (CDR) program that are applicable to the scenario. Manufacturers are required to report these product categories to CDR for any chemical substances listed in the TSCA Inventory that are used in quantities that meet or exceed the program's reporting thresholds.

Table 1-1. Summary of Plastics Additives Present in Compounded Plastic Resins

Additive Type	Function	Types of Chemicals	Typical Physical State	Minimum Weight Fraction In Plastic Resin	Maximum Weight Fraction In Plastic Resin	Average Weight Fraction In Plastic Resin
Antioxidants	Inhibit the oxidation of plastic materials that are exposed to oxygen or air at normal or high temperatures.	Alkylated phenols, amines, organic phosphites and phosphates, esters	Solid powder or pellets	0.001	0.005	0.003
Antistatics	Impart a minimal to moderate degree of electrical conductivity to the plastic compound, preventing electrostatic charge accumulation on the finished product.	Quaternary ammonium compounds, anionics, amines	Solid	0.001	0.01	0.005
Colorants	Impart color to the plastic resin.	Titanium dioxides, iron oxides, anthraquinones, carbon black	Fine powder (pigments) and liquid or waxy solid (dyes)	0.01	0.2	0.04
Coupling Agent	Interface between filler and plastic, bonding with both phases to improve interfacial adhesion. Typically introduced during the treatment stage of filler manufacture.	Organometallic compounds, silanes	Low viscosity liquid or low melting point solid	0.005	0.005	0.005
Fillers	Inert materials which reduce polymer cost, improve processability, and improve mechanical properties.	Not Available	Solid (fiber or powder)	0.1	0.55	0.35
Flame Retardants	Reduce the tendency of the plastic product to burn.	Chlorinated paraffins, bromophenols, aluminum compounds, ammonium compounds, boron compounds, phosphates, phosphonates, benzenes, toluenes, xylenes, styrenes, phenols, phthalic acids derivatives	Solid	0.05	0.4	0.18

Table 1-1. Summary of Plastics Additives Present in Compounded Plastic Resins

Additive Type	Function	Types of Chemicals	Typical Physical State	Minimum Weight Fraction In Plastic Resin	Maximum Weight Fraction In Plastic Resin	Average Weight Fraction In Plastic Resin
Heat Stabilizers	Assist in maintaining the chemical and physical properties of the plastic, such as color changes, undesirable surface changes, and decreases in electrical and mechanical properties, by protecting it from the effects of heat.	Lead, barium-cadmium, tin, calcium zinc	Solid (sometimes liquid)	0.0015	0.05	0.014
Impact Modifiers	Prevent brittleness and increase the resistance of the plastic to cracking.	Natural rubber, acrylonitrile, ethylene as copolymers	Granular solid	Not Available		
Lubricants	Assist in easing the flow of the plastic in molding and extruding processes by lubricating the metal surfaces that come into contact with the plastic.	Stearic acid, waxes, fatty acid esters, fatty acid amines	Waxy solid or soft powder	0.001	0.012	0.009
Plasticizers	Increase the plastic product's flexibility and workability.	Adipates, azelates, trimellitates, DOP/DIOP/DIDP	Liquids or waxy solids (i.e., chemicals with low melting points)	0.01	0.5	0.15
Preservatives	Protects against fungi and bacteria.	Organotin, organomercury compounds	Solid	Not Available		
Slip promoters	Improve surface lubrication during processing and use.	Calcium and zinc stearates, waxes and fatty acid amines or esters	Soft powders or waxy solids	0.0005	0.25	0.13
Ultraviolet Stabilizers	Absorb or screen out ultra-violet radiation, thereby preventing premature degradation of the plastic product.	Benzophenones, benzotriazole, silicates	Solid	0.002	0.05	0.015

Sources: Environment Agency, 2003; Kirk-Othmer, 2003; OECD, 2009

Table 1-2. Typical Weight Fractions of Plastics Additives in Various Thermoplastic Resins

Additive Type	Typical Fraction of Additive in Each Type of Plastic Resin												
	LDPE	HDPE	Poly-propylene	Rigid PVC	Flexible PVC	Poly-styrene	Expanded Poly-styrene	ABS	PET	Poly-amides	Acrylics	Acetals	Poly-carbonate
Antioxidants	0.001	0.0025	0.005	0.002	-	-	-	-	-	-	-	-	-
Antistatics	0.001	0.003	-	-	-	-	-	-	-	-	-	0.01	-
Colorants	0.03	0.03	0.03	0.005-0.03	0.02	0.01	-	0.05	0.03	0.2	0.01	0.02	0.03
Coupling agents	-	-	0.005	-	-	-	-	-	-	0.005	0.005	0.005	0.005
Fillers	-	-	0.4	0.1	0.1-0.3	-	-		0.55	0.4	0.35	0.3	0.4
Flame Retardants	0.2	0.2	0.05-0.4	-	0.05	0.2	0.15	0.2	0.15	0.15-0.25	-	-	-
Heat Stabilizers	-	-	-	0.01-0.05	0.02-0.05	-	-	0.0075-0.01	-	0.005	-	0.002	0.0015-0.0025
Impact Modifiers^a	Unknown												
Lubricants	-	-	-	0.01	0.001-0.003	0.012	-	-	-	-	-	-	0.012
Plasticizers	-	-	-	-	0.3-0.45	-	-		0.05	0.01			
Preservatives^a	Unknown												
Slip promoters	0.0005	-	-	-	-	-	-	-	-	-	-	0.25	-
UV Stabilizers	-	-	0.05	0.005	-	0.005	-	0.005	0.005	0.03	0.002	0.03	0.003
Total Weight Fraction (F_{all additives_resin})	0.23	0.24	0.49	0.13-0.2	0.49-0.87	0.23	0.15	0.26-0.27	0.79	0.80-0.90	0.37	0.62	0.45
Minimum F_{all additives_resin}	0.13												
Maximum F_{all additives_resin}	0.90												
Average F_{all additives_resin}	0.44												

Source: OECD, 2009

LDPE – Low density polyethylene

HDPE – High density polyethylene

PVC – Poly(vinyl chloride)

ABS – Acrylonitrile-butadiene-styrene copolymer

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PET – Poly(ethylene terephthalate)

^a Weight fraction data were not identified for this additive type.

Table 1-3. Plastic Articles Produced from Thermoplastic Resins and Associated CDR Product Categories/Codes

Thermoplastic Resin	Plastic Articles^a	CDR Product Categories^a	CDR Product Codes^a
LDPE	Squeeze bottles	Plastic and rubber products	C303
	Toys	Toys, playground, and sporting equipment	C304
	Carrier bags	Plastic and rubber products	C303
	High frequency insulation	Building/Construction materials not covered elsewhere	C204
	Chemical tank linings	No applicable product category.	
	Heavy-duty sacks	Plastic and rubber products	C303
	General packaging	Plastic and rubber products	C303
	Gas and water pipes	Building/Construction materials not covered elsewhere	C204
HDPE	Chemical drums, jerricans, carboys	No applicable product category.	
	Toys	Toys, playground, and sporting equipment	C304
	Picnic ware	Plastic and rubber products	C303
	Household and kitchenware	Plastic and rubber products	C303
	Cable insulation	Electrical and electronic products	C205
	Carrier bags	Plastic and rubber products	C303
	Food wrapping material	Food packaging	C301
Polypropylene	Coffee pot parts	Plastic and rubber products	C303
	Washing machine parts	Electrical and electronic products	C205
	Drink vending machines	Electrical and electronic products	C205
	Microwave components	Electrical and electronic products	C205
PVC	Window frames	Building/Construction materials not covered elsewhere	C204
	Drainage pipe	Building/Construction materials not covered elsewhere	C204
	Water service pipe	Building/Construction materials not covered elsewhere	C204
	Medical devices	No applicable product category.	
	Blood storage bags	No applicable product category.	

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Thermoplastic Resin	Plastic Articles ^a	CDR Product Categories ^a	CDR Product Codes ^a
	Cable and wire insulation	Electrical and electronic products	C205
	Resilient flooring	Floor coverings	C101
	Roofing membranes	Building/Construction materials not covered elsewhere	C204
	Automotive interiors and seat coverings	No applicable product category.	
	Fashion and footwear	Plastic and rubber products	C303
	Packaging	No applicable product category.	
	Cling film	Food packaging	C301
	Credit cards	No applicable product category.	
	Synthetic leather and other coated fabrics	Fabric, Textile, and leather products not elsewhere covered	C104
Polystyrene.	Toys	Toys, playground, and sporting equipment	C304
	Rigid packaging	No applicable product category.	
	Refrigerator trays and boxes	Plastic and rubber products	C303
	Cosmetic packs	Plastic and rubber products	C303
	Costume jewelry	Plastic and rubber products	C303
	Lighting diffusers	Plastic and rubber products	C303
	Audio cassette and CD cases	Plastic and rubber products	C303
	Yogurt containers	Food packaging	C301
	Refrigerator linings	Electrical and electronic products	C205
	Vending cups	Plastic and rubber products	C303
	Bathroom cabinets	Plastic and rubber products	C303
	Toilet seats and tanks	Plastic and rubber products	C303
	Instrument control knobs	Electrical and electronic products	C205
ABS	Telephone handsets	Plastic and rubber products	C303
	Rigid luggage	Plastic and rubber products	C303
	Domestic appliance housings (e.g., food mixers)	Electrical and electronic products	C205
	Computer housings	Electrical and electronic products	C205
	Radiator grills	No applicable product category.	
PET	Automotive window wiper holders	No applicable product category.	
	Automotive exterior mirror housing	No applicable product category.	
Polyamides	Fishing line	Plastic and rubber products	C303

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Thermoplastic Resin	Plastic Articles^a	CDR Product Categories^a	CDR Product Codes^a
	Carpets	Plastic and rubber products	C303
	High-temperature food packaging	Food packaging	C301
Acrylics	Drinking tumblers	Plastic and rubber products	C303
	Lenses	Plastic and rubber products	C303
	Water jugs	Plastic and rubber products	C303
	Toothbrush handles	Plastic and rubber products	C303
	Kitchen and picnic ware	Plastic and rubber products	C303
	Radio dials	Electrical and electronic products	C205
	TV set screens	Electrical and electronic products	C205
	Washing machine trims	Electrical and electronic products	C205
Acetals	Business machine parts	Electrical and electronic products	C205
	Clock and watch parts	Plastic and rubber products	C303
	Plumbing systems	Building/Construction materials not covered elsewhere	C204
	Shoe components	Plastic and rubber products	C303
Polycarbonate	Compact discs	Plastic and rubber products	C303
	Riot shields	Plastic and rubber products	C303
	Baby feeding bottles	Plastic and rubber products	C303
	Safety helmets	Plastic and rubber products	C303
	Headlamp lenses	Plastic and rubber products	C303

Sources: BPF, no date and EPA, 2012

^a CDR product categories are based on the end use market associated with a given product. CDR does not provide any information about the products themselves. The products identified above for each CDR product category is based on supplemental research conducted by EPA. The information is not intended to be exhaustive. It is intended to provide examples of common products and associated CDR consumer product categories (based on engineering judgment).

1.4 **Market Profile**

The plastics manufacturing industry can be divided into three stages: polymer manufacturing, compounding, and converting. The compounding and converting stages typically occur at separate sites, although they also may occur at the same site. As stated previously, this document focuses on release and exposure assessments during converting operations. Therefore, polymer manufacturing and compounding operations are outside the scope of this document.

Compounders produce masterbatches of plastic resins with specific properties by blending the polymer (i.e., the plastic resin), additives, fillers, and reinforcements. Converters receive the masterbatch of plastic resin from these compounders and convert the compounded resin into finished plastic articles or products. A separate generic scenario covers the compounding of plastic resins.

The plastics converting industry comprises a subset of the North American Industrial Classification System (NAICS) industry group 3261 (Plastics Product Manufacturing). This industry group consists of establishments primarily engaged in processing new or spent (i.e., recycled) plastics resins into intermediate or final products, using processes such as compression molding, extrusion molding, injection molding, blow molding, and casting. The specific 6-digit NAICS codes that make up the plastics converting industry include:

- 326111 – Plastics Bag and Pouch Manufacturing;
- 326112 – Plastics Packaging Film and Sheet (including Laminated) Manufacturing;
- 326113 – Unlaminated Plastics Film and Sheet (except Packaging) Manufacturing;
- 326121 – Unlaminated Plastics Profile Shape Manufacturing;
- 326122 – Plastics Pipe and Pipe Fitting Manufacturing;
- 326130 – Laminated Plastics Plate, Sheet (except Packaging), and Shape Manufacturing;
- 326160 – Plastics Bottle Manufacturing;
- 326191 – Plastics Plumbing Fixture Manufacturing;
- 326192 – Resilient Floor Covering Manufacturing; and
- 326199 – All Other Plastics Product Manufacturing.

Table 1-4 summarizes U.S. Census data for the number of sites associated with the plastics converting NAICS codes. The data reflects all sites that reported the plastics converting primary NAICS code to the U.S. Census Bureau; therefore, some of the sites in this table also may conduct compounding operations in addition to converting (no NAICS code exists that is specific to sites where both compounding and converting occur).

Table 1-4. Number of Converting Sites Based on 2011 U.S. Census Data

NAICS Code	NAICS Code Description	Sites
326111	Plastics bag and pouch manufacturing	368
326112	Plastics packaging film and sheet (including laminated) manufacturing	341
326113	Unlaminated plastics film and sheet (except packaging) manufacturing	601
326121	Unlaminated plastics profile shape manufacturing	436
326122	Plastics pipe and pipe fitting manufacturing	442
326130	Laminated plastics plate, sheet (except packaging), and shape manufacturing	238
326160	Plastics bottle manufacturing	443
326191	Plastics plumbing fixture manufacturing	431
326192	Resilient floor covering manufacturing	54
326199	All other plastics product manufacturing	6,353
<i>Total Converting Sites</i>		<i>9,707</i>

Source: USCB, 2011a

Market data (Freedonia, 2013a) indicate that the demand for thermoplastic additives in the U.S. totaled approximately 1.5 billion kilograms in 2012. The market data, which are reproduced below in Table 1-5, provide historical and forecasted U.S. demand for thermoplastic additives (aggregated by resin type). Note that the market data defines “demand” as being the total U.S. production of additives including imports and exports. Table 1-5 shows that the total U.S. demand for thermoplastic additives in 2012 was 1,463 million kg, of which most (approximately 60 percent) were incorporated into poly(vinyl chloride) resins. The industry forecast expects demand to increase over the next ten years and attributes the rise to a strong rebound in construction activity, which they anticipate will generate over two thirds of new demand for plastics additives (Freedonia, 2013b).

Table 1-5. Historical and Forecasted U.S. Demand for Thermoplastic Additives by Resin Type

Resin Type	Plastics Additives (million kg)				
	2002	2007	2012	2017	2022
Poly(vinyl chloride)	1,229	1,149	862	1,104	1,234
Polyethylene	114	127	120	147	168
Polypropylene	108	115	111	134	150
Polyurethane	64	64	53	64	72
Polystyrene	51	49	40	45	49
Other Resins	305	327	277	331	378
<i>Total Demand</i>	<i>1,872</i>	<i>1,831</i>	<i>1,463</i>	<i>1,826</i>	<i>2,050</i>

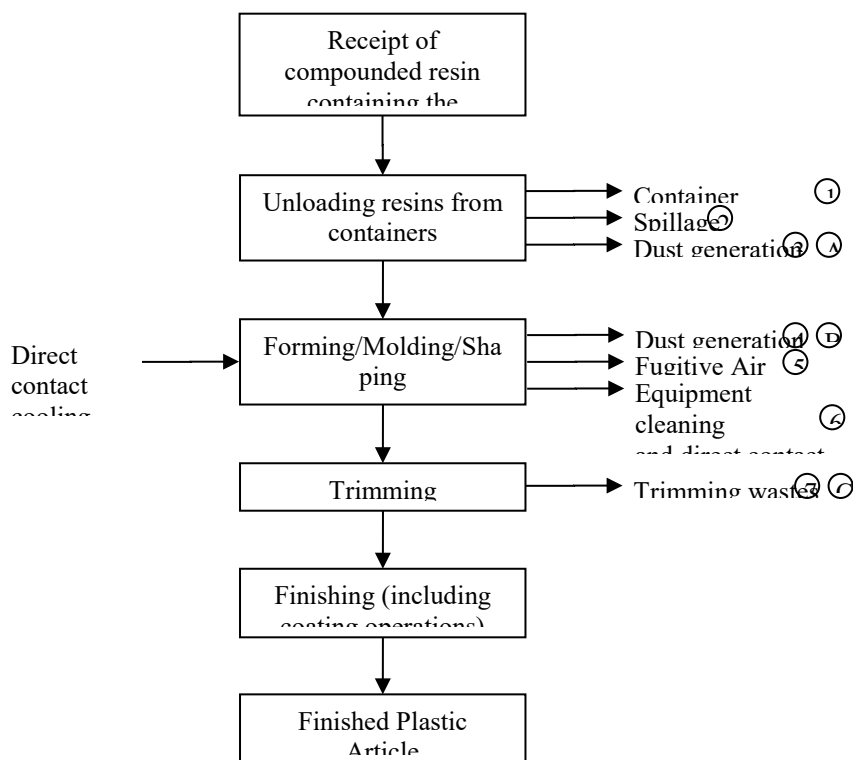
Source: Freedonia, 2013a

2.0 PROCESS DESCRIPTION

Plastics converters receive the masterbatch of plastic resin from compounders and convert the plastic resin into a finished plastic product. The plastic resins, which contain the chemical additives, are received at the converting site as solid pellets, sheets, or films. They are then heated and are formed into the desired shape through a variety of converting methods, including extrusion, injection molding, and thermoforming (BPF, no date b). The converted plastics may then undergo finishing operations, where secondary modifications yield the final, finished plastic product. Finishing operations include filing, grinding, sanding, polishing, painting, bonding, coating, engraving, etc.

Figure 2-1 illustrates the general process for plastics converting, including associated environmental release sources and occupational exposure activities. Releases and exposures specific to each application method are discussed in greater detail in Section 4.0 and 5.0, respectively.

Figure 2-1. Typical Release and Exposure Points during Plastics Converting



Environmental Releases:

1. Container residue cleaning/disposal losses to landfill or incineration
2. Spillage from compounded resin handling to water, landfill, or incineration
3. Dust emissions from container transfers to air, water, landfill or incineration
4. Dust emissions from forming and molding processes to air, water, or landfill
5. Fugitive air emissions from forming and molding processes to air or water
6. Equipment cleaning and direct contact cooling water from forming/molding processes to water, landfill, or incineration
7. Solid waste from trimming operations to landfill or incineration

Occupational Exposure:

- A. Inhalation exposures to solids during unloading/transferring of compounded resins
- B. Inhalation exposure to dusts generated during converting processes
- C. Inhalation exposure to solids during trimming activities

EPA expects most plastics additives to be non-volatile liquids or solids. For EPA new chemical assessments, volatile chemicals are considered to be those whose vapor pressures are above 0.001 torr (CEB, 2008). Based on a review of 71 PMNs submitted to EPA between 2007 and 2012, EPA found that 98% had vapor pressures below 0.001 torr. Only one PMN was for a chemical with a vapor pressure greater than 0.001 torr. The review also indicates that plastics additives are typically solids. Of the 71 PMNs, 65% were for solid plastics additives while the remaining 35% were for liquids.

In the first process step, plastics converters receive the thermoplastic resin from compounders, who blend resins and additives together into a masterbatch. Compounded plastic resins are shipped in bulk containers in pellet, sheet, pipe, or film form (Kirk-Othmer, 1991). Thermoplastic resins in pellet form are routinely shipped in containers ranging from 25-kg (55-lb) bags to 500-kg (1,100-lbs) gaylords, or even larger truck or rail car shipments for high-volume users of thermoplastic resins (EC, 2007; Kirk-Othmer, 2003).

Shipping containers are unloaded into mixing vessels. Environmental releases may result during this transfer activity, particularly for powdered solids due to the generation of airborne particulates. Depending on process controls, the dusts may be released directly to the atmosphere or it may be captured by engineering controls (e.g., bag filters). The portion captured by the bag filters are disposed to incineration or landfill. Particulate emissions within the facility that are not captured by emission controls will settle, resulting in losses to landfill or wastewater during wash downs (OECD, 2009). Environmental releases also may occur from spillage during container transfers and similarly may result in releases to water, incineration, or landfill. Exposures also are expected from dust inhalation.

Empty containers either are immediately disposed of or they are cleaned prior to disposal, depending on the type of container. Based on engineering judgment, boxes and bags are not likely to be cleaned prior to disposal, whereas cleaning would be much more likely for steel drums.

At the converting site, thermoplastic resin is shaped into the desired form for the final plastic product. Thermoplastic resins are received at the converting site in solid form (e.g., pellets, sheets, films). The resins must be heated and melted to form the final product. In this regard, plastics converters use numerous methods to convert thermoplastics into final products. Conversion methods include:

- Extrusion: Plastic pellets or granules are heated, fluidized, homogenized, and formed continuously as the extrusion machine feeds them through a die. Immediately after the die, the material is quenched, resulting in a very long plastic shape (e.g., tube, pipe, sheet, or coated wire).
- Injection Molding: Plastic granules or pellets are heated and homogenized in a cylinder (usually by extrusion). The resin is injected via pressure into a cold mold where the plastic takes the shape of the mold as it solidifies.
- Blow Molding: A plastic forming process in which air is used to stretch and form plastic materials.
- Rotational Molding: Finely ground plastic powders are heated in a rotating mold to the point of melting and/or fusion. The melted resin evenly coats the inner surface of the rotating mold.
- Thermoforming: Heat and pressure are applied to plastic sheets that are placed over molds and formed into various shapes.

Process equipment may be cleaned using scrap resins or purging compounds (Pizzo, 2009), which are plastic resins specially designed for cleaning converting equipment. Equipment may also be disassembled and physically cleaned with wire brushes and scrapers. Physical cleaning may occur at near-processing temperatures or cold (Mitchell, 1996). Based on engineering judgment, the residual plastic that is cleaned from converting equipment, whether through purging compounds or physical cleaning, is subsequently disposed to landfill or incineration. Water releases from equipment cleaning are not expected to occur.

Exposures during equipment cleaning are not expected to occur because workers will have minimal interaction with the chemical. Even if workers physically remove scrap resins from the converting equipment, the activity is not expected to generate respirable dusts containing the chemical additive. Potential dermal exposures during this activity are negligible since the additive is entrained within the compounded plastic.

After heating and forming, finishing operations such as filing, grinding, sanding, polishing, painting, bonding, coating, engraving, etc. are performed to complete the finished plastic product. The plastic finishing operations will depend on the type of product produced. For example, most molded plastic articles require trimming in order to remove excess plastic. Trimming is performed via filing, grinding, and sanding. Other possible finishing operations include coating, polishing, bonding, and engraving. Waste from coating operations also are expected but are beyond the scope of this scenario.

Particulate emissions are expected from transferring and mixing of dry components, forming and molding, and during cleaning or changing of emission control filters. Many of the converting processes use or create heat to mix the materials. The heat can result in the volatilization of liquid plastics additives; therefore, fugitive air emissions also are expected during plastics conversion. After the final product is made, it is then trimmed and/or coated. Solid waste releases are expected from trimming operations.

The process activities described above are likely to generate dusts. If occurring at elevated temperatures, volatile releases of liquid additives may occur as well. EPA did not find information on typical process temperatures; however, based on the melting temperatures of various thermoplastics (Kirk-Othmer, 2003), temperatures are expected to range from 65°C to 365°C. For closed processes, air releases from dusts or volatilization are most likely released as stack emissions. Release from open processes can include both fugitive and stack emissions, depending on the extent of engineering controls used at the site, and may include a potential pathway for dust inhalation exposures. Note that, although inhalation exposures to volatilized additives are possible, the GS does not provide methods for estimating such exposures given that the additives have negligible vapor pressures well below 0.001 torr, as observed during EPA's review of the PMN submissions.

The engineering controls utilized during the compounding process are described in detail in Section 4.1. Air pollution control treatment methods primarily include incineration and scrubbing (EPA, 2011). Process waters generated from cooling water and cleaning rinsates are discharged to publicly owned treatment works (POTW), where the concentration of additives in the wastewater is reduced primarily by neutralization, biological treatment, settling or clarification, or sludge treatment (EPA, 2011).

3.0 OVERALL APPROACH AND GENERAL FACILITY ESTIMATES FOR THE USE OF ADDITIVES IN PLASTICS CONVERTING

This methodology review draft presents EPA's standard approach for estimating environmental releases of and worker exposures to plastics additives during converting operations. Although there are several types of converting processes, their associated release and exposure points are expected to be the same.

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 industry data would enhance the estimates presented herein. These data needs are summarized in Section 7.0. It should be noted that the default values cited throughout this document are intended to be used only when appropriate site-specific or industry-specific information is not available.

This section of the methodology review draft presents general facility calculations for the plastics converting industry, which include estimates of the daily use rates of plastics additives, the number of operating days at these sites, and the number of converting sites using the plastics additives.

Section 4.0 of the methodology review draft presents environmental release assessments from the use of plastics additives during converting operations. Section 4.0 utilizes the general facility estimates presented in this section to determine the quantity of chemical additive released from various points in the converting process, and the most likely media of release for each source.

Section 5.0 of the methodology review draft presents occupational exposure assessments from the use of plastics additives during converting operations. Section 5.0 utilizes both the general facility estimates presented in this section and the release estimates from Section 4.0 to estimate the number of workers potentially exposed while performing various converting process activities and their corresponding potential exposure level (quantity) and routes of exposures.

3.1 Introduction to the General Facility Estimates

Throughout the remainder of this section, EPA utilized available industry and U.S. Census data to estimate the number of plastics converting sites in the U.S. This section also describes the methods and assumptions used to estimate typical daily use rates of the chemical of interest at a plastics converting site. The daily use rate can be estimated using several facility parameters, including the annual facility use rate of the chemical of interest ($Q_{\text{chem_site_yr}}$), days of operation ($\text{TIME}_{\text{operating_days}}$), and the number of converting sites using the chemical of interest (N_{sites}). Industry data on U.S. demand for plastics additives is provided in Table 1-5. Additional information on the number of converting sites was obtained from the 2011 U.S. Census (USCB, 2011a).

Table 3-1 summarizes the parameters that this document uses to develop general facility estimates and identifies the corresponding sections in which they are discussed in detail. In addition, Table A-2 (Appendix A) presents a detailed summary of the default values used as inputs to each of the general facility estimates, accompanied by their references. Combined, market data, Census data, and the parameters in Table 3-1 allow for calculation of annual and daily use rates on a per site basis, as well as determining the number of shipping containers used annually.

Table 3-1: Summary of General Facility Parameters for Plastics Converting Sites

Parameter	Description	Section
TIME _{operating days}	Number of operating days at the converting site (days/yr)	3.2
Q _{all_additives_site_yr}	Annual facility use rate of all plastics additives (kg all additives/site-year)	3.3
F _{chem_additive}	Mass fraction of chemical of interest in the plastics additive (kg chemical of interest/kg additive containing chemical of interest)	3.4
F _{additive_resin}	Mass fraction of the plastics additive containing the chemical of interest in the plastic resin (kg additive/kg resin)	3.5
F _{chem_resin}	Mass fraction of chemical of interest in the plastic resin (kg chemical/ kg resin)	3.6
F _{all_additives_resin}	Mass fraction of all additives in the plastic resin (kg all additives/kg resin)	3.7
Q _{chem_site_yr}	Annual facility use rate of the chemical of interest (kg chemical of interest/site-yr)	3.8
Q _{chem_site_day}	Daily facility use rate of the chemical of interest (kg chemical of interest/site-day)	3.9
Q _{chem_bt}	Mass of the chemical of interest used per batch (kg chemical/batch)	3.10
N _{chem_bt}	Daily number of batches of the chemical of interest used at each site (batches/site-day)	
N _{bt_site_yr}	Annual number of batches at each site (batches/site-yr)	
N _{sites}	Number of sites using the chemical of interest (sites)	3.11
Q _{chem_yr}	Annual production volume of the chemical of interest (kg chemical of interest/yr).	
N _{containers_unloaded_site_yr}	Number of transport containers unloaded per site per year (containers/site-yr)	3.12
Q _{container}	Mass of the plastics additive in the transport container (kg plastics additive/container)	
V _{container}	Volume of plastics additive in the transport container (L plastics additive)	
RHO _{plastics_additive}	Density of the plastics additive (kg plastics additive/L plastics additive)	

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

3.2 **Days of Operation (TIME_{operating_days})**

Table 3-2 summarizes the number of production workers and production hours for converting facilities as reported in the 2011 Annual Survey of Manufacturers (USCB, 2011a). Dividing the total production worker hours by the average number of production workers (each aggregated over all sites) results in an average of 254 worker days/year, assuming a worker works eight hours per day. EPA often estimates a work frequency per worker of 250 days/year, assuming a work schedule of five days per week and 50 weeks per year (allowing for a vacation time of two weeks per year). The converting industry-specific data estimate a work frequency per worker similar to CEB's default assumption.

Table 3-2. Number of Workers, Worker Hours, and Worker Days for Plastics Converting Facilities

NAICS Code	Industry Description	Number of Production Workers ^a	Number of Production Worker Hours ^a	Calculated Worker Days/Year ^b
326111	Plastics bag and pouch manufacturing	25,517	50,362,000	247
326112	Plastics packaging film and sheet (including laminated) manufacturing	19,118	38,288,000	251
326113	Unlaminated plastics film and sheet (except packaging) manufacturing	25,885	54,331,000	263
326121	Unlaminated plastics profile shape manufacturing	13,410	26,844,000	251
326122	Plastics pipe and pipe fitting manufacturing	15,006	30,040,000	251
326130	Laminated plastics plate, sheet (except packaging), and shape manufacturing	7,256	14,397,000	249
326160	Plastics bottle manufacturing	25,756	55,173,000	268
32619M	Other plastics product manufacturing ^c	253,000	502,262,000	249
<i>Average</i>				254

^a USCB, 2011a

^b Calculated by dividing the number of production worker hours by the number of production workers and assuming eight hours worked per day.

^c Comprises NAICS codes 326191 (Plastics Plumbing Fixture Manufacturing), 326192 (Resilient Floor Covering Manufacturing), and 326199 (All Other Plastics Product Manufacturing).

For supplemental information on the number of operating days, EPA also conducted a review of Premanufacture Notices (PMNs) submitted under Section 5 of the Toxic Substances Control Act (TSCA). The PMNs were submitted to EPA between 2007 and 2012. During the review, EPA assumed that the reported number of operating days per year was equal to the number of exposure days per year reported in the PMN submissions. Table 3-3 presents the results of the review and shows that the number of operating days at a given site can range from a minimum of 5 days per year to a maximum of 365 days per year. The average of the reported values is 137 days per year.

If site-specific information is not available to estimate the days of operation (TIME_{operating_days}) at converting sites, the days of operation should be assumed based on

assessment concerns. For environmental release concerns, EPA typically minimizes the number of operating days when assessing releases. This yields the most conservative daily environmental release estimates. For occupational exposure concerns, EPA typically maximizes the number of operating days, in this case up to a maximum of 254 days per year since it is known from Table 3-2 that the typical worker works up to 254 days per year. For both environmental and exposure concerns, EPA recommends assuming the average value for TIME_{operating_days} (i.e., 137 days per year).

Table 3-3. Number of Operating Days Reported in PMN Submissions for Plastics Converting Facilities

Submission	Operating Days per Year ^a
1	50
2	75
3	50
4	5
5	220
6	50
7	200
8	75
9	153
10	200
11	50
12	300
13	60
14	80
15	200
16	200
17	365
Minimum	5
Maximum	365
Average	137

^a EPA assumes the reported number of operating days per year is equal to the number of exposure days per year reported in the PMN submissions.

3.3 Annual Facility Use Rate of Plastics Additives ($Q_{all_additives_site_yr}$)

The annual facility use rate of plastics additives can be estimated using plastics additives market data (Table 1-5) and data on the number of converting sites obtained from the 2011 Census (USCB, 2011a). Table 3-4 presents the market and Census data inputs and the resulting estimated default value for the annual facility use rate of plastics additives. It is

important to note that the market data utilized in Table 3-4 aggregates plastics additives of all types. Therefore, the use rate in Table 3-4 represents the use of *all* plastics additives incorporated into the resin, not just the specific additive containing the chemical of interest. For this reason, it is critical that the use rate estimate accounts for the chemical-, additive-, and plastic resin-related mass fractions presented in Sections 3.4, 3.5, and 3.7, respectively.

Table 3-4. Input Data and Resulting Annual Facility Use Rate of Plastics Additives at Converting Sites

Annual U.S. Demand for Plastics Additives (kg additives/year) ^a	Number of Sites ^b	Default $Q_{all_additives_site_yr}$ (kg all additives/site-year)
1,463,000,000	9,707	150,716

^a Freedonia, 2013a (data reproduced in Table 1-5)

^b USCB, 2011a

3.4 Mass Fraction of the Chemical of Interest in the Plastics Additive ($F_{chem_additive}$)

The chemical of interest may only be a fraction of the plastics additive that is incorporated into plastic resins. If the concentration of the chemical of interest within the plastics additive ($F_{chem_additive}$) is not known, EPA recommends a conservative-case assumption of 100 percent when performing the calculations in this assessment:

$$F_{chem_additive} = \text{Mass fraction of chemical of interest in the plastics additive (Default: 1 kg chemical of interest/ kg additive containing chemical of interest)}$$

3.5 Mass Fraction of the Plastics Additive of Interest in the Plastic Resin ($F_{additive_resin}$)

This value represents the mass fraction of the specific plastics additive within the plastic resin that contains the chemical of interest (hereafter referred to as the “additive of interest”). If $F_{additive_resin}$ is not known, EPA recommends referencing the most appropriate value from Table 1-1 or Table 1-2. Which table is used will depend on what is known about the additive of interest and the resin into which it will be compounded.

If both additive type and resin type are known, EPA recommends referencing Table 1-2 for the corresponding value of $F_{additive_resin}$. For example, if the additive of interest is a flame retardant compounded into low density polyethylene resins, then EPA recommends using the corresponding value of 0.2 from Table 1-2. Note that if the value from Table 1-2 is a range, then the assessor should select a value within that range that most suitably addresses the assessment concerns for the chemical of interest (i.e., whether environmental releases, occupational exposures, or both are of concern). Figure 3-1 presents a logic diagram that should be used to determine the appropriate default value for $F_{additive_resin}$.

If neither the additive type nor resin type is unknown, EPA instead recommends referencing Table 1-1 for the most appropriate value. Table 1-1 summarizes the minimum, maximum, and average mass fractions typical of each additive type. The most appropriate value

will depend on the assessment concerns for the chemical of interest (i.e., whether environmental releases, occupational exposures, or both are of primary concern); therefore, the assessor should use the logic diagram (Figure 3-1) to determine the appropriate default value for $F_{\text{additive_resin}}$.

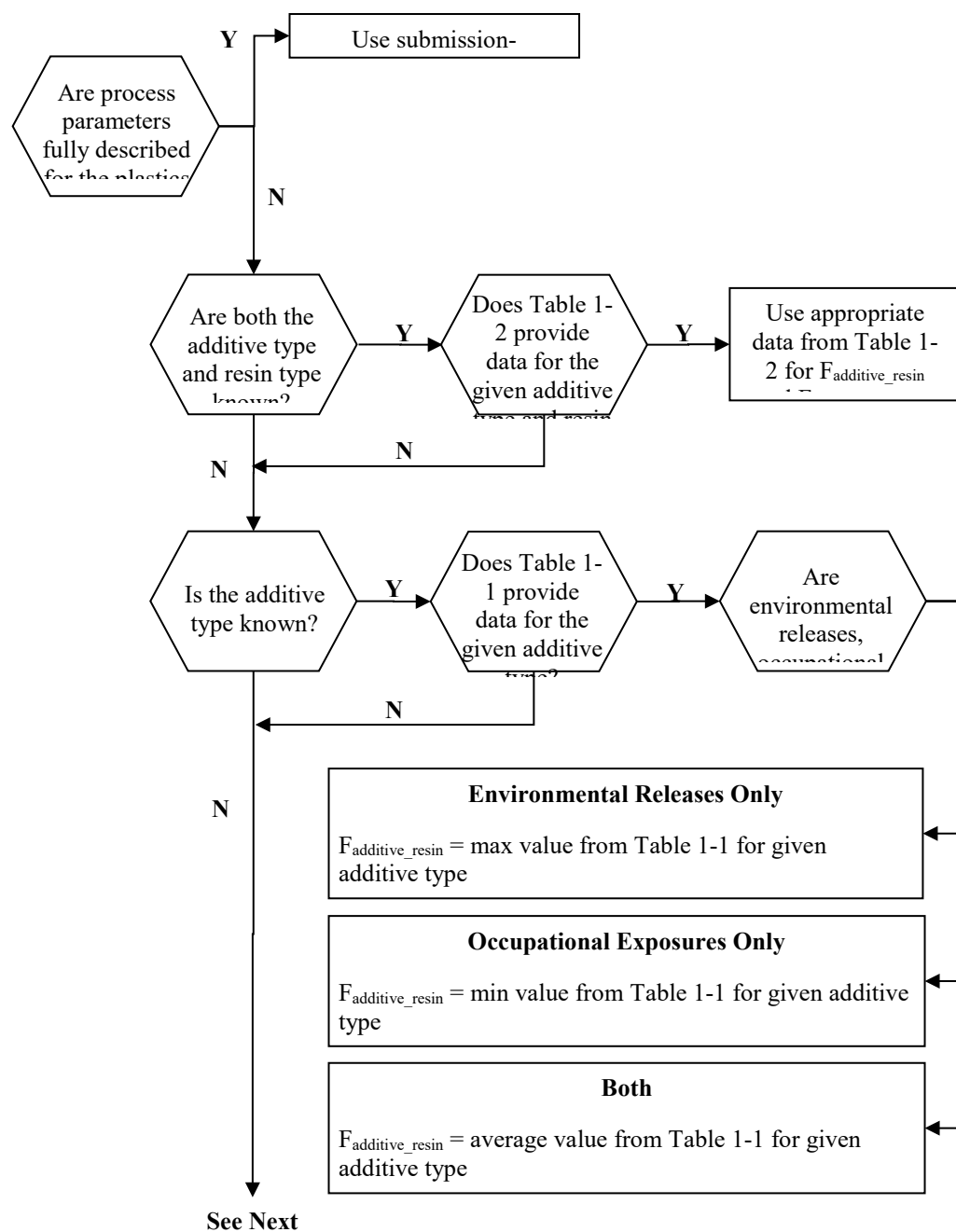


Figure 3-1. Logic Diagram for Determining Appropriate Defaults for $F_{\text{additive_resin}}$ and $F_{\text{all_additives_resin}}$

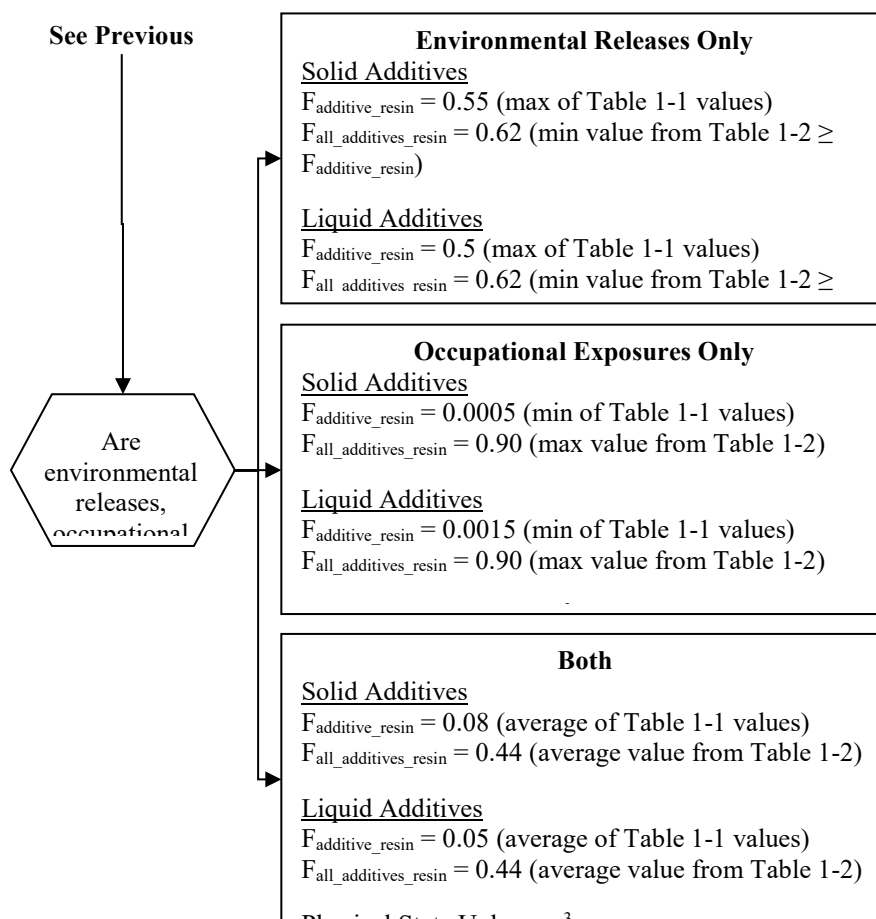


Figure 3-1. Logic Diagram for Determining Appropriate Defaults for $F_{\text{additive_resin}}$ and $F_{\text{all_additives_resin}}$ (Continued)

Footnotes:

- 1) If the compounding operation is fully described in the PMN submission (e.g., additive concentrations, number of sites, days of operation per year) then submission data should be used.
- 2) If additive type or resin type is unknown, assumptions must be made based on assessment concerns. EPA typically uses the following methodology to make conservative assessments:
 - a. Environmental release assessments: for a conservative release assessment, maximize the facility throughput rate of the chemical of interest. This is achieved by maximizing $F_{\text{additive_resin}}$ while minimizing $F_{\text{all_additives_resin}}$.
 - b. Occupational exposure assessments: for a conservative occupational exposure assessment, minimize the facility throughput rate of the chemical of interest. This maximizes the number of

use sites and therefore maximizes the number of workers. This is achieved by minimizing $F_{\text{additive_resin}}$ while maximizing $F_{\text{all_additives_resin}}$.

- c. Releases and Exposures: use the average facility throughput rate of the chemical of interest. This is achieved by using the average values presented above for $F_{\text{additive_resin}}$ and $F_{\text{all_additives_resin}}$.
- 3) Care should be taken to select values from Table 1-1 that are consistent with the physical state of the chemical of interest (i.e., solid or liquid). If the physical state of the additive is unknown, EPA recommends assuming the additive is a solid. This assumption will provide the most conservative environmental release and occupational exposure assessments. It also is consistent with the results of EPA's review of PMNs submissions, where approximately 65% of the additives were reported to be solids.

3.6 Mass Fraction of the Chemical of Interest in the Plastic Resin ($F_{\text{chem_resin}}$)

This value represents the mass fraction of the chemical of interest that is incorporated into the plastic resin. This value is calculated using the following equation:

$$F_{\text{chem_resin}} = F_{\text{chem_additive}} \times F_{\text{additive_resin}} \quad (3-1)$$

Where:

$F_{\text{chem_resin}}$	=	Mass fraction of chemical of interest in the plastic resin (kg chemical/kg resin)
$F_{\text{chem_additive}}$	=	Mass fraction of chemical of interest in the plastics additive (Default: 1 kg chemical of interest/kg additive containing chemical of interest) (See Section 3.4)
$F_{\text{additive_resin}}$	=	Mass fraction of the plastics additive containing the chemical of interest in the plastic resin (Defaults: 0.55 kg additive/kg resin (release concerns only), 0.0005 kg additive/kg resin (exposure concerns only), or 0.08 kg additive/kg resin (both concerns)) (See Section 3.5)

The defaults provided above for $F_{\text{additive_resin}}$ assumes no information on the chemical of interest is available. If additive or resin type is known, reference the logic diagram in Figure 3-1 to determine the most appropriate default for $F_{\text{additive_resin}}$.

3.7 Mass Fraction of All Plastics Additives Contained in the Plastic Resin ($F_{\text{all_additives_resin}}$)

Typically, several types of plastics additives are compounded into a given resin. $F_{\text{all_additives_resin}}$ represents the mass fraction of all plastics additives within the compounded resin, including the additive of interest. It is important to note that this fraction will vary according to resin type and intended purpose of the final compounded resin, as these parameters dictate what additives must be incorporated into the resin. If $F_{\text{all_additives_resin}}$ is not known, EPA recommends referencing the most appropriate value from Table 1-2. The value will depend on the assessment concerns for the chemical of interest (i.e., whether environmental releases, occupational exposures, or both are of concern)

If the resin type is known, EPA recommends referencing Table 1-2 for the corresponding value. For example, if the resin type is known to be rigid PVC, then EPA recommends using the corresponding value of 0.17 to 0.24 from Table 1-2. Since the value is a range, the assessor should select a value within that range that most suitably addresses the assessment concerns for the chemical of interest (i.e., whether environmental releases, occupational exposures, or both are of concern). Figure 3-1 presents a logic diagram that should be used to determine the appropriate default value for $F_{all_additives_resin}$.

Care should be taken when selecting a value for $F_{all_additives_resin}$, particularly if $F_{additive_resin}$ is known but assumptions must be made about $F_{all_additives_resin}$. When selecting a value for $F_{all_additives_resin}$, the resulting value must be less than $F_{additive_resin}$. If, when using the logic diagram, $F_{additive_resin}$ is greater than $F_{all_additives_resin}$, the assessor instead must assume $F_{additive_resin}$ and $F_{all_additives_resin}$ are equal.

3.8 Annual Facility Use Rate of the Chemical of Interest ($Q_{chem_site_yr}$)

The annual use rate of the chemical of interest during converting is estimated using the following equation, based on the annual facility use rate of all plastics additives ($Q_{all_additives_site_yr}$) and the mass fractions of the chemical of interest, the plastics additive of interest, and of all plastics additives contained in the plastic resin.

$$Q_{chem_site_yr} = Q_{all_additives_site_yr} \frac{F_{chem_resin}}{F_{all_additive_resin}} \quad (3-2)$$

Where:

$Q_{chem_site_yr}$	=	Annual facility use rate of the chemical of interest (kg chemical of interest/site-yr)
$Q_{all_additives_site_yr}$	=	Annual facility use rate of plastics additives (Default: 150,716 kg all additives/site-year) (See Section 3.3)
F_{chem_resin}	=	Mass fraction of chemical of interest in the plastic resin (kg chemical/kg resin) (See Section 3.6)
$F_{all_additives_resin}$	=	Mass fraction of all additives in the plastic resin (Defaults: 0.62 kg all additives/kg resin (release concerns only), 0.90 kg all additives/kg resin (exposure concerns only), or 0.44 kg all additives/kg resin (both concerns)) (See Section 3.7)

The defaults provided above for $F_{all_additives_resin}$ assume no information is available for the chemical of interest. If additive or resin type is known, reference the logic diagram in Figure 3-1 to determine the most appropriate defaults.

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

The daily use rate of the chemical of interest during converting is estimated using the following equation, based on the annual facility use rate of the chemical of interest and the number of operating days.

$$Q_{\text{chem_site_day}} = \frac{Q_{\text{chem_site_yr}}}{\text{TIME}_{\text{operating_days}}} \quad (3-3)$$

Where:

$Q_{\text{chem_site_day}}$	=	Daily facility use rate of the chemical of interest (kg chemical of interest/site-day)
$Q_{\text{chem_site_yr}}$	=	Annual facility use rate of the chemical of interest (kg chemical of interest/site-yr) (See Section 3.8)
$\text{TIME}_{\text{operating_days}}$	=	Number of operating days at the converting site (Defaults: 5 days/yr (release concerns only), 254 days/yr (exposure concerns only), or 137 days/yr (both concerns)) (See Section 3.2)

3.10 Annual Number of Batches ($N_{\text{bt_site_yr}}$)

To estimate the annual number of batches, a batch size must be calculated. The batch size can be estimated using the following equation, assuming the number of batches used per site per day is one:

$$N_{\text{bt_site_yr}} = \text{TIME}_{\text{operating_days}} \times N_{\text{chem_bt}} \quad (3-4)$$

Where:

$N_{\text{bt_site_yr}}$	=	Annual number of batches at each site (batches/site-yr)
$\text{TIME}_{\text{operating_days}}$	=	Number of operating days at the converting site (Defaults: 5 days/yr (release concerns only), 254 days/yr (exposure concerns only), or 137 days/yr (both concerns)) (See Section 3.2)
$N_{\text{chem_bt}}$	=	Daily number of batches of the chemical of interest used at each site (Default: 1 batch/site-day)

3.11 Number of Sites (N_{sites})

The following calculation estimates the number of converting sites (N_{sites}) that utilize the chemical of interest by dividing the annual use volume of the chemical of interest ($Q_{\text{chem_yr}}$) by the annual facility use rate of the chemical of interest ($Q_{\text{chem_site_yr}}$):

$$N_{\text{sites}} = \frac{Q_{\text{chem_yr}}}{Q_{\text{chem_site_yr}}} \quad (3-5)$$

Where:

N_{sites}^2	=	Number of sites using the chemical of interest (sites)
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ata. Several of these standard models are described in Appendix B to this GS.

e nearest non-zero integer value. Then, to avoid errors due to rounding, $\text{TIME}_{\text{operating_days}}$ and $Q_{\text{chem_site_yr}}$ should be adjusted to reflect the integer value for N_{sites} while maintaining the same value of $Q_{\text{chem_site_day}}$ calculated in Section 3.9.

$Q_{\text{chem_yr}}$	=	Annual production volume of the chemical of interest (kg chemical of interest/yr)
$Q_{\text{chem_site_yr}}$	=	Annual facility use rate of the chemical of interest (kg chemical of interest/site-yr) (See Section 3.8)

Note that the calculated value of N_{sites} should not exceed the total number of converting sites known to operate in the U.S. (i.e., 9,707 sites, see Table 3-4).

Summary of the Relationship between General Facility Parameters

It is important to recognize that the days of operation ($TIME_{\text{operating_days}}$), the daily facility use rate of the chemical of interest ($Q_{\text{chem_site_day}}$), and the number of compounding sites (N_{sites}) are interrelated. This methodology review draft presents a method for estimating N_{sites} using the annual production volume of the chemical of interest ($Q_{\text{chem_yr}}$) and the estimated default value for the annual facility use rate of the chemical of interest ($Q_{\text{chem_site_yr}}$).

If N_{sites} and $TIME_{\text{operating_days}}$ are known, $Q_{\text{chem_site_day}}$ can be calculated directly without using Equation 3-3. This alternative calculation is:

$$Q_{\text{chem_site_day}} = \frac{Q_{\text{chem_yr}}}{N_{\text{sites}} \times TIME_{\text{operating_days}}}$$

If N_{sites} is known but $TIME_{\text{operating_days}}$ is unknown, EPA recommends using the default assumptions discussed in Section 3.2 for $TIME_{\text{operating_days}}$. $Q_{\text{chem_site_day}}$ then is calculated using the above equation.

EPA recommends calculating the daily facility use rate ($Q_{\text{chem_site_day}}$) using the methodology presented in Section 3.9, and then comparing it to the throughput based on number of sites and operating days, as calculated above.

3.12 Number of Transport Containers Unloaded per Site ($N_{\text{containers_unloaded_site_yr}}$)

Compounded plastic resins are shipped in bulk containers in pellet, sheet, pipe, or film form (Kirk-Othmer, 1991). Thermoplastic resins in pellet form are routinely shipped in containers ranging from 25-kg (55-lb) bags to 500-kg (1,100-lbs) gaylords, or even larger truck or rail car shipments for high-volume users of thermoplastic resins (EC, 2007; Kirk-Othmer, 2003).

First, $TIME_{\text{operating_days}}$ is recalculated using $Q_{\text{chem_site_day}}$ and the rounded number of sites:

$$TIME_{\text{operating_days}} = \frac{Q_{\text{chem_yr}}}{N_{\text{sites}} \times Q_{\text{chem_site_day}}}$$

Next, $TIME_{\text{operating_days}}$ is rounded to the nearest non-zero integer. Then, $Q_{\text{chem_site_yr}}$ is recalculated using the rounded number of operating days:

$$Q_{\text{chem_site_yr}} = Q_{\text{chem_site_day}} \times TIME_{\text{operating_days}}$$

The number of transport containers unloaded annually per site can be estimated based on the daily facility use rate ($Q_{\text{chem_site_day}}$), the container size, and the concentration of the chemical of interest in the plastics additive ($F_{\text{chem_additive}}$), as shown below.

In the absence of site-specific information, EPA recommends assuming a default transportation container size of 25 kg.

$$N_{\text{container_unloaded_site_yr}} = \frac{Q_{\text{chem_site_day}} \times \text{TIME}_{\text{operating_days}}}{F_{\text{chem_resin}} \times Q_{\text{container}}} \quad (3-6)$$

Where:

$N_{\text{container_unloaded_site_yr}}$	=	Number of transport containers unloaded per site per year (containers/site-yr)
$Q_{\text{chem_site_day}}$	=	Daily facility use rate of the chemical of interest (kg chemical of interest/site-day) (See Section 3.9)
$\text{TIME}_{\text{operating_days}}$	=	Number of operating days at the converting site (Defaults: 5 days/yr (release concerns only), 254 days/yr (exposure concerns only), or 137 days/yr (both concerns)) (See Section 3.2)
$F_{\text{chem_resin}}$	=	Mass fraction of chemical of interest in the plastic resin (kg chemical/kg resin) (See Section 3.6)
$Q_{\text{container}}^3$	=	Mass of the additive in the transport container (Default: solids, 25 kg additive/container)

³ If the mass of the plastics additive in each container ($Q_{\text{container}}$) is not known, it can be calculated using the known volume of plastics additive per container and its density:

$$Q_{\text{container}} = V_{\text{container}} \times \text{RHO}_{\text{additive}}$$

Where:

$V_{\text{container}}$	=	Volume of additive in the transport container (L additive)
$\text{RHO}_{\text{additive}}$	=	Density of the additive (kg additive/L additive)

4.0 ENVIRONMENTAL RELEASE ASSESSMENTS FOR THE USE OF ADDITIVES IN PLASTICS CONVERTING

This section presents approaches for estimating the amount of additives released during the converting process. The release sources are presented in the order discussed in Section 2.0 (see Figure 2-1) and include the most likely receiving media (i.e., water, landfill, or incineration). The primary sources of release include: container residue, dust and fugitive air emissions from forming and molding processes, process equipment cleaning, and solid waste from trimming operations. Key default values used for the release estimates, accompanied by their respective references, are provided in Table A-1, Appendix A.

It is generally assumed that during plastics converting, losses of additives are minimized in actual practice; however, some pre-process or other upstream releases will occur. Because losses are assumed to be minimized, the methodology presented in this section for estimating releases of additives from the converting process does not include adjustments to account for pre-process or other upstream releases of additives (e.g., while additive residue 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 additives 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 the release and by the total number of sites using additives (N_{sites}) (See Section 3.11).

Some of the 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.

Many of the environmental release estimates presented in this document are based on standard EPA release models. Table 4-1 summarizes the release estimation methods used in this methodology review draft.

Note that the standard model default values cited are current as of the date of this methodology review draft; 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. 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 Use of Additives in Plastics Converting Scenario Release Models

Release Source #	Description	Model Name or Description	Standard EPA Model (✓)
1	Container residue from plastic resin transport container released to incineration or landfill	<i>EPA/OPPT Solids Residual Model</i>	✓
2	Spillage from raw material handling to water, incineration, or landfill	<i>Loss from this operation is estimated based on industry data</i>	
3	Dust emissions from unloading compounded resins containing the chemical of interest to air, water, incineration, or landfill	<i>EPA/OPPT Dust Emissions from Solid Transfers Model</i>	✓
4	Dust generation from forming processes released to air, water or landfill	<i>Loss from this operation is estimated based on industry data</i>	
5	Fugitive air emissions from forming and molding processes released to water or air (liquid additives only)	<i>Loss from this operation is estimated based on industry data</i>	
6	Equipment cleaning and cooling water from forming and molding processes released to water, incineration, or landfill	<i>Specific model is based on whether direct or indirect contact cooling water is used:</i> <ul style="list-style-type: none"> • <i>EPA/OPPT Single Process Vessel Residual Model (indirect contact)</i> • <i>EPA/OPPT Multiple Process Vessel Residual Model (direct contact)</i> 	✓
7	Solid waste from trimming operations released to water or landfill	<i>Loss from this operation is estimated based on industry data</i>	

OPPT – Office of Pollution Prevention and Toxics.

All release equations below estimate daily release rates for a given site. To estimate annual releases for all sites for a given source, the daily release rates must be multiplied by the number of days of release and by the total number of sites using the additives (N_{sites}).

4.1 Control Technologies

The plastics industry may employ various types of control technologies to reduce the amount of waste generated during plastics converting. This subsection discusses some of the control technologies identified from the literature search and their effects on environmental releases.

The majority of waste streams generated at plastics converting sites are air or water streams. Air control technologies may be used to reduce worker exposure and

environmental releases due to dust generation, fugitive emissions, or incinerator emissions (EPA, 2011).

Most plastics converting facilities are indirect dischargers to POTWs (EPA, 1995). Wastewater generated at plastics converting sites includes cooling water or cleaning water. On-site wastewater treatment processes are used to reduce pollutants in the wastewater discharged to POTWs or directly to surface waters (EPA, 2011).

The efficiencies of the control technologies used to break down or capture the additives are presented in Table 4-2. Note, since facilities are not required to report waste quantities treated on site within their TRI submission, it is not possible to use the data to develop facility-level environmental release estimates that are directly attributable to on-site waste treatment. When assessing releases, EPA conservatively assumes treatment of waste streams does not occur.

Table 4-2. Summary of Waste Streams and Treatment Methods and Efficiencies for the NAICS Codes Associated with Plastics Converting

Waste Treatment Method, by Waste Stream	No. of Facilities	Treatment Method Distribution, by Waste Stream (%)	Minimum Reported Treatment Efficiency (%) ^a		Maximum Reported Treatment Efficiency (%) ^a	
			Lower Limit	Upper Limit	Lower Limit	Upper Limit
Plastics Converting Industries	540					
<i>Gaseous (gases, vapors, airborne particulates)^b</i>	<i>288</i>					
Incineration - thermal destruction other than use as a fuel	166	57.6	≥0	≤50	>99.99	≤99.9999
Other Air Emission Treatment	50	17.4	>50	≤95	>99	≤99.99
Scrubber	24	8.3	≥0	≤50	>99	≤99.99
Mechanical Separation	13	4.5	≥0	≤50		>99.9999
Condenser	12	4.2	>50	≤95	>99	≤99.99
Adsorption	9	3.1	>95	≤99	>99	≤99.99
Biological treatment with or without precipitation	5	1.7	≥0	≤50	>50	≤95
Electrostatic Precipitator	3	1.0	>50	≤95	>50	≤95
Absorber	2	0.7	>95	≤99	>99	≤99.99
Other treatment	2	0.7	>95	≤99	>95	≤99
Phase separation	1	0.3	>95	≤99	>95	≤99
Neutralization	1	0.3	>99	≤99.99	>99	≤99.99
<i>Wastewater (aqueous waste)^c</i>	<i>167</i>					
Neutralization	40	24.0	≥0	≤50	>99.9999	--
biological treatment with or without precipitation	25	15.0	≥0	≤50	>99.9999	--
Other treatment	24	14.4	≥0	≤50	>99.9999	--
Settling or clarification	23	13.8	≥0	≤50	>99.9999	--
Sludge treatment and/or dewatering	17	10.2	≥0	≤50	>99.9999	--
Other chemical precipitation with or without pre-treatment	12	7.2	≥0	≤50	>99.9999	--
Air or steam stripping	5	3.0	>95	≤99	>99.99	≤99.9999

Waste Treatment Method, by Waste Stream	No. of Facilities	Treatment Method Distribution, by Waste Stream (%)	Minimum Reported Treatment Efficiency (%) ^a		Maximum Reported Treatment Efficiency (%) ^a	
			Lower Limit	Upper Limit	Lower Limit	Upper Limit
Chemical reduction with or without precipitation	5	3.0	>50	≤95	>99	≤99.99
Evaporation	5	3.0	≥0	≤50	>95	≤99
Incineration - thermal destruction other than use as a fuel	5	3.0	>99	≤99.99	>99.99	≤99.9999
Absorption	4	2.4	>50	≤95	>50	≤95
Phase separation	2	1.2	≥0	≤50	>50	≤95
<i>Liquid waste streams (non-aqueous waste)^c</i>	62					
Stabilization or chemical fixation prior to disposal	21	33.9	>95	≤99	>99.9999	--
Other treatment	19	30.6	>95	≤99	>99.9999	--
Incineration - thermal destruction other than use as a fuel	18	29.0	>99	≤99.99	>99	≤99.99
Neutralization	3	4.8	≥0	≤50	>99	≤99.99
Evaporation	1	1.6	≥0	≤50	>50	≤95
<i>Solid waste streams (including sludges and slurries)^d</i>	23					
Stabilization or chemical fixation prior to disposal	5	21.7	>95	≤99	>99.9999	--
Evaporation	5	21.7	>50	≤95	>95	≤99
Sludge treatment and/or dewatering	4	17.4	>50	≤95	>95	≤99
Other treatment	4	17.4	>50	≤95	>50	≤95
Incineration - thermal destruction other than use as a fuel	4	17.4	>99	≤99.99	>99.9999	--
Chemical oxidation	1	4.3	>99	≤99.99	>99	≤99.99

^a Minimum and maximum treatment efficiencies are reported to TRI as ranges, hence the lower- and upper-end values presented herein.

^b Applicable to release point 5.

^c Applicable to release points 2, 3, 4, 5, and 6.

^d Applicable to release points 1, 2, 3, 4, 6, and 7.

4.2 Container Residue Losses to Incineration or Landfill (Release 1)

Compounded plastic resins are shipped in bulk containers in pellet, sheet, pipe, or film form (Kirk-Othmer, 1991). Dust residual may be created due to wearing of pellets during transportation. Therefore, EPA recommends estimating container cleaning residuals based on the generation of solid particulates.

The amount of additive remaining in transport containers can be estimated using the following standard EPA model:

- *EPA/OPPT Solid Residuals in Transport Containers Model* may be used for containers of all sizes containing solids.

Note that this model estimates one weight percent of the received material may be released to the environment. The rationale, defaults, and limitations of this model are further explained in Appendix B. The release estimates are based on the current version of the model. Standard EPA/OPPT models are subject to change; therefore, the current version of the standard EPA/OPPT model should be used.

Thermoplastic resins in pellet form are routinely shipped in containers ranging from 25-kg (55 lb) bags to 500-kg (1100 lb) gaylords, or even larger truck or rail car shipments for high-volume users of thermoplastic resins (EC, 2007; Kirk-Othmer, 2003). In the absence of site-specific information, EPA recommends assuming a default transportation container size of 25 kg.

Containers are likely to be disposed of as solid waste (OECD, 2009; EC, 2007). Therefore, the container residue loss should conservatively be assessed as released to incineration or landfill.

If the $N_{\text{container_unloaded_site_yr}}$ value is fewer than the days of operation ($\text{TIME}_{\text{operating_days}}$), the days of release equal $N_{\text{container_unloaded_site_yr}}$ and the daily release is calculated based on the following equation:

$$\text{Elocal}_{\text{container_residue_disp}} = Q_{\text{container}} \times F_{\text{chem_additive}} \times F_{\text{container_residue}} \times N_{\text{container_unloaded_site_day}} \quad (4-1a)$$

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

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

$$\text{Elocal}_{\text{container_residue_disp}} = Q_{\text{chem_site_day}} \times F_{\text{container_residue}} \quad (4-1b)$$

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

Where:

$\text{Elocal}_{\text{container_residue_disp}}$	=	Daily release of the chemical of interest from container residue (kg chemical/site-day)
$Q_{\text{container}}$	=	Mass of the additive in the transport container (Default: 25 kg additive/container) (See Section 3.12)
$F_{\text{chem_additive}}$	=	Mass fraction of the chemical of interest in the additive (kg chemical/kg additive) (See Section 3.4)
$F_{\text{container_residue}}$	=	Fraction of the chemical of interest remaining in the container as residue (Default: 0.01 kg chemical remaining/kg shipped) (CEB, 2002a)

$N_{\text{container_unloaded_site_day}}^4$	=	Number of containers unloaded per site, per day (Default: 1 container/site-day)
$Q_{\text{chem_site_day}}$	=	Daily use rate of the chemical of interest (kg chemical/site-day) (See Section 3.9)

4.3 **Spillage from Unloading Compounded Resin Released to Water, Incineration, or Landfill (Release 2)**

When compounded resins are unloaded, spillage may occur resulting in a worst case scenario loss of 0.01% of the transported material (OECD, 2009). It has been noted that passive controls, such as closed sinks and basins, can be used to mitigate spillage releases to wastewater as well as surface water (INEOS, 2010). EPA recommends conservatively assessing spillage releases to water, incineration, or landfill using a loss fraction of 0.01%.

The following equation may be utilized to estimate potential releases from spillage during transfer operations.

$$E_{\text{local_spillage}} = Q_{\text{chem_site_day}} \times F_{\text{spillage}} \quad (4-2)$$

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

Where:

$E_{\text{local_spillage}}$	=	Daily release of spillage from unloading (kg chemical/site-day)
$Q_{\text{chem_site_day}}$	=	Daily facility use rate of the chemical of interest (kg chemical/site-day) (See Section 3.9)
F_{spillage}	=	Fraction of the chemical of interest lost during unloading (Default = 0.0001 kg chemical released/kg handled)

4.4 **Transfer Operations Losses to Air, Water, Incineration, or Landfill from Unloading Compounded Resins containing the Additive of Interest (Release 3)**

When solid powders are unloaded, dust may be generated. The OECD ESD on Plastic Additives estimates a loss factor of up to 0.5% for fine particles and 0.1% for coarse particles (particle size $>40 \mu\text{m}$) based on expert judgment (OECD, 2009). The *EPA/OPPT Dust Emissions from Transferring Solids Model* may be used to estimate dust releases generated

⁴ The daily number of containers unloaded per site may be estimated as:

$$N_{\text{container_unloaded_site_day}} = \frac{N_{\text{container_unloaded_site_yr}}}{\text{TIME}_{\text{operating_days}}}$$

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

Where:

$N_{\text{container_unloaded_site_yr}}$	=	Number of transport containers unloaded per site per year (containers/site-yr) (See Section 3.12)
$\text{TIME}_{\text{operating_days}}$	=	Annual number of days the additive is used (days/yr) (See Section 3.2)

during transfers. This model assumes that up to 0.5 percent of the transferred quantity may be released to the environment (consistent with the worst case presented in OECD, 2009). The rationale, defaults, and limitations of these models are further explained in Appendix B.

Most facilities utilize some type of control device(s) to collect fugitive dust 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 are originally released to air, but may also settle to facility floors and be disposed of when floors are cleaned (water if the floors are rinsed, or land or incineration if the floors are swept). Therefore, the lost quantity of dust should conservatively be assessed as released to air, water, incineration, or landfill.

The following equation may be utilized to estimate potential releases from dust generation during transfer operations. If control technologies for capturing dust emissions are utilized, the assessor should utilize the alternate equations presented in Appendix B.

$$E_{\text{local}_{\text{dust_generation}}} = Q_{\text{chem_site_day}} \times F_{\text{dust_generation}} \quad (4-3)$$

Where:

$E_{\text{local}_{\text{dust_generation}}}$	=	Daily release of dust from transfers/unloading (kg chemical/site-day)
$Q_{\text{chem_site_day}}$	=	Daily use rate of the chemical of interest per site-day (kg/site-day)
$F_{\text{dust_generation}}$	=	Fraction of the chemical of interest lost during transfers/unloading of solid powders (Default: 0.005 kg chemical released/kg handled)

4.5 Process Dust Emissions to Air, Landfill, or Water (Release 4)

Dust generation is expected during converting activities for solid compounded resins. This includes not only dusts generated during plastics forming and molding, but also from changing or cleaning any emission control filters used at the converting site. The daily release of solid additives during converting activities can be estimated by a loss fraction of 0.01% (OECD, 2009, based on estimates for filler additives). EPA recommends assessing dust emissions from forming processes using a loss fraction of 0.01%.

Fugitive dust emissions are originally lost to air, but are expected to eventually settle to the ground. Settled dust particles are expected to be cleaned with water or disposed of directly to landfill (OECD, 2009). Therefore, EPA recommends assessing dust releases to air, water, or landfill.

$$E_{\text{local}_{\text{dust_generation}}} = Q_{\text{chem_site_day}} \times F_{\text{dust_generation}} \quad (4-4)$$

This release will occur over $[\text{TIME}_{\text{operating_days}}]$ days/year from $[\text{N}_{\text{sites}}]$ sites.

Where:

$\text{E}_{\text{local_dust_generation}}$	=	Daily release of the chemical of interest from fugitive dust emissions during forming processes (kg chemical/site-day)
$\text{Q}_{\text{chem_site_day}}$	=	Daily use rate of the chemical of interest (kg chemical/site-day) (See Section 3.9)
$\text{F}_{\text{dust_generation}}$	=	Fraction of the chemical of interest lost during forming processes (Default: 0.0001 kg chemical released/kg processed)

4.6 Fugitive Air Emissions from Forming and Molding Processes to Air or Water (Release 5)

For additives with a low adjusted vapor pressure, (e.g., those with a vapor pressure of <0.001 torr), releases to air are expected to be negligible. However, due to the elevated temperatures at which converting operations may be performed, volatilization of liquid additives may occur. Fugitive emission loss rates are based on the volatility at 200°C for typical plasticizers in open processes (e.g., blown films): high – 0.25%; medium – 0.05%; and low – 0.01% (OECD, 2009). EPA recommends assessing fugitive emissions from forming and molding using a loss fraction of 0.25% as conservative.

Fugitive emissions from liquid additives are originally lost to air, but subsequent condensation may result in losses to water. Therefore, EPA recommends assuming fugitive air emissions from forming and molding processes are released to water (50%) and air (50%). The following equation can be used to estimate these releases:

$$\text{E}_{\text{local_fugitive_emissions}} = \text{Q}_{\text{chem_site_day}} \times \text{F}_{\text{fugitive_emissions}} \quad (4-5)$$

This release will occur over $[\text{TIME}_{\text{operating_days}}]$ days/year from $[\text{N}_{\text{sites}}]$ sites.

Where:

$\text{E}_{\text{local_fugitive_emissions}}$	=	Daily release of the chemical of interest from fugitive emissions during forming and molding processes (kg chemical/site-day)
$\text{Q}_{\text{chem_site_day}}$	=	Daily use rate of the chemical of interest (kg chemical/site-day) (See Section 3.9)
$\text{F}_{\text{fugitive_emissions}}$	=	Fraction of the chemical of interest lost during forming and molding processes (Default: 0.0025 kg chemical released/kg formed or molded) (OECD, 2009)

4.7 **Equipment Cleaning and Cooling Water from Forming and Molding Processes to Water, Incineration, or Landfill (Release 6)**

Process equipment may be cleaned using scrap resins or purging compounds (Pizzo, 2009), which are plastic resins specially designed for cleaning converting equipment. Purging compounds are most often used to clean injection molding equipment; however, they also can be used to clean extrusion and blow molding equipment (Pizzo, 2011 and Reeder, no date). Equipment may also be disassembled and physically cleaned with wire brushes and scrapers. Physical cleaning may occur at near-processing temperatures or cold (Mitchell, 1996). Based on engineering judgment, the residual plastic that is cleaned from converting equipment, whether through purging compounds or physical cleaning, is subsequently disposed to landfill or incineration. Water releases from equipment cleaning are not expected to occur.

EPA recommends using the *EPA/OPPT Single Process Vessel Residual Model*, which assumes that no more than one percent of the batch size or capacity of the process remains in the equipment as residue and is released as equipment cleaning waste. However, if the converting process also utilizes direct contact cooling water, EPA recommends using the *Multiple Vessel Residual Model*, as opposed to the *Single Vessel Residual Model*, because cooling lines will also have to be cleaned. (The *Multiple Vessel Residual Model* assumes two percent is released as equipment cleaning waste.)

It is important to note that environmental releases to water from cooling lines will only occur if the converting equipment utilizes direct contact cooling water. Converting processes that employ indirect contact cooling water are not expected to generate water releases since there is no physical contact between the water and the plastics additive. Typically, extrusion processes utilize direct contact cooling water while thermoforming and injection, blow, and rotational molding processes utilize indirect cooling water (Radian, 1984). If the conversion process or cooling method used at the converting site is unknown, EPA recommends conservatively assuming the use of direct contact cooling water, and assessing subsequent releases from equipment cleaning and cooling water to water, incineration, or landfill.

Equipment cleaning may occur at the end of each campaign or as needed to maintain proper converting. EPA did not find information on how frequently equipment cleaning occurs at converting sites. In lieu of site-specific information, EPA recommends conservatively assuming that cleaning occurs daily.

If $N_{bt_site_yr}$ or known number of cleanings is fewer than the days of operation ($TIME_{operating_days}$), the days of release equal $N_{bt_site_yr}$ (as calculated in Section 3.10) and the daily release of additive residue in the process equipment is calculated using the following equation:

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

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

If $N_{bt_site_yr}$ is greater than $TIME_{operating_days}$, the days of release equal the days of operation, and the daily release of additive residue in the process equipment is calculated using the following equation:

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

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

Where:

$E_{local_equipment_cleaning}$	=	Daily release of the chemical of interest from equipment cleaning (kg chemical/site-day)
Q_{chem_bt}	=	Mass of the chemical of interest used per batch (kg chemical/batch) (See Section 3.10)
F_{chem_resin}	=	Mass fraction of chemical of interest in the plastic resin (kg chemical/kg resin) (See Section 3.6)
$N_{bt_site_day}$	=	Daily number of batches converted at each site (batches/site-day)
$F_{equipment_cleaning}$	=	Fraction of polymer resin containing the chemical of interest released as residual in process equipment (Default: 0.02 kg product released/kg batch holding capacity (CEB, 1992))
$Q_{chem_site_day}$	=	Daily use rate of the chemical of interest in the polymer resin (kg chemical/site-day) (See Section 3.9)

4.8 Solid Waste from Trimming Operations to Landfill or Incineration (Release 7)

Off-spec batch and scrap waste represent a potential release point that may be applicable during the converting process. Waste generated from trimming, filing, and grinding is estimated to be 2.5 to 10% of production. The loss of 10% is typical of waste generated during the trimming of back-coated fabric (Radian, 1984). Back coating operations are not included in the scope of this scenario and therefore 2.5% waste from grinding and trimming of plastic parts is representative of the industry covered in this scenario.

Cutting and trimming operations will generate scraps that are either ground and recycled back into the converting process or that are disposed as solid waste (Radian, 1984 and OECD, 2009). EPA recommends conservatively assuming that recycling does not occur, and assessing trimming operation releases to landfill or incineration.

$$E_{local_trimming} = Q_{chem_site_day} \times F_{trimming} \quad (4-7)$$

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

Where:

$E_{\text{local trimming}}$	=	Daily release of the chemical of interest from trimming operations (kg chemical/site-day)
$Q_{\text{chem_site_day}}$	=	Daily use rate of the chemical of interest (kg chemical/site-day)
F_{trimming}	=	Fraction of the chemical of interest lost during trimming operations (Default: 0.025 kg chemical released/kg trimmed)

5.0 OCCUPATIONAL EXPOSURE ASSESSMENTS FOR THE USE OF ADDITIVES IN PLASTICS CONVERTING

The following section presents estimation methods for worker exposures to additives during the converting process. Figure 2-1 illustrates the occupational activities performed within the process that have the greatest potential for worker exposure to additives. Table 5-1 summarizes the exposure estimation methods used in this methodology review draft.

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

EPA has developed a software package (ChemSTEER) containing these models as well as all current EPA defaults. 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.

Table 5-1. Summary of Additive Use Scenario Exposure Models

Exposure Activity	Description	Route of Exposure / Physical Form	Model Name or Description ^a	Standard EPA Model (✓)
A	Exposure to plastic resin during container unloading	Inhalation of solid powder dust emissions	Specific model is based on the total volume of material handled: <ul style="list-style-type: none">• <i>EPA Small Volume Handling Model</i>• <i>OSHA Total PNOR PEL-Limiting Model</i>	✓
B	Exposure to dusts generated from converting processes	Inhalation of solid powder dust emissions	<i>OSHA Total PNOR PEL-Limiting Model</i>	✓
C	Exposure to liquids during equipment cleaning	Dermal exposure to liquids containing the chemical	<i>EPA/OPPT 2-Hand Dermal Contact with Liquids Model</i>	✓
D	Exposure to solids generated during trimming activities	Inhalation of solids from trimming activities	<i>OSHA Total PNOR PEL-Limiting Model</i>	✓

^a Additional detailed descriptions for each of the models presented in this section are provided in Appendix B to this methodology review draft.

5.1 Personal Protective Equipment

No specific information was identified about the typical PPE used during converting processes. Please note that EPA does not assess the effectiveness of PPE at mitigating

occupational exposures in this methodology review draft. 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 methodology review draft do not account for PPE. Actual occupational exposure may be significantly less than the estimates presented in this methodology review draft.

5.2 Number of Workers Exposed Per Site

Limited industry-specific data on the number of workers potentially exposed while performing each of the converting activities were found in the references reviewed for this methodology review draft (refer to Section 8.0). Table 5-2 summarizes the most recent data collected from the U.S Census Bureau for various industries potentially involved in plastics converting.

In combination with use rate information provided in Section 3.0, the total number of workers can be estimated by end-use market; however, not all workers are expected to work in the production areas. The Census also provides estimates for *production workers* (USCB, 2011b), 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, 2011b).

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, 2011b).

The Census data does not provide information that could provide bases for estimating the specific numbers of production workers that perform each of the exposure activities discussed in this section. In the absence of data, the number of workers potentially exposed to additives during each activity should be conservatively estimated as 45 workers per site; however, the total number of workers per site does not equal the sum of the number of workers assumed to be exposed during each activity.

No information was found on the typical hours of operation per day or number of shifts supporting operations at plastics converting facilities; however, this section presents an estimate for the exposure duration for each work activity (based on EPA standard defaults and methodology).

Table 5-2. Number of Workers Potentially Exposed During the Plastics Converting Process

NAICS Code	Description	Number of Establishments ^a	Number of Production Workers ^b	Average Number of Workers per Facility ^c
326111	Plastics bag manufacturing	368	25,517	69
326112	Plastics packaging film and sheet (including laminated) manufacturing	341	19,118	56
326113	Unlaminated plastics film and sheet (except packaging) manufacturing	601	25,885	43
326121	Unsupported plastics profile shape manufacturing	436	13,410	31
326122	Plastics pipe and pipe fitting manufacturing	442	15,006	34
326130	Laminated plastics plate, sheet, and shape manufacturing	238	7,256	30
326160	Plastics bottle manufacturing	443	25,756	58
32619M ^d	Other plastics product manufacturing	6,838	253,000	37
<i>Average</i>				<i>45</i>

^a USCB, 2011a

^b USCB, 2011b

^c Calculated by dividing the number of production workers by the number of establishments.

^d 32619M comprises the NAICS codes 326191, 326192, and 326199.

5.3 Exposure from Unloading and Transferring Compounded Resins (Exposure A)

During transportation, pellets may grind against each other and create residual dusts that contain the chemical additive. Workers may be exposed to this residual dust when connecting transfer lines or manually unloading compounded resins from transport containers into process equipment or storage. If the concentration of the chemical of interest within the plastics resin ($F_{\text{chem_resin}}$) is not known, EPA recommends assuming 55 percent as a conservative default, as previously discussed in Section 3.6.

Inhalation Exposure:

The transfer of compounded resins containing plastics additives from containers to storage or process equipment generates particulates. The degree of inhalation exposure to particulates depends on the concentration of the chemical of interest in the plastic resin ($F_{\text{chem_resin}}$), the potential concentration of the plastic resin containing the chemical of interest in

the worker's breathing zone ($C_{\text{particulate}}$), and the total amount of plastic resin containing the chemical of interest that the worker is exposed to per day in performing this activity ($Q_{\text{resin_site_day}}$).

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

$$Q_{\text{resin_site_day}} = \frac{Q_{\text{chem_site_day}}}{F_{\text{chem_resin}}} \quad (5-1)$$

Where:

$Q_{\text{resin_site_day}}$	=	Daily amount of compounded resin containing the chemical of interest transferred into the process (kg resin/site-day)
$Q_{\text{chem_site_day}}$	=	Daily use rate of the chemical of interest (kg chemical/site-day) (See Section 3.9)
$F_{\text{chem_resin}}$	=	Mass fraction of chemical of interest in the plastic resin (kg chemical/kg resin) (See Section 3.6)

In lieu of airborne concentration data that is specific to the chemical of interest, EPA typically references personal monitoring data collected by the Occupational Safety and Health Administration (OSHA) for particulates not otherwise regulated (PNOR) for both respirable and total dust (OSHA, 2011). The personal monitoring data, which span from between 2002 to 2011, were collected using the primary NAICS codes associated with the plastics converting industry. Sampling times ranged from 40 to 487 minutes (8.1 hours). Table 5-3 summarizes the OSHA monitoring data for the NAICS codes associated with the plastics converting industry. These data include the number of facilities, number of monitoring samples taken, and statistics on minimum, maximum, and average exposure concentrations for PNOR (respirable fraction and total dust). The average exposure concentration at converting sites for PNOR (respirable fraction) is 2.13 mg/m³ and for PNOR (total dust) is 12.0 mg/m³. It is important to note that the monitoring data presented is not activity-specific, and therefore, it is not possible to directly correlate the exposure data to unloading and transfer activities.

Table 5-3. Summary of OSHA Monitoring Data for the NAICS Codes Associated with the Plastics Converting Industry

Industry	Substance	No. of Facilities	No. of Samples	Min	Max	Average ^a	OSHA PEL	Units
Converting	PNOR (Respirable Fraction)	35	80	0.0162	52.6	2.13	5	mg/m ³
	PNOR (Total Dust)	54	180	0.0293	293	12.0	15	mg/m ³

^a The average value for PNOR (total dust) omits sample measurements from one facility. The inclusion of the facility would result in the average exposure concentration exceeding the OSHA PEL for total dust, which would not be representative of occupational exposures at similar facilities nationwide.

The *OSHA Total PNOR PEL-Limiting Model* presented in the following sections conservatively assumes an airborne particulate concentration equal to that of the OSHA PEL for PNOR (total dust). As the monitoring data in Table 5-3 show, this approach yields conservative

exposure estimates since actual dust concentrations of the chemical of interest are likely to be reduced by utilization of process enclosures and engineering controls. As an example of this, sampling data for medium-chained chlorinated paraffins (MCCPs), as measured at two sites in the European Union (EU), yielded minimum and maximum dust exposure values of 0.02 and 0.44 mg/m³, respectively (ECHA, 2008). The report containing this data indicates that operations at these sites are believed to be representative of operations presented in the EU, but it did not include specific information about site process enclosures and engineering controls associated with the sampling data.

Two equations can be used to determine worker exposure. Selection of the appropriate equation should be based on the amount of compounded resin containing the chemical of interest that the worker is exposed to per day ($Q_{\text{resin_site_day}}$), rather than the amount of chemical of interest ($Q_{\text{chem_site_day}}$). Additional explanation of the two standard EPA models used to estimate inhalation exposure to solid powder is presented in Appendix B.

Note that the two estimation methods provided below are defaults. If using the *OSHA Total PNOR PEL-Limiting Model*, the data presented in Table 5-3 can be used to develop typical and high-end exposure estimates by setting $C_{\text{particulate}}$ equal to the respective average or high-end values (i.e., 12.0 or 293 mg/m³, respectively).

If the daily amount of compounded resin containing the chemical of interest ($Q_{\text{resin_site_day}}$) is *greater than* 54 kg/site-day; EPA recommends using the *OSHA Total PNOR PEL-Limiting Model*:

$$\text{EXP}_{\text{inhalation}} = C_{\text{particulate}} \times \text{RATE}_{\text{breathing}} \times \text{TIME}_{\text{exposure}} \times F_{\text{chem_resin}} \quad (5-2a)$$

This exposure will occur over the lesser of $N_{\text{bt_site_yr}}$ or $\text{TIME}_{\text{operating_days}}$.

Where:

$\text{EXP}_{\text{inhalation}}$	=	Inhalation exposure to chemical per day (mg chemical/day)
$C_{\text{particulate}}$	=	Concentration of resin particulates in the worker breathing zone (Default: 15 mg/m ³ ; based on OSHA PEL for particulates not otherwise regulated)
$\text{RATE}_{\text{breathing}}$	=	Typical worker breathing rate (Default: 1.25 m ³ /hr (CEB, 1991))
$\text{TIME}_{\text{exposure}}$	=	Duration of exposure (Default: 8 hr/day)
$F_{\text{chem_resin}}$	=	Mass fraction of chemical of interest in the plastic resin (kg chemical/kg resin) (See Section 3.6)

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

$$EXP_{inhalation} = Q_{resin_site_day} \times F_{chem_resin} \times F_{exposure} \quad (5-2b)$$

This exposure will occur over the lesser of $N_{bt_site_yr}$ or $TIME_{operating_days}$.

Where:

$EXP_{inhalation}$	=	Inhalation exposure to chemical per day (mg chemical/day)
$Q_{resin_site_day}$	=	Daily amount of compounded resin containing the chemical of interest transferred into the process (kg resin/site-day) (See Equation 5-1)
F_{chem_resin}	=	Mass fraction of chemical of interest in the plastic resin (kg chemical/kg resin) (See Section 3.6)
$F_{exposure}$	=	Fraction of the total particulate in the worker breathing zone (Default: 0.0477 (typical) to 0.161 (worst case) mg chemical in breathing zone/kg chemical handled (CEB, 1992))

Dermal Exposure:

Compounded plastics are transported to converting sites as pellets, sheets, films or pipes (Kirk-Othmer, 1991). The additives, which are entrained within the compounded plastic, are tightly bound to the polymer matrix and are not likely to leach out of the plastic during converting operations. Therefore, dermal exposures are expected to be negligible.

5.4 Exposure from Dusts Generated during Converting Processes (Exposure B)

Workers may be exposed to dust generated during the converting process.

Inhalation Exposure:

OSHA monitoring data presented in Table 5-3 provides the average concentration at converting sites for respirable and total dust, 2.13 and 12.0 mg/m³, respectively (see Section 5.3). EPA recommends conservatively estimating exposures associated with dust generation from converting activities using the OSHA PEL for particulates not otherwise regulated, 15 mg/m³. The *OSHA Total PNOR PEL-Limiting Model* may be used to determine inhalation exposure estimates:

$$EXP_{inhalation} = C_{particulate} \times RATE_{breathing} \times TIME_{exposure} \times F_{chem_resin} \quad (5-3)$$

This exposure will occur over the lesser of $N_{bt_site_yr}$ or $TIME_{operating_days}$.

Where:

$EXP_{inhalation}$	=	Inhalation exposure to chemical per day (mg chemical/day)
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$C_{\text{particulate}}$	=	Concentration of particulate in the worker breathing zone (Default: 15 mg/m ³ (average); based on OSHA PEL for particulates not otherwise regulated)
$\text{RATE}_{\text{breathing}}$	=	Typical worker breathing rate (Default: 1.25 m ³ /hr (CEB, 1991))
$\text{TIME}_{\text{exposure}}$	=	Duration of exposure (Default: 8 hr/day)
$F_{\text{chem_resin}}$	=	Mass fraction of chemical of interest in the plastic resin (kg chemical/kg resin) (See Section 3.6)

Note that the OSHA monitoring data presented in Table 5-3 can be used to develop typical and high-end exposure estimates by setting $C_{\text{particulate}}$ equal to the respective average or high-end values.

Dermal Exposure:

Dermal exposure is not expected during converting activities due to the high temperatures at which these processes typically occur.

5.5 Exposure during Trimming Activities (Exposure C)

Trimming activities include sanding and grinding excess plastic from finished articles or regrinding off-spec products to reintroduce in the process. Workers may be exposed to dust while performing manual trimming operations.

Inhalation Exposure:

No industry-specific data was found on exposure concentrations during trimming activities. EPA recommends conservatively estimating exposures associated with dust generation from converting activities using the OSHA PEL for particulates not otherwise regulated, 15 mg/m³. The *OSHA Total PNOR PEL-Limiting Model* may be used to determine inhalation exposure estimates:

$$EXP_{inhalation} = C_{particulate} \times RATE_{breathing} \times TIME_{exposure} \times F_{chem_resin} \quad (5-4)$$

This exposure will occur over the lesser of $N_{bt_site_yr}$ or $TIME_{operating_days}$.

Where:

$EXP_{inhalation}$	=	Inhalation exposure to chemical per day (mg chemical/day)
$C_{particulate}$	=	Concentration of particulate in the worker breathing zone (Default: 15 mg/m ³ (average); based on OSHA PEL for particulates not otherwise regulated)
$RATE_{breathing}$	=	Typical worker breathing rate (Default: 1.25 m ³ /hr (CEB, 1991))
$TIME_{exposure}$	=	Duration of exposure (Default: 8 hr/day)
F_{chem_resin}	=	Mass fraction of chemical of interest in the plastic resin (kg chemical/kg resin) (See Section 3.6)

Note that the OSHA monitoring data presented in Table 5-3 can be used to develop typical and high-end exposure estimates by setting $C_{particulate}$ equal to the respective average or high-end values.

Dermal Exposure:

The additives are entrained within the compounded plastic and are tightly bound to the polymer matrix. They are not likely to leach out of the plastic during trimming operations; therefore, dermal exposures are expected to be negligible.

6.0 SAMPLE CALCULATIONS

This section presents an example of how the equations introduced in Sections 3.0 through 5.0 can be used to estimate releases of and exposures to additives during converting processes. The default values used in these calculations are presented in Sections 3.0 through 5.0 and should be used only in the absence of site-specific information. The following data are used in the example calculations:

1. The production volume for the chemical of interest ($Q_{\text{chem_yr}}$) is *100,000 kg chemical/yr*.
2. The chemical of interest is a *solid* (type of additive and resin are unknown).
3. The chemical assessment must address environmental release and occupational exposure concerns.

6.1 General Facility Estimates

6.1.1 Days of Operation ($\text{TIME}_{\text{operating_days}}$)

If specific information is not available to estimate the days of operation ($\text{TIME}_{\text{operating_days}}$) at a converting site, assume a default value based on chemical assessment concerns, as discussed in Section 3.2. To address both environmental release and occupational exposure concerns, it is necessary to assume a value of 137 days of operation per year.

6.1.2 Annual Facility Use Rate of Plastics Additives ($Q_{\text{all_additives_site_yr}}$)

Aside from the annual production volume and physical state of the chemical of interest, no other site-specific information or data are known. Therefore, it is necessary to use default assumptions to determine site throughputs of the chemical of interest. The first step is to assume an annual facility use rate for plastics additives ($Q_{\text{all_additives_site_yr}}$). This rate subsequently is used to calculate the corresponding site throughput of the chemical of interest. Per Section 3.3, the default annual facility use rate is 150,716 kg all additives/site-yr.

6.1.3 Mass Fraction of the Chemical of Interest in the Plastics Additive ($F_{\text{chem_additive}}$)

If the weight fraction of the chemical of interest in the plastics additive is not known, assume the additive contains no other chemicals besides the chemical of interest (i.e., 1 kg chemical/kg additive containing chemical).

6.1.4 Mass Fraction of the Plastics Additive of Interest in the Plastic Resin ($F_{\text{additive_resin}}$)

Little is known about the chemical of interest outside of its physical state (i.e., solid); therefore, it is necessary to reference the logic diagram in Figure 3-1. Since both environmental

releases and occupational exposures are of concern, EPA recommends assuming a weight fraction of 0.08 kg additive/kg resin.

6.1.5 Mass Fraction of the Chemical of Interest in the Plastic Resin ($F_{\text{chem_resin}}$)

This value can be calculated using Equation 3-1:

$$\begin{aligned} F_{\text{chem_resin}} &= F_{\text{chem_additive}} \times F_{\text{additive_resin}} \\ &= 1 \frac{1 \text{ kg chemical}}{\text{kg additive containing chemical}} \times 0.08 \frac{\text{kg additive containing chemical}}{\text{kg resin}} \\ &= 0.08 \frac{\text{kg chemical}}{\text{kg resin}} \end{aligned}$$

6.1.6 Mass Fraction of All Plastics Additives Contained in the Plastic Resin ($F_{\text{all_additives_resin}}$)

If this value is not known and both environmental releases and occupational exposures are of concern, assume the default value of 0.44 kg all additives/kg resin (per Figure 3-1).

6.1.7 Annual Facility Use Rate of the Chemical of Interest ($Q_{\text{chem_site_yr}}$)

The annual use rate of the chemical of interest can be estimated using the following equation. To address environmental release and occupational exposure assessment concerns, assume $F_{\text{all_additives_resin}}$ is equal to 0.44 kg all additives/kg resin (per Figure 3-1).

$$\begin{aligned} Q_{\text{chem_site_yr}} &= Q_{\text{all_additives_site_yr}} \frac{F_{\text{chem_resin}}}{F_{\text{all_additive_resin}}} \\ &= 150,716 \frac{\text{kg all additives}}{\text{site - yr}} \times \frac{0.08 \frac{\text{kg chemical}}{\text{resin}}}{0.44 \frac{\text{kg all additives}}{\text{kg resin}}} \\ &= 27,403 \text{ kg/site - yr} \end{aligned}$$

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

The daily use rate of the chemical of interest can be estimated using the following equation:

$$\begin{aligned}
 Q_{\text{chem_site_day}} &= \frac{Q_{\text{chem_site_yr}}}{\text{TIME}_{\text{operating_days}}} \\
 &= \frac{27,403 \frac{\text{kg chemical}}{\text{site - yr}}}{137 \frac{\text{days}}{\text{yr}}} \\
 &= 200 \text{ kg/site - day}
 \end{aligned}$$

6.1.9 Annual Number of Batches ($N_{\text{bt_st_yr}}$)

The following calculation estimates the batch size, assuming the number of batches used per site per day ($N_{\text{chem_bt}}$) is one:

$$\begin{aligned}
 Q_{\text{chem_bt}} &= \frac{Q_{\text{chem_site_yr}}}{\text{TIME}_{\text{operating_days}} \times N_{\text{chem_bt}}} \\
 &= \frac{27,403 \frac{\text{kg chemical}}{\text{site - yr}}}{137 \frac{\text{days}}{\text{yr}} \times 1 \frac{\text{batch}}{\text{site - day}}} \\
 &= 200 \text{ kg chemical/batch}
 \end{aligned}$$

The following calculation estimates the annual number of batches for each converting site based on the annual facility use rate and the batch size:

$$\begin{aligned}
 N_{\text{bt_site_yr}} &= \frac{Q_{\text{chem_site_yr}}}{Q_{\text{chem_bt}}} \\
 &= \frac{27,403 \frac{\text{kg chemical}}{\text{site - yr}}}{200 \frac{\text{kg chemical}}{\text{batch}}} \\
 &= 137 \text{ batches/site - yr}
 \end{aligned}$$

The annual number of batches per year is consistent with the number of operating days per year (i.e., 137). This will be the case when assuming $N_{\text{chem_bt}}$ is equal to one batch/site-day.

6.1.10 Number of Sites (N_{sites})

The number of sites can be estimated using the following equation:

$$\begin{aligned} N_{\text{sites}} &= \frac{Q_{\text{chem_yr}}}{Q_{\text{chem_site_yr}}} \\ &= \frac{100,000 \frac{\text{kg chemical}}{\text{yr}}}{27,403 \frac{\text{kg chemical}}{\text{site - yr}}} \\ &= 3.6 \text{ sites} \end{aligned}$$

N_{sites} must be rounded to the nearest non-zero integer value (i.e., 4 sites). To avoid errors due to rounding, $Q_{\text{chem_site_day}}$ must be recalculated as follows:

$$\begin{aligned} Q_{\text{chem_site_day}} &= \frac{Q_{\text{chem_yr}}}{N_{\text{sites}} \times \text{TIME}_{\text{operating_days}}} \\ &= \frac{100,000 \frac{\text{kg chemical}}{\text{yr}}}{4 \text{ sites} \times 137 \frac{\text{days}}{\text{yr}}} \\ &= 182 \text{ kg/site - day} \end{aligned}$$

6.1.11 Number of Transport Containers Unloaded per Site ($N_{\text{container_unloaded_site_yr}}$)

The number of transport containers can be estimated using the following equation, using the default container size of 25 kg/container (per Section 3.12):

$$\begin{aligned} N_{\text{container_unloaded_site_yr}} &= \frac{Q_{\text{chem_site_day}} \times \text{TIME}_{\text{operating_days}}}{F_{\text{chem_resin}} \times Q_{\text{container}}} \\ &= \frac{182 \frac{\text{kg chemical}}{\text{site - day}} \times 137 \frac{\text{days}}{\text{yr}}}{0.08 \frac{\text{kg chemical}}{\text{kg resin}} \times 25 \frac{\text{kg resin}}{\text{container}}} \\ &= 12,467 \text{ containers/site - yr} \end{aligned}$$

6.2 Environmental Releases

6.2.1 Release to Incineration or Landfill from Container Residue (Release 1)

For solids, the *EPA/OPPT Solid Residuals in Transport Containers Model* may be used to estimate container residue releases. Since $N_{\text{container_unloaded_site_yr}}$ is greater than $\text{TIME}_{\text{operating_days}}$, the days of release should equal days of operation, and the average daily release can be estimated using the following equation:

$$\begin{aligned} \text{Elocal}_{\text{container_residue_disp}} &= Q_{\text{chem_site_day}} \times F_{\text{container_residue}} \\ &= 182 \frac{\text{kg chemical}}{\text{site - day}} \times \frac{0.01 \text{ kg chemical remaining}}{\text{kg shipped}} \\ &= 1.8 \text{ kg/site - day} \end{aligned}$$

...over 137 days/year from 4 sites.

Containers are likely to be disposed of as solid waste (OECD, 2009; EC, 2007). Therefore, the container residue loss should conservatively be assessed as released to incineration or landfill.

6.2.2 Releases to Water, Incineration, or Landfill from Spillage during Unloading Compounded Resin (Release 2)

$$\begin{aligned} \text{Elocal}_{\text{spillage}} &= Q_{\text{chem_site_day}} \times F_{\text{spillage}} \\ &= 182 \frac{\text{kg chemical}}{\text{site - day}} \times 0.0001 \frac{\text{kg released}}{\text{kg handled}} \\ &= 0.02 \text{ kg/site - day} \end{aligned}$$

...over 137 days/year from 4 sites.

Spillage releases should conservatively be assessed to water, incineration, or landfill.

6.2.3 Releases to Air, Water, Incineration, or Landfill from Container Transfers (Release 3)

$$\begin{aligned} \text{Elocal}_{\text{dust_generation}} &= Q_{\text{chem_site_day}} \times F_{\text{dust_generation}} \\ &= 182 \frac{\text{kg}}{\text{site - day}} \times 0.005 \frac{\text{kg released}}{\text{kg handled}} \\ &= 0.9 \text{ kg/site - day} \end{aligned}$$

...over 137 days/year from 4 sites.

Fugitive dust emissions are originally released to air, but may also settle to facility floors and be disposed of when floors are cleaned (water if the floors rinsed or land or incineration if the floors are swept). Therefore, the lost quantity of dust should conservatively be assessed as released to air, water, incineration, or landfill.

6.2.4 Release to Air, Water, or Landfill from Dust Emissions during Forming and Molding Processes (Release 4)

$$\begin{aligned} E_{\text{local fugitive_dust_emissions}} &= Q_{\text{chem_site_day}} \times F_{\text{fugitive_dust_emissions}} \\ &= 182 \frac{\text{kg chemical}}{\text{site - day}} \times \frac{0.0001 \text{ kg released}}{\text{kg converted}} \\ &= 0.02 \text{ kg/site - day} \end{aligned}$$

...over 137 days/year from 4 sites.

Fugitive dust emissions are originally lost to air, but are expected to eventually settle to the ground. Settled dust particles are expected to be cleaned from the equipment and floor with water or disposed of directly to landfill (OECD, 2009). Therefore, EPA recommends assessing dust releases to water or landfill.

6.2.5 Release to Air or Water from Fugitive Emissions during Forming and Molding Processes (Release 5)

Fugitive air emissions only occur from the volatilization of liquid additives. Since the chemical of interest is a solid, fugitive air emissions are not expected to occur during forming and molding.

6.2.6 Release to Water, Incineration, or Landfill from Equipment Cleaning and Cooling Water (Release 6)

The type of conversion process and cooling method is unknown; therefore, conservatively assume the use of direct contact cooling water, and assess subsequent releases from equipment cleaning and cooling water to water, incineration, or landfill using the *Multiple Vessel Residual Model*.

$$\begin{aligned} E_{\text{local equipment_cleaning}} &= Q_{\text{chem_site_day}} \times F_{\text{equipment_cleaning}} \\ &= 182 \frac{\text{kg chemical}}{\text{site - day}} \times \frac{0.02 \text{ kg released}}{\text{kg batch holding capacity}} \\ &= 3.6 \text{ kg/site - day} \end{aligned}$$

...over 137 days/year from 4 sites.

6.2.7 Release to Landfill or Incineration from Trimming Operations (Release 7)

$$\begin{aligned} E_{\text{local}_{\text{trimming}}} &= Q_{\text{chem_site_day}} \times F_{\text{trimming}} \\ &= 182 \frac{\text{kg chemical}}{\text{site - day}} \times \frac{0.025 \text{ kg released}}{\text{kg trimmed}} \\ &= 4.6 \text{ kg/site - day} \end{aligned}$$

...over 137 days/year from 4 sites.

Scrap wastes that cannot be reground are disposed of via landfill (Radian, 1984 and OECD, 2009). EPA recommends assessing trimming operation releases to landfill or incineration.

6.3 Occupational Exposures

6.3.1 Total Number of Workers Potentially Exposed to the Chemical

It is assumed that 45 workers are potentially exposed to the chemical of interest at each site; therefore, the total number of workers is calculated as:

$$45 \frac{\text{workers}}{\text{site}} \times N_{\text{sites}} = 45 \frac{\text{workers}}{\text{site}} \times 4 \text{ sites} = 180 \text{ total workers}$$

Note that all 180 workers are assumed to be exposed during each of the exposure activities performed at the 4 converting sites.

6.3.2 Exposure from Unloading and Transferring Compounded Resins (Exposure A)

The potential worker exposure to the chemical of interest is calculated using the *OSHA Total PNOR PEL-Limiting Model* or the *EPA/OPPT Small Volume Solids Handling Inhalation Model*. To determine the appropriate model to estimate exposure from unloading and transferring activities, the daily transfer rate of the compounded resin must be calculated.

$$\begin{aligned} Q_{\text{resin_site_day}} &= \frac{Q_{\text{chem_site_day}}}{F_{\text{chem_resin}}} \\ &= 182 \frac{\text{kg chemical}}{\text{site - day}} \bigg/ 0.08 \frac{\text{kg chemical}}{\text{kg resin}} \\ &= 2,300 \text{ kg additive/site - day} \end{aligned}$$

Since the daily amount of solid additives containing the chemical of interest ($Q_{\text{additive_residue_site_day}}$) is *greater than* 54 kg/site-day; EPA recommends using the *OSHA Total PNOR PEL-Limiting Model*:

$$\begin{aligned}\text{EXP}_{\text{inhalation}} &= C_{\text{particulate}} \times \text{RATE}_{\text{breathing}} \times \text{TIME}_{\text{exposure}} \times F_{\text{chem_resin}} \\ &= 15 \frac{\text{mg}}{\text{m}^3} \times 1.25 \frac{\text{m}^3}{\text{hr}} \times 8 \frac{\text{hr}}{\text{day}} \times 0.08 \frac{\text{kg chemical}}{\text{kg resin}} \\ &= 12 \frac{\text{mg chemical}}{\text{day}}\end{aligned}$$

...over 137 days/year

6.3.3 Exposure from Dusts Generated during Converting Processes (Exposure B)

The potential worker exposure to the chemical of interest is calculated using the *OSHA Total PNOR PEL-Limiting Model*:

$$\begin{aligned}\text{EXP}_{\text{inhalation}} &= C_{\text{particulate}} \times \text{RATE}_{\text{breathing}} \times \text{TIME}_{\text{exposure}} \times F_{\text{chem_resin}} \\ &= 15 \frac{\text{mg}}{\text{m}^3} \times 1.25 \frac{\text{m}^3}{\text{hr}} \times 8 \frac{\text{hr}}{\text{day}} \times 0.08 \frac{\text{kg chemical}}{\text{kg resin}} \\ &= 12 \frac{\text{kg chemical}}{\text{day}}\end{aligned}$$

...over 137 days/year

6.3.4 Exposure during Trimming Activities (Exposure C)

The potential worker exposure to the chemical of interest is calculated using the *OSHA Total PNOR PEL-Limiting Model*:

$$\begin{aligned}\text{EXP}_{\text{inhalation}} &= C_{\text{particulate}} \times \text{RATE}_{\text{breathing}} \times \text{TIME}_{\text{exposure}} \times F_{\text{chem_resin}} \\ &= 15 \frac{\text{mg}}{\text{m}^3} \times 1.25 \frac{\text{m}^3}{\text{hr}} \times 8 \frac{\text{hr}}{\text{day}} \times 0.08 \frac{\text{kg chemical}}{\text{kg resin}} \\ &= 12 \frac{\text{kg chemical}}{\text{day}}\end{aligned}$$

...over 137 days/year

7.0 DATA GAPS/UNCERTAINTIES AND FUTURE WORK

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

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

1. The environmental release and occupational exposure assessment methodologies presented in this document assume that converting sites produce plastic articles from compounded thermoplastic polymers that contain the chemical additive of interest. A consequence of this assumption is that the document does not apply to foams or thermoset plastics, where the chemical additives are most typically added during the converting process, and without any preceding compounding operations.

Expansion of the scope to include foams and thermosets requires revisions, supplemental data gathering, and development of assessment methodologies specific to these products. These efforts are beyond the scope of current update efforts. Future work on this document could expand the scope to include assessment methodologies that are specific to foams and thermoset polymers, allowing for a more comprehensive treatment of the chemical additives used in the plastics industry.

2. The GS estimates the typical annual facility use rate of plastics additives ($Q_{\text{all_additives_site_yr}}$) by averaging U.S. consumption of plastics additives over the number of converting sites in the U.S. using market and U.S. Census data, respectively. The quality of the annual facility use rate could be improved with additional, site-specific data on annual use rates (e.g., kg/site-day, kg/site-bt). This would allow the GS to present low- and high-end estimates, in addition to the typical-case estimate presented in this document.
3. Activity-specific data for number of workers exposed were not identified in the literature; therefore, the GS assumes all workers at a given facility perform each activity. Data on the number of workers associated with each activity would further enhance exposure estimates.
4. 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.
5. Industry-specific monitoring data for operations involving fugitive or dust emissions would enhance estimates for vented or fugitive releases and associated worker inhalation exposures.

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Appendix A

ESTIMATION EQUATION SUMMARY AND DEFAULT PARAMETER VALUES

Summary of Release and Exposure Estimation Equations for Plastics Converting 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 plastics converting. A description of each input variable and associated default is provided in Table A-2.

Table A-1. Plastics Converting Release and Exposure Calculation Summary

General Facility Estimates	
Mass Fraction of Chemical in the Plastic Resin (F_{chem_resin}):	
$F_{chem_resin} = F_{chem_additive} \times F_{additive_resin}$	(3-1)
Annual Facility Use Rate of the Chemical of Interest ($Q_{chem_site_yr}$):	
$Q_{chem_site_yr} = Q_{all_additives_site_yr} \frac{F_{chem_additive} \times F_{additive_resin}}{F_{all_additives_resin}}$	(3-2)
Daily Facility Use Rate of the Chemical of Interest ($Q_{chem_site_day}$):	
$Q_{chem_site_day} = \frac{Q_{chem_site_yr}}{TIME_{operating_days}}$	(3-3)
Annual Number of Batches ($N_{bt_site_yr}$):	
$N_{bt_site_yr} = TIME_{operating_days} \times N_{chem_bt}$	(3-4)
Number of Sites (N_{sites}):	
$N_{sites} = \frac{Q_{chem_yr}}{Q_{chem_site_yr}}$	(3-5)
Number of Transport Containers Unloaded per Site ($N_{containers_unloaded_site_yr}$):	
$N_{container_unloaded_site_yr} = \frac{Q_{chem_site_day} \times TIME_{operating_days}}{F_{chem_additive} \times Q_{container}}$	(3-6)

Table A-1 (Continued)

Release Calculations		
Source	Possible Medium	Daily Release Rates (kg/site-day), Elocal (for Given Sources)
Container Residue (Solids)	Incineration Landfill	<p>If $N_{\text{container_unloaded_site_yr}}$ is fewer than $\text{TIME}_{\text{operating_days}}$:</p> $\text{Elocal}_{\text{container_residue_disp}} = Q_{\text{container}} \times F_{\text{chem_additive}} \times F_{\text{container_residue}} \times N_{\text{container_unloaded_site_day}} \quad (4-1a)$ <p>...released over $[N_{\text{container_unloaded_site_yr}}]$ days/year from $[N_{\text{sites}}]$</p> <p>If $N_{\text{container_unloaded_site_yr}}$ is greater than $\text{TIME}_{\text{operating_days}}$:</p> $\text{Elocal}_{\text{container_residue_disp}} = Q_{\text{chem_site_day}} \times F_{\text{container_residue}} \quad (4-1b)$ <p>...released over $[\text{Time}_{\text{operating_days}}]$ days/year from $[N_{\text{sites}}]$</p>
Spillage	Water Incineration Landfill	$\text{Elocal}_{\text{spillage}} = Q_{\text{chem_site_day}} \times F_{\text{spillage}} \quad (4-2)$ <p>...released over $[\text{Time}_{\text{operating_days}}]$ days/year from $[N_{\text{sites}}]$</p>
Transfer Operations (Dust Emissions)	Air Water Incineration Landfill	<p>EPA/OPPT Dust Emissions from Solid Transfers Model (See Section 4.4)</p> $\text{Elocal}_{\text{dust_generation}} = Q_{\text{chem_site_day}} \times F_{\text{dust_generation}} \quad (4-3)$ <p>...released over $[\text{Time}_{\text{operating_days}}]$ days/year from $[N_{\text{sites}}]$</p>
Process Dust Emissions	Air Water Landfill	<p>EPA/OPPT Dust Emissions from Solid Transfers Model (See Section 4.5)</p> $\text{Elocal}_{\text{dust_generation}} = Q_{\text{chem_site_day}} \times F_{\text{dust_generation}} \quad (4-4)$ <p>...released over $[\text{Time}_{\text{operating_days}}]$ days/year from $[N_{\text{sites}}]$</p>
Process Fugitive Emissions	Air Water	$\text{Elocal}_{\text{fugitive_emissions}} = Q_{\text{chem_site_day}} \times F_{\text{fugitive_emissions}} \quad (4-5)$ <p>...released over $[\text{Time}_{\text{operating_days}}]$ days/year from $[N_{\text{sites}}]$</p>
Equipment Cleaning and Cooling Water from Forming and Molding Processes	Water Landfill Incineration	<p>If $N_{\text{bt_site_yr}}$ is fewer than $\text{TIME}_{\text{operating_days}}$:</p> $\text{Elocal}_{\text{equipment_cleaning}} = Q_{\text{chem_bt}} \times F_{\text{chem_resin}} \times N_{\text{bt_site_day}} \times F_{\text{equipment_cleaning}} \quad (4-6a)$ <p>...released over $[N_{\text{bt_site_yr}}]$ days/year from $[N_{\text{sites}}]$</p> <p>If $N_{\text{bt_site_yr}}$ is greater than $\text{TIME}_{\text{operating_days}}$:</p> $\text{Elocal}_{\text{equipment_cleaning}} = Q_{\text{chem_site_day}} \times F_{\text{equipment_cleaning}} \quad (4-6b)$ <p>...released over $[\text{Time}_{\text{operating_days}}]$ days/year from $[N_{\text{sites}}]$</p>
Trimming Operations	Landfill Incineration	$\text{Elocal}_{\text{trimming}} = Q_{\text{chem_site_day}} \times F_{\text{trimming}} \quad (4-7)$ <p>...released over $[\text{Time}_{\text{operating_days}}]$ days/year from $[N_{\text{sites}}]$</p>

Table A-1 (Continued)

Occupational Exposure Calculations	
Number of Workers Exposed Per Site: See Section 5.2.	
Exposures from Unloading and Transferring Compounded Resins: <i>Inhalation:</i> The daily transfer rate of the resin containing the chemical of interest may be estimated using the following equation: $Q_{\text{resin_site_day}} = \frac{Q_{\text{chem_site_day}}}{F_{\text{chem_resin}}} \quad (5-1)$ If $Q_{\text{resin_site_day}}$ is greater than 54 kg/site-day: OSHA Total PNOR PEL-Limiting Model (See Section 5.3) If $Q_{\text{resin_site_day}}$ is less than or equal to 54 kg/site-day: EPA/OPPT Small Volume Handling Inhalation Model (See Section 5.3)	
Exposure from Dusts Generated during Converting Processes: <i>Inhalation:</i> $\text{EXP}_{\text{inhalation}} = C_{\text{particulate}} \times \text{RATE}_{\text{breathing}} \times \text{TIME}_{\text{exposure}} \times F_{\text{chem_resin}} \quad (5-3)$	
Exposure during Trimming Activities: <i>Inhalation:</i> $\text{EXP}_{\text{inhalation}} = C_{\text{particulate}} \times \text{RATE}_{\text{breathing}} \times \text{TIME}_{\text{exposure}} \times F_{\text{chem_resin}} \quad (5-4)$	

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

Variable	Variable Description	Default Value	Data Source
AREA _{surface}	Surface area of contact (cm ²)	1,070 (2 hands) 535 (1 hand)	CEB, 2013
C _{particulate}	Mass concentration of particulate in air (mg/m ³)	15	OSHA
F _{chem_additive}	Mass fraction of the chemical of interest in the plastics additive (kg chemical/kg additive)	1	EPA assumption
F _{additive_resin}	Mass fraction of the plastics additive containing chemical of interest in the plastic resin (kg additive/kg resin)	0.55 kg additive/kg resin (release concerns only), 0.0005 kg additive/kg resin (exposure concerns only), or 0.08 kg additive/kg resin (both concerns)	EPA assumption. See Section 3.5.
F _{all_additives_resin}	Mass fraction of all additives in the plastic resin (kg all additives/kg resin)	0.62 kg all additives/kg resin (release concerns only), 0.90 kg all additives/kg resin (exposure concerns only), or 0.44 kg all additives/kg resin (both concerns)	EPA assumption. See Section 3.7.
F _{dust_generation}	Fraction of the chemical of interest lost during transfers/unloading of solids (kg chemical released/kg handled)	0.005	EPA assumption
F _{spillage}	Fraction of the chemical of interest lost during transfers (kg chemical released/kg handled)	0.0001	OECD, 2009
F _{container_residue}	Fraction of the chemical of interest remaining in the container as residue (kg chemical remaining/kg additive)	0.01	CEB, 2002
F _{fugitive_dust_emissions}	Fraction of the chemical of interest lost during forming processes(kg chemical released/kg blended)	0.0001	OECD, 2009
F _{fugitive_emissions}	Fraction of the chemical of interest lost during forming and molding processes (kg chemical released/kg formed or molded)	0.0025	OECD, 2009
F _{equipment_cleaning}	Fraction of polymer resin containing the chemical of interest released as residual in process equipment	0.01 (converting processes with indirect cooling) or 0.02 (converting processes with direct cooling)	CEB, 1992
F _{exposure}	Weight fraction of the total particulate in the worker breathing zone (mg chemical/kg chemical handled)	0.0477 (typical) 0.161 (worst)	CEB, 1992
N _{exp_incident}	Number of exposure incidents per day (incidents/day)	1	CEB, 2000
Q _{all_additives_site_yr}	Annual facility use rate of plastics additives (kg all additives/site-yr)	150,716	U.S. Census and industry data. See Section 3.3.

Table A-2 (Continued)

Variable	Variable Description	Default Value	Data Source
RATE _{breathing}	Typical worker breathing rate (m ³ /hr)	1.25	CEB, 1991a
RHO _{formulation}	Density of the adhesive formulation (kg/L)	1	EPA assumption
TIME _{exposure}	Duration of exposure (hrs/day)	8	EPA assumption
TIME _{operating_days}	Annual number of days the plastic resin is compounded at each facility (days/yr)	137	PMN data. See Section 3.2.

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: Dust Emissions from Transferring Solids Model;
- Section B.3: Container Residue Release Models (non-air);
- Section B.4: Process Equipment Residue Release Models (non-air);
- Section B.5: Particle Inhalation Exposure Models; and

Please refer to the guidance provided in the GS 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 website:

www.epa.gov/oppt/exposure/pubs/chemsteerdl.htm

B.2. DUST GENERATION

Model Description and Rationale:

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).

The EPA/OPPT Dust Emissions from Transferring Solids Model estimates that 0.5% 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 3% of the transferred volume. The mean of the upper bound from each data set was 0.5%.

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 0.5%. These data further justified the adoption of a 0.5% 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-1 provides estimated efficiencies for common control technologies.

Table B-1. 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.

$$E_{\text{local}_{\text{dust_fugitive}}} = Q_{\text{transferred}} \times F_{\text{dust_generation}} \times (1 - F_{\text{dust_control}}) \quad (\text{B-1})$$

Where:

$E_{\text{local}_{\text{dust_fugitive}}}$	=	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-1.

$$E_{\text{local}_{\text{dust_captured}}} = Q_{\text{transferred}} \times F_{\text{dust_generation}} \times F_{\text{dust_control}} \quad (\text{B-2})$$

Where:

$E_{\text{local}_{\text{dust_captured}}}$	=	Daily amount 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-1).

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.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:

$$E_{\text{local_container_residue_disp}} = F_{\text{container_residue}} \times Q_{\text{total_daily_container}} \quad (\text{Eqn. B-3})$$

Where:

$E_{\text{local_container_residue_disp}}$	=	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-2 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-3 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-2 and Table B-3. 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 ($TIME_{days_container_residue}$, days/site-year) must be appropriately “paired” with the total daily quantity of chemical contained in the containers ($Q_{total_daily_container}$) used in calculating the daily release. Thus, Table B-3 also contains the appropriate EPA default values for $TIME_{days_container_residue}$.

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-2. 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-3. 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:

$$E_{\text{local}_{\text{equip_cleaning}}} = F_{\text{equip_residue}} \times Q_{\text{total_chem_capacity}} \quad (\text{Eqn. B-4})$$

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-4 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-5 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-4 and Table B-5. 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-5 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-4. Standard EPA Default Values for Use in the Process Equipment Residual Release Models

Model Title	Fequip_residue ^a
<i>EPA/OPPT Single Process Vessel Residual Model</i>	<p>Conservative: 0.01 (for <u>pumping</u> process materials from the vessel)</p> <p>*Alternative defaults: Central Tendency: 0.0007 High End to Bounding: 0.002 (alternative defaults for <u>gravity-draining</u> materials from the vessel)</p>
<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-5. Standard EPA Methodology for Calculating Default Q_{equip_chem_capacity} and TIME_{days_equip_residue} Values for Use in the Process Equipment Residual Models

Process Type	Number of Batches per Day	Q _{equip_chem_capacity} (kg/site-day)	TIME _{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 GS 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 TIME_{days_equip_residue} summarized above in Table B-6. Care should be given in defining the appropriate Q_{total_daily_container} and TIME_{days_container_residue} to be used in either of the standard EPA process equipment residue models.

B.5. 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.5.1 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*⁵ (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

⁵Worker 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).

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:

$$\text{EXP}_{\text{inhalation}} = (Q_{\text{shift_handled}} \times N_{\text{shifts}}) \times F_{\text{chem}} \times F_{\text{exposure}} \quad (\text{B-5})$$

Where:

$\text{EXP}_{\text{inhalation}}$	=	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-6 for appropriate EPA default values; must be ≤ 54 kg/worker-shift for this model to be valid)
N_{shifts}^6	=	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 GS 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))

⁶Note 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.

Table B-6. Standard EPA Default Values for $Q_{\text{daily_handled}}$ in the EPA/OPPT Small Volume Solids Handling Inhalation Model

Activity Type	Default $Q_{\text{shift_handled}}$ ⁷ (kg/worker-day)
Loading and Unloading Containers	Quantity of material in each container (kg/container) × Number of containers/worker-shift
Container Cleaning	Quantity of residue in each container (kg/container) × Number of container/worker-shift
Process-Related Activity (equipment cleaning, sampling): Continuous process: Batch process (<1 batch per day): Batch process (>1 batch per day):	 Daily throughput of material / Number of shifts per day Quantity of material per batch Quantity of material per batch × Number of batches per shift

References:

U.S. EPA. Chemical Engineering Branch. Generic Scenario: *Textile Dyeing*. October 15, 1992.

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 Division⁸. *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.5.2 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.

⁷The 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 GS activity description in determining the most appropriate default value for $Q_{\text{daily_handled}}$.

⁸Note: This reference is currently available for viewing in the ChemSTEER Help System.

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*⁹. As stated in Section B.5.1, 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-6 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.

Model Equations:

The model first calculates the mass concentration of the airborne particulate chemical using the following equation:

$$C_{\text{chem_mass}} = C_{\text{total_mass}} \times F_{\text{chem}} \quad (\text{B-6})$$

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 GS discussion for guidance on appropriate default value)

The *OSHA Total PNOR PEL-Limiting Model* then uses the mass airborne concentration of the chemical ($C_{\text{mass_chem}}$) in Equation B-6, to calculate the inhalation exposure to the particulate chemical using the following equation:

⁹Worker 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).

$$\text{EXP}_{\text{inhalation}} = \text{C}_{\text{chem_mass}} \times \text{RATE}_{\text{breathing}} \times \text{TIME}_{\text{exposure}} \quad (\text{B-7})$$

Where:

$\text{EXP}_{\text{inhalation}}$	=	Inhalation exposure to the airborne particulate chemical per day (mg chemical/worker-day)
$\text{C}_{\text{chem_mass}}$	=	Mass concentration of the particulate chemical in air (mg/m ³ ; see Equation B-7)
$\text{RATE}_{\text{breathing}}$	=	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 ¹⁰)

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.

¹⁰Since 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.

Appendix C

GLOSSARY OF TERMS

This glossary provides definitions for a limited set of terms that have a particular usage or meaning within the plastics industry or within the context of this document. A few others are included to ensure understanding of the intended meaning because they are key terms within this report. The glossary does not include other scientific terms for which standard definitions are readily available.

Adhesives: Polymeric substances that can bind surfaces or objects together.

Coatings: Polymeric formulations that form protective or decorative films on surfaces.

Elastomers: Synthetic and naturally occurring rubbers, which exhibit low modulus and good resilience (ability to return to their original shape after being stretched).

Fibers: Synthetic and naturally occurring fibers, which exhibit high strength and modulus, good stretchability and thermal stability.

Plastics: Polymeric formulations, including both commodity and engineering plastics, which exhibit a range of modulus (stiffness).

Thermoplastics: Plastics that are melted and become fluid when heat and pressure are applied. The molten polymers are formed into finished products via pressure. Thermoplastics solidify when cooled, and the heating and cooling process can be repeated many times with little loss in properties.

Thermosetting plastics: Plastics that are formed into finished products during a chemical reaction under pressure and heat. This process creates permanent cross-linking, and the product retains its shape during subsequent cooling and heating.