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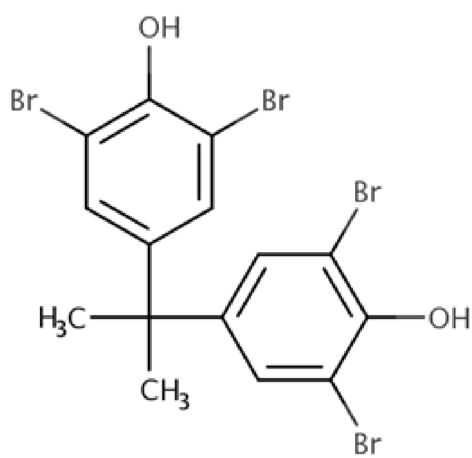
Environmental Protection Agency

Draft Occupational Exposure Assessment for 4,4′-(1-Methylethylidene)bis[2,6-dibromophenol] (TBBPA)

Technical Support Document for the Draft Risk Evaluation

CASRN 79-94-7



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KEY ABBREVIATIONS AND ACRONYMS

ABS	Acrylonitrile-butadiene-styrene
ACGIH	American Conference of Governmental Industrial Hygienists
ACC	American Chemistry Council
ADC	Average daily concentration
APF	Assigned protection factor
BLS	Bureau of Labor Statistics (U.S.)
CASRN	Chemical Abstracts Service Registry Number
CBI	Confidential business information
CDR	Chemical Data Reporting
CEHD	Chemical Exposure Health Data
COU	Condition of use
CRD	Chronic retained dose
DMR	Discharge Monitoring Report
ECB	European Chemicals Bureau
EPA	Environmental Protection Agency (U.S.)
ESD	Emission scenario document
GS	Generic scenario
HHE	Health hazard evaluation
IADC	Intermediate average daily concentration
IRD	Intermediate retained dose
LBT	Laboratory technician
LGT	Logistics technician
LOD	Limit of detection
MT	Maintenance technician
NAICS	North American Industry Classification System
NEI	National Emissions Inventory
NIOSH	National Institute for Occupational Safety and Health
OARS	Occupational Alliance for Risk Science

OCSPP	Office of Chemical Safety and Pollution Prevention (EPA)
OEL	Occupational exposure limit
OES	Occupational exposure scenario
ONU	Occupational non-user
OP	Processing operator
OPPT	Office of Pollution Prevention and Toxics (EPA)
OSHA	Occupational Safety and Health Administration (U.S.)
PBZ	Personal breathing zone
PCB	Printed circuit board
PEL	Permissible exposure limit
PF	Protection factor
PNOR	Particulates not otherwise regulated
POD	Point of departure
PPE	Personal protective equipment
PV	Production volume
REL	Recommended exposure limit
SDS	Safety data sheet
SEG	Similar exposure group
SIC	Standard Industrial Classification
SOC	Standard Occupational Classification
SUSB	Statistics of U.S. Businesses
TBBPA	4,4′-(1-Methylethylidene)bis[2,6-dibromophenol], also called Tetrabromobisphenol A
TLV	Threshold limit value
TRI	Toxics Release Inventory
TSD	Technical support document
TSCA	Toxic Substances Control Act
TWA	Time-weighted average
UOP	User operator
U.S.	United States
WEEL	Workplace environmental exposure level

SUMMARY

This technical support document (TSD) is part of the Toxic Substanced Control Act (TSCA) *Draft Risk Evaluation for 4,4'-(1-Methylethylidene)bis[2,6-dibromophenol] (TBBPA)* (U.S. EPA, 2026i) (also called the "draft risk evaluation for TBBPA"). TBBPA is a Toxics Release Inventory (TRI)-reportable substance and is on the TSCA Inventory, making it reportable under the Chemical Data Reporting (CDR) rule. This draft TSD describes the use of reasonably available information to assess occupational exposure of workers to TBBPA. See Appendix C of the draft risk evaluation for TBBPA for a complete list of all TSDs and supplemental files.

Focus of this Draft TSD on Occupational Exposure Assessment

During scoping, the U.S. Environmental Protection Agency (EPA or the Agency) considered all known conditions of use (COUs) under TSCA for TBBPA. The 2020 CDR report indicated that 20 to 100 million pounds (lb) of TBBPA (CASRN 79-94-7) were manufactured or imported in the United States in 2019 (U.S. EPA, 2022). The latest 2024 CDR indicates further decrease in the U.S. production volume (PV) of TBBPA, with the reported total PV in 2023 to be between 10 and 50 million pounds (lb) (U.S. EPA, 2026a). TBBPA is primarily used as a flame retardant in plastics material and resin manufacturing.

Exposures to workers, consumers, the general population, and ecological species may occur from industrial, commercial, and consumer uses of TBBPA and TBBPA-containing articles—as well as from releases to air, water, or land. This draft TSD provides the details of the assessment of the occupational exposures from each occupational exposure scenario (OES) of TBBPA. It does not include exposures resulting from consumer uses, which are assessed in the *Draft Consumer and Indoor Dust Exposure Assessment for 4,4'-(1-Methylethylidene)bis[2,6-dibromophenol] (TBBPA)* (U.S. EPA, 2026c).

Approach for Assessing Occupational Exposures

EPA evaluated intermediate and chronic exposures to workers. Upon review of reasonably available data, the Agency determined TBBPA was not expected to be acutely toxic (refer to Section 3.8.2.1 of the *Draft Human Health and Environmental Hazard Assessment for 4,4'-(1-Methylethylidene)bis[2,6-dibromophenol] (TBBPA)* (U.S. EPA, 2026e)). EPA mapped 21 applicable COUs for TBBPA to 14 OESs based on data and information gathered during systematic review, industry outreach, and public comments. Each OES is developed based on a set of occupational activities and operational conditions such that similar occupational exposures are expected from the use(s) covered under the OES. To assess occupational exposure, EPA prefers to use monitoring data applicable to the chemical and the OES. If no monitoring data are available, the Agency will use analogous and surrogate data to estimate exposure or conduct exposure modeling. In this draft assessment, EPA used inhalation monitoring data from test orders and literature sources, as well as modeling.

Results for Occupational Exposures

EPA evaluated inhalation and dermal exposures to worker populations for each OES and used inhalation monitoring data for 9 of the 14 OESs. Data from the PNOR Model was used to assess occupational exposures from four OESs where inhalation monitoring data were not available. For one OES with limited data, EPA assessed exposures qualitatively. Dermal exposures were modeled for all 21 OESs.

The preliminary occupational exposure assessment has shown that inhalation exposures are expected to be higher during manufacturing and repackaging; the American Chemistry Council's (ACC) TBBPA Consortium's Group 2: Production of TBBPA-Containing Mixtures and Formulations (full-shift inhalation estimates ranged from 1.4×10^{-3} to 43 mg/m^3). Inhalation exposures to all other OESs are expected to be low (full-shift inhalation estimates ranged from 1.4×10^{-6} to 3.3 mg/m^3). Dermal exposure

for all modeled scenarios (except commercial use in plastic and rubber products) is 3.7 mg/day for central tendency and 7.5 mg/day for high-end estimates. Detailed exposure results for each OES and exposure route can be found in Section 3.

Uncertainties

Uncertainties exist with the modeling and monitoring approaches used to assess TBBPA occupational exposures. For example, EPA used data from the PNOR Model when site-specific monitoring data were not available. In addition, site-specific differences in use practices and engineering controls exist, but are largely unknown, which represent another source of variability that EPA could not quantify in this draft assessment.

1 INTRODUCTION

1.1 Overview

This draft TSD provides details on the occupational exposure assessment and supports the risk evaluation for TBBPA under the Frank R. Lautenberg Chemical Safety for the 21st Century Act amending TSCA. TSCA section 6(b)(4) requires EPA to establish a risk evaluation process. In performing risk evaluations for existing chemicals, the Agency is directed to "determine whether a chemical substance presents an unreasonable risk of injury to health or the environment, without consideration of costs or other nonrisk factors, including an unreasonable risk to a potentially exposed or susceptible subpopulation identified as relevant to the risk evaluation by the Administrator under the conditions of use." In December 2019, EPA published a list of 20 chemical substances designated high-priority substances for risk evaluations (84 FR 71924, December 30, 2019), as required by TSCA section 6(b)(2)(B), which initiated the risk evaluation process for those chemical substances. TBBPA is one of the chemicals designated as a high-priority substance for risk evaluation.

TBBPA is a common chemical name for a chemical substance that includes the following names: 4,4′-(1-methylethylidene)bis[2,6-dibromophenol] (CASRN 79-94-7), tetrabromobisphenol A, 3,3',5,5'-tetrabromobisphenol A. It is a white crystalline solid that is primarily used as a reactant for flame retardants in plastic material and resin manufacturing and as a flame retardant incorporated into electrical equipment. TBBPA has a total production volume in the United States between 10 and 50 million lb reported in 2023 (U.S. EPA, 2026a)—a decrease in PV from the 20 to 100 million lb from the 2020 Chemistry Data Reporting (CDR) reporting period (U.S. EPA, 2022). TBBPA is a TRI-reportable substance, included on the TSCA Inventory, and reported under CDR.

This draft assessment addresses occupational exposures of TBBPA in industrial and commercial settings. In the sections that follow, the scope, the methods used, and the results are described in detail. For more information on the reviewed sources used to build this assessment, as well as the evaluation strategies for these sources, refer to the *Draft Systematic Review Protocol Supporting TSCA Risk Evaluations for Chemical Substances, Version 1.0: A Generic TSCA Systematic Review Protocol with Chemical-Specific Methodologies* (U.S. EPA, 2021a) (also referred to as the "[2021] Draft Systematic Review Protocol") and *Draft Systematic Review Protocol for 4,4'-(1-Methylethylidene)bis[2,6-dibromophenol] (TBBPA)* (U.S. EPA, 2026j), respectively.

1.2 Scope of the Assessment

EPA assessed occupational exposures for TBBPA COUs as described in Table 4-1 of the draft risk evaluation for TBBPA (U.S. EPA, 2026i) (see also Table 3-1 below).

EPA's assessment of occupational exposures includes quantifying inhalation and dermal exposures to TBBPA. The Agency categorizes occupational exposures into two groups: (1) exposures to workers, and (2) exposures to occupational non-users (ONUs). Generally, EPA distinguishes workers as directly handling TBBPA as part of their duties and have direct contact with the chemical, while ONUs work in the vicinity of the chemical but do not handle it or have direct contact with TBBPA being handled by the workers. EPA evaluated inhalation exposures to both workers and ONUs and dermal exposure to workers. The Agency assessed intermediate and chronic inhalation and dermal exposures only and did not assess acute and chronic/cancer exposures. EPA determined that TBBPA is not acutely toxic and did not warrant setting an acute point of departure (POD). An intermediate duration POD was derived. A chronic duration POD was derived, which accounts for all chronic toxicity, including non-cancer and cancer effects. This is because EPA determined that TBBPA is not likely carcinogenic to humans at doses below levels associated with the chronic POD. Thus, acute and cancer hazard values are not included for risk estimates, but non-cancer intermediate and chronic are included.

2 APPROACH AND METHODOLOGY

An occupational exposure assessment was conducted for each OES specified in Section 4.1.1 of the draft risk evaluation for TBBPA (U.S. EPA, 2026i) (see Table 3-1). For each OES, the following components are presented:

- **Worker Activities:** A description of the worker activities, including an assessment of potential points of worker and ONU exposure.
- **Number of Workers and ONUs:** An estimate of the number of workers and ONUs potentially exposed to the chemical for the given OES.
- **Occupational Inhalation Exposure Results:** Central tendency and high-end estimates of inhalation exposure to workers and ONUs. See Section 2.3 for a discussion of EPA's statistical analysis approach for assessing inhalation exposure.
- **Occupational Dermal Exposure Results:** Central tendency and high-end estimates of dermal exposure to workers. See Section 2.4 for a discussion of EPA's approach for assessing dermal exposure.

For the remainder of this section, the approach and methodology for completing each of the above components are described in additional detail.

For workplace exposures, EPA considered exposures to both workers who directly handle TBBPA and ONUs who do not directly handle TBBPA but may be exposed to vapors, particulates, or mists that enter their breathing zone while working in the vicinity to where TBBPA is being used. EPA evaluated inhalation exposures to both workers and ONUs and dermal exposures to workers. The Agency's estimates of occupational exposure presented in this document do not assume the use of personal protective equipment (PPE); however, the effect of respiratory and dermal protection factors on EPA's occupational exposure estimates can be explored under the "Risk Reduction" tab in the *Draft Risk Calculator for 4,4'-(1-Methylethylidene)bis[2,6-dibromophenol] (TBBPA)* (U.S. EPA, 2026h). For more discussion on respiratory protection and glove protection, refer to Appendix E.

Figure 2-1 presents the conceptual model for exposure pathways, exposure routes, and hazards to human populations from industrial and commercial activities and uses of TBBPA. There is potential for exposure to workers and/or ONUs via inhalation of particulates due to the activities and uses (manufacturing, processing and use of TBBPA. Exposure may occur due to fugitive emissions from activities such as the manufacture and processing of TBBPA. Fugitive air emissions are emissions that are not routed through a stack and may occur during sampling, equipment cleaning, and container loading/unloading. Stack air releases may occur from vented losses during process operations. Exposure may also occur due to uses of TBBPA such as use as a laboratory chemical or recycling articles containing TBBPA. Exposure may also occur through the dermal route for workers who handle TBBPA. Dermal exposure is not expected for ONUs as they are not expected to directly handle TBBPA.

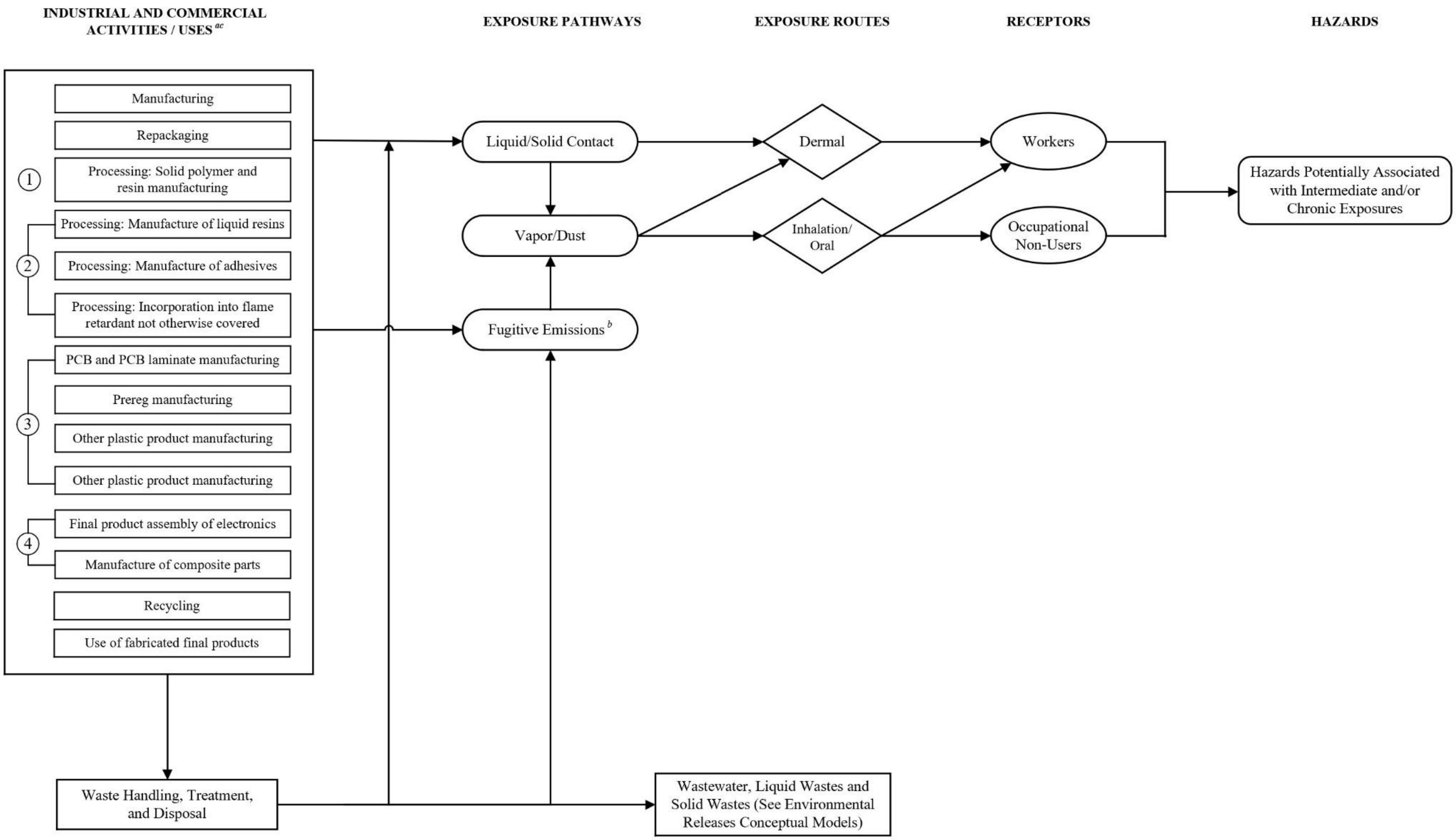

Figure 2-1. TBBPA Conceptual Model for Industrial and Commercial Activities and Uses: Potential Exposure and Hazards

[a] Some products are used in both commercial and consumer applications. See Table 3-1 for categories and subcategories of COUs.

[b] Fugitive air emissions are emissions that are not routed through a stack and may occur during sampling, equipment cleaning, and container loading/unloading.

[c] Use groupings are based on test report data submitted to EPA by ACC's TBBPA Consortium.

EPA provided occupational inhalation and dermal exposure results representative of *central tendency* and *high-end* (HE) conditions. A central tendency is assumed to be representative of occupational exposures that are expected to be typical for a given COU. For the draft risk evaluation and this assessment/TSD, EPA used the 50th percentile (median), mean (arithmetic or geometric), mode, or midpoint values of a distribution as representative of the central tendency scenario. The Agency's preference is to provide the 50th percentile of the distribution. However, if the full distribution is not known, EPA may assume that the mean, mode, or midpoint of the distribution represents the central tendency depending on the statistics available for the distribution.

A high-end is assumed to be representative of occupational exposures that occur at probabilities above the 90th percentile but below the exposure of the individual with the highest exposure (U.S. EPA, 1992b). For the draft risk evaluation and this assessment, EPA provided high-end results at the 95th percentile. If the 95th percentile is not available, the Agency used a different percentile greater than or equal to the 90th percentile but less than or equal to the 99.9th percentile, depending on the statistics available for the distribution. If the full distribution is not known and the preferred statistics are not available, EPA estimated a maximum or bounding estimate in lieu of the high-end.

For each OES, EPA attempted to provide central tendency and high-end full-shift time-weighted averages (TWAs) (typically as 8-hour TWAs) inhalation exposure concentrations and central tendency and high-end intermediate and chronic (non-cancer) potential dermal dose rates. EPA uses the following hierarchy in selecting data and approaches for assessing occupational exposures:

1. Monitoring data:
    a. Personal and directly applicable
    b. Area and directly applicable
    c. Personal and potentially applicable or similar
    d. Area and potentially applicable or similar
2. Modeling approaches:
    a. Surrogate or analogous monitoring data
    b. Fundamental modeling approaches
    c. Statistical regression modeling approaches
3. Occupational exposure limits (these limits would likely be used jointly in an assessment)[1]:
    a. Company-specific occupational exposure limits (OELs)
    b. Occupational Safety and Health Administration (OSHA) permissible exposure limits (PELs)
    c. Voluntary limits (American Conference of Governmental Industrial Hygienists [ACGIH] Threshold Limit Values [TLV], National Institute for Occupational Safety and Health [NIOSH] Recommended Exposure Limits [REL], Occupational Alliance for Risk Science (OARS) workplace environmental exposure level (WEEL) [formerly by AIHA])

For TBBPA, EPA used the estimated central tendency and high-end full-shift TWA inhalation exposure concentrations and acute potential dose rate (APDR) to calculate exposure metrics required for risk evaluation. These metrics are presented in the draft risk evaluation for TBBPA (U.S. EPA, 2026i). Exposure metrics for inhalation exposures include intermediate average daily concentrations (IADC),

[1] Most often, when modeled results exceed a regulatory or otherwise relevant exposure limit, the limit may be used as the high-end estimate of exposure. For example, some of the industries in the PNOR Model often yield 95th percentiles above the regulatory limit for PNOR (15 mg/m^3 for total and 5 mg/m^3 for respirable). Due to this exceedance, the regulatory limit is used in lieu of the 95th percentile. Further discussion of this model is provided in Appendix D.

and average daily concentrations (ADC). Exposure metrics for dermal exposures include intermediate retained dose (IRD) and chronic retained dose (CRD). Relevant equations and sample calculations can be found in Appendix C. With exposure estimates identified for all OESs using monitoring data and modeling, occupational exposure limits, as described in items #3a to c above, were not used in this assessment.

Under the "Inhalation Exposure" tab in the *Draft Risk Calculator for Occupational Exposures for 4,4'-(1-Methylethylidene)bis[2,6-dibromophenol] (TBBPA)* (U.S. EPA, 2026h), there is a summary of the inhalation data that were used in this assessment. Click on the "Dermal Exposure" tab for details on how dermal exposure was estimated for this draft risk evaluation.

2.1 Identifying Worker Activities

EPA relied on industry-provided data and literature searches to identify worker activities that could potentially result in occupational exposures. Where worker activities were unclear or not available, the Agency referenced relevant emission scenario documents (ESDs) or generic scenarios (GSs). Worker activities for each COU can be found for each OES in Section 3. This section also discusses PPE typically worn by workers and ONUs, if available—though EPA's occupational exposure estimates do not assume the use of PPE. However, the effect of respiratory protection and dermal protection factors on EPA's occupational exposure estimates can be explored under the "Risk Reduction" tab of the *Draft Risk Calculator for Occupational Exposures for 4,4'-(1-Methylethylidene)bis[2,6-dibromophenol] (TBBPA)* (U.S. EPA, 2026h). For more discussion on respiratory protection and glove protection, refer to Appendix E.

2.2 Number of Workers and Occupational Non-Users

Where available, EPA used CDR data to provide a basis to estimate the number of workers and ONUs. EPA supplemented the available CDR data with U.S. economic data using the following method:

1. Identify the North American Industry Classification System (NAICS) codes for the industry sectors associated with these uses.
2. Estimate total employment by industry/occupation combination using the U.S. Bureau of Labor Statistics' (BLS) Occupational Employment Statistics data (also referred to as "BLS Data").
3. Refine the Occupational Employment Statistics estimates where they are not sufficiently granular by using the U.S. Census' Statistics of U.S. Businesses (SUSB) (also referred to as "SUSB Data") data on total employment by 6-digit NAICS.
4. Use market penetration data to estimate the percentage of employees likely to be using TBBPA instead of other chemicals.
5. Where market penetration data are not available, use the estimated workers/ONUs per site in the 6-digit North American Industry Classification System (NAICS) code and multiply by the number of sites estimated from CDR, TRI, Discharge Monitoring Reports (DMR) and/or the National Emissions Inventory (NEI). In DMR data, sites report Standard Industrial Classification (SIC) codes rather than NAICS codes; therefore, EPA mapped each reported SIC code to a NAICS code for use in this analysis.
6. Combine the data generated in Steps 1 through 5 to produce an estimate of the number of employees using TBBPA in each industry/occupation combination and sum these to arrive at a total estimate of the number of employees with exposure within the OES.

There are uncertainties surrounding the estimated number of workers potentially exposed to TBBPA. First, BLS employment data for each industry/occupation combination are only available at the 3-, 4-, or 5-digit NAICS level, rather than at the full 6-digit NAICS level. This lack of specificity could result in an overestimate of the number of exposed workers if some 6-digit NAICS are included in the less granular BLS estimates but are not likely to use TBBPA for the assessed applications. EPA addressed this issue by refining the Occupational Employment Statistics data using total employment data from the U.S. Census' SUSB. However, this approach assumes that the distribution of occupation types (Standard Occupational Classification [SOC] codes) in each 6-digit NAICS is equal to the distribution of occupation types at the parent 5-digit NAICS level. If the distribution of workers in occupations with TBBPA exposure differs from the overall distribution of workers in each NAICS, then this approach will result in inaccuracy. The effects of this uncertainty on the number of worker estimates are unknown, as the uncertainties may result in either over or underestimation of the estimates depending on the actual distribution.

Second, EPA's determinations of industries (represented by NAICS codes) and occupations (represented by SOC codes) that are associated with the OESs assessed in this report are based on EPA's understanding of how TBBPA is used in each industry. The designations of which industries and occupations have potential exposures is a matter of professional judgment; therefore, the possibility exists for the erroneous inclusion or exclusion of some industries or occupations. This may result in inaccuracy, but it would be unlikely to systematically either overestimate or underestimate the number of exposed workers.

2.3 Inhalation Exposure Approach and Methodology

2.3.1 Inhalation Exposure Monitoring

EPA reviewed workplace inhalation monitoring data found in published literature (*i.e.,* personal exposure monitoring data and area monitoring data), and monitoring data submitted via test orders and public comments. Studies were evaluated using the evaluation strategies laid out in EPA's *Application of Systematic Review in TSCA Risk Evaluations* (U.S. EPA, 2018). Data and studies considered in this assessment can be found in *Draft Systematic Review Protocol for 4,4'-(1-Methylethylidene)bis[2,6-dibromophenol] (TBBPA)* (U.S. EPA, 2026j), and under the "Inhalation Exposure" tab of the *Draft Risk Calculator for Occupational Exposures for 4,4'-(1-Methylethylidene)bis[2,6-dibromophenol] (TBBPA)* (U.S. EPA, 2026h).

Exposures are calculated from the monitoring datasets provided in the sources depending on the size of the dataset. For datasets with six or more data points, central tendency and high-end exposures were estimated using the 50th and 95th percentile. For datasets with three to five data points, central tendency exposure was calculated using the 50th percentile and the maximum was presented as the high-end exposure estimate. For datasets with two data points, the midpoint was presented as a midpoint value and the higher of the two values was presented as a higher value. Finally, datasets with only one data point presented the single exposure value. For datasets including exposure data that were reported as below the limit of detection (LOD), EPA estimated the exposure concentrations for these data, following EPA's *Guidelines for Statistical Analysis of Occupational Exposure Data* (U.S. EPA, 1994), which recommends using the $\frac{LOD}{\sqrt{2}}$ if the geometric standard deviation of the data are less than 3.0 and $\frac{LOD}{2}$ if the geometric standard deviation is 3.0 or greater. For datasets where all monitoring data were reported as below the LOD, one-half of the LOD was assessed as a central tendency estimate, and the LOD was assessed as a high-end estimate.

If full-shift TWA personal breathing zone (PBZ) monitoring samples were not available, area samples were used for exposure estimates.

For each OES, EPA endeavored to distinguish exposures for workers and ONUs. A primary difference between workers and ONUs is that workers may handle TBBPA and have direct contact with the chemical, while ONUs work in the general vicinity of workers but do not handle TBBPA and do not have direct dermal contact with TBBPA being handled by the workers. EPA recognizes that worker job titles and activities may vary significantly from site to site; therefore, the Agency typically identified samples as worker samples unless it was explicitly clear from the job title (*e.g.,* inspectors) and the description of activities in the report that the employee was not directly involved in the scenario. Samples from employees determined not to be directly involved in the scenario were designated as ONU samples. Where EPA was not able to estimate ONU inhalation exposure from monitoring data or models, ONU exposure was assumed to be equivalent to the central tendency experience by workers for the corresponding OES.

The primary strength of the approach is that the monitoring data are chemical-specific and directly applicable to the exposure scenario. The use of applicable monitoring data are preferable to other assessment approaches such as modeling or the use of OELs/PELs.

The principal limitation of monitoring data are the uncertainty in the representativeness of the data due to some scenarios having limited exposure monitoring data. Where few data are available, the assessed exposure levels may not be representative of worker exposure across the entire job category or industry. This may particularly be the case when monitoring data were available for only one site. Additionally, site locations may introduce uncertainty, because OSHA and NIOSH reports tend to target facilities with expected higher exposures. Differences in work practices and engineering controls across sites can introduce variability and limit the representativeness of monitoring data.

Age of the monitoring data can also introduce uncertainty due to differences in workplace practices and equipment used at the time the monitoring data were collected compared to those currently in use. Therefore, older data may overestimate or underestimate exposures, depending on these differences. The effects of these uncertainties on the occupational exposure assessment are unknown, as the uncertainties may result in either overestimation or underestimation of exposures depending on the actual distribution of TBBPA air concentrations and the variability of work practices among different sites.

In some scenarios where monitoring data were available, EPA did not find sufficient data to determine complete statistical distributions. Ideally, EPA will present 50th and 95th percentiles for each exposed population. In the absence of percentile data for monitoring, the mean or midpoint of the range may serve as a substitute for the 50th percentile of the actual distributions. Similarly, the highest value of a range may serve as a substitute for the 95th percentile of the actual distribution. However, these substitutes are uncertain. The effects of these substitutes on the occupational exposure assessment are unknown, as the substitutes may result in either overestimation or underestimation of exposures depending on the actual distribution.

In some cases where inhalation exposures were expected for an OES but monitoring data specific to that OES were not available, monitoring data for a different but similar OES for TBBPA was used. In these cases, EPA compared the use conditions of each OES to find the most appropriate OES to use as analogous. Specific details related to the use of monitoring data for each COU can be found in Section 3.

2.3.2 Inhalation Exposure Modeling

Where inhalation exposures are expected for an OES but monitoring data were not available or where EPA determined monitoring data did not sufficiently capture the exposures for an OES, EPA utilized models to estimate inhalation exposures of TBBPA (specifically, the PNOR Model).

This model estimates worker inhalation exposure to respirable solid particulates using personal breathing zone PNOR monitoring data from OSHA's Chemical Exposure Health Data (CEHD) dataset. The data also include facility NAICS code information for each data point. To estimate particulate exposures for relevant OESs, EPA used the 50th and 95th percentiles of respirable PNOR values for applicable NAICS codes as the central tendency and high-end exposure estimates, respectively. The model assumes that the concentration of TBBPA in the airborne particulates is the same as the TBBPA concentration in the bulk product, which is a limitation of the model. This is a conservative assumption used in this assessment and may lead to overestimation of the potential exposure to airborne particulates. Model approaches and parameters are described in Appendix D.

2.3.3 Intermediate and Chronic (Non-Cancer) Inhalation Exposure

For each OES, the estimated TWA exposures were used to calculate IADC and ADC concentrations for chronic, non-cancer risks. These calculations require additional parameter inputs, such as years of exposure, exposure duration and frequency, and lifetime years.

For the final exposure result metrics, each of the input parameters (*e.g.,* air concentrations, working years, exposure frequency, lifetime years) is presented as a point estimate (*i.e.,* a single descriptor or statistic, such as central tendency or high-end). EPA used combinations of point estimates of each parameter to estimate a central tendency and high-end for each final exposure metric result. EPA documented the method and rationale for selecting parametric combinations to be representative of central tendency and high-end.

Equations, parameter inputs, and sample calculations for these exposures can be found in Appendix B and Appendix C, respectively.

2.4 Dermal Exposure Approach and Methodology

TBBPA dermal exposure monitoring data were not available. EPA obtained TBBPA *in vitro* dermal absorption study data (Charles River Laboratories, 2024) as a result of a test order that EPA issued pursuant to TSCA section 4(a)(2). The Agency assumed that workers are potentially exposed to TBBPA dermally and assumed exposure levels in accordance with EPA's standard methods for assessing dermal exposure (refer to Section 2.4.1.2 for the rationales and details of these assumptions). The Agency then assessed the potential absorption of TBBPA from worker dermal exposures. To assess this absorption, the Agency estimated the quantity of TBBPA that is dermally transferred into systemic circulation during a single day as a result of TBBPA dermal exposure occuring that day. To estimate this absorbed quantity of TBBPA, the Agency estimated a maximal TBBPA dermal absorption flux from data about cumulative quantity of TBBPA in receptor fluid that is reported in the TBBPA *in vitro* dermal absorption study final report (Charles River Laboratories, 2024). The Agency assessed TBBPA occupational dermal exposure that possibly results from the TBBPA COUs in general from this maximal flux value. The Agency then calculated the quantity of absorbed TBBPA as follows:

Equation 2-1.

$$
\begin{aligned}
&\mathit{Quantity\ of\ Absorbed\ TBBPA} \\
&\qquad = (\mathit{Maximal\ TBBPA\ flux}) \times (\mathit{Percutaneous\ absorption\ period\ of\ 24\ hrs}) \\
&\qquad \times (\mathit{Exposure\ surface\ area})
\end{aligned}
$$

Although EPA typically assesses exposure duration to be equal to the shift duration (*e.g.,* 8-hour), percutaneous absorption may continue beyond the exposure period as can be inferred from the TBBPA *in vitro* dermal absorption study (Charles River Laboratories, 2024), which is described in detail in

Section 2.4.1.1. The absorption period of this study was limited to 24 hours in accordance with OECD guidelines because risk is typically calculated based on daily exposure and absorption.

A central tendency and high-end value of the amount of TBBPA absorbed was calculated from central tendency and high-end values of exposure surface area, respectively. The Agency conservatively assessed central tendency and high-end dermal exposures to TBBPA in the case of all OESs to be equal to this central tendency and high-end value of the amount of TBBPA absorbed, respectively. A detailed description of the assessment method follows.

2.4.1 Dermal Exposure Assessment Method

This section contains a summary of Charles River Laboratories (2024), a discussion of the relevancy of the information of this report to the assessment of TBBPA occupational dermal exposure, an analysis of the results reported in this report in accordance with OECD Guidance No. 156: Guidance Notes on Dermal Absorption Studies (2nd Edition) (OECD, 2022), the rationale for assessment of TBBPA occupational dermal exposure based on dermal absorption flux, and the method of calculation of this flux.

2.4.1.1 Summary of the TBBPA *In Vitro* Dermal Absorption Study Final Report

The *in vitro* dermal absorption study (Charles River Laboratories, 2024) was conducted in accordance with Good Laboratory Practice (GLP) regulations and relevant OECD guidelines. This study involved radiolabeled TBBPA, a static diffusion cell apparatus, and ten full-thickness human skin (abdominal) samples that were obtained from 10 donors. These skin samples were cut with an electric dermatome to thickness of 300 to 400 µm. Eight skin samples from four donors were used in the case of each test preparation for replication purposes. The dosing conditions, application rate, TBBPA concentration and vehicle in the case of each test preparation is provided in Table 2-1. The receptor fluid was phosphate buffered saline containing polyoxyethylene 20 oleyl ether (PEG, ≈6%, w/v) and gentamicin (≈0.01%, w/v). The solubility of TBBPA in this receptor fluid is 11.5 g/L which is equal to 32.72% of the TBBPA concentration that would result if the maximum TBBPA applied amount is entirely transferred to the receptor fluid. The receptor chamber was sampled at 10 and 30 minutes and at 1, 2, 4, 8, 12, 16, 20, and 24 hours after dosing. Skin surface was washed 8 hours after dosing (*i.e.,* the exposure period equals 8 hours) and the skin and the cell were washed 24 hours after dosing. The stratum corneum was removed with 20 successive tape strips and each strip was analyzed for TBBPA. Study results associated with finite doses are shown in Table 2-2, Table 2-3, and Table 2-4. The data in these tables is the arithmetic mean of eight replicate values. The following are definitions of the variables listed in the above tables:

- 8-hour dislodgeable dose = 8-hour skin wash + 8-hour tissue swab + 8-hour pipette tip;
- 24-hour dislodgeable dose = 24-hour skin wash + 24-hour tissue swab + 24-hour pipette tip;
- total dislodgeable dose = 8-hour dislodgeable dose + 24-hour dislodgeable dose + donor chamber wash;
- stratum corneum = tape strips 1 to 20;
- total unabsorbed dose = total dislodgeable dose + stratum corneum + unexposed skin;
- total absorbed dose = cumulative receptor fluid + receptor chamber wash;
- dermal delivery = absorbed dose + exposed skin;
- potentially absorbable dose = dermal delivery + stratum corneum 3 to 20; and
- mass balance = unabsorbed dose + dermal delivery.

Dermal delivery is defined in OECD Guidance No. 28: Guidance Document for the Conduct of Skin Absorption Studies (OECD, 2004) as "the sum of the applied dose found in the treated skin and the absorbed dose at the end of the experiment" whereas the term "potentially absorbable dose" is not defined in this OECD guidance document. EPA chose the terminology of this OECD document and therefore mentions the term "potentially absorbable dose" minimally.

Table 2-1. TBBPA *In Vitro* Dermal Absorption Study Dosing Conditions, Application Rates, TBBPA Concentrations and Vehicles

Test Group (Test Preparation)	Dosing Condition	Application Rate	TBBPA Concentration	Vehicle
Group 1	Finite	10 mg/cm^2 (equivalent to 5.075 mg/cm^2 of neat TBBPA)	Neat application in acetone solution[a]	N/A
Group 2		10 mg/cm^2 (equivalent to 1.027 mg/cm^2 of neat TBBPA)	Neat application in acetone solution[b]	N/A
Group 3		10 $\mu L/cm^2$	50%, w/v	Isopropyl myristate (IPM)
Group 4			10%, w/v	
Group 5			1%, w/v	
Group 6			50%, w/v	Receptor fluid
Group 7			10%, w/v	
Group 8			1%, w/v	
Group 9	Infinite	>500 $\mu L/cm^2$	50%, w/v	Isopropyl myristate (IPM)
Group 10			10%, w/v	
Group 11			1%, w/v	

[a] 3.2 mg of sodium chloride solution (0.9% w/v) added after the acetone evaporated.
[b] 5.76 mg of sodium chloride solution (0.9% w/v) added after the acetone evaporated.

Table 2-2. TBBPA *In Vitro* Dermal Absorption Study Results for Test Groups Involving Finite Doses and Neat TBBPA

Test Preparation	1	2
Concentration of test item	Neat	Neat
Applied mass of test item ($\mu g/cm^2$)	5,075	1,027
Distribution	% Applied Dose ± SD	
Total dislodgeable dose	93.38 ± 3.90	81.66 ± 6.45
Stratum Corneum	4.11 ± 1.42	12.45 ± 4.66
Total absorbed dose	0.05 ± 0.02	0.15 ± 0.10
Dermal delivery	0.25 ± 0.10	1.63 ± 1.06
Potentially absorbable dose	0.86 ± 0.47	6.61 ± 2.89
Mass balance	97.75 ± 3.64	95.81 ± 5.32
Distribution	$\mu g/cm^2$ ± SD	
Total dislodgeable dose	4,739 ± 198	839 ± 66.3
Stratum Corneum	208 ± 72.1	128 ± 47.9
Total absorbed dose	2.55 ± 0.80	1.58 ± 1.05

Test Preparation	1	2
Dermal delivery	12.6 ± 4.96	16.8 ± 10.9
Potentially absorbable dose	43.4 ± 23.9	67.9 ± 29.6
Mass balance	4,960 ± 185	984 ± 54.6

Table 2-3. TBBPA *In Vitro* Dermal Absorption Study Results for Test Groups Involving Finite Doses and IPM as the Vehicle

Test Preparation	3	4	5
Concentration of test item	50% w/v	10% w/v	1% w/v
Vehicle	IPM	IPM	IPM
Applied mass of test item ($\mu g/cm^2$)	5,347	1,049	104
Distribution	% Applied Dose ± SD		
Total dislodgeable dose	94.01 ± 3.56	95.86 ± 1.71	95.67 ± 1.45
Stratum Corneum	4.66 ± 2.37	1.83 ± 0.53	2.39 ± 0.47
Total absorbed dose	0.03 ± 0.03	0.05 ± 0.03	0.10 ± 0.05
Dermal delivery	0.27 ± 0.28	0.40 ± 0.14	0.50 ± 0.28
Potentially absorbable dose	1.87 ± 1.60	1.52 ± 0.25	1.95 ± 0.36
Mass balance	98.94 ± 2.81	98.19 ± 1.89	98.59 ± 1.07
Distribution	$\mu g/cm^2$ ± SD		
Total dislodgeable dose	5,027 ± 191	1005 ± 18.0	99.48 ± 1.50
Stratum Corneum	249 ± 127	19.2 ± 5.51	2.49 ± 0.49
Total absorbed dose	1.42 ± 1.73	0.57 ± 0.35	0.10 ± 0.05
Dermal delivery	14.6 ± 15.0	4.22 ± 1.44	0.52 ± 0.29
Potentially absorbable dose	99.7 ± 85.4	15.9 ± 2.63	2.03 ± 0.37
Mass balance	5,291 ± 150	1030 ± 19.9	103 ± 1.12

Table 2-4. TBBPA *In Vitro* Dermal Absorption Study Results for Test Groups Involving Finite Doses and Receptor Fluid as the Vehicle

Test Preparation	6	7	8
Concentration of test item	50% w/v	10% w/v	1% w/v
Vehicle	Receptor fluid	Receptor fluid	Receptor fluid
Applied mass of test item ($\mu g/cm^2$)	5,592	1,077	108
Distribution	% Applied Dose ± SD		
Total dislodgeable dose	94.78 ± 2.21	95.21 ± 14.29	92.86 ± 3.28
Stratum corneum	1.13 ± 1.32	6.46 ± 4.69	2.83 ± 1.08
Total absorbed dose	0.01 ± 0.01	0.19 ± 0.31	0.07 ± 0.03

Test Preparation	6	7	8
Dermal delivery	0.33 ± 0.48	1.64 ± 2.35	0.86 ± 1.00
Potentially absorbable dose	0.88 ± 1.20	4.32 ± 3.01	2.55 ± 1.13
Mass balance	96.25 ± 1.20	103.37 ± 11.32	96.56 ± 2.33
Distribution	$\mu g/cm^2$ ± SD		
Total dislodgeable dose	5,300 ± 124	1,026 ± 154	101 ± 3.56
Stratum Corneum	63.1 ± 73.7	69.6 ± 50.6	3.07 ± 1.17
Total absorbed dose	0.71 ± 0.79	2.05 ± 3.33	0.07 ± 0.04
Dermal delivery	18.7 ± 26.8	17.7 ± 25.3	0.94 ± 1.09
Potentially absorbable dose	49.1 ± 67.1	46.5 ± 32.4	2.76 ± 1.22
Mass balance	5,382 ± 67.2	1,114 ± 122	105 ± 2.53

2.4.1.2 Applicability of the TBBPA *In Vitro* Dermal Absorption Data to Occupational Dermal Exposure Assessment

This section contains a brief description of the TBBPA occupational dermal exposure scenarios that the Agency assessed, EPA's standard method for the assessment of occupational dermal exposure and a comparison of the parameters of this method and the corresponding experimental conditions of the TBBPA *in vitro* dermal absorption study.

Workers handle small and large containers of powder containing more than 90% TBBPA by weight, operate equipment which may involve the use of handheld tools or the handling of material, collect samples, conduct laboratory tests, package products, and clean or maintain equipment. These activities involve materials containing TBBPA including pellets, granules, liquid resins (*e.g.,* epoxy resin), semisolid adhesives, and articles such as prepregs (pre-impregnated material), adhesive films and panels. Maximum concentration of TBBPA in liquids and semisolids is 26% by weight (Integral Consulting, 2025a). Based on this information, EPA infers possible dermal exposure of workers to TBBPA powder, and TBBPA in solid particulates, liquids, semisolids and solid matrices. A summary of EPA's method for assessing such dermal exposure and a comparison of the parameters of this method and the corresponding experimental conditions of the TBBPA *in vitro* dermal absorption study follows.

Table 2-5 and Table 2-6 present EPA's typical values for the mass of powder remaining on skin after exposure, the exposed skin surface area, and the resulting normalized values (*i.e.,* the ratios of quantity remaining on skin and skin exposure surface areas). The normalized values range from 0.84 to 2.90 mg/cm^2. These normalized quantities are similar to or less than the applied mass of the test item in the case of preparations one and two (the two test preparation that involve neat TBBPA), which are equal to 5.075 mg/cm^2 and 1.027 mg/cm^2, respectively, as stated in Table 2-2 (Lansink et al., 1996; U.S. EPA, 2015).

Lansink et al. (1996) measured calcium carbonate ($CaCO_3$) powder adherence to gloves at various sites in the paint industry. Workers wore cotton gloves covering their hands and part of their forearms while performing tasks such as transferring and dumping bags containing the raw material, manual weighing, and handling of empty bags. For each activity, the study reports the total mass of calcium carbonate on the gloves (range, geometric mean, and 10th and 90th percentile). EPA uses these results as the basis of the dermal exposure model for solids. For routine direct handling of solids, the Agency applies 3,100 and 1,100 mg (90th percentiles[2] in the original study) depending on the activity being assessed (U.S. EPA, 2015). Additionally, EPA also uses the geometric means[2] of 900 mg and 450 mg for central tendency estimates as needed. These values were normalized to the amount of loading per surface area using the surface area of two hands (1,070 cm^2) and one hand (535 cm^2) as shown in Table 2-5 and Table 2-6.

With regard to exposure to liquids, EPA typically assesses exposure to liquids in general to be equal to 0.7 to 2.1 mg /cm^2 if the exposure scenario does not involve immersion (U.S. EPA, 1992c, 2015). These dermal loading values were measured from an EPA's *A Laboratory Method to Determine the Retention of Liquids on the Surface of the Hands* (U.S. EPA, 1992c) which serves as the basis for liquid dermal loads. These quantities are equivalent to 0.18 to 0.55 mg of TBBPA/cm^2, respectively, given the maximum concentration of TBBPA in liquids or semisolids is equal to 26% by weight. These quantities of TBBPA are similar to or less than the applied masses of the test item in the case of test preparations three through seven (the test preparations that involve liquid solutions of TBBPA), which are equal to 0.103 to 5.592 mg of TBBPA/cm^2 as stated in Table 2-2. Also, the maximum liquid concentration of TBBPA of any OES, which is 26% by weight, is less than the maximum concentration of TBBPA in the applied mass of a test preparations involving liquids. In conclusion, the test conditions of the TBBPA *in vitro* dermal absorption testing in terms of amount and concentration of TBBPA in the applied mass are adequate because these conditions are similar to or greater than the exposure parameters that EPA would have assessed such that the measured TBBPA dermal absorption would be health protective. Based on this analysis, the Agency analyzed the results of the dermal absorption study as discussed in the following section.

Table 2-5. EPA's Typically Assessed Central Tendency Values of Quantity Remaining on Skin and Skin Exposure Surface Area

EPA's Typically Assessed Quantity Remaining on Skin (mg/day)	EPA's Typically Assessed Skin Exposure Surface Area of a Worker (cm^2)	Normalized Values (mg/cm^2-day)
900	535	1.68
450	535	0.84

Table 2-6. EPA's Typically Assessed High-End Values of Quantity Remaining on Skin and Skin Exposure Surface Area

EPA's Typically Assessed Quantity Remaining on Skin (mg/day)	EPA's Typically Assessed Skin Exposure Surface Area (cm^2)	Normalized Values (mg/cm^2-day)
3,100	1,070	2.90
1,100	1,070	1.03

2.4.1.3 Analysis of the TBBPA *In Vitro* Dermal Absorption Data per OECD Guidance No. 156

EPA analyzed the results reported in Charles River Laboratories (2024) accordance with OECD Guidance No. 156 (OECD, 2022). According to this document, if "essentially complete absorption (*e.g.*, evidenced by >75% permeation by the midpoint of the sampling period)" has not occurred, then "dermal

[2] Parameter values used are rounded values from the actual values reported in Lansink et al. (1996).

absorption = % in receptor fluid + % in receptor chamber wash + % in skin sample (excluding tape strips 1 + 2)". This document also states that "in some jurisdictions (*e.g.,* United States) the skin sample may be excluded altogether on a case-by-case basis." EPA determined whether complete absorption in the case of the TBBPA *in vitro* dermal absorption study (Charles River Laboratories, 2024) occurred. Specifically, the Agency calculated cumulative absorption into the receptor fluid after 12 hours as a percentage of cumulative absorption into the receptor fluid after 24 hours in the case of each finite dose test result. The results of EPA's calculations are given in Table 2-7. As shown in this table, permeation into the receptor chamber by the midpoint of the sampling period in general does not exceed 63%. Despite this result, the Agency did not equate TBBPA dermal absorption to the sum of dermal delivery and amount in stratum corneum 3 to 20 (*i.e.,* the potentially absorbed dose) and instead assessed the quantity of absorbed TBBPA by estimating a maximal TBBPA dermal absorption flux from data about cumulative quantity of TBBPA in receptor fluid that is reported in Charles River Laboratories (2024). EPA's rationale for deviating from OECD guidance and taking this approach is discussed below.

Table 2-7. Permeation by Midpoint of Sampling Period Calculated from the TBBPA *in Vitro* Dermal Absorption Study Results

Test Preparation	Applied Mass (mg/cm^2)	Concentration (w/v)	Mean Cumulative Absorption into Receptor Fluid ($\mu g/cm^2$)			Amount Permeated into Receptor Fluid After 12 Hours as a Fraction of the Cumulative Amount Permeated at 24 Hours
			Time	Absorbed Amount	Standard Deviation	
1	5.075	Neat	12 hours	1.284 [a]	0.428 [a]	53%
			24 hours	2.401	0.692	
2	1.027	Neat	12 hours	0.380 [a]	0.314 [a]	44%
			24 hours	0.873	0.445 [a]	
3	5.347	50% in IPM	12 hours	0.330 [a]	0.090 [a]	48%
			24 hours	0.690	0.160	
4	1.049	10% in IPM	12 hours	0.120 [a]	0.067 [a]	25%
			24 hours	0.485	0.305	
5	0.104	1% in IPM	12 hours	0.0495 [a]	0.0336 [a]	58%
			24 hours	0.0847	0.0453	
6	5.592	50% in receptor fluid	12 hours	0.0624 [a]	0.021 [a]	24%
			24 hours	0.263 [a]	0.198 [a]	
7	1.077	10% in receptor fluid	12 hours	0.0278 [a]	0.0258 [a]	18%
			24 hours	0.1530	0.0613	
8	0.108	1% in receptor fluid	12 hours	0.0084 [a]	0.0026 [a]	21%
			24 hours	0.0398	0.0182	

[a] Mean includes results calculated from data less than the limit of reliable measurement (LoRM). This LoRM is 30 d.p.m. and values below this limit are true values (Charles River Laboratories, 2024).

2.4.1.4 Rationale for Assessing TBBPA Occupational Dermal Exposure Based on TBBPA Dermal Absorption Flux

Percutaneous absorption of chemical substances in general may be limited as a result of any resistance to mass transfer in the stratum corneum and/or the viable epidermis (U.S. EPA, 1992a; WHO, 2006). TBBPA is highly lipophilic (U.S. EPA, 2026f), and therefore resistance to mass transfer of TBBPA in the viable epidermis is likely (U.S. EPA, 1992a; WHO, 2006). EPA infers such resistance to mass transfer from the results of the *in vitro* dermal absorption study (Charles River Laboratories, 2024) and specifically in the large quantity of TBBPA remaining in the stratum corneum as compared with the quantity of TBBPA remaining in the viable epidermis. Despite this resistance, mass transfers, of TBBPA in the stratum corneum and the viable epidermis probably continue following the end period of 24 hours since the commencement of exposure as can be inferred from the analysis presented in Section 2.4.1.3. In such case, transfer of TBBPA in the stratum corneum and the viable epidermis would transfer into systemic circulation and the concentrations of TBBPA in these parts of the skin would decline.

The decline of the TBBPA concentration gradients in each of the stratum corneum and the viable epidermis would result in declines of the TBBPA mass transfer rates in these parts of the skin and in a decline of the percutaneous absorption of TBBPA. Thus, the rate of percutaneous absorption after the period of 24 hours since the commencement of exposure ends will be lower than the rate of percutaneous absorption during this period. If dermal absorption is accurately measured via the *in vitro* dermal absorption study, then assessment of dermal absorption in accordance with OECD Guidance No. 156 (OECD, 2022) is equivalent to the assessment of dermal exposure during multiple 24-hour periods that are consecutive with percutaneous absorption declining after the first 24-hour period until TBBPA is exhausted from the skin. However, the pertinent dermal absorption period is the 24 hours since the commencement of exposure only and not any consecutive period because the exposure scenario that EPA assessed is exposure of a worker each work day during multiple years. Thus, the TBBPA concentration gradients in the stratum corneum and the viable epidermis during each consecutive 24-hour period would be similar to what is reported in Charles River Laboratories (2024). Also, percutaneous absorption during each consecutive 24-hour period would be equal to the rate reported in Charles River Laboratories (2024). Accordingly, EPA assessed the quantity of absorbed TBBPA by estimating a maximal TBBPA dermal absorption flux from data about cumulative quantity of TBBPA in receptor fluid that is reported in Charles River Laboratories (2024). This is a conservative approach because the assessed daily rate of TBBPA percutaneous absorption is the maximum of the rates that would be derived from assessment in accordance with OECD Guidance No. 156 (OECD, 2022). EPA specifically estimated a maximal TBBPA dermal absorption flux, which is also a conservative approach. EPA's method for accomplishing this assessment is discussed next.

2.4.1.5 Method of Calculation of TBBPA Dermal Absorption Flux

To estimate a maximal flux, EPA calculated flux from the cumulative quantity of TBBPA that was measured in the receptor fluid as reported in Charles River Laboratories (2024). EPA did this for each of the eight test preparations. In the case of each test preparation, the Agency calculated flux from the difference of the following two quantities: (1) the sum of cumulative quantity of TBBPA that was measured in the receptor fluid at 24 hours plus the receptor fluid wash, and (2) the cumulative quantity of TBBPA that was measured in the receptor fluid at 20 hours. EPA selected the data corresponding to 20 hours and 24 hours to minimally incorporate data that are below the reliable limit of measurement and to assess the maximum flux. EPA then divided this difference by 4 hours to calculate flux. The Agency did this calculation from the data of the replicate that results in the maximum flux for a given test preparation. This resulted in eight calculated values of flux, each associated with a test preparation, and each determined as the maximum value for that test preparation. The Agency then selected the maximum of these eight values to assess a single flux value for the purpose of assessing all OESs. This is a screening-level approach.

The maximum flux was calculated from the data of test preparation number one and is equal to 2.9×10^{-4} mg/cm^2-h. These calculations are given in *Draft Calculations of Dermal Absorption Fluxes for 4,4'-(1-Methylethylidene)bis[2,6-dibromophenol] (TBBPA)* (U.S. EPA, 2026b).

2.4.2 Intermediate and Chronic (Non-Cancer) Dermal Exposure

For each COU, the estimated exposures were used to calculate intermediate and chronic (non-cancer) dermal doses. These calculations require additional parameter inputs, such as years of exposure, exposure duration and exposure frequency. For the final exposure result metrics, each of the input parameters (*e.g.,* dermal doses, working years, exposure frequency) may be a point estimate (*i.e.,* a single descriptor or statistic, such as central tendency or high-end) or a full distribution. As described in Section 2.3.3 EPA used combinations of point estimates of each parameter to estimate a central tendency and high-end for each final exposure metric result. EPA documented the method and rationale for selecting parametric combinations to be representative of central tendency and high-end. Equations, parameter inputs, and sample calculations for these exposures can be found in Appendix B and Appendix C, respectively.

2.5 Evidence Integration for Occupational Exposure

Evidence integration for the occupational exposure assessment includes analysis, synthesis, and integration of information and data to produce estimates occupational inhalation exposures. During evidence integration, EPA considered the likely location, duration, intensity, frequency, and quantity of releases while also considering factors that increase or decrease the strength of evidence when analyzing and integrating the data. Key factors the Agency considered when integrating evidence include the following:

1. **Data Quality:** EPA only integrated data or information rated as *high*, *medium*, or *low* obtained during the data evaluation phase. Data and information rated as *uninformative* are not used in exposure evidence integration. In general, higher rankings are given preference over lower ratings; however, lower ranked data may be used over higher ranked data when specific aspects of the data are carefully examined and compared. For example, a lower ranked dataset that precisely matches the OES of interest may be used over a higher ranked study that does not as closely match the OES of interest.
2. **Data Hierarchy:** EPA used measured data to obtain accurate and representative estimates (*e.g.,* central tendency, high-end) of the occupational exposures resulting directly from a specific source, medium, or product.

EPA considered both data quality and data hierarchy when determining evidence integration strategies. The final integration of the occupational exposure evidence combined decisions regarding the strength of the available information, including information on plausibility and coherence across each evidence stream.

3 OCCUPATIONAL EXPOSURE ASSESSMENT

The following sections contain worker activities, analysis for determining number of workers, exposure assessment approach, and results for the assessment for each TBBPA OES. Annual and daily central tendencies and high-end estimates for these occupational exposures can be found under the "Inhalation Data" and "Dermal Exposure" tabs of the *Draft Risk Calculator for Occupational Exposures for 4,4'-(1-Methylethylidene)bis[2,6-dibromophenol] (TBBPA)* (U.S. EPA, 2026h).

3.1 TBBPA COU to OES Crosswalk

As described in Section 1.2, EPA assessed occupational exposures for OESs. Table 3-1 shows mapping between the COUs in Table 4-1 of the draft risk evaluation for TBBPA (U.S. EPA, 2026i) to the OES assessed in this report. For TBBPA, EPA mapped OESs to COUs based on data and information gathered during systematic review, industry outreach, and public comments. Some of the COU categories and subcategories were grouped and assessed together in a single OES due to similarities in the processes or lack of data to differentiate between them. This grouping minimized repetitive assessments.

ACC's TBBPA Consortium submitted monitoring data in response to TSCA section 4(a)(2) test order for TBBPA (Integral Consulting, 2025a). These monitoring data are divided into four "groups" defined by process type and exposure potential, spanning multiple life cycle stages and/or categories and subcategories of COUs. EPA used these four ACC groupings as OESs due to the availability of monitoring data. Some of the ACC OESs encompass multiple COUs. For example, the OES, "ACC TBBPA Consortium's Group 2: Production of TBBPA-Containing Mixtures and Formulations" includes the following COUs: Processing as a reactant, Processing: Additive flame retardant in plastics, paints and coatings, and Adhesive manufacturing. Conversely, one COU corresponds to multiple ACC OESs: the Processing: Additive flame retardant in plastics, paints and coatings COU corresponds to ACC Groups 1, 2, and 3.

A total of 14 unique OESs were identified and mapped to 21 COUs. Table 3-1 lists each COU (defined by its unique combination of a life cycle stage, category, and subcategory) and its corresponding OES.

Table 3-1. Crosswalk of TBBPA Conditions of Use (COUs) to Occupational Exposure Scenarios (OESs)

#	Life Cycle Stage	Category	Subcategory	COU	OES in this Draft TSD
1	Manufacture	Domestic manufacture	N/A	Manufacturing	Manufacturing
2		Import	N/A	Import	N/A[a]
3	Processing	As a reactant	Flame retardant in plastic material and resin manufacturing	Processing as a reactant	ACC TBBPA Consortium's Group 2: Production of Intermediate Products (Liquid, Semi-Solid and Powder) from TBBPA Powder
4			Intermediate in all other chemical product and preparation manufacturing		
5		Incorporation into formulation, mixture, or reaction product	Flame retardant in: plastic material and resin manufacturing; plastics product manufacturing; custom compounding of purchased resins; paint and coating manufacturing	Processing: Additive flame retardant in plastics, paints and coatings	ACC TBBPA Consortium's Groups 1: Production of Formulations (Particulate Solids) from TBBPA Powder
					ACC TBBPA Consortium's Group 2: Production of Intermediate Products (Liquid, Semi-Solid and Powder) from TBBPA Powder
					ACC TBBPA Consortium's Group 3: Production of Intermediate Solid Products (Sheet, Film, and Pellet) from the Products of Group 2
6			Adhesive manufacturing	Adhesive manufacturing	ACC TBBPA Consortium's Group 2: Production of Intermediate Products (Liquid, Semi-Solid and Powder) from TBBPA Powder

#	Life Cycle Stage	Category	Subcategory	COU	OES in this Draft TSD
7	Processing	Incorporation into article	Reactive flame retardant in: computer and electronic product manufacturing; electrical equipment, appliance, and component manufacturing; plastic product manufacturing (*e.g.,* printed circuit boards and semiconductor packages)	Processing – Incorporation into printed circuit boards (PCBs) and electronic products	ACC TBBPA Consortium's Group 3: Production of Intermediate Solid Products (Sheet, Film, and Pellet) from the Products of Group 2
8			Reactive flame retardant in transportation equipment manufacturing (*e.g.,* interior material for automotive and aviation articles)	Processing – Incorporation into transportation equipment	ACC TBBPA Consortium's Group 3: Production of Intermediate Solid Products (Sheet, Film, and Pellet) from the Products of Group 2
9			Additive flame retardant in: computer and electronic product manufacturing; electrical equipment, appliance, and component manufacturing; plastic product manufacturing (*e.g.,* plastic electronic enclosures)	Processing – Incorporation into plastic products	ACC TBBPA Consortium's Group 3: Production of Intermediate Solid Products (Sheet, Film, and Pellet) from the Products of Group 2
10		Repackaging	N/A	See Repackaging above	Repackaging of TBBPA Powder
11		Recycling	N/A	Recycling	Recycling
12	Distribution in commerce	N/A	N/A	N/A	N/A[b]
13	Industrial use	Construction, paint, electrical, and metal products	Powder coatings	Industrial use in powder coatings	Use of Powder Coatings in Electronics
14	Industrial and commercial use	Construction, paint, electrical, and metal products	Reactive flame retardant in electrical and electronic articles	Industrial and commercial use in electrical and electronic articles	ACC TBBPA Consortium's Group 4: Production of Composite Parts from Prepreg and Adhesive Film
15			Additive flame retardant in electrical and electronic articles (*i.e.,* plastic enclosures)	Industrial and commercial use in electrical and electronic	Industrial and Commercial Use in Electrical and Electronic Articles

#	Life Cycle Stage	Category	Subcategory	COU	OES in this Draft TSD
	Industrial and commercial use	Construction, paint, electrical, and metal products		articles	
16			Reactive flame retardant in automotive and aviation articles (*i.e.,* laminate and prepreg material)	Industrial and commercial use in automotive and aviation articles	ACC TBBPA Consortium's Group 4: Production of Composite Parts from Prepreg and Adhesive Film
17			Building/construction materials	Industrial and commercial use in building and construction materials	Industrial and Commercial Use in Building and Construction Materials
18		Packaging, paper, plastic, hobby products	Plastic and rubber products	Industrial use in plastic and rubber products	Industrial Use in Plastic and Rubber Products
19			Plastic and rubber products	Commercial use in plastic and rubber products	Commercial Use in Plastic and Rubber Products
20		Other	Laboratory chemical	Industrial and commercial laboratory chemical use	Industrial and Commercial Laboratory Chemical Use
21	Disposal	N/A	N/A	Disposal	Disposal

[a] Importation results in potential exposure once the contents of imported containers are transferred for repackaging or processing. Repackaging of imported containers is part of the Repackaging OES and unloading of imported containers for processing is part of the OESs involving TBBPA Processing.
[b] For the purpose of the draft risk evaluation and this assessment/TSD, Distribution in commerce COU is the transportation of TBBPA and TBBPA-containing products between sites at which TBBPA manufacturing, processing, and use occurs or the transportation of TBBPA-containing wastes for recycling or disposal. EPA expects all of the above-mentioned materials to be transported in closed system or otherwise to be transported in a form (*e.g.,* articles containing TBBPA) such that there is negligible potential for occupational exposure except during an accident.

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3.2 Manufacturing

As listed in Table 3-1, this OES includes the following COU: Manufacturing.

3.2.1 Worker Activities

Process information indicates that TBBPA is manufactured as a solid. During manufacturing, worker exposures to TBBPA may occur via inhalation of dust or dermal contact with solids during worker activities such as product sampling, equipment cleaning, container cleaning, reactor operation, and packaging and loading of TBBPA into reactors or transport containers for shipment.

PPE used at a facility manufacturing TBBPA included gloves, safety glasses, and disposable coveralls, which would minimize potential dermal exposure to workers handling TBBPA (Integral Consulting, 2025b). Packagers and loaders of the product were reported to wear half face respirators with particulate cartridges (Integral Consulting, 2025b). Engineering controls from facilities manufacturing TBBPA included the use of local exhaust ventilation controls and other air pollution control devices to reduce dust exposures (CRCS Inc., 1984; Integral Consulting, 2025b).

ONUs include employees (*e.g.,* supervisors and managers) who work at the manufacturing facility but do not directly handle TBBPA. Generally, EPA expects ONUs to have lower inhalation exposures than workers who handle the chemicals directly. Because ONUs do not handle TBBPA directly, dermal exposures would be limited to incidental contact, such as of TBBPA dusts that settle onto surfaces that the ONUs contact.

See Section 3.3.1 of the *Draft Release Assessment for 4,4'-(1-Methylethylidene)bis[2,6-dibromophenol] (TBBPA)* (U.S. EPA, 2026g) for a full manufacturing process description.

3.2.2 Number of Workers and Occupational Non-Users

EPA used data from BLS and the SUSB specific to the OES to estimate the number of workers and ONUs per site potentially exposed to TBBPA during manufacturing (U.S. Census Bureau, 2017; U.S. BLS, 2023a). This approach involved first identifying the relevant NAICS codes for the OES. The next step is the identification of relevant SOC codes within the BLS data for the identified NAICS codes, from which total number of workers can be determined. This number is divided by the number of sites identified to obtain the exposed workers per site. Appendix A includes further details regarding methodology for estimating the number of workers and ONUs per site. EPA assigned the following NAICS codes for this OES:

- 325998 – All Other Miscellaneous Chemical Product and Preparation Manufacturing;
- 325199 – All Other Basic Organic Chemical Manufacturing; and
- 325180 – Other Basic Inorganic Chemical Manufacturing.

Table 3-2 summarizes the per site estimates for this OES based on the methodology described, including the number of sites identified in Section 3.3.2 of the *Draft Release Assessment for 4,4'-(1-Methylethylidene)bis[2,6-dibromophenol] (TBBPA)* (U.S. EPA, 2026g).

Table 3-2. Estimated Average Number of Workers per Site Potentially Exposed to TBBPA During Manufacturing

Potential Number of Sites	NAICS Code	Potentially Exposed Workers per Site[a]	Potentially Exposed ONUs per Site[a]
1	325998 – All Other Miscellaneous Chemical Product and Preparation Manufacturing	23	11
	325199 – All Other Basic Organic Chemical Manufacturing		
	325180 – Other Basic Inorganic Chemical Manufacturing		

[a] Number of workers and ONUs per site calculated by dividing the exposed number of workers or ONUs by the number of establishments.

3.2.3 Occupational Inhalation Exposure Results

EPA assessed inhalation exposure concentrations based on surrogate data. These surrogate data are total dust personal worker monitoring data. The data were collected by monitoring TBBPA manufacturing workers during the manufacture of TBBPA at Albemarle Corporation's Magnolia, Arkansas, site between July 2003 and November 2021. These data were collected by Albemarle Corporation as surrogate TBBPA inhalation exposure surrogate data because a TBBPA sampling and analysis method was lacking. The data comprise 10 full-shift personal monitoring samples that were collected for 4 packagers, a maintenance team member, an electrical and instrumentation (E&I) technician, a back-end operator, a loader operator, and two general operators. Detailed information about the tasks performed during sampling was unavailable, but Albemarle Corporation reported that operators generally handled front-end processes in the reactor area but could also move between the reactor and packaging areas. Sample durations ranged from 330 to 490 minutes. Two other samples were excluded from this dataset because these samples were obtained by monitoring workers who work at the front-end of the process and raw material for TBBPA manufacture was present in that location but not TBBPA; each of these samples was below the limit of detection (<0.01 and <0.32 mg/m^3) (Integral Consulting, 2025b).

EPA assessed central tendency and high-end full-shift TWA exposure concentrations to be equal to the 50th and 95th percentile of the 10 samples, or 0.8 and 2.8 mg/m^3, respectively. In contrast, the ACC TBBPA Consortium, Albemarle Corporation, and Integral Consulting, LLC estimated the central tendency and high-end exposures to be equal to 0.82 mg/m^3 and 3.75 mg/m^3, respectively, because they assumed that the 10 samples were lognormally distributed (Integral Consulting, 2025b). Using the assessed 8-hour TWA exposure concentration, EPA calculated the IADC and ADC, as described in Appendix B. In absence of data specific to ONU exposure, the Agency assumed that worker central tendency exposure was representative of ONU exposure and used this data to generate estimates for ONUs. The results of these calculations are shown in Table 3-3 below.

Table 3-3. Summary of Worker Inhalation Exposure Metrics to TBBPA During Manufacturing

Exposure Concentration Type	Worker Inhalation Estimates (mg/m^3)		ONU Inhalation Estimates (mg/m^3)
	Central Tendency	High-End	
8-Hour TWA exposure concentration	0.80	2.8	0.80
Intermediate average daily concentration (IADC) based on 8-hour TWA	0.41	1.4	0.41
Average daily concentration (ADC) based on 8-hour TWA	0.36	1.3	0.36

3.2.4 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES using the methodology outlined in Section 2.4. The various "Exposure Concentration Types" from Table 3-4. are explained in Appendix B. Table 3-4. summarizes APDR, intermediate average daily dose (IADD), average daily dose (ADD) for chronic non-cancer for all applicable similar exposure groups (SEGs). For workers, dermal exposure is assessed to neat solid TBBPA. For ONUs, dermal exposure is assessed from contact with surfaces onto which the dusts have deposited were assessed. Dermal exposure to workers is generally expected to be greater than dermal exposure to ONUs. In absence of data specific to ONU exposure, EPA assumes that worker central tendency exposure to solids is representative of ONU exposure.

Table 3-4. Summary of Worker Dermal Exposure Metrics to TBBPA During Manufacturing

Worker Description	Exposure Concentration Type	Central Tendency	High-End
Average adult worker	Dose rate (APDR, mg/day)	3.7	7.5
	Intermediate (IADD, mg/kg-day)	3.6E−02	7.3E−02
	Chronic, non-cancer (ADD, mg/kg-day)	3.2E−02	6.4E−02
ONU	Dose rate (APDR, mg/day)	3.7	
	Intermediate (IADD, mg/kg-day)	3.6E−02	
	Chronic, non-cancer (ADD, mg/kg-day)	3.2E−02	

3.3 Repackaging of TBBPA Powder

As listed in Table 3-1, this OES includes the following COU: Import and repackaging.

3.3.1 Worker Activities

Worker exposures may include inhalation of dust and dermal contact with solids when repackaging TBBPA powder.

Task-specific PPE used at one facility repackaging TBBPA included a full-face air-purifying respirator equipped with organic vapor/acid gas filters and high efficiency particulate air (HEPA) filtration, fire-resistant uniforms, and chemical-protective gloves, which would minimize potential inhalation and dermal exposure to workers handling TBBPA (Integral Consulting, 2025c). At another site, PPE included N95 respirators, leather gloves, and Tyvek suits. Engineering controls from facilities repackaging TBBPA included the use of enclosed funnel cones and automatic repacking machines (Integral Consulting, 2025c).

ONUs include employees (*e.g.,* supervisors, managers) that work at the import site where repackaging occurs but do not directly handle TBBPA. Therefore, EPA expects ONUs to have lower inhalation exposures than workers. Since ONUs do not handle TBBPA directly, dermal exposures would be limited to incidental contact, such as of TBBPA dusts that settle onto surfaces that the ONUs contact.

See Section 3.4.1 of the *Draft Release Assessment for 4,4'-(1-Methylethylidene)bis[2,6-dibromophenol] (TBBPA)* (U.S. EPA, 2026g) for a full repackaging process description.

3.3.2 Number of Workers and Occupational Non-Users

EPA used data from BLS and the SUSB specific to the OES to estimate the number of workers and ONUs per site potentially exposed to TBBPA during repackaging (U.S. Census Bureau, 2017; U.S. BLS, 2023a). This approach involved first identifying the relevant NAICS codes for the OES. The next step is the identification of relevant SOC codes within the BLS data for the identified NAICS codes. From there total number of workers can be determined. This number is divided by the number of sites identified to obtain the exposed workers per site. Appendix A includes further details regarding methodology for estimating the number of workers and ONUs per site. EPA assigned the following NAICS codes for this OES:

- 325199 – All Other Basic Organic Chemical Manufacturing;
- 325998 – All Other Miscellaneous Chemical Product and Preparation Manufacturing;
- 424610 – Plastics Materials and Basic Forms and Shapes Merchant Wholesalers; and
- 424690 – Other Chemical and Allied Products Merchant Wholesalers

Table 3-5 summarizes the per site estimates for this OES based on the methodology described, including the number of sites identified in Section 3.4.2 of the *Draft Release Assessment for 4,4'-(1-Methylethylidene)bis[2,6-dibromophenol] (TBBPA)* (U.S. EPA, 2026g).

Table 3-5. Estimated Average Number of Workers per Site Potentially Exposed to TBBPA During Repackaging

Potential Number of Sites	NAICS Code	Potentially Exposed Workers per Site[a]	Potentially Exposed ONUs per Site[a]
2	325199 – All Other Basic Organic Chemical Manufacturing	4	2
	325998 – All Other Miscellaneous Chemical Product and Preparation Manufacturing		
	424610 – Plastics Materials and Basic Forms and Shapes Merchant Wholesalers		
	424690 – Other Chemical and Allied Products Merchant Wholesalers		

[a] Number of workers and ONUs per site are calculated by dividing the exposed number of workers or ONUs by the number of establishments.

3.3.3 Occupational Inhalation Exposure Results

Albemarle Corporation imported 98 to 100% TBBPA powder in 1-ton (approximately 2,200 lb) super sacks and transloaded this material into trucks that are located outdoors using a custom funnel cone that is placed on top of the truck. A worker untied the supersack after it was placed on top of the cone and the contents of the sack flowed by gravity with some manual jostling of the sack. The cone prevented some dust emissions. A truck was filled by emptying multiple super sacks during a period of 4 to 5 hours. The number of super sacks emptied in a truck and the number of trucks that are filled per day is confidential business information (CBI). This work was done by workers who worked 12-hour shifts (Integral Consulting, 2025b, c). This repackaging operation ceased at Albemarle Corporation's site and is conducted instead at the site of a toller (contract facility) (Albemarle Corporation, 2025). The ACC TBBPA Consortium submitted TBBPA full-shift TWA and task-based PBZ worker monitoring data as surrogate data for assessing the repackaging OES. EPA assessed the inhalation exposure concentrations of the repackaging OES based on this surrogate data.

The surrogate data that is the basis of EPA's assessment of the repackaging OES are data that the ACC TBBPA Consortium collected at two TBBPA processing sites in response to an order that EPA had issued pursuant to TSCA section 4(a) (Integral Consulting, 2025c). At one of these sites, which is Site L, workers repackaged 100% TBBPA powder from super sacks into smaller bags using a self-contained machine with dust collection. At the other site, which is Site K, workers transferred 100% TBBPA powder in 2,000 lb super sacks into a reactor using a mechanism that automatically empties the super sacks after the worker unties the sack. EPA lacks information about the toll repackaging site at which Albemarle conducts repackaging. Furthermore, the Agency assumed engineering controls for truck loading that are more robust than the funnel used by Albemarle are possible. Accordingly, EPA assessed exposure in the case of two scenarios: Scenario 1, which involves robust engineering controls; and Scenario 2, which involves less robust engineering controls. The Agency assessed Scenarios 1 and 2 based on the data of Sites L and K, respectively.

In the case of Site L, which corresponds to Scenario 1, three full-shift TWA PBZ samples (each from a different worker) and two task-based samples (each paired with 1 of those full-shift samples) were collected. The monitored workers' activities included activities other than repackaging super sacks. The task-based samples were collected while the workers repackaged the super sacks; observers noted a very clean area with little visible dust. The ranges of these full-shift TWA and task-based PBZ data are 0.11 to 0.45 mg/m^3 and 0.36 to 0.74 mg/m^3, respectively. Sample durations are 510 to 675 minutes (full-shift samples) and 190 to 270 minutes (task-based samples) (Integral Consulting, 2025c). EPA assessed central tendency and high-end full-shift TWA concentrations of Scenario 1 as the 50th and 95th percentile of the three full-shift TWA PBZ samples of Site L.

In the case of Site K, which corresponds to Scenario 2, six task-based samples (each from a different worker) were collected while the workers transferred the contents of the super sacks into the reactor. The range of these data are 4.2 to 48 mg/m^3. The sample durations are mostly 15 or 17 minutes, and the exception is one sample with a duration of 25 minutes. The sampling duration of each task-length sample is equal to the duration of transferring a super sack into the reactor (Integral Consulting, 2025c). To assess the exposure of Scenario 2, EPA assumed that two trucks are filled per day because of the following: first, as stated above, a truck was filled at Albemarle's site by emptying multiple super sacks during a period of 4 to 5 hours. Second, EPA assumed a work shift of 12 hours because Albemarle's works shift was 12 hours. Based on this, a worker is able to fill two trucks at most because the work shift will include work breaks (*i.e.,* there are two 4- to 5-hour work periods in a 12-hour work shift at most.) In conclusion, EPA assumed that a worker unloads the super sacks during 10 hours of the 12-hour shift. The Agency converted each of the 6 task-based samples to 12-hour full-shift TWA samples and then assessed central tendency and high-end full-shift TWA concentrations as the 50th and 95th percentile of the resulting six full-shift TWA concentrations. To convert each task-based concentration to a full-shift concentration, EPA divided the 10-hour work period by the sampling duration of the task-length sample to determine the number of super sacks that would be emptied if the duration of emptying a super sack equaled the sampling duration and did not vary during the day. Nextn, the Agency assumed that exposure concentration during the emptying of each super sack is equal to the concentration of task-length sample and did not vary by sack. The Agency then multiplied the task-length concentration by the number of sacks and divided by the shift duration of 12 hours.

Using these TWA exposure concentrations, EPA calculated the IADC and ADC as described in Appendix B. In absence of data specific to ONU exposure, the Agency assumed that worker central tendency exposure was representative of ONU exposure and used this data to generate estimates for ONUs. The results of these calculations are shown in Table 3-6.

Table 3-6. Summary of Worker Inhalation Exposure Metrics to TBBPA During Repackaging

SEG	Number of Samples	12- or 12.5-Hour TWA Exposure Concentration		Intermediate Average Daily Concentration (IADC)		Average Daily Concentration (ADC)	
		Central Tendency (mg/m^3)	High-End (mg/m^3)	Central Tendency (mg/m^3)	High-End (mg/m^3)	Central Tendency (mg/m^3)	High-End (mg/m^3)
Worker (Scenario 1)	3	0.25	0.45	0.20	0.36	0.12	0.21
Worker (Scenario 2)	6	14	39	11	31	6.5	18
ONU	3	0.25	0.25	0.20	0.20	0.12	0.12

3.3.4 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES using the methodology outlined in Section 2.4. The various "Exposure Concentration Types" from Table 3-7 are explained in Appendix B. Table 3-7 summarizes the APDR, IADD, and ADD for chronic non-cancer for all applicable SEGs. For workers, dermal exposure is assessed to neat solid TBBPA. For ONUs, dermal exposure is assessed from contact with surfaces onto which the dusts have deposited were assessed. Dermal exposure to workers is generally expected to be greater than dermal exposure to ONUs. Where EPA was not able to estimate ONU dermal exposure from monitoring data or models, ONU exposure was assumed equivalent to the central tendency exposure to solids experienced by workers.

Table 3-7. Summary of Worker Dermal Exposure Metrics to TBBPA During Repackaging

Worker Description	Exposure Concentration Type	Central Tendency	High-End
Worker (Scenarios 1 and 2)	Dose rate (APDR, mg/day)	3.7	7.5
	Intermediate (IADD, mg/kg-day)	3.6E−02	7.3E−02
	Chronic, non-cancer (ADD, mg/kg-day)	3.2E−02	6.4E−02
ONU	Dose rate (APDR, mg/day)	3.7	
	Intermediate (IADD, mg/kg-day)	3.6E−02	
	Chronic, non-cancer (ADD, mg/kg-day)	3.2E−02	

3.4 Test Order – ACC OES to COU Crosswalk

As described in Section 3.1, ACC submitted monitoring data in response to TSCA section 4(a)(2) test order for TBBPA (Integral Consulting, 2025a). ACC divided these monitoring data into four groups defined by process type and exposure potential, spanning multiple life cycle stages and/or categories and subcategories of COUs. EPA used these four ACC groupings as OESs. In addition to monitoring data, the final test report also provides information on physical form and concentration of TBBPA, unit operations, worker activities, and operating schedules for each grouping. Table 3-8 presents this information for each ACC OES.

Table 3-8. Process Information and COU Mapping for ACC Test Order OES

OES (ACC Group)	COU #	Process Description										
		Feed Material		Process Type	Unit Operations	Equipment	Process Conditions	Worker Activities	Product			Production Frequency
		Physical Form	TBBPA Conc.						Physical Form	TBBPA Conc.	Function	
Group 1	5	Particulates (powder)	>98%	• Batch • Some equipment such as rollers are not enclosed • Equipment is manually operated	Mixing	• Hopper/ Tumbler • Kneading equipment/ roller/ blender	Heating	• Handle bags and drums • Feed material into equipment via shovel • Operate equipment	Granules	<5%	Polymer material	6–13 days/yr
					Size reduction	• Cutting tables • Slicers • Grinders			Pellets	15–19.5%	Resin	
Group 2	3, 4	Particulates (powder)	90–>98%	• Batch (primarily) • Continuous • Manual loading of mixer • Manual or automatic repackaging of feed material depending on container size	Reaction	Reactor	Unknown	• Repackage supersacks into smaller bags via repackaging machine • Manually transfer material from large bags into 25 kg bags • Manually transfer contents for weighing • Manually transfer material from 25 kg bags into mixer • Cleaning with vacuum after loading mixer	Liquids	20–500 ppm	Resin	• Batch: 2–305 days/yr • Continuous: 260–312 days/yr
	5				Mixing	• Mixer • Mogul			Liquids	5–26%	Resin	
	5				Reaction	Reactor			Powder	<1%	Flame-retarded powder	
	6								Semi-solids	0.05–20%	Adhesive	

OES (ACC Group)	COU #	Process Description										
		Feed Material		Process Type	Unit Operations	Equipment	Process Conditions	Worker Activities	Product			Production Frequency
		Physical Form	TBBPA Conc.						Physical Form	TBBPA Conc.	Function	
	5	Pellets (solids)								<17%	Engineering resin pellets	
	7	1. Batch 2. Continuous								1. Up to 6% 2. <0.1% (trace)	1. Copper clad laminate 2. Electronic component	
Group 3	8	Liquid resin	<30%	• Batch • Continuous	• Coating • Heating	• Coater • Oven	Unknown		Solid sheets, films, and/or pellets	≥ 5–20%	• Prepreg composite • Adhesive film	• Batch: 4–156 days/yr • Continuous: 104–260 days/yr
	8	Semi-solid adhesive								15–20%	Structural film adhesive	
	9	Pellets (solids)			Mixing	Extrusion				<1% (trace)	Molded electronic part	
Group 4	13, 15	Prepreg composite and adhesive films	<30%				Unknown			2–17%	Composite parts for aerospace industry, including aviation interiors, composite products for electrical utilities	• Batch: 12–365 days/yr • Continuous: 260–275 days/yr

3.4.1 ACC TBBPA Consortium's Group 1: Production of Formulations (Particulate Solids) from TBBPA Powder

As listed in Table 3-1, this OES includes the following COU: Processing: Additive flame retardant in plastics, paints and coatings.

3.4.1.1 Worker Activities

Group 1 processing operators (OPs) are closely involved with the processing and handling of powders containing TBBPA, frequently cleaning equipment, collecting samples of products, mixing materials, loading and operating equipment, and performing preventative maintenance. User operators include workers that handle TBBPA in industrial/commercial settings, performing tasks such as loading and operating equipment, and cutting, packaging and visually inspecting final TBBPA-containing solid products such as granules. Therefore, worker exposures to TBBPA may occur via inhalation of particulates or dermal contact with solids during worker activities such as sampling, equipment cleaning, reactor operation and maintenance, and packaging and loading TBBPA into reactors or transport containers for shipment.

PPE used at the facilities producing TBBPA-containing solids in the ACC test order data includes baseline PPE (*e.g.,* safety shoes, safety glasses, gloves, and hard hats), task-specific PPE that is used during certain activities (*e.g.,* respirators, aprons, goggles), and emergency-use PPE that is applied in the case of a disruption or emergent event like a spill or a leak (*e.g.,* self-contained breathing apparatus, escape air respirators) (Integral Consulting, 2025a). Engineering controls listed in the ACC test order from facilities producing TBBPA-containing solids include the use of general mechanical ventilation, negative pressure, open doors and windows, and working under ventilated hoods. Other precautions used are enclosed conveyors and lifts to assist with emptying materials into hoppers and blenders (Integral Consulting, 2025a).

ONUs as defined by the ACC test order are personnel who may enter process areas, but do not spend substantial time around points of exposure that a worker may engage with. This definition is similar to EPA's definition of ONUs and therefore EPA is using these values to estimate occupational exposures for ONUs. Therefore, EPA expects ONUs to have lower inhalation exposures than workers. Since ONUs do not handle TBBPA directly, dermal exposures would be limited to incidental contact, such as of TBBPA dusts that settle onto surfaces that the ONUs contact.

See Section 3.6.1 of the *Draft Release Assessment for 4,4'-(1-Methylethylidene)bis[2,6-dibromophenol] (TBBPA)* (U.S. EPA, 2026g) for a full process description for the Processing: additive flame retardant in plastics, paints and coatings COU.

3.4.1.2 Number of Workers and Occupational Non-Users

EPA used data from the ACC test order, BLS, and the SUSB specific to the OES to estimate the number of workers and ONUs per site potentially exposed to TBBPA during the production of TBBPA-containing solids (Integral Consulting, 2025a; U.S. Census Bureau, 2017; U.S. BLS, 2023a). This approach involved first identifying the relevant NAICS codes for the OES. The next step is the identification of relevant SOC codes within the BLS data for the identified NAICS codes, from which total number of workers can be determined. This number is divided by the number of sites identified to obtain the exposed workers per site. Appendix A includes further details regarding methodology for estimating the number of workers and ONUs per site. EPA assigned the following NAICS codes for this OES:

- 325211 – Plastics Material and Resin Manufacturing; and
- 325991 – Custom Compounding of Purchased Resins.

Table 3-9 summarizes the per site estimates for this OES based on the methodology described, including the number of sites identified in Section 3.6.2 of the *Draft Release Assessment for 4,4'-(1-Methylethylidene)bis[2,6-dibromophenol] (TBBPA)* (U.S. EPA, 2026g).

Table 3-9. Estimated Average Number of Workers per Site Potentially Exposed to TBBPA During Production of Formulations (Particulate Solids) from TBBPA Powder

Potential Number of Sites	NAICS Code	Potentially Exposed Workers per Site[a]	Potentially Exposed ONUs per Site[a]
3	325211 – Plastics Material and Resin Manufacturing	20	13
	325991 – Custom Compounding of Purchased Resins		
[a] Number of workers and ONUs per site are calculated by dividing the exposed number of workers or ONUs by the number of establishments.			

3.4.1.3 Occupational Inhalation Exposure Results

For the production of TBBPA-containing solids, EPA was provided with inhalation monitoring data from ACC test order data. The singular company that provided data for this OES uses 98% TBBPA in powder form to create solid, non-particulate products (*e.g.,* granules and pellets) and is referred to as Group 1 in the study, which is the same nomenclature EPA used for this OES. The company in Group 1 runs batch operations that occur based on customer demand ranging from 6 to 13 days per year (Integral Consulting, 2025a). The ACC Group 1 data includes eight occupational full-shift (8-hour TWA) personal air samples from processing operators, user operators, and ONUs.

From this monitoring data, EPA used the test order's calculated 50th and 95th percentile full-shift TWA concentrations that are not adjusted for shift-duration to represent a central tendency and high-end estimate of potential occupational inhalation exposures, respectively, for this scenario. Using these full-shift TWA exposure concentrations, EPA calculated the IADC and ADC as described in Appendix B assuming that workers work 40 hours per week on average and a total of 2,000 hours per year, which is equivalent to working 8 hours per day for 250 days per year, irrespective of shift duration and actual exposure frequency. The results of these calculations are shown in Table 3-10 below.

Table 3-10. Summary of Worker Inhalation Exposure Metrics to TBBPA During ACC TBBPA Consortium's Group 1: Production of Formulations (Particulate Solids) from TBBPA Powder

SEG	No. of Samples	8-Hour TWA Exposure Concentration		Intermediate Average Daily Concentration (IADC)		Average Daily Concentration (ADC)	
		Central Tendency (mg/m^3)	High-End (mg/m^3)	Central Tendency (mg/m^3)	High-End (mg/m^3)	Central Tendency (mg/m^3)	High-End (mg/m^3)
Processing operator (OP)	4	0.16	0.31	7.9E−02	0.15	3.9E−03	7.5E−03
User operator (UOP)	2	1.9E−02	3.3E−02	9.3E−03	1.6E−02	4.6E−04	7.7E−04
ONU	2	5.5E−04	6.9E−04	2.6E−04	3.3E−04	1.3E−05	1.6E−05

3.4.1.4 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES using the methodology outlined in Section 2.4. The various "Exposure Concentration Types" from Table 3-11 are explained in Appendix B. Table 3-11 summarizes the APDR, IADD, and ADD for chronic non-cancer for all applicable SEGs. For both processing operators and user operators, dermal exposure is assessed to solids containing TBBPA. For ONUs, dermal exposure is assessed from contact with surfaces onto which the dusts have deposited were assessed. Dermal exposure to workers is generally expected to be greater than dermal exposure to ONUs. In absence of data specific to ONU exposure, EPA assumes that worker central tendency exposure to solids is representative of ONU exposure.

Table 3-11. Summary of Worker Dermal Exposure Metrics to TBBPA During ACC TBBPA Consortium's Group 1: Production of Formulations (Particulate Solids) from TBBPA Powder

Worker Description	Exposure Concentration Type	Central Tendency	High-End
Processing operator (OP); User operator (UOP)	Dose rate (APDR, mg/day)	3.7	7.5
	Intermediate (IADD, mg/kg-day)	3.6E−02	7.3E−02
	Chronic, non-cancer (ADD, mg/kg-day)	3.2E−02	6.4E−02
ONU	Dose rate (APDR, mg/day)	3.7	
	Intermediate (IADD, mg/kg-day)	3.6E−02	
	Chronic, non-cancer (ADD, mg/kg-day)	3.2E−02	

3.4.2 ACC TBBPA Consortium's Group 2: Production of Intermediate Products (Liquid, Semi-Solid, and Powder) from TBBPA Powder

As listed in Table 3-1, this OES includes the following COUs: Processing as a reactant, Processing: Additive flame retardant in plastics, paints and coatings, and Processing: Adhesive manufacturing. EPA combined these conditions of use into one OES due to similarities in expected exposure scenarios.

3.4.2.1 Worker Activities

Group 2 processing operators are closely involved with the processing and handling of powders containing TBBPA, frequently cleaning equipment, collecting samples of products, mixing materials, loading and operating equipment, and performing preventative maintenance. Group 2 processing operators conducted tasks involving powders and solids but also worked with liquid raw materials. Laboratory technicians commonly perform quality assurance tasks and perform sample analysis and laboratory testing. Therefore, worker exposures to TBBPA may occur via inhalation of particulates or dermal contact with solid during worker activities such as product sampling, equipment cleaning, reactor operation and maintenance, packaging and loading of TBBPA into reactors or transport containers for shipment and visually inspecting solid material.

PPE used at the facilities producing Intermediate products (liquid, semi-solid, and powder) from TBBPA powder in the ACC test order data includes baseline PPE (*e.g.,* safety shoes, safety glasses, gloves, and hard hats), task-specific PPE which is used during certain activities (*e.g.,* respirators, aprons, goggles), and emergency-use PPE which is applied in the case of a disruption or emergent event like a spill or a leak (*e.g.,* self-contained breathing apparatus, escape air respirators) (Integral Consulting, 2025a). Engineering controls listed in the ACC test order from facilities producing Intermediate products (liquid, semi-solid, and powder) from TBBPA powder include the use of local exhaust ventilation, general mechanical ventilation, and negative pressure. Another precaution used is automatic loading of solvents to mogul (Integral Consulting, 2025a).

ONUs as defined by the ACC test order are personnel who may enter process areas, but do not spend substantial time around points of exposure that a worker may engage with. ONUs do not directly handle TBBPA. Therefore, EPA expects ONUs to have lower inhalation exposures than workers. Because ONUs do not handle TBBPA directly, dermal exposures would be limited to incidental contact, such as of TBBPA dusts that settle onto surfaces that the ONUs contact.

See Sections 3.5.1, 3.6.1, and 3.7.1 of the *Draft Release Assessment for 4,4'-(1-Methylethylidene)bis[2,6-dibromophenol] (TBBPA)* (U.S. EPA, 2026g) for full process descriptions for the COUs Processing: As a reactant; Processing: Additive flame retardant in plastics, paints and coatings; and Processing: Adhesive manufacturing.

3.4.2.2 Number of Workers and Occupational Non-Users

EPA used data from the ACC test order, BLS, and the SUSB specific to the OES to estimate the number of workers and ONUs per site potentially exposed to TBBPA during the production of Intermediate products (liquid, semi-solid, and powder) from TBBPA powder (Integral Consulting, 2025a; U.S. Census Bureau, 2017; U.S. BLS, 2023a). This approach involved first identifying the relevant NAICS codes for the OES. The next step is the identification of relevant SOC codes within the BLS data for the identified NAICS codes, from which total number of workers can be determined. This number is divided by the number of sites identified to obtain the exposed workers per site. Appendix A includes further details regarding methodology for estimating the number of workers and ONUs per site. EPA assigned the following NAICS codes for this OES:

- 325199 – All Other Basic Organic Chemical Manufacturing;
- 322220 – Paper Bag and Coated and Treated Paper Manufacturing;
- 325110 – Petrochemical Manufacturing;
- 325180 – Other Basic Inorganic Chemical Manufacturing;
- 325211 – Plastics Material and Resin Manufacturing;
- 325520 – Adhesive Manufacturing;
- 325991 – Custom Compounding of Purchased Resins;
- 325998 – All Other Miscellaneous Chemical Product and Preparation Manufacturing; and
- 335931 – Current-Carrying Wiring Device Manufacturing.

Table 3-12 summarizes the per site estimates for this OES based on the methodology described, including the number of sites identified in Sections 3.5.2, 3.6.2, and 3.7.2 of the *Draft Release Assessment for 4,4'-(1-Methylethylidene)bis[2,6-dibromophenol] (TBBPA)* (U.S. EPA, 2026g).

Table 3-12. Estimated Average Number of Workers per Site Potentially Exposed to TBBPA During Production of Intermediate Products (Liquid, Semi-Solid, and Powder) from TBBPA Powder

Potential Number of Sites	NAICS Code	Potentially Exposed Workers per Site[a]	Potentially Exposed ONUs per Site[a]
10	325199 – All Other Basic Organic Chemical Manufacturing	22	11
	322220 – Paper Bag and Coated and Treated Paper Manufacturing		
	325110 – Petrochemical Manufacturing		
	325180 – Other Basic Inorganic Chemical Manufacturing		
	325211 – Plastics Material and Resin Manufacturing		
	325520 – Adhesive Manufacturing		
	325991 – Custom Compounding of Purchased Resins		
	325998 – All Other Miscellaneous Chemical Product and Preparation Manufacturing		
	335931 – Current-Carrying Wiring Device Manufacturing		

[a] Number of workers and ONUs per site are calculated by dividing the exposed number of workers or ONUs by the number of establishments.

3.4.2.3 Occupational Inhalation Exposure Results

For the production of Intermediate products (liquid, semi-solid, and powder) from TBBPA powder, EPA was provided with inhalation monitoring data from ACC test order data. The four companies that provided data for this OES use 90 to 98% TBBPA in powder form to create mixtures or reaction products, often used as intermediates in the production of the end product. The group of companies performing these production activities is referred to as Group 2 in the study, which is the same nomenclature that EPA uses for this OES. The companies run batch operations that occur based on customer demand ranging from 2 to 305 days per year (Integral Consulting, 2025a). The ACC Group 2 data include 38 occupational full-shift (8-hour TWA) personal air samples from processing operators, laboratory technicians, and ONUs.

From this monitoring data, EPA used the test order's calculated 50th and 95th percentile full-shift TWA concentrations that are not adjusted for shift duration to represent a central tendency and high-end estimate of potential occupational inhalation exposures, respectively, for this scenario. Using these full-shift TWA exposure concentrations, EPA calculated the IADC and ADC as described in Appendix B assuming that workers work 40 hours per week on average and a total of 2,000 hours per year, which is equivalent to working 8 hours per day for 250 days per year, irrespective of shift duration and actual exposure frequency. The results of these calculations are shown in Table 3-13 below.

Table 3-13. Summary of Worker Inhalation Exposure Metrics to TBBPA During ACC TBBPA Consortium's Group 2: Production of Intermediate Products (Liquid, Semi-Solid, and Powder) from TBBPA Powder

SEG	Number of Samples	8-Hour TWA Exposure Concentration		Intermediate Average Daily Concentration (IADC)		Average Daily Concentration (ADC)	
		Central Tendency (mg/m^3)	High-End (mg/m^3)	Central Tendency (mg/m^3)	High-End (mg/m^3)	Central Tendency (mg/m^3)	High-End (mg/m^3)
Processing operator (OP)	18	6.5E−03	1.2	3.4E−03	0.60	3.0E−03	0.53
Laboratory technician (LBT)	4	2.1E−04	4.2E−04	1.1E−04	2.2E−04	9.6E−05	1.9E−04
ONU	16	1.4E−03	2.1E−02	7.3E−04	1.1E−02	6.4E−04	9.4E−03

3.4.2.4 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES using the methodology outlined in Section 2.4. The various "Exposure Concentration Types" from Table 3-14 are explained in Appendix B. Table 3-14 summarizes the APDR, IADD, and ADD for chronic non-cancer for all applicable SEGs. For both processing operators and laboratory technicians, dermal exposure may occur to both solids and liquids containing TBBPA. However, because absorption to TBBPA is flux-limited and the addition of the APDRs from both physical forms does not impact on the overall intermediate and chronic doses, only the higher APDR between the two physical forms is presented, which is for liquid exposure in this case. For ONUs, dermal exposure is assessed from contact with surfaces onto which the dusts have deposited were assessed. ONU dermal exposure to liquid is not expected. Dermal exposure to workers is generally expected to be greater than dermal exposure to ONUs. In absence of data specific to ONU exposure, EPA assumes that worker central tendency exposure to solids is representative of ONU exposure.

Table 3-14. Summary of Worker Dermal Exposure Metrics to TBBPA During ACC TBBPA Consortium's Group 2: Production of Intermediate Products (Liquid, Semi-Solid, and Powder) from TBBPA Powder

Worker Description	Exposure Concentration Type	Central Tendency	High-End
Processing operator (OP); Laboratory technician (LBT)	Dose rate (APDR, mg/day)	3.7	7.5
	Intermediate (IADD, mg/kg-day)	3.6E−02	7.3E−02
	Chronic, non-cancer (ADD, mg/kg-day)	3.2E−02	6.4E−02
ONU	Dose rate (APDR, mg/day)	3.7	
	Intermediate (IADD, mg/kg-day)	3.6E−02	
	Chronic, non-cancer (ADD, mg/kg-day)	3.2E−02	

3.4.3 ACC TBBPA Consortium's Group 3: Production of Intermediate Solid Products (Sheet, Film, and Pellet) from the Products of Group 2

As listed in Table 3-1, this OES includes the following COUs: Processing: Additive flame retardant in plastics, paints and coatings; Processing: Incorporation into PCBs and electronic products; Processing:

Incorporation into transportation equipment; and Processing: Incorporation into plastic products. EPA combined these COUs into one OES due to similarities in expected exposure scenarios.

3.4.3.1 Worker Activities

Group 3 processing operators worked only with liquid raw materials and solid composite final products. Group 3 user operators performed tasks like setting up and operating coater machines, collecting samples, pulling fibers through extruders, conducting color corrections, loading materials, etc. Laboratory technicians conducted color tests. Logistics technicians performed packaging tasks and other general warehousing duties. Maintenance technicians completed tasks involving repairs to process equipment. Therefore, worker exposures to TBBPA may occur via inhalation of vapor or dermal contact with liquid or semi-solid during worker activities such as product sampling, equipment cleaning, reactor operation and maintenance, packaging and loading of TBBPA into reactors or transport containers for shipment and visually inspecting solid material.

PPE used at the facilities producing Intermediate solid products (sheet, film, and pellet) from the products of Group 2 in the ACC test order data includes baseline PPE (*e.g.,* safety shoes, safety glasses, gloves, and hard hats), task-specific PPE which is used during certain activities (*e.g.,* respirators, aprons, goggles), and emergency-use PPE which is applied in the case of a disruption or emergent event like a spill or a leak (*e.g.,* self-contained breathing apparatus, escape air respirators). Operators at Group 3 facilities wore full-face respirators during cutting bags of solid powders, compounding and weighing solid powders, loading and unloading tasks, and cleaning equipment with solvents (Integral Consulting, 2025a). Engineering controls listed in the ACC test order from facilities producing TBBPA-containing mixtures and formulations include the use of local exhaust ventilation, general mechanical ventilation, dust collection systems, and negative pressure (Integral Consulting, 2025a).

ONUs as defined by the ACC test order are personnel who may enter process areas, but do not spend substantial time around points of exposure that a worker may engage with. ONUs do not directly handle TBBPA. Therefore, EPA expects ONUs to have lower inhalation exposures than workers. Since ONUs do not handle TBBPA directly, dermal exposures would be limited to incidental contact, such as of TBBPA dusts that settle onto surfaces that the ONUs contact.

See Sections 3.6.1, 3.8.1, 3.9.1 and 3.10.1 of the *Draft Release Assessment for 4,4'-(1-Methylethylidene)bis[2,6-dibromophenol] (TBBPA)* (U.S. EPA, 2026g) for full process descriptions for the COUs: Processing: Additive flame retardant in plastics, paints and coatings; Processing: Incorporation into PCBs and electronic products; Processing: Incorporation into transportation equipment; and Processing: Incorporation into plastic products.

3.4.3.2 Number of Workers and Occupational Non-Users

EPA used data from the ACC test order, BLS, and the SUSB specific to the OES to estimate the number of workers and ONUs per site potentially exposed to TBBPA during the production of Intermediate solid products (sheet, film, and pellet) from the products of Group 2 (Integral Consulting, 2025a; U.S. Census Bureau, 2017; U.S. BLS, 2023a). This approach involved first identifying the relevant NAICS codes for the OES. The next step is the identification of relevant SOC codes within the BLS data for the identified NAICS codes, from which total number of workers can be determined. This number is divided by the number of sites identified to obtain the exposed workers per site. Appendix A includes further details regarding methodology for estimating the number of workers and ONUs per site. EPA assigned the following NAICS codes for this OES:

- 313320 – Fabric Coating Mills
- 325211 – Plastics Material and Resin Manufacturing

- 325991 – Custom Compounding of Purchased Resins
- 326113 – Unlaminated Plastics Film and Sheet (except Packaging) Manufacturing
- 326130 – Laminated Plastics Plate, Sheet (except Packaging), and Shape Manufacturing
- 326199 – All Other Plastics Product Manufacturing
- 334413 – Semiconductor and Related Device Manufacturing
- 334419 – Other Electronic Component Manufacturing
- 335929 – Other Communication and Energy Wire Manufacturing
- 335991 – Carbon and Graphite Product Manufacturing
- 335999 – All Other Miscellaneous Electrical Equipment and Component Manufacturing
- 336411 – Aircraft Manufacturing
- 336413 – Other Aircraft Parts and Auxiliary Equipment Manufacturing.

Table 3-15 summarizes the per site estimates for this OES based on the methodology described, including the number of sites identified in Sections 3.6.2, 3.8.2, 3.9.2 and 3.10.2 of the *Draft Release Assessment for 4,4'-(1-Methylethylidene)bis[2,6-dibromophenol] (TBBPA)* (U.S. EPA, 2026g).

Table 3-15. Estimated Average Number of Workers per Site Potentially Exposed to TBBPA During Production of Intermediate Solid Products (Sheet, Film, and Pellet) from the Products of Group 2

Potential Number of Sites	NAICS Code	Potentially Exposed Workers per Site[a]	Potentially Exposed ONUs per Site[a]
8	313320 – Fabric Coating Mills	65	20
	325211 – Plastics Material and Resin Manufacturing		
	325991 – Custom Compounding of Purchased Resins		
	326113 – Unlaminated Plastics Film and Sheet (except Packaging) Manufacturing		
	326130 – Laminated Plastics Plate, Sheet (except Packaging), and Shape Manufacturing		
	326199 – All Other Plastics Product Manufacturing		
	334413 – Semiconductor and Related Device Manufacturing		
	334419 – Other Electronic Component Manufacturing		
	335929 – Other Communication and Energy Wire Manufacturing		
	335991 – Carbon and Graphite Product Manufacturing		
	335999 – All Other Miscellaneous Electrical Equipment and Component Manufacturing		

Potential Number of Sites	NAICS Code	Potentially Exposed Workers per Site[a]	Potentially Exposed ONUs per Site[a]
	336411 – Aircraft Manufacturing		
	336413 – Other Aircraft Parts and Auxiliary Equipment Manufacturing		
[a] Number of workers and ONUs per site are calculated by dividing the exposed number of workers or ONUs by the number of establishments.			

3.4.3.3 Occupational Inhalation Exposure Results

For the production of Intermediate solid products (sheet, film, and pellet) from the products of Group 2, EPA was provided inhalation monitoring data from ACC test order data. The two companies that provided data for this OES use materials containing less than 30%t TBBPA (*e.g.,* solid or liquid resin) to create other TBBPA-containing materials (*e.g.,* molded part, sheet, pellet, prepreg composite). The end product is usually not further cut or manipulated within the facility after production. The group of companies performing these production activities is referred to as Group 3 in the study, which is the same nomenclature that EPA used for this OES. The companies in Group 3 run both batch and continuous operations. Batch operation days range from 4 to 156 days per year, and continuous operations range from 2 to 5 days per week, or approximately 104 to 260 days per year assuming 52 weeks of operation per calendar year (Integral Consulting, 2025a). The ACC Group 3 data include 29 occupational full-shift (8-hour TWA) personal air samples from processing operators, user operators, laboratory technicians, logistics technicians, maintenance technicians, and ONUs.

From this monitoring data, EPA used the test order's calculated 50th and 95th percentile full-shift TWA concentrations that are not adjusted for shift-duration to represent a central tendency and high-end estimate of potential occupational inhalation exposures, respectively, for this scenario. Using these full-shift TWA exposure concentrations, EPA calculated the IADC, and ADC as described in Appendix B assuming that workers work 40 hours per week on average and a total of 2,000 hours per year, which is equivalent to working 8 hours per day for 250 days per year, irrespective of shift duration and actual exposure frequency. The results of these calculations are shown in Table 3-16 below.

Table 3-16. Summary of Worker Inhalation Exposure Metrics to TBBPA During ACC TBBPA Consortium's Group 3: Production of Intermediate Solid Products (Sheet, Film, and Pellet) from the Products of Group 2

SEG	Number of Samples	8-Hour TWA Exposure Concentration		Intermediate Average Daily Concentration (IADC)		Average Daily Concentration (ADC)	
		Central Tendency (mg/m^3)	High-End (mg/m^3)	Central Tendency (mg/m^3)	High-End (mg/m^3)	Central Tendency (mg/m^3)	High-End (mg/m^3)
Processing operator (OP)	2	2.8E−04	4.0E−04	1.5E−04	2.1E−04	1.3E−04	1.8E−04
User operator (UOP)	8	6.9E−04	1.1E−02	3.6E−04	5.5E−03	3.2E−04	4.8E−03
Laboratory technician (LBT)	5	9.2E−05	2.1E−03	4.8E−05	1.1E−03	4.2E−05	9.6E−04
Logistics technician	3	2.2E−04	4.4E−04	1.1E−04	2.3E−04	1.0E−04	2.0E−04

SEG	Number of Samples	8-Hour TWA Exposure Concentration		Intermediate Average Daily Concentration (IADC)		Average Daily Concentration (ADC)	
		Central Tendency (mg/m³)	High-End (mg/m³)	Central Tendency (mg/m³)	High-End (mg/m³)	Central Tendency (mg/m³)	High-End (mg/m³)
(LGT)							
Maintenance technician (MT)	3	5.7E−04	8.0E−04	3.0E−04	4.1E−04	2.6E−04	3.7E−04
ONU	8	1.0E−04	9.5E−04	5.2E−05	4.9E−04	4.6E−05	4.3E−04

3.4.3.4 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES using the methodology outlined in Section 2.4. The various "Exposure Concentration Types" from Table 3-17 are explained in Appendix B. Table 3-17 summarizes the APDR, IADD, and ADD for chronic non-cancer for all applicable SEGs. For processing operators and laboratory technicians, dermal exposure may occur to both solids and liquids containing TBBPA. However, because absorption to TBBPA is flux-limited and the addition of the APDRs from both physical forms does not impact on the overall intermediate and chronic doses, only the higher APDR between the two physical forms is presented, which is for liquid exposure in this case. For user operators, logistic technicians, and maintenance technicians, dermal exposure is only expected to be to solids containing TBBPA. For ONUs, dermal exposure is assessed from contact with surfaces onto which the dusts have deposited were assessed. ONU dermal exposure to liquid is not expected. Dermal exposure to workers is generally expected to be greater than dermal exposure to ONUs. In absence of data specific to ONU exposure, EPA assumes that worker central tendency exposure to solids is representative of ONU exposure.

Table 3-17. Summary of Worker Dermal Exposure Metrics to TBBPA During ACC TBBPA Consortium's Group 3: Production of Intermediate Solid Products (Sheet, Film, and Pellet) from the Products of Group 2

Worker Description	Exposure Concentration Type	Central Tendency	High-End
Processing operator (OP); User operator (UOP); Laboratory technician (LBT); Logistics technician (LGT); Maintenance technician (MT)	Dose rate (APDR, mg/day)	3.7	7.5
	Intermediate (IADD, mg/kg-day)	3.6E−02	7.3E−02
	Chronic, non-cancer (ADD, mg/kg-day)	3.2E−02	6.4E−02
ONU	Dose rate (APDR, mg/day)	3.7	
	Intermediate (IADD, mg/kg-day)	3.6E−02	
	Chronic, non-cancer (ADD, mg/kg-day)	3.2E−02	

3.4.4 ACC TBBPA Consortium's Group 4: Production of Composite Parts from Prepreg and Adhesive Film

As listed in Table 3-1, this OES includes the following COUs: Industrial and commercial use in electrical and electronic articles; and Industrial and commercial use in automotive and aviation articles. EPA combined these COUs into one OES due to similarities in expected exposure scenarios.

3.4.4.1 Worker Activities

Group 4 user operators performed tasks involving the use of handheld tools manipulating solid products into their final shapes and forms, using techniques such as cutting, grinding, sawing, and sanding. Logistics technicians performed packaging tasks and other general warehousing duties. Maintenance technicians completed tasks involving repairs to process equipment. Therefore, worker exposures to TBBPA in dust may occur via inhalation or dermal routes during worker activities such as cutting, grinding, sawing, and sanding activities, loading and unloading TBBPA-containing products, and visually inspecting solid material.

PPE used at the facilities producing composite parts from prepreg and adhesive film in the ACC test order data includes baseline PPE (*e.g.,* safety shoes, safety glasses, gloves, and hard hats), task-specific PPE which is used during certain activities (*e.g.,* respirators, aprons, goggles), and emergency-use PPE which is applied in the case of a disruption or emergent event like a spill or a leak (*e.g.,* self-contained breathing apparatus, escape air respirators). Operators at Group 4 facilities wore full-faced respirators during cutting bags of solid powders, loading and unloading tasks involving solid powders, trimming and sanding tasks, clean-up of solid powders, and repacking tasks (Integral Consulting, 2025a). Engineering controls listed in the ACC test order from facilities producing TBBPA-containing mixtures and formulations include the use of local exhaust ventilation (Integral Consulting, 2025a).

ONUs as defined by the ACC TBBPA Consortium are personnel who may enter process areas, but do not spend substantial time around points of exposure that a worker may engage with. ONUs do not directly handle TBBPA. Therefore, EPA expects ONUs to have lower inhalation exposures than workers. Since ONUs do not handle TBBPA directly, dermal exposures would be limited to incidental contact, such as of TBBPA dusts that settle onto surfaces that the ONUs contact.

See Section 3.12.1 and 3.13.1 of the *Draft Release Assessment for 4,4'-(1-Methylethylidene)bis[2,6-dibromophenol] (TBBPA)* (U.S. EPA, 2026g) for full process descriptions for the COUs Industrial and commercial use in electrical and electronic articles, and Industrial and commercial use in automotive and aviation articles.

3.4.4.2 Number of Workers and Occupational Non-Users

EPA used data from the ACC test order, BLS, and the SUSB specific to the OES to estimate the number of workers and ONUs per site potentially exposed to TBBPA during the production of Composite parts from prepreg and adhesive film (Integral Consulting, 2025a; U.S. Census Bureau, 2017; U.S. BLS, 2023a). This approach involved first identifying the relevant NAICS codes for the OES. The next step is the identification of relevant SOC codes within the BLS data for the identified NAICS codes, from which total number of workers can be determined. This number is divided by the number of sites identified to obtain the exposed workers per site. Appendix A includes further details regarding methodology for estimating the number of workers and ONUs per site. EPA assigned the following NAICS codes for this OES:

- 334100 – Computer and Peripheral Equipment Manufacturing;
- 334419 – Other Electronic Component Manufacturing;
- 335300 – Electrical Equipment Manufacturing;
- 335900 – Other Electrical Equipment and Component Manufacturing;
- 336110 – Automobile and Light Duty Motor Vehicle Manufacturing;
- 336411 – Aircraft Manufacturing;
- 336412 – Aircraft Engine and Engine Parts Manufacturing; and
- 336413 – Other Aircraft Parts and Auxiliary Equipment Manufacturing.

Table 3-18 summarizes the per site estimates for this OES based on the methodology described, including the number of sites identified in Section 3.12.2 and 3.13.2 of the *Draft Release Assessment for 4,4'-(1-Methylethylidene)bis[2,6-dibromophenol] (TBBPA)* (U.S. EPA, 2026g).

Table 3-18. Estimated Average Number of Workers per Site Potentially Exposed to TBBPA During Production of TBBPA-Containing Mixtures and Formulations

Potential Number of Sites	NAICS Code	Potentially Exposed Workers per Site[a]	Potentially Exposed ONUs per Site[a]
4	334100 – Computer and Peripheral Equipment Manufacturing	35	29
	334419 – Other Electronic Component Manufacturing		
	335300 – Electrical Equipment Manufacturing		
	335900 – Other Electrical Equipment and Component Manufacturing		
	336110 – Automobile and Light Duty Motor Vehicle Manufacturing		
	336411 – Aircraft Manufacturing		
	336412 – Aircraft Engine and Engine Parts Manufacturing		
	336413 – Other Aircraft Parts and Auxiliary Equipment Manufacturing		

[a] Number of workers and ONUs per site are calculated by dividing the exposed number of workers or ONUs by the number of establishments.

3.4.4.3 Occupational Inhalation Exposure Results

For the production of Composite parts from prepreg and adhesive film, EPA was provided inhalation monitoring data from ACC test order data. The two companies that provided data for this OES use TBBPA-containing materials, typically in solid matrix form like a sheet, cloth, or prepreg composite, containing less than 30% TBBPA to create new solid components containing TBBPA. These components are frequently heated, shaped, or formed into final products or articles. The group of companies performing these production activities is referred to as Group 4 in the study, which is the same nomenclature used by EPA for this OES. The companies in Group 4 run both batch and continuous processes. Batch operations range in frequency from 12 to 365 days per year, and continuous operations operate for approximately 5 days per week, or approximately 260 days per year assuming 52 weeks of operation per calendar year, up to 275 days per year (Integral Consulting, 2025a). The ACC Group 4 data include 31 occupational full-shift (8-hour TWA) personal air samples from user operators, logistics technicians, maintenance technicians, and ONUs.

The dataset for Group 4 shows that over 80% of the results were non-detects for TBBPA, so the ACC TBBPA Consortium reported that estimating statistics are unreliable and did not report them. Therefore, EPA calculated the high-end and central tendency statistics via the raw data. For the SEGs Logistics Technician and Maintenance Technician, EPA used $\frac{LOD}{2}$ as the central tendency estimate and LOD as the high-end estimate, as there were two data points each, per Section 2.3.1. For the SEGs User Operator and ONUs, EPA calculated the central tendency and high-end estimates using the detected values and either $\frac{LOD}{2}$ or $\frac{LOD}{\sqrt{2}}$ depending on the geometric standard deviation of the data, as per Section 2.3.1.

From this monitoring data, EPA used the test order's calculated 50th and 95th percentile full-shift TWA concentrations to represent a central tendency and high-end estimate of potential occupational inhalation exposures, respectively, for this scenario. Using these full-shift TWA exposure concentrations, EPA calculated the IADC, and ADC, as described in Appendix B assuming that workers work 40 hours per week on average and a total of 2,000 hours per year, which is equivalent to working 8 hours per day for 250 days per year, irrespective of shift duration and actual exposure frequency. The results of these calculations are shown in Table 3-19 below.

Table 3-19. Summary of Worker Inhalation Exposure Metrics to TBBPA During ACC TBBPA Consortium's Group 4: Production of Composite Parts from Prepreg and Adhesive Film

SEG	Number of Samples	8-Hour TWA Exposure Concentration		Intermediate Average Daily Concentration (IADC)		Average Daily Concentration (ADC)	
		Central Tendency (mg/m^3)	High-End (mg/m^3)	Central Tendency (mg/m^3)	High-End (mg/m^3)	Central Tendency (mg/m^3)	High-End (mg/m^3)
User operator (UOP)	18	8.5E−05	2.6E−04	4.4E−05	1.3E−04	3.9E−05	1.2E−04
Logistics technician (LGT)	2	6.5E−05	1.3E−04	3.4E−05	6.7E−05	3.0E−05	5.9E−05
Maintenance technician (MT)	2	6.5E−05	1.3E−04	3.4E−05	6.7E−05	3.0E−05	5.9E−05
ONU	9	9.2E−05	9.6E−05	4.8E−05	5.0E−05	4.2E−05	4.4E−05

3.4.4.4 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES using the methodology outlined in Section 2.4. The various "Exposure Concentration Types" from Table 3-20 are explained in Appendix B. Table 3-20 summarizes the APDR, IADD, and ADD for chronic non-cancer for all applicable SEGs. For user operators, logistic technicians, and maintenance technicians, dermal exposure is expected to be to solids containing TBBPA. For ONUs, dermal exposure is assessed from contact with surfaces onto which the dusts have deposited were assessed. Dermal exposure to workers is generally expected to be greater than dermal exposure to ONUs. In absence of data specific to ONU exposure, EPA assumes that worker central tendency exposure to solids is representative of ONU exposure.

Table 3-20. Summary of Worker Dermal Exposure Metrics to TBBPA During ACC TBBPA Consortium's Group 4: Production of Composite Parts from Prepreg and Adhesive Film

Worker Description	Exposure Concentration Type	Central Tendency	High-End
User operator (UOP); Logistic technician (LGT); Maintenance technician (MT)	Dose rate (APDR, mg/day)	3.7	7.5
	Intermediate (IADD, mg/kg-day)	3.6E−02	7.3E−02
	Chronic, non-cancer (ADD, mg/kg-day)	3.2E−02	6.4E−02
ONU	Dose rate (APDR, mg/day)	3.7	
	Intermediate (IADD, mg/kg-day)	3.6E−02	

Worker Description	Exposure Concentration Type	Central Tendency	High-End
	Chronic, non-cancer (ADD, mg/kg-day)	3.2E−02	

3.5 Recycling

As listed in Table 3-1, this OES includes the following COU: Recycling.

3.5.1 Worker Activities

Electronic waste (e-waste) recycling process typically includes dismantling, upgrading, and refining (Ashiq et al., 2019). Worker exposures to TBBPA may occur from dermal exposure to the solid TBBPA-containing waste or via inhalation of particulates that are formed during these three processing stages.

ONUs include employees (*e.g.,* supervisors, managers) who work at the recycling facility but do not directly handle TBBPA. Generally, EPA expects ONUs to have lower inhalation exposures than workers who handle the chemicals directly. Since ONUs do not directly handle chemicals and materials, dermal exposures would be limited to incidental contact, such as of TBBPA dusts that settle onto surfaces that the ONUs contact.

See Section 3.11.1 of the *Draft Release Assessment for 4,4'-(1-Methylethylidene)bis[2,6-dibromophenol] (TBBPA)* (U.S. EPA, 2026g) for a full recycling process description.

3.5.2 Number of Workers and Occupational Non-Users

EPA used data from BLS and the SUSB specific to the OES to estimate the number of workers and ONUs per site potentially exposed to TBBPA during repackaging (U.S. Census Bureau, 2017; U.S. BLS, 2023a). This approach involved first identifying the relevant NAICS codes for the OES. The next step is the identification of relevant SOC codes within the BLS data for the identified NAICS codes. From there total number of workers can be determined. This number is divided by the number of sites identified to obtain the exposed workers per site. Appendix A includes further details regarding methodology for estimating the number of workers and ONUs per site. EPA assigned the following NAICS codes for this OES:

- 562920 – Materials Recovery Facilities

Table 3-21 summarizes the per site estimates for this OES based on the methodology described, including the number of sites identified in Section 3.11.2 of the *Draft Release Assessment for 4,4'-(1-Methylethylidene)bis[2,6-dibromophenol] (TBBPA)* (U.S. EPA, 2026g).

Table 3-21. Estimated Average Number of Workers per Site Potentially Exposed to TBBPA During Recycling

Potential Number of Sites	NAICS Code	Potentially Exposed Workers per Site[a]	Potentially Exposed ONUs per Site[a]
860	562920 – Materials Recovery Facilities	1	1
[a] Number of workers and ONUs per site are calculated by dividing the exposed number of workers or ONUs by the number of establishments.			

3.5.3 Occupational Inhalation Exposure Results

For recycling of e-waste containing TBBPA, EPA identified two NIOSH Health Hazard Evaluation (HHE) reports that conducted exposure sampling at two different electronics recycling facilities and one exposure study from Finland. The NIOSH HHE data comprised 42 full-shift (8-hour) personal breathing zone samples for worker activities that include sorting and shredding e-waste, disassembling batteries and other electronics, and refurbishing e-waste components for reuse (Beaucham et al., 2018; Grimes et al., 2019). These data were divided into four groups by worker activities. The central tendency and the range of TBBPA TWA full-shift exposure concentrations were reported in these studies for some groups but only the ranges of TBBPA full-shift exposure concentrations were reported for other groups because of the number of TBBPA non-detects for these groups. The exposure study from Finland conducted worker PBZ sampling at various commercial e-waste recycling and sorting facilities, including a total of four full-shift PBZ samples (Rosenberg et al., 2011). EPA calculated summary statistics for the Finland study, then used these summary statistics to along with the four datasets from the NIOSH HHEs to estimate overall central tendency and high-end values as discussed below.

From this monitoring data, EPA calculated the median of the median values for the five distributions to represent a central tendency estimate of potential occupational inhalation exposures. EPA calculated the 95th percentile of maximum values from the five datasets to represent a high-end estimate of potential occupational inhalation exposures for this scenario. The Agency assessed high-end concentration from maximum values because only maximum values were reported as stated above. Using these 8-hour TWA exposure concentration, EPA calculated the IADC and ADC, as described in Appendix B. In absence of data specific to ONU exposure, the Agency assumed that worker central tendency exposure was representative of ONU exposure and used this data to generate estimates for ONUs. The results of these calculations are shown in Table 3-22 below.

Table 3-22. Summary of Worker Inhalation Exposure Metrics to TBBPA During Recycling

Exposure Concentration Type	Worker Inhalation Estimates (mg/m^3)		ONU Inhalation Estimates (mg/m^3)
	Central Tendency	High-End	
8-Hour TWA exposure concentration	1.4E−06	2.9E−04	1.4E−06
Intermediate average daily concentration (IADC) based on 8-hour TWA	7.3E−07	1.5E−04	7.3E−07
Average daily concentration (ADC) based on 8-hour TWA	6.4E−07	1.3E−04	6.4E−07

3.5.4 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES using the methodology outlined in Section 2.4. The various “Exposure Concentration Types” from Table 3-23 are explained in Appendix B. Table 3-23 summarizes the APDR, IADD, and ADD for chronic non-cancer for all applicable SEGs. For workers, dermal exposure is assessed to solids containing TBBPA. For ONUs, dermal exposure is assessed from contact with surfaces onto which the dusts have deposited were assessed. Dermal exposure to workers is generally expected to be greater than dermal exposure to ONUs. In absence of data specific to ONU exposure, EPA assumes that worker central tendency exposure to solids is representative of ONU exposure.

Table 3-23. Summary of Worker Dermal Exposure Metrics to TBBPA During Recycling

Worker Description	Exposure Concentration Type	Central Tendency	High-End
Average adult worker	Dose rate (APDR, mg/day)	3.7	7.5
	Intermediate (IADD, mg/kg-day)	3.6E−02	7.3E−02
	Chronic, non-cancer (ADD, mg/kg-day)	3.2E−02	6.4E−02
ONU	Dose rate (APDR, mg/day)	3.7	
	Intermediate (IADD, mg/kg-day)	3.6E−02	
	Chronic, non-cancer (ADD, mg/kg-day)	3.2E−02	

3.6 Industrial and Commercial Additive Use in Electrical and Electronic Articles

As listed in Table 3-1, this OES includes the following COU: Industrial and commercial use in electrical and electronic articles.

3.6.1 Worker Activities

Solid components containing TBBPA may be assembled to build electronic products. Use of such components may include melting, drilling, cutting, grinding, or otherwise shaping the parts containing TBBPA in order to form/assemble other products. During this process, worker exposures to TBBPA may occur via dermal contact while handling and shaping the solid articles containing TBBPA as an additive. Worker exposures may also occur via particulate inhalation during activities such as cutting, grinding, shaping, drilling, and/or abrasive actions that generate particulates from the product. EPA did not identify chemical-specific information on engineering controls and worker PPE used at final product or article formulation or use sites.

ONUs include supervisors, managers, and other employees that may be present in production areas but do not directly handle TBBPA-containing materials or articles. ONU inhalation exposures may occur when ONUs are present in the manufacturing area during dust generating activities. Generally, EPA expects ONUs to have lower inhalation exposures than workers who handle the chemicals directly. Since ONUs do not directly handle chemicals and materials, dermal exposures would be limited to incidental contact, such as of TBBPA dusts that settle onto surfaces that the ONUs contact.

See Section 3.12.1 of the *Draft Release Assessment for 4,4'-(1-Methylethylidene)bis[2,6-dibromophenol] (TBBPA)* (U.S. EPA, 2026g) for a full process description for industrial and commercial additive use in electrical and electronic articles.

3.6.2 Number of Workers and Occupational Non-Users

EPA used data from BLS and the SUSB specific to the OES to estimate the number of workers and ONUs per site potentially exposed to TBBPA during industrial and commercial additive use in electrical and electronic articles (U.S. Census Bureau, 2017; U.S. BLS, 2023a). This approach involved first identifying the relevant NAICS codes for the OES. The next step is the identification of relevant SOC codes within the BLS data for the identified NAICS codes. From there total number of workers can be determined. This number is divided by the number of sites identified to obtain the exposed workers per site. Appendix A includes further details regarding methodology for estimating the number of workers and ONUs per site. EPA assigned the following NAICS codes for this OES:

- 334100 – Computer and Peripheral Equipment Manufacturing;
- 334419 – Other Electronic Component Manufacturing;
- 335300 – Electrical Equipment Manufacturing; and
- 335900 – Other Electrical Equipment and Component Manufacturing.

Table 3-24 summarizes the per site estimates for this OES based on the methodology described as discussed in Section 3.12.2 of the *Draft Release Assessment for 4,4'-(1-Methylethylidene)bis[2,6-dibromophenol] (TBBPA)* (U.S. EPA, 2026g), EPA did not identify site-specific data for the number of facilities in the United States for this OES.

Table 3-24. Estimated Average Number of Workers per Site Potentially Exposed to TBBPA During Industrial and Commercial Additive Use in Electrical and Electronic Articles

Potential Number of Sites	NAICS Code	Potentially Exposed Workers per Site[ab]	Potentially Exposed ONUs per Site[ab]
Unknown	334100 – Computer and Peripheral Equipment Manufacturing	12	15
	334419 – Other Electronic Component Manufacturing		
	335300 – Electrical Equipment Manufacturing		
	335900 – Other Electrical Equipment and Component Manufacturing		

[a] Number of workers and ONUs per site are calculated by dividing the exposed number of workers or ONUs by the number of establishments.
[b] As EPA did not identify site-specific data for the number of facilities in the United States for this OES, the workers per site estimates are calculated using the BLS data's value for number of sites.

3.6.3 Occupational Inhalation Exposure Results

EPA identified one relevant source for this OES during data extraction and evaluation, a risk assessment for TBBPA by the European Chemicals Bureau (ECB) which provided area data with a concentration range of 1.1×10^{-7} to 3.7×10^{-7} mg/m^3; mean value 2.0×10^{-7} mg/m^3 (ECB, 2008). However, EPA did not use this source because it only included static area sampling, which is not expected to be representative of worker exposures for this risk evaluation. The Agency expects the primary exposure route for this OES to be from inhalation of particulates generated during activities such as cutting, grinding, drilling, and other abrasive actions used to shape the solid component into the final electronic. Therefore, EPA estimated worker inhalation exposures using the PNOR Model (U.S. EPA, 2021b). Model approaches and parameters are described in Appendix D. The area data provided in (ECB, 2008) differ significantly from the calculated 8-hour central tendency and high-end values from the PNOR Model shown in Table 3-25, which suggests that the assessed values are overestimates.

EPA used a subset of the PNOR Model (U.S. EPA, 2021b) data specific to facilities with NAICS codes starting with 334 – Computer and Electronic Product Manufacturing to estimate total particulate concentrations in the air. EPA multiplied the total particulate air concentration from the model by the highest expected concentration of TBBPA in final products for this OES to estimate the concentration of total TBBPA in the particulates. For this OES, EPA identified 20% by mass as the highest expected TBBPA concentration based on an identified product safety data sheet (SDS) (Panduit Corporation, 2017). The estimated exposures assume that TBBPA is present in particulates at the same concentration as products and that this concentration is fixed throughout the working shift.

The PNOR Model (U.S. EPA, 2021b) estimates an 8-hour TWA concentration for particulate by assuming exposures outside the sample duration are zero. The model does not determine exposures during individual worker activities. Using the 50th and 95th percentile total particulate exposures from the model and maximum TBBPA concentration, EPA estimated the central tendency and high-end 8-hour TWA TBBPA exposure estimates. EPA then calculated the IADC and ADC as described in Appendix B. In absence of data specific to ONU exposure, the Agency assumed that worker central tendency exposure was representative of ONU exposure and used this data to generate estimates for ONUs. The results of these calculations are shown in Table 3-25 below.

Table 3-25. Summary of Worker Inhalation Exposure Metrics to TBBPA During Industrial and Commercial Additive Use in Electrical and Electronic Articles

Exposure Concentration Type	Worker Inhalation Estimates (mg/m^3)		ONU Inhalation Estimates (mg/m^3)
	Central Tendency	High-End	
8-Hour TWA exposure concentration	6.6E−02	1.2	6.6E−02
Intermediate average daily concentration (IADC) based on 8-hour TWA	3.5E−02	0.63	3.5E−02
Average daily concentration (ADC) based on 8-hour TWA	3.1E−02	0.56	3.1E−02

3.6.4 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES using the methodology outlined in Section 2.4. The various "Exposure Concentration Types" from Table 3-26 are explained in Appendix B. Table 3-26 summarizes the APDR, IADD, and ADD for chronic non-cancer for all applicable SEGs. For workers, dermal exposure is assessed to solids containing TBBPA. For ONUs, dermal exposure is assessed from contact with surfaces onto which the dusts have deposited were assessed. Dermal exposure to workers is generally expected to be greater than dermal exposure to ONUs. In absence of data specific to ONU exposure, EPA assumes that worker central tendency exposure to solids is representative of ONU exposure.

Table 3-26. Summary of Worker Dermal Exposure Metrics to TBBPA During Industrial and Commercial Additive Use in Electrical and Electronic Articles

Worker Description	Exposure Concentration Type	Central Tendency	High-End
Average adult worker	Dose rate (APDR, mg/day)	3.7	7.5
	Intermediate (IADD, mg/kg-day)	3.6E−02	7.3E−02
	Chronic, non-cancer (ADD, mg/kg-day)	3.2E−02	6.4E−02
ONU	Dose rate (APDR, mg/day)	3.7	
	Intermediate (IADD, mg/kg-day)	3.6E−02	
	Chronic, non-cancer (ADD, mg/kg-day)	3.2E−02	

3.7 Industrial and Commercial Use in Building and Construction Materials

As listed in Table 3-1, this OES includes the following COU: Industrial and commercial use in electrical and electronic articles.

3.7.1 Worker Activities

Building components containing TBBPA (including expanded polystyrene and polyurethane foam, fiberglass composites, pipelines, storage tanks, and decorative laminates) may be combined or reshaped to build structures or form new products. During this use, worker exposures to TBBPA may occur via dermal contact while handling and shaping articles containing TBBPA as an additive. Worker exposures may also occur via particulate inhalation during activities such as cutting, grinding, shaping, drilling, and/or abrasive actions that generate particulates from the product. EPA did not identify chemical-specific information on engineering controls and worker PPE used at final product or article formulation or use sites.

ONUs include supervisors, managers, and other employees that may be present in areas where the product is being used but do not directly handle TBBPA-containing materials or articles. ONU inhalation exposures may occur when ONUs are present in the product use area during dust generating activities. Generally, EPA expects ONUs to have lower inhalation exposures than workers who handle the chemicals directly. Since ONUs do not directly handle chemicals and materials, dermal exposures would be limited to incidental contact, such as of TBBPA dusts that settle onto surfaces that the ONUs contact.

See Section 3.14.1 of the *Draft Release Assessment for 4,4'-(1-Methylethylidene)bis[2,6-dibromophenol] (TBBPA)* (U.S. EPA, 2026g) for a full use in building and construction materials process description.

3.7.2 Number of Workers and Occupational Non-Users

EPA used data from BLS and the SUSB specific to the OES to estimate the number of workers and ONUs per site potentially exposed to TBBPA during industrial and commercial use in building and construction materials (U.S. Census Bureau, 2017; U.S. BLS, 2023a). This approach involved first identifying the relevant NAICS codes for the OES. The next step is the identification of relevant SOC codes within the BLS data for the identified NAICS codes. From there total number of workers can be determined. This number is divided by the number of sites identified to obtain the exposed workers per site. Appendix A includes further details regarding methodology for estimating the number of workers and ONUs per site. EPA assigned the following NAICS codes for this OES:

- 236100 – Residential Building Construction;
- 236200 – Nonresidential Building Construction;
- 237100 – Utility System Construction;
- 237310 – Highway, Street, and Bridge Construction; and
- 237990 – Other Heavy and Civil Engineering Construction.

Table 3-27 summarizes the per site estimates for this OES based on the methodology described, including the number of sites identified in Section 3.14.2 of the *Draft Release Assessment for 4,4'-(1-Methylethylidene)bis[2,6-dibromophenol] (TBBPA)* (U.S. EPA, 2026g).

Table 3-27. Estimated Average Number of Workers per Site Potentially Exposed to TBBPA During Industrial and Commercial Use in Building and Construction Materials

Potential Number of Sites	NAICS Code	Potentially Exposed Workers per Site[ab]	Potentially Exposed ONUs per Site[ab]
1	236100 – Residential Building Construction	2	2
	236200 – Nonresidential Building Construction		
	237100 – Utility System Construction		
	237310 – Highway, Street, and Bridge Construction		
	237990 – Other Heavy and Civil Engineering Construction		

[a] Number of workers and ONUs per site are calculated by dividing the exposed number of workers or ONUs by the number of establishments.

3.7.3 Occupational Inhalation Exposure Results

EPA did not identify any sources of relevant worker exposure data for this OES. The Agency expects the primary exposure route to be from inhalation of particulates generated during activities such as cutting, grinding, drilling, and other abrasive actions used to install the building materials. Therefore, EPA estimated worker inhalation using the Generic Model for Central Tendency and High-End Inhalation Exposure to Total and Respirable PNOR (U.S. EPA, 2021b). Model approaches and parameters are described in Appendix D.

EPA used a subset of the PNOR Model (U.S. EPA, 2021b) data specific to facilities with NAICS codes starting with 23 – Construction to estimate respirable total concentrations in the air. EPA multiplied the total particulate air concentration from the model by the highest expected concentration of TBBPA in final products for this OES to estimate the concentration of TBBPA in the total particulates. For this OES, EPA identified 22% by mass as the highest expected TBBPA concentration based on levels of TBBPA in acrylonitrile-butadiene-styrene (ABS) plastic (ECB, 2006). The estimated exposures assume that TBBPA is present in total particulates at the same concentration as products and that this concentration is fixed throughout the working shift.

The PNOR Model (U.S. EPA, 2021b) estimates an 8-hour TWA concentration for total particulate by assuming exposures outside the sample duration are zero. The model does not determine exposures during individual worker activities. Using the 50th and 95th percentile total particulate exposures from the model and maximum TBBPA concentration, EPA estimated the central tendency and high-end 8-hour TWA TBBPA exposure estimates. EPA then calculated the IADC and ADC as described in Appendix B. In absence of data specific to ONU exposure, the Agency assumed that worker central tendency exposure was representative of ONU exposure and used this data to generate estimates for ONUs. The results of these calculations are shown in Table 3-28 below.

Table 3-28. Summary of Worker Inhalation Exposure Metrics to TBBPA During Industrial and Commercial Use in Building and Construction Materials

Exposure Concentration Type	Worker Inhalation Estimates (mg/m³)		ONU Inhalation Estimates (mg/m³)
	Central Tendency	High-End	
8-Hour TWA exposure concentration	0.53	3.3	0.53
Intermediate average daily concentration (IADC) based on 8-hour TWA	0.28	1.7	0.28
Average daily concentration (ADC) based on 8-hour TWA	0.25	1.5	0.25

3.7.4 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES using the methodology outlined in Section 2.4. The various "Exposure Concentration Types" from Table 3-29 are explained in Appendix B. Table 3-29 summarizes the APDR, IADD, and ADD for chronic non-cancer for all applicable SEGs. For workers, dermal exposure is assessed to solids containing TBBPA. For ONUs, dermal exposure is assessed from contact with surfaces onto which the dusts have deposited were assessed. Dermal exposure to workers is generally expected to be greater than dermal exposure to ONUs. In absence of data specific to ONU exposure, EPA assumes that worker central tendency exposure to solids is representative of ONU exposure.

Table 3-29. Summary of Worker Dermal Exposure Metrics to TBBPA During Industrial and Commercial Use in Building and Construction Materials

Worker Description	Exposure Concentration Type	Central Tendency	High-End
Average adult worker	Dose rate (APDR, mg/day)	3.7	7.5
	Intermediate (IADD, mg/kg-day)	3.6E−02	7.3E−02
	Chronic, non-cancer (ADD, mg/kg-day)	3.2E−02	6.4E−02
ONU	Dose rate (APDR, mg/day)	3.7	
	Intermediate (IADD, mg/kg-day)	3.6E−02	
	Chronic, non-cancer (ADD, mg/kg-day)	3.2E−02	

3.8 Use of Powder Coatings in Electronics

As listed in Table 3-1, this OES includes the following COU: Industrial use in powder coatings.

3.8.1 Worker Activities

EPA identified a powder coating product containing TBBPA that is used in electronics manufacturing as a flame retardant (U.S. EPA, 2022). During this use, EPA expects that worker exposures to TBBPA may occur via inhalation of dust and dermal contact with solids during activities such as unloading the powder coating, container cleaning, equipment cleaning, or during powder coating application. EPA did not identify chemical-specific information on engineering controls and worker PPE used at powder coating sites.

ONUs include supervisors, managers, and other employees that may be present in areas where the product is being used but do not directly handle TBBPA-containing materials or articles. ONU inhalation exposures may occur when ONUs are present in the product use area during dust generating activities. Generally, EPA expects ONUs to have lower inhalation exposures than workers who handle the chemicals directly. Since ONUs do not directly handle chemicals and materials, dermal exposures would be limited to incidental contact, such as of TBBPA dusts that settle onto surfaces that the ONUs contact.

See Section 3.15.1 of the *Draft Release Assessment for 4,4'-(1-Methylethylidene)bis[2,6-dibromophenol] (TBBPA)* (U.S. EPA, 2026g) for a full use in powder coatings process description.

3.8.2 Number of Workers and Occupational Non-Users

EPA used data from BLS and the SUSB specific to the OES to estimate the number of workers and ONUs per site potentially exposed to TBBPA during the use of powder coatings in electronics (U.S. Census Bureau, 2017; U.S. BLS, 2023a). This approach involved first identifying the relevant NAICS codes for the OES. The next step is the identification of relevant SOC codes within the BLS data for the identified NAICS codes. From there total number of workers can be determined. This number is divided by the number of sites identified to obtain the exposed workers per site. Appendix A includes further details regarding methodology for estimating the number of workers and ONUs per site. EPA assigned the following NAICS codes for this OES:

- 332200 – Cutlery and Handtool Manufacturing;
- 332900 – Other Fabricated Metal Product Manufacturing;
- 335300 – Electrical Equipment Manufacturing; and
- 335900 – Other Electrical Equipment and Component Manufacturing.

Table 3-30 summarizes the per site estimates for this OES based on the methodology described. As discussed in Section 3.15.2 of the *Draft Release Assessment for 4,4'-(1-Methylethylidene)bis[2,6-dibromophenol] (TBBPA)* (U.S. EPA, 2026g), EPA did not identify site-specific data for the number of facilities in the United States for this OES.

Table 3-30. Estimated Average Number of Workers per Site Potentially Exposed to TBBPA During Use of Powder Coatings in Electronics

Potential Number of Sites	NAICS Code	Potentially Exposed Workers per Site[a b]	Potentially Exposed ONUs per Site[a b]
Unknown	332200 – Cutlery and Handtool Manufacturing	11	7
	332900 – Other Fabricated Metal Product Manufacturing		
	335300 – Electrical Equipment Manufacturing		
	335900 – Other Electrical Equipment and Component Manufacturing		

[a] Number of workers and ONUs per site are calculated by dividing the exposed number of workers or ONUs by the number of establishments.
[b] As EPA did not identify site-specific data for the number of facilities in the United States for this OES, the workers per site estimates are calculated using the BLS data's value for number of sites.

3.8.3 Occupational Inhalation Exposure Results

EPA did not identify any sources of relevant worker exposure data for this OES. EPA expects the primary exposure route to be from inhalation of particulates generated during activities such as powder coating application. Therefore, EPA estimated worker inhalation exposures using the Generic Model for Central Tendency and High-End Inhalation Exposure to Total and Respirable PNOR (U.S. EPA, 2021b). Model approaches and parameters are described in Appendix D.

EPA used a subset of the PNOR Model (U.S. EPA, 2021b) data specific to facilities with NAICS codes starting with 334 – Computer and Electronic Product Manufacturing, 335 – Electrical Equipment, Appliance, and Component Manufacturing, and 336 – Transportation Equipment Manufacturing to estimate total particulate concentrations in the air. EPA multiplied the total particulate air concentration from the model by the highest expected concentration of TBBPA in final products for this OES to estimate the concentration of total TBBPA in the particulates. For this OES, EPA identified 10% by weight as the highest expected TBBPA concentration based on a documented epoxy powder product for the electronics industry that contains 5 to 10% TBBPA by weight, produced by SolEpoxy, Inc. (Earthjustice, 2019). The estimated exposures assume that TBBPA is present in total particulates at the same concentration as products and that this concentration is fixed throughout the working shift.

The PNOR Model (U.S. EPA, 2021b) estimates an 8-hour TWA concentration for total particulate by assuming exposures outside the sample duration are zero. The model does not determine exposures during individual worker activities. Using the 50th and 95th percentile total particulate exposures from the model and maximum TBBPA concentration, EPA estimated the central tendency and high-end 8-hour TWA TBBPA exposure estimates. EPA then calculated the IADC and ADC as described in Appendix B. In absence of data specific to ONU exposure, the Agency assumed that worker central tendency exposure was representative of ONU exposure and used this data to generate estimates for ONUs. The results of these calculations are shown in Table 3-31 below.

Table 3-31. Summary of Worker Inhalation Exposure Metrics to TBBPA During Use of Powder Coatings in Electronics

Exposure Concentration Type	Worker Inhalation Estimates (mg/m^3)		ONU Inhalation Estimates (mg/m^3)
	Central Tendency	High-End	
8-Hour TWA exposure concentration	0.20	1.5	0.20
Intermediate average daily concentration (IADC) based on 8-hour TWA	0.11	0.79	0.11
Average daily concentration (ADC) based on 8-hour TWA	9.3E−02	0.70	9.3E−02

3.8.4 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES using the methodology outlined in Section 2.4. The various "Exposure Concentration Types" from Table 3-32 are explained in Appendix B. Table 3-32 summarizes the APDR, IADD, and ADD for chronic non-cancer for all applicable SEGs. For workers, dermal exposure is assessed to solids containing TBBPA. For ONUs, dermal exposure is assessed from contact with surfaces onto which the dusts have deposited were assessed. Dermal exposure to workers is generally expected to be greater than dermal exposure to ONUs. In absence of data specific to ONU exposure, EPA assumes that worker central tendency exposure to solids is representative of ONU exposure.

Table 3-32. Summary of Worker Dermal Exposure Metrics to TBBPA During Use of Powder Coatings in Electronics

Worker Description	Exposure Concentration Type	Central Tendency	High-End
Average adult worker	Dose rate (APDR, mg/day)	3.7	7.5
	Intermediate (IADD, mg/kg-day)	3.6E−02	7.3E−02
	Chronic, non-cancer (ADD, mg/kg-day)	3.2E−02	6.4E−02
ONU	Dose rate (APDR, mg/day)	3.7	
	Intermediate (IADD, mg/kg-day)	3.6E−02	
	Chronic, non-cancer (ADD, mg/kg-day)	3.2E−02	

3.9 Industrial Use in Plastic and Rubber Products

As listed in Table 3-1, this OES includes the following COU: Industrial use in plastic and rubber products.

3.9.1 Worker Activities

This OES captures the use of plastic and rubber for other applications like assembling appliances and light fixtures with plastic parts at industrial sites. Worker exposures during use of such plastic and rubber articles may include dermal and inhalation exposures to dust generated during melting, drilling, cutting, grinding, or otherwise shaping the parts containing TBBPA in order to form/assemble other products. EPA did not identify chemical-specific information on engineering controls and worker PPE used at sites that use plastic and rubber products.

ONUs include supervisors, managers, and other employees that may be present in production areas but do not directly handle TBBPA-containing materials or articles. ONU inhalation exposures may occur when ONUs are present in the manufacturing area during dust generating activities. Generally, EPA expects ONUs to have lower inhalation exposures than workers who handle the chemicals directly. Since ONUs do not directly handle chemicals and materials, dermal exposures would be limited to incidental contact, such as of TBBPA dusts that settle onto surfaces that the ONUs contact.

See Section 3.16.1 of the *Draft Release Assessment for 4,4'-(1-Methylethylidene)bis[2,6-dibromophenol] (TBBPA)* (U.S. EPA, 2026g) for a full use in plastic and rubber products process description.

3.9.2 Number of Workers and Occupational Non-Users

EPA used data from BLS and the SUSB specific to the OES to estimate the number of workers and ONUs per site potentially exposed to TBBPA during industrial use in plastic and rubber products (U.S. Census Bureau, 2017; U.S. BLS, 2023a). This approach involved first identifying the relevant NAICS codes for the OES. The next step is the identification of relevant SOC codes within the BLS data for the identified NAICS codes. From there total number of workers can be determined. This number is divided by the number of sites identified to obtain the exposed workers per site. Appendix A includes further details regarding methodology for estimating the number of workers and ONUs per site. EPA assigned the following NAICS codes for this OES:

- 326112 – Plastics Packaging Film and Sheet (including Laminated) Manufacturing
- 334100 – Computer and Peripheral Equipment Manufacturing
- 334200 – Communications Equipment Manufacturing
- 335100 – Electric Lighting Equipment Manufacturing
- 335200 – Household Appliance Manufacturing
- 335300 – Electrical Equipment Manufacturing
- 335900 – Other Electrical Equipment and Component Manufacturing
- 336100 – Motor Vehicle Manufacturing
- 336200 – Motor Vehicle Body and Trailer Manufacturing
- 336300 – Motor Vehicle Parts Manufacturing
- 336900 – Other Transportation Equipment Manufacturing.

Table 3-33 summarizes the per site estimates for this OES based on the methodology described. As discussed in Section 3.16.2 of the *Draft Release Assessment for 4,4'-(1-Methylethylidene)bis[2,6-dibromophenol] (TBBPA)* (U.S. EPA, 2026g), EPA did not identify site-specific data for the number of facilities in the United States for this OES.

Table 3-33. Estimated Average Number of Workers per Site Potentially Exposed to TBBPA During Industrial Use in Plastic and Rubber Products

Potential Number of Sites	NAICS Code	Potentially Exposed Workers per Site[a] [b]	Potentially Exposed ONUs per Site[a] [b]
Unknown	326112 – Plastics Packaging Film and Sheet (including Laminated) Manufacturing	46	16
	334100 – Computer and Peripheral Equipment Manufacturing		
	334200 – Communications Equipment Manufacturing		
	335100 – Electric Lighting Equipment Manufacturing		
	335200 – Household Appliance Manufacturing		
	335300 – Electrical Equipment Manufacturing		
	335900 – Other Electrical Equipment and Component Manufacturing		
	336100 – Motor Vehicle Manufacturing		
	336200 – Motor Vehicle Body and Trailer Manufacturing		
	336300 – Motor Vehicle Parts Manufacturing		
	336900 – Other Transportation Equipment Manufacturing		

[a] Number of workers and ONUs per site are calculated by dividing the exposed number of workers or ONUs by the number of establishments.

Potential Number of Sites	NAICS Code	Potentially Exposed Workers per Site[a b]	Potentially Exposed ONUs per Site[a b]

[b] As EPA did not identify site-specific data for the number of facilities in the United States for this OES, the workers per site estimates are calculated using the BLS data's value for number of sites.

3.9.3 Occupational Inhalation Exposure Results

EPA was unable to identify specific monitoring data for the industrial use of TBBPA in plastic and rubber parts. EPA expects dust inhalation during drilling, cutting, grinding, or otherwise shaping solid parts containing TBBPA to form/assemble other products to be the primary mode of worker exposure. Because of expected similarities in worker activities, EPA used data provided by the ACC for Group 4 as surrogate data for this OES.

Group 4 data covers the production of Composite parts from prepreg and adhesive film. The companies that provided data for Group 4 use TBBPA-containing materials, typically in solid matrix form like a sheet, cloth, or prepreg composite, containing less than 30% TBBPA to create a new solid component in its final form containing TBBPA. EPA expects the same type of activities to occur for this OES, making the Group 4 data a suitable surrogate. See Section 3.4.4.3 for additional information on these data, including a summary of the 8-hour TWA exposure concentration, IADC, and ADC.

3.9.4 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES using the methodology outlined in Section 2.4. The various "Exposure Concentration Types" from Table 3-34 are explained in Appendix B. Table 3-34 summarizes the APDR, IADD, and ADD for chronic non-cancer for all applicable SEGs. For workers, dermal exposure is assessed to solids containing TBBPA. For ONUs, dermal exposure is assessed from contact with surfaces onto which the dusts have deposited were assessed. Dermal exposure to workers is generally expected to be greater than dermal exposure to ONUs. In absence of data specific to ONU exposure, EPA assumes that worker central tendency exposure to solids is representative of ONU exposure.

Table 3-34. Summary of Worker Dermal Exposure Metrics to TBBPA During Industrial Use in Plastic and Rubber Products

Worker Description	Exposure Concentration Type	Central Tendency	High-End
Average adult worker	Dose rate (APDR, mg/day)	3.7	7.5
	Intermediate (IADD, mg/kg-day)	3.6E−02	7.3E−02
	Chronic, non-cancer (ADD, mg/kg-day)	3.2E−02	6.4E−02
ONU	Dose rate (APDR, mg/day)	3.7	
	Intermediate (IADD, mg/kg-day)	3.6E−02	
	Chronic, non-cancer (ADD, mg/kg-day)	3.2E−02	

3.10 Commercial Use in Plastic and Rubber Products

As listed in Table 3-1, this OES includes the following COU: Commercial use in plastic and rubber products.

3.10.1 Worker Activities

This OES captures the use of plastic and rubber for other applications like assembling appliances and light fixtures with plastic parts at commercial sites. Workers are not expected to manipulate the solid articles containing TBBPA in such a way as to generate dust. Thus, worker exposures are limited to any TBBPA that may volatilize from the article or be present on the article surfaces. EPA did not identify chemical-specific information on engineering controls and worker PPE used at sites that use plastic and rubber products.

ONUs include supervisors, managers, and other employees that may be present in production areas but do not directly handle TBBPA-containing materials or articles. Therefore, ONU inhalation exposures would only be to any TBBPA that may volatilize from the solid articles. Dermal exposure is not expected for ONUs for this OES.

See Section 3.16.1 of the *Draft Release Assessment for 4,4'-(1-Methylethylidene)bis[2,6-dibromophenol] (TBBPA)* (U.S. EPA, 2026g) for a full use in plastic and rubber products process description.

3.10.2 Number of Workers and Occupational Non-Users

EPA used data from BLS and the SUSB specific to the OES to estimate the number of workers and ONUs per site potentially exposed to TBBPA during commercial use in plastic and rubber products (U.S. Census Bureau, 2017; U.S. BLS, 2023a). This approach involved first identifying the relevant NAICS codes for the OES. The next step is the identification of relevant SOC codes within the BLS data for the identified NAICS codes. From there total number of workers can be determined. This number is divided by the number of sites identified to obtain the exposed workers per site. Appendix A includes further details regarding methodology for estimating the number of workers and ONUs per site. EPA assigned the following NAICS codes for this OES:

- 326112 – Plastics Packaging Film and Sheet (including Laminated) Manufacturing
- 334100 – Computer and Peripheral Equipment Manufacturing
- 334200 – Communications Equipment Manufacturing
- 335100 – Electric Lighting Equipment Manufacturing
- 335200 – Household Appliance Manufacturing
- 335300 – Electrical Equipment Manufacturing
- 335900 – Other Electrical Equipment and Component Manufacturing
- 336100 – Motor Vehicle Manufacturing
- 336200 – Motor Vehicle Body and Trailer Manufacturing
- 336300 – Motor Vehicle Parts Manufacturing
- 336900 – Other Transportation Equipment Manufacturing.

Table 3-35 summarizes the per site estimates for this OES based on the methodology described. As discussed in Section 3.16.2 of the *Draft Release Assessment for 4,4'-(1-Methylethylidene)bis[2,6-dibromophenol] (TBBPA)* (U.S. EPA, 2026g), EPA did not identify site-specific data for the number of facilities in the United States for this OES.

Table 3-35. Estimated Average Number of Workers per Site Potentially Exposed to TBBPA During Commercial Use in Plastic and Rubber Products

Potential Number of Sites	NAICS Code	Potentially Exposed Workers per Site[a b]	Potentially Exposed ONUs per Site[a b]
Unknown	326112 – Plastics Packaging Film and Sheet (including Laminated) Manufacturing	46	16
	334100 – Computer and Peripheral Equipment Manufacturing		
	334200 – Communications Equipment Manufacturing		
	335100 – Electric Lighting Equipment Manufacturing		
	335200 – Household Appliance Manufacturing		
	335300 – Electrical Equipment Manufacturing		
	335900 – Other Electrical Equipment and Component Manufacturing		
	336100 – Motor Vehicle Manufacturing		
	336200 – Motor Vehicle Body and Trailer Manufacturing		
	336300 – Motor Vehicle Parts Manufacturing		
	336900 – Other Transportation Equipment Manufacturing		

[a] Number of workers and ONUs per site are calculated by dividing the exposed number of workers or ONUs by the number of establishments.
[b] As EPA did not identify site-specific data for the number of facilities in the United States for this OES, the workers per site estimates are calculated using the BLS data's value for number of sites.

3.10.3 Occupational Inhalation Exposure Results

EPA identified one relevant source for this OES during data extraction and evaluation, a risk assessment conducted for TBBPA by ECB (2008). This source included inhalation monitoring data at relevant facilities in Sweden and Germany, with a total of twelve 8-hour TWA area samples. Two of these samples were for workers and the remaining ten were for employees that worked in offices, which EPA would not consider to be workers or ONUs because they are not present where TBBPA-containing solid components are being used to produce final plastic and rubber articles. The two worker samples were taken in a computer repair facility and had 8-hour TWA values of 3.1×10^{-8} and 3.8×10^{-8} mg/m^3. The office worker samples ranged in TBBPA concentration from 9.6×10^{-9} to 3.6×10^{-8} mg/m^3. Based on this data, EPA decided to not quantitatively assess worker exposures for this OES because the low concentrations provided by these samples are not expected to generate considerable exposure or risk to workers. These concentrations will not result in MOEs that are less than the benchmark.

3.10.4 Occupational Dermal Exposure Results

As discussed in Section 3.10.1, worker dermal exposure is limited to contact with solid articles containing TBBPA. Because TBBPA is entrained in solid articles, worker dermal exposure to TBBPA is non-quantifiable for this OES. ONU dermal exposures are not expected.

3.11 Industrial and Commercial Laboratory Chemical Use

As listed in Table 3-1, this OES includes the following COU: Industrial and commercial laboratory chemical use.

3.11.1 Worker Activities

Process information indicates that TBBPA is used as a solid laboratory chemical. Therefore, worker exposures to TBBPA may occur through the inhalation of solid powders and dermal contact with solids during worker activities such as unloading and transferring laboratory chemicals, laboratory analysis, container cleaning, labware equipment cleaning, and disposal of laboratory wastes (U.S. EPA, 2023).

Per information provided in the ACC's test order data, PPE used by laboratory technicians may include baseline PPE (*e.g.,* safety shoes, safety glasses, gloves, and hard hats) and emergency-use PPE, which is applied in the case of a disruption or emergent event like a spill or leak (*e.g.,* self-contained breathing apparatus, escape air respirators). Engineering controls in laboratories may include the use of general mechanical ventilation, negative pressure, open doors and windows, and working under ventilated hoods (Integral Consulting, 2025a).

ONUs include supervisors, managers, and other employees that do not directly handle the laboratory chemical or laboratory equipment but may be present in the laboratory or analysis area. ONUs are potentially exposed through the inhalation route while in the laboratory area from airborne dust and through the dermal route from contact with surfaces where dust has been deposited.

See Section 3.17.1 of the *Draft Release Assessment for 4,4'-(1-Methylethylidene)bis[2,6-dibromophenol] (TBBPA)* (U.S. EPA, 2026g) for a full laboratory chemical use process description.

3.11.2 Number of Workers and Occupational Non-Users

EPA used data from BLS and the SUSB specific to the OES to estimate the number of workers and ONUs per site potentially exposed to TBBPA during industrial and commercial laboratory chemical use (U.S. Census Bureau, 2017; U.S. BLS, 2023a). This approach involved first identifying the relevant NAICS codes for the OES. The next step is the identification of relevant SOC codes within the BLS data for the identified NAICS codes. From there total number of workers can be determined. This number is divided by the number of sites identified to obtain the exposed workers per site. Appendix A includes further details regarding methodology for estimating the number of workers and ONUs per site. EPA assigned the following NAICS codes for this OES:

- 541380 – Testing Laboratories and Services; and
- 541714 – Research and Development in Biotechnology (except Nanobiotechnology).

Table 3-36 summarizes the per site estimates for this OES based on the methodology described. as discussed in Section 3.17.2 of the *Draft Release Assessment for 4,4'-(1-Methylethylidene)bis[2,6-dibromophenol] (TBBPA)* (U.S. EPA, 2026g), EPA did not identify site-specific data for the number of facilities in the United States for this OES.

Table 3-36. Estimated Average Number of Workers per Site Potentially Exposed to TBBPA During Industrial and Commercial Laboratory Chemical Use

Potential Number of Sites	NAICS Code	Potentially Exposed Workers per Site[a]	Potentially Exposed ONUs per Site[a]
Unknown	541380 – Testing Laboratories and Services;	3	7
	541714 – Research and Development in Biotechnology (except Nanobiotechnology)		

[a] Number of workers and ONUs per site are calculated by dividing the exposed number of workers or ONUs by the number of establishments.

3.11.3 Occupational Inhalation Exposure Results

For use of TBBPA as a laboratory chemical, EPA was provided with inhalation monitoring data from ACC. The ACC data includes nine occupational full-shift (8-hour TWA) personal air samples taken from three different sites for quality control and laboratory technicians that analyzed chemical samples containing TBBPA (Integral Consulting, 2025a).

From this monitoring data, EPA calculated the 50th percentile and 95th percentile 8-hour TWA concentrations from these nine data points to represent a central tendency and high-end estimate of potential occupational inhalation exposures, respectively, for this scenario. Using these 8-hour TWA exposure concentration, EPA calculated the IADC and ADC as described in Appendix B. In absence of data specific to ONU exposure, the Agency assumed that worker central tendency exposure was representative of ONU exposure and used this data to generate estimates for ONUs. The results of these calculations are shown in
Table 3-37 below.

Table 3-37. Summary of Worker Inhalation Exposure Metrics to TBBPA During Industrial and Commercial Laboratory Chemical Use

Exposure Concentration Type	Worker Inhalation Estimates (mg/m^3)		ONU Inhalation Estimates (mg/m^3)
	Central Tendency	High-End	
8-Hour TWA exposure concentration	6.50E−05	2.47E−03	6.50E−05
8-Hour TWA exposure concentration	6.50E−05	2.47E−03	6.50E−05
8-Hour TWA exposure concentration	6.50E−05	2.47E−03	6.50E−05
Intermediate average daily concentration (IADC) based on 8-hour TWA	3.4E−05	1.3E−03	3.4E−05
Average daily concentration (ADC) based on 8-hour TWA	3.0E−05	1.1E−03	3.0E−05

3.11.4 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES using the methodology outlined in Section 2.4. The various "Exposure Concentration Types" from Table 3-38 are explained in Appendix B. Table 3-38 summarizes the APDR, IADD, and ADD for chronic non-cancer for all applicable SEGs. For workers, dermal exposure is assessed to neat solid TBBPA. For ONUs, dermal exposure is assessed from contact with surfaces onto which the dusts have deposited were assessed. Dermal exposure to workers is generally expected to be greater than dermal exposure to ONUs. In absence of data specific to ONU exposure, EPA assumes that worker central tendency exposure to solids is representative of ONU exposure.

Table 3-38. Summary of Worker Dermal Exposure Metrics to TBBPA During Industrial and Commercial Laboratory Chemical Use

Worker Description	Exposure Concentration Type	Central Tendency	High-End
Average adult worker	Dose rate (APDR, mg/day)	3.7	7.5
	Intermediate (IADD, mg/kg-day)	3.6E−02	7.3E−02
	Chronic, non-cancer (ADD, mg/kg-day)	3.2E−02	6.4E−02
ONU	Dose rate (APDR, mg/day)	3.7	
	Intermediate (IADD, mg/kg-day)	3.6E−02	
	Chronic, non-cancer (ADD, mg/kg-day)	3.2E−02	

3.12 Disposal

As listed in Table 3-1, this OES includes the following COU: Disposal.

3.12.1 Worker Activities

Waste materials that contain TBBPA include the following two major categories of waste material:

1. Materials that are transferred off-site from manufacturing, processing and industrial use sites for disposal; and
2. Products containing TBBPA that are used commercially or by consumers and then disposed of.

At waste disposal sites, workers are potentially exposed via dermal contact with liquid or solid waste containing TBBPA or via inhalation of TBBPA vapor or dust generated during waste management activities. More information on specific types of waste management site is provided below (U.S. EPA, 2025a).

Municipal Waste Incineration

At municipal waste incineration facilities, there may be one or more technicians present on the tipping floor to oversee operations, direct trucks, inspect incoming waste, or perform other tasks as warranted by individual facility practices. These workers may wear PPE such as gloves, safety glasses, or dust masks. Specific worker protocols are largely up to individual companies, although state or local regulations may specify worker safety standards. Federal operator training requirements pertain more to the operation of the regulated combustion unit rather than operator health and safety (U.S. EPA, 2024, 2025b, c).

Workers are potentially exposed via inhalation of vapors and dust while working on the tipping floor. Potentially exposed workers include workers stationed on the tipping floor, including front-end loader operators, crane operators, and truck drivers. The potential for dermal exposures is minimized by using trucks and cranes to handle the wastes.

Hazardous Waste Incineration

EPA did not identify information on the potential for worker exposures during hazardous waste incineration or for any requirements for personal protective equipment. There is likely a greater potential for worker exposures for smaller scale incinerators that involve more direct handling of the wastes.

Municipal and Hazardous Waste Landfill

At landfills, typical worker activities include operating refuse vehicles to weigh and unload the waste materials, operating bulldozers to spread and compact wastes, and monitoring, inspecting, and surveying and landfill site (U.S. EPA, 2024, 2025b, c).[3]

See Section 3.18.1 of the *Draft Release Assessment for 4,4'-(1-Methylethylidene)bis[2,6-dibromophenol] (TBBPA)* (U.S. EPA, 2026g) for a full disposal process description.

3.12.2 Number of Workers and Occupational Non-Users

EPA used data from BLS and the SUSB specific to the OES to estimate the number of workers and ONUs per site potentially exposed to TBBPA during disposal (U.S. Census Bureau, 2017; U.S. BLS, 2023a). This approach involved first identifying the relevant NAICS codes for the OES. The next step is the identification of relevant SOC codes within the BLS data for the identified NAICS codes. From there total number of workers can be determined. This number is divided by the number of sites identified to obtain the exposed workers per site. Section 2.2 includes further details regarding methodology for estimating the number of workers and ONUs per site. EPA assigned the following NAICS codes for this OES:

- 562211 – Hazardous Waste Treatment and Disposal;
- 562212 – Solid Waste Landfill;
- 562213 – Solid Waste Combustors and Incinerators; and
- 562219 – Other Nonhazardous Waste Treatment and Disposal.

Table 3-39 summarizes the per site estimates for this OES based on the methodology described, including the potential number of sites identified in Section 3.18.2 of the *Draft Release Assessment for 4,4'-(1-Methylethylidene)bis[2,6-dibromophenol] (TBBPA)* (U.S. EPA, 2026g).

Table 3-39. Estimated Number of Workers Potentially Exposed to TBBPA During Disposal

Potential Number of Sites	NAICS Code	Potentially Exposed Workers per Site[a]	Potentially Exposed ONUs per Site[a]
11	562211 – Hazardous Waste Treatment and Disposal	3	8
	562212 – Solid Waste Landfill		
	562213 – Solid Waste Combustors and Incinerators		
	562219 – Other Nonhazardous Waste Treatment and Disposal		

[a] Number of workers and ONUs per site are calculated by dividing the exposed number of workers or ONUs by the number of establishments.

3.12.3 Occupational Inhalation Exposure Results

EPA did not identify inhalation monitoring data to assess exposures to TBBPA during disposal processes. Based on the presence of TBBPA as an additive in plastics, rubbers, and other solid articles (U.S. EPA, 2020), EPA expects the primary route of worker inhalation exposures to TBBPA to be from particulates generated during handling of these discarded solid materials. Therefore, EPA estimated worker inhalation exposures during disposal using the PNOR Model (U.S. EPA, 2021b), which includes

[3] https://calrecycle.ca.gov/swfacilities/ (accessed March 5, 2026)

8-hour full-shift worker total dust PBZ concentrations. These data were derived from the data of OSHA's CEHD (OSHA, 2020) that are total dust worker monitoring data that OSHA collected in association with OSHA's PEL for PNOR. To derive the model's data, EPA estimated an 8-hour TWA concentration for total particulate by assuming exposures outside the sample duration are zero. OSHA's CEHD data do not include information about worker activities and therefore the model does not determine exposures during individual worker activities. Model approaches and parameters are further described in Appendix D.

EPA assessed this OES based on the subset of the PNOR Model (U.S. EPA, 2021b) data that are specific to facilities with the NAICS code starting with 56 – Administrative and Support and Waste Management and Remediation Services. This subset of the PNOR Model (U.S. EPA, 2021b) data comprises data for facilities with the NAICS codes given in Table 3-40. This dataset comprises 130 8-hour full-shift worker total dust PBZ concentration values. The range, mean and median values of these data are 0.016 to 1,203 mg/m^3, 53 mg/m^3, and 2.5 mg/m^3, respectively (U.S. EPA, 2021b). The central tendency and high-end values of this dataset are assessed as the 50th percentile value of the dataset, or 2.5 mg/m^3 and OSHA's PEL for total dust PNOR, or 15 mg/m^3, respectively (U.S. EPA, 2021b). EPA multiplied these assessed total dust air concentrations by the greatest concentration of TBBPA in products containing TBBPA that are used commercially or by consumers, which is equal to 22% by mass (ECB, 2006), to estimate the concentration of total TBBPA present in particulates. This approach involves the following assumptions:

1. Dust is generated at disposal facilities as the result of the disposal of a single type of products which contain TBBPA at the maximum concentration of TBBPA in products used commercially and by consumers, which is 22 wt%; and
2. The dust results from the degradation of the products containing TBBPA into particulate solids that become airborne. This occurs continuously throughout the work shift.

Table 3-40. NAICS Sector 56 Facility Codes in EPA's Generic Model for Central Tendency and High-End Inhalation Exposure to Total and Respirable PNOR (U.S. EPA, 2021b)

NAICS	NAICS Description
562111	Solid Waste Collection
562112	Hazardous Waste Collection
562211	Hazardous Waste Treatment and Disposal
561910	Packaging and Labeling Services
561431	Private Mail Centers
561730	Landscaping Services
562910	Remediation Services
562920	Materials Recovery Facilities
561790	Other Services to Buildings and Dwellings
561499	All Other Business Support Services
561320	Temporary Help Services
561990	All Other Support Services
562219	Other Nonhazardous Waste Treatment and Disposal
562998	All Other Miscellaneous Waste Management Services

561612	Security Guards and Patrol Services
562212	Solid Waste Landfill

Using the 50th and 95th percentile total particulate exposures from the model and maximum TBBPA concentration, EPA estimated the central tendency and high-end 8-hour TWA TBBPA exposure estimates. EPA then calculated the IADC and ADC as described in Appendix B. In absence of data specific to ONU exposure, the Agency assumed that worker central tendency exposure was representative of ONU exposure and used this data to generate estimates for ONUs. The results of these calculations are summarized in Table 3-41.

Table 3-41. Summary of Worker Inhalation Exposure Metrics to TBBPA During Disposal

Exposure Concentration Type	Worker Inhalation Estimates (mg/m^3)		ONU Inhalation Estimates (mg/m^3)
	Central Tendency	High-End	
8-Hour TWA exposure concentration	0.55	3.3	0.55
Intermediate average daily concentration (IADC) based on 8-hour TWA	0.29	1.7	0.29
Average daily concentration (ADC) based on 8-hour TWA	0.26	1.5	0.26

3.12.4 Occupational Dermal Exposure Results

EPA estimated dermal exposures for this OES using the methodology outlined in Section 2.4. The various “Exposure Concentration Types” from Table 3-42 are explained in Appendix B. Table 3-42 summarizes the APDR, IADD, and ADD for chronic non-cancer for all applicable SEGs. For workers, dermal exposure is assessed to solids containing TBBPA. For ONUs, dermal exposure is assessed from contact with surfaces onto which the dusts have deposited were assessed. Dermal exposure to workers is generally expected to be greater than dermal exposure to ONUs. In absence of data specific to ONU exposure, EPA assumes that worker central tendency exposure to solids is representative of ONU exposure.

Table 3-42. Summary of Worker Dermal Exposure Metrics to TBBPA During Disposal

Worker Description	Exposure Concentration Type	Central Tendency	High-End
Average adult worker	Dose rate (APDR, mg/day)	3.7	7.5
	Intermediate (IADD, mg/kg-day)	3.6E−02	7.3E−02
	Chronic, non-cancer (ADD, mg/kg-day)	3.2E−02	6.4E−02
ONU	Dose rate (APDR, mg/day)	3.7	
	Intermediate (IADD, mg/kg-day)	3.6E−02	
	Chronic, non-cancer (ADD, mg/kg-day)	3.2E−02	

4 WEIGHT OF SCIENTIFIC EVIDENCE CONCLUSIONS FOR OCCUPATIONAL EXPOSURE ASSESSMENT

For each OES, EPA considered the assessment approach, the quality of the data and models, and the strengths, limitations, assumptions, and key sources of uncertainties in the assessment results to determine the weight of scientific evidence rating. For each OES, EPA considered the assessment approach, the quality of the data and models, and the strengths, limitations, assumptions, and key sources of uncertainties in the assessment results to determine the weight of scientific evidence rating. EPA also considered factors that increase or decrease the strength of the evidence supporting the estimate (*e.g.,* quality of the data/information), the applicability of the data to the OES (*e.g.,* temporal relevance, locational relevance) and the representativeness of the estimate for the whole industry. The Agency used the descriptors of robust, moderate, slight, or indeterminant to categorize the available scientific evidence using its best professional judgment, according to the 2021 Draft Systematic Review Protocol (U.S. EPA, 2021a). For example, EPA used moderate to categorize measured release data from a limited number of sources such that there is a limited number of data points that may not cover most or all the sites within the OES. EPA used slight to describe limited information that does not sufficiently cover all sites within the OES, and for which the assumptions and uncertainties are not fully known or documented. See the 2021 Draft Systematic Review Protocol (U.S. EPA, 2021a) for additional information on weight of scientific evidence conclusions.

The weight of scientific evidence ratings for the occupational exposure estimates for each OES, including details on the basis EPA used to determine the rating, are provided in the sections and tables that follow.

EPA estimated occupational exposure using several sources of air monitoring data, however the primary source for this assessment was an inhalation exposure monitoring study submitted to EPA by the ACC TBBPA Consortium in response to a test order (Integral Consulting, 2025a). These data were determined to have an overall data quality rating of high through EPA's systematic review process. Other sources of worker exposure data included studies provided by industry or identified during systematic review; these sources had data quality ratings of medium to high. Further information on these sources is provided later in this section.

Number of Workers

There are several uncertainties surrounding the estimated number of workers potentially exposed to TBBPA, as outlined below. Most are unlikely to result in a systematic underestimate or overestimate but could lead to some inaccuracies in the final estimates.

There are uncertainties with BLS data, which are used to estimate the number of workers for all conditions of use. First, BLS' Occupational Employment Statistics employment data for each industry/occupation combination are only available at the 3-, 4-, or 5-digit NAICS level, rather than the full 6-digit NAICS level. This lack of granularity could result in an overestimate of the number of exposed workers if some 6-digit NAICS are included in the less granular BLS estimates but are not likely to use TBBPA for the assessed applications. EPA addressed this issue by refining the OES estimates using total employment data from the U.S. Census' SUSB. However, this approach assumes that the distribution of occupation types (SOC codes) in each 6-digit NAICS is equal to the distribution of occupation types at the parent 5-digit NAICS level. If the distribution of workers in occupations with TBBPA exposure differs from the overall distribution of workers in each NAICS, then this approach will result in inaccuracy.

Second, EPA's judgments about which industries (represented by NAICS codes) and occupations (represented by SOC codes) are associated with the uses assessed in this report are based on the Agency's understanding of how TBBPA is used in each industry. Designations of which industries and occupations have potential exposures is nevertheless subjective, and some industries/occupations with few exposures might erroneously be included, or some industries/occupations with exposures might erroneously be excluded. This would result in inaccuracy but would be unlikely to systematically either overestimate or underestimate the number of exposed workers.

Analysis of Exposure Monitoring Data

For several of the OESs, TBBPA test order monitoring data were used to estimate inhalation exposures. The primary strength of these data are the use of personal and directly applicable data, and the number of samples available for workers and ONUs. The primary limitation is that when the test order data did not provide sufficient information on exposure frequency, EPA assumed 250 exposure days per year based on typical worker schedules. It is uncertain whether this captures actual worker schedules and exposures. In some cases, there is also uncertainty in the representativeness of the data. Where few data are available, the assessed exposure levels may not be representative of worker exposure across the entire job category or industry. Differences in work practices and engineering controls across sites can introduce variability and limit the representativeness of monitoring data.

For the Industrial and Commercial Laboratory Chemical Use OES, a subset of TBBPA test order monitoring data were used as surrogate. Any monitoring data from the SEG, Laboratory technician was assessed. This is likely to be applicable to most laboratory workers, however a limitation is that this may overestimate or underestimate inhalation exposures from other non-industry laboratory settings, such as university or medical research labs.

Apart from the test order data, which is broken out by SEG, EPA typically categorized each inhalation exposure data point as either worker or ONU. The categorizations are based on descriptions of worker job activity as provided in literature and EPA's judgment. In general, samples for employees that are expected to have the highest exposure from direct handling of TBBPA are categorized as workers and samples for employees that are expected to have the lower exposure and do not directly handle TBBPA are categorized as ONU.

Table 4-1 summarizes EPA's overall confidence in the inhalation exposure estimates for each OES.

With regard to the assessment of dermal exposure, estimates are based on an *in vitro* dermal absorption study specific to TBBPA (Charles River Laboratories, 2024). The study provides dermal absorption data for a wide range of chemical doses and multiple vehicles relevant to OESs of TBBPA. EPA chose the maximal flux value obtained among the various *in vitro* dermal absorption experiments to demonstrate the potential of dermal exposure at the upper bound. Because the highest measured flux value was used to estimate upper-bound dermal exposures for both workers and ONUs, it is likely that the reported dermal exposure values overestimate occupational dermal exposures. Consequently, EPA has moderate confidence that the results of the occupational dermal exposure assessment represent an upper bound of exposure.

Table 4-1. Summary of Assumptions, Uncertainty, and Overall Confidence in Occupational Inhalation Exposure Estimates by OES

OES	Weight of Scientific Evidence Conclusion in Occupational Inhalation Exposure Estimates
Manufacturing	EPA assessed inhalation exposure concentrations based on surrogate data that are total dust personal worker monitoring data. These data were collected by monitoring TBBPA manufacturing workers during the manufacture of TBBPA at Albemarle Corporation's Magnolia, AR site between July 2003–November 2021 and were collected as surrogate TBBPA inhalation exposure surrogate data because a TBBPA sampling and analysis method was lacking. Refer to Section 3.2.3 for a description of the assessment method. The strength of the assessment is that the assessment of worker exposure is based on total dust full-shift PBZ worker monitoring data that are of high quality as surrogate monitoring data. These data are of high-quality as surrogate data because of the following: a) TBBPA is primarily found in workplace air in the particle-associated phase according to the scientific literature (Integral Consulting, 2025b). b) The data were collected during the manufacture of TBBPA at a TBBPA manufacturing facility in the United States. This facility was located separately from other facilities at the same site that were used in the production of other powders (Integral Consulting, 2025b). Also, there is a single TBBPA manufacturing facility in the United States according to the 2023 TRI. c) Measurements were less than the limits of detection (<0.01 mg/m^3 and <0.32 mg/m^3) in the PBZ samples of two workers who worked in areas of the TBBPA production facility that did not contain TBBPA (these areas and all other areas of the TBBPA production facility are contiguous) (Integral Consulting, 2025b). Because no dust was detected for workers in areas that do not contain TBBPA, the dust detected in the case of workers in areas that contain TBBPA is likely predominantly TBBPA. Another strength is that the job titles of the monitored workers are reported and include various job titles. The limitation of the data are that the data are total dust data and not TBBPA-specific data. Therefore, the exposure concentrations possibly result in an overestimate of TBBPA exposure. The uncertainties of the assessment result from the following factors: a) The total number of samples is only 10. b) Worker tasks are not reported. c) The monitoring data does not include ONU information. Based on these strengths, limitations and uncertainties, EPA has concluded that the weight of scientific evidence for this assessment is moderate.

OES	Weight of Scientific Evidence Conclusion in Occupational Inhalation Exposure Estimates
Repackaging	This scenario involves the transloading of TBBPA powder from imported super sacks to trucks. EPA assessed inhalation exposure concentrations based on surrogate data that are TBBPA full-shift TWA and task-based PBZ worker monitoring data. These data were collected by monitoring workers at the two identified TBBPA processing sites during repackaging of supersacks into smaller sacks or transferring the contents of super sacks into a reactor. The Agency assessed two scenarios: robust engineering controls (Scenario 1) and less robust engineering controls (Scenario 2). Refer to Section 3.3.3 for a description of the assessment method. The strengths of the assessment are as follows: 1. The data source has a high data quality rating from the systematic review process. 2. The surrogate data are TBBPA PBZ worker monitoring data that are associated with worker activities that are similar to the worker activities of the OES. The worker activities of the surrogate data involve the emptying of super sacks of TBBPA powder into other containers, which are small bags in the case of Scenario 1 and a process vessel in the case of Scenario 2. Similarly, the worker activity of the OES is emptying super sacks into a truck. 3. For Scenario 1, the surrogate data are full-shift PBZ worker monitoring data. 4. For Scenario 2, the surrogate data are task-length PBZ worker monitoring data, and the sampling duration of each sample is equal to the duration of emptying a single super sack. EPA combined these task-length PBZ worker monitoring concentrations to estimate full-shift PBZ exposure concentrations. In general, the estimation of full-shift exposure from task-length exposure monitoring data accords with standard industrial hygiene practice. In the case of the assessment of this OES specifically and as explained in Section 3.3.3, EPA combined the task-length concentrations based on information about the truck filling operation that occurred at Albemarle's AR site which is that a single truck is filled during a period of 4–5 hours, and the worker shift is 12 hours. EPA assumed two trucks are filled per shift at Albemarle's toll repackaging site. The limitations of the assessment are as follows: 1. The engineering controls of Scenarios 1 and 2 are not engineering controls for transferring material to a truck. In the case of Scenario 1 (robust engineering controls), the controls are engineering controls for repackaging super sacks into smaller sacks and in the case of Scenario 2 less robust engineering controls) the controls are for transferring material to a process vessel. 2. The surrogate full-shift PBZ 8-hour TWA exposure concentration in the case of Scenario1 are associated with not only emptying a super sack but also other worker activities. The duration of emptying a supersack did not exceed 40% of the sampling duration of the full-shift samples. The uncertainties of the assessment are as follows: a) EPA is uncertain about the number of trucks that are filled per day. By assuming that 2 trucks are filled per day, EPA likely assessed a high-end scenario because the filling of 2 trucks of the size that were filled at Albemarle's Magnolia, AR site is likely the maximum truck filling rate in a 12-hour shift given that the time to fill a single truck is 4–5 hours and workers will take work breaks during the shift. b) There is great variability in the task-length worker monitoring data of Scenario 2. Excluding a concentration value of 2.6 mg/m^3 with a sampling duration of 25 minutes, the range of this data are 4.2–48 mg/m^3 and the corresponding range of sample duration is 15–17 minutes. EPA estimated a full-shift exposure concentration from all of this data which results in uncertainty in the high-end assessed result. The assessed high-end 8-hour full-shift concentration is high compared to values reported in the literature. Based on these strengths and limitations, EPA has concluded that the weight of scientific evidence for this assessment is moderate in the case of the assessed central tendency exposures and slight in the assessed high-end exposures.

OES	Weight of Scientific Evidence Conclusion in Occupational Inhalation Exposure Estimates
ACC TBBPA Consortium's Group 1: Production of Formulations (Particulate Solids) from TBBPA Powder	For this OES, EPA used the worker and ONU inhalation monitoring data that the ACC TBBPA Consortium provided for their Group 1 processes. The strengths of the assessment are as follows: 1. The data source has a high data quality rating from the systematic review process. 2. The data that EPA used are TBBPA full-shift TWA PBZ worker and ONU inhalation monitoring data. 3. The ACC TBBPA Consortium monitored workers at 2 of the consortium's 3 sites that the consortium associated with Group 1 processes. 4. 6 workers and 2 ONUs were monitored, and these were associated with 3 SEGs, including a SEG of ONUs. The uncertainties of the assessment result from the following factors: 1. The ACC TBBPA Consortium conducted worker and ONU monitoring at the sites at which they expected worst-case exposure to occur. 2. Few of the monitored workers did non-routine tasks (*i.e.,* activities done weekly, monthly or annually). 3. EPA assumed that workers work 40-hour weeks on average and 2,000 hours per year, which is equivalent to 8-hour shifts and 250 days per year) irrespective of shift duration. This assumption may result in uncertainty, especially in the case of assessing intermediate risk because a worker conceivably may work more than 40 hours per week for a short period of time if the shift duration is greater than 8 hours. Based on these strengths and limitations, EPA has concluded that the weight of scientific evidence for this assessment is robust.
ACC TBBPA Consortium's Group 2: Production of Intermediate Products (Liquid, Semi-Solid and Powder) from TBBPA Powder	For this OES, EPA used the worker and ONU inhalation monitoring data that the ACC TBBPA Consortium provided for their Group 2 processes. This consortium collected this data in response to EPA's test order. The strengths of the assessment are as follows: 1. The data source has a high data quality rating from the systematic review process. 2. The data that EPA used are TBBPA full-shift TWA PBZ worker and ONU inhalation monitoring data. 3. The ACC TBBPA Consortium monitored workers at 3 of the consortium's 10 sites that the consortium associated with Group 2 processes. 4. 22 workers and 16 ONUs were monitored and these were associated with 3 SEGs, including a SEG of ONUs. The uncertainties of the assessment result from the following factors: 1. The ACC TBBPA Consortium conducted worker and ONU monitoring at the sites at which they expected worst-case exposure to occur. 2. Few of the monitored workers did non-routine tasks (*i.e.,* activities done weekly, monthly or annually). 3. EPA assumed that workers work 40-hour weeks on average and 2,000 hours per year, which is equivalent to 8-hour shifts and 250 days per year) irrespective of shift duration. This assumption may result in uncertainty, especially in the case of assessing intermediate risk because a worker conceivably may work more than 40 hours per week for a short period of time if the shift duration is greater than 8 hours. Based on these strengths and limitations, EPA has concluded that the weight of scientific evidence for this assessment is robust.

<table>
<tr><th>OES</th><th>Weight of Scientific Evidence Conclusion in Occupational Inhalation Exposure Estimates</th></tr>
<tr><td>ACC TBBPA Consortium’s Group 3: Production of Intermediate Solid Products (Sheet, Film, and Pellet) from the Products of Group 2</td><td>For this OES, EPA used the worker and ONU inhalation monitoring data that the ACC TBBPA Consortium provided for their Group 3 processes. This consortium collected this data in response to EPA’s test order.

The strengths of the assessment are as follows:
1. The data source has a high data quality rating from the systematic review process.
2. The data that EPA used are TBBPA full-shift TWA PBZ worker and ONU inhalation monitoring data.
3. To collect the data that EPA used, the ACC TBBPA Consortium monitored workers at 2 of the consortium’s 8 sites that the consortium associated with Group 3 processes.
4. 21 workers and 8 ONUs were monitored and these were associated with 6 SEGs, including an SEG of ONUs.
The uncertainties of the assessment result from the following factors:
1. The ACC TBBPA Consortium conducted worker and ONU monitoring at the sites at which they expected worst-case exposure to occur.
2. Few of the monitored workers did non-routine tasks (i.e., activities done weekly, monthly or annually).
3. EPA assumed that workers work 40-hour weeks on average and 2,000 hours per year, which is equivalent to 8-hour shifts and 250 days per year) irrespective of shift duration. This assumption may result in uncertainty, especially in the case of assessing intermediate risk because a worker conceivably may work more than 40 hours per week for a short period of time if the shift duration is greater than 8 hours.
Based on these strengths and limitations, EPA has concluded that the weight of scientific evidence for this assessment is robust.</td></tr>
<tr><td>ACC TBBPA Consortium’s Group 4: Production of Composite Parts from Prepreg and Adhesive Film</td><td>For this OES, EPA used the worker and ONU inhalation monitoring data that the ACC TBBPA Consortium provided for their Group 4 processes. This consortium collected this data in response to EPA’s test order.

The strengths of the assessment are as follows:
1. The data source has a high data quality rating from the systematic review process.
2. The data that EPA used are TBBPA full-shift TWA PBZ worker and ONU inhalation monitoring data.
3. To collect the data that EPA used, the ACC TBBPA Consortium monitored workers at 2 of the consortium’s 10 sites that the consortium associated with Group 4 processes
4. 22 workers and 9 ONUs were monitored and these were associated with 4 SEGs, including a SEG of ONUs.
The uncertainties of the assessment result from the following factors:
1. The ACC TBBPA Consortium conducted worker and ONU monitoring at the sites at which they expected worst-case exposure to occur.
2. Few of the monitored workers did non-routine tasks (i.e., activities done weekly, monthly or annually).
3. EPA assumed that workers work 40-hour weeks on average and 2,000 hours per year, which is equivalent to 8-hour shifts and 250 days per year) irrespective of shift duration. This assumption may result in uncertainty, especially in the case of assessing intermediate risk because a worker conceivably may work more than 40 hours per week for a short period of time if the shift duration is greater than 8 hours.
Based on these strengths and limitations, EPA has concluded that the weight of scientific evidence for this assessment is robust.</td></tr>
</table>

OES	Weight of Scientific Evidence Conclusion in Occupational Inhalation Exposure Estimates
Recycling	For this OES, EPA identified 860 sites. EPA used PBZ air concentration data pulled from three sources to assess inhalation exposures. EPA considered the assessment approach, the quality of the data, and the uncertainties in the assessment results to determine the weight of scientific evidence conclusion for the 8-hour TWA inhalation exposure estimates. The primary strength of this approach is the use of directly applicable monitoring data, which is preferrable to other potential assessment approaches such as modeling or the use of OELs. EPA used 3 different studies (Rosenberg et al., 2011; Beaucham et al., 2018; Grimes et al., 2019) and all received ratings of high from EPA's systematic review process. These studies contained five distributions created from 46 full-shift personal breathing zone samples from workers at three facilities. The primary limitations of these data include uncertainty in the representativeness of the monitoring data in capturing the true distribution of inhalation concentrations for this OES. Additionally, the monitoring dataset did not contain ONU information, so the central tendency of worker values was used, which is EPA's standard approach. Finally, EPA assumed 8 exposure hours per day and 250 exposure days per year based on continuous TBBPA exposure during each working day for a typical worker schedule. It is uncertain whether this assumption captures actual worker schedules and exposures. Based on these strengths and limitations, EPA has concluded that the weight of scientific evidence for this assessment is moderate.
Industrial and Commercial Additive Use in Electrical and Electronic Articles	For this OES, EPA did not identify site-specific data for the number of facilities in the United States for this OES. EPA used the PNOR Model (U.S. EPA, 2021b) to assess inhalation exposures. EPA considered the assessment approach, the quality of the data, and the uncertainties in the assessment results to determine the weight of scientific evidence conclusion for the inhalation exposure estimates. The strength of the model is that the respirable PNOR range was refined using the Computer and Electronic Product Manufacturing NAICS code (NAICS 334) and the resulting dataset contains 32 discrete sample data points. EPA estimated the highest expected concentration of TBBPA based on an identified product SDS (Panduit Corporation, 2017). The SDS has a medium data quality rating from the systematic review process. The primary limitations of these data include uncertainty in the representativeness of the PNOR Model in capturing the true distribution of inhalation concentrations for this OES. The PNOR model uses an OSHA CEHD dataset of PNOR measurements that is not specific to TBBPA or sites confirmed to process TBBPA-containing materials. Additionally, the model assumes the percentage of TBBPA in the dust matches the mass concentration in the bulk electronic material (20%). This assumes that all workplace dust originates from the TBBPA-related activities, whereas dust may also arise from other processes and materials used at the facilities. Considering these uncertainties and that the maximum mass concentration identified from electronics products containing TBBPA is used, the estimates are likely to overestimate exposures. Additionally, the monitoring dataset did not contain ONU information, so the central tendency of worker values was used. Finally, EPA assumed 8 exposure hours per day and 250 exposure days per year based on continuous TBBPA exposure during each working day for a typical worker schedule. It is uncertain whether this assumption captures actual worker schedules and exposures. Based on these strengths and limitations, EPA has concluded that the weight of scientific evidence for this assessment is moderate.

OES	Weight of Scientific Evidence Conclusion in Occupational Inhalation Exposure Estimates
Industrial and Commercial Use in Building and Construction Materials	For this OES, EPA identified a single site based on TRI data. EPA used EPA's PNOR Model (U.S. EPA, 2021b) data for NAICS sector 23 (construction of buildings; heavy and civil engineering construction; specialty trade contractors) to assess inhalation exposures. EPA considered the assessment approach, the quality of the data, and the uncertainties in the assessment results to determine the weight of scientific evidence conclusion for the inhalation exposure estimates. The strength of the assessment is that the EPA PNOR model data are total PNOR 8-hour TWA PBZ worker inhalation exposure concentration data for workers associated with NAICS code 23. Another strength is that EPA estimated the concentration of TBBPA in products to be equal to the concentration of TBBPA in ABS which is used in pipes and fittings used in construction (ECB, 2006). This source has a high data quality rating from the systematic review process. The limitations of the assessment are that the PNOR Model data are surrogate data and the mass fraction of TBBPA in ABS is the maximum fraction of TBBPA in a product that is possibly used in construction. The assessment includes uncertainty about whether the PNOR Model data are applicable to worker exposure as a result of using products that contain TBBPA. Additionally, the monitoring dataset did not contain ONU information, so the central tendency of worker values was used. Finally, EPA assumed 8 exposure hours per day and 250 exposure days per year based on continuous TBBPA exposure during each working day for a typical worker schedule. It is uncertain whether this assumption captures actual worker schedules and exposures. Based on these strengths and limitations, EPA has concluded that the weight of scientific evidence for this assessment is slight to moderate.
Use of Powder Coatings in Electronics	For this OES, EPA did not identify site-specific data for the number of facilities in the United States for this OES. EPA used the PNOR Model (U.S. EPA, 2021b) to assess inhalation exposures. EPA considered the assessment approach, the quality of the data, and the uncertainties in the assessment results to determine the weight of scientific evidence conclusion for the inhalation exposure estimates. A strength of the model is that the respirable PNOR range was refined using three NAICS codes: Computer and Electronic Product Manufacturing (NAICS 334), Electrical Equipment, Appliance, and Component Manufacturing (NAICS 335), and Transportation Equipment Manufacturing (NAICS 336). The resulting dataset contains 301 discrete sample data points. EPA estimated the highest expected concentration of TBBPA based on a documented epoxy powder product for the electronics industry (Earthjustice, 2019). The SDS has a high data quality rating from the systematic review process. The primary limitations of these data include uncertainty in the representativeness of the PNOR Model in capturing the true distribution of inhalation concentrations for this OES. Further, the OSHA CEHD dataset used in the PNOR Model is not specific to TBBPA. Additionally, the monitoring dataset did not contain ONU information, so the central tendency of worker values was used. Finally, EPA assumed 8 exposure hours per day and 250 exposure days per year based on continuous TBBPA exposure during each working day for a typical worker schedule. It is uncertain whether this assumption captures actual worker schedules and exposures. Based on these strengths and limitations, EPA has concluded that the weight of scientific evidence for this assessment is moderate.

OES	Weight of Scientific Evidence Conclusion in Occupational Inhalation Exposure Estimates
Industrial Use in Plastic and Rubber Products	For this OES, EPA did not identify site-specific data for the number of facilities in the United States for this OES, or relevant inhalation monitoring data. Due to expected similarities in process descriptions, the Agency used surrogate monitoring data from ACC TBBPA Consortium's Group 4: Production of Composite parts from prepreg and adhesive film. EPA considered the assessment approach, the quality of the data, and uncertainties in assessment results to determine the weight of scientific evidence conclusion for the 8-hour TWA inhalation exposure estimates. The primary strengths of these data are the use of PBZ data, the similarity in worker activities between the surrogate data and this OES, and the number of samples available for workers and ONUs. EPA identified 22 worker and 9 ONU full-shift PBZ samples from two industrial use facilities from this dataset to estimate inhalation exposures. The data source has a high data quality rating from the systematic review process. The primary limitation of the data are that these two sites may not be representative of all sites. Also, EPA assumed 250 exposure days per year based on TBBPA exposure each working day for a typical worker schedule; it is uncertain whether this captures actual worker schedules and exposures. Based on these strengths and limitations, EPA has concluded that the weight of scientific evidence for this assessment is moderate to robust.
Commercial Use in Plastic and Rubber Products	For this OES, workers are not expected to manipulate the solid articles containing TBBPA in such a way as to generate dust. Thus, worker exposures are limited to any TBBPA that may volatilize from the article or be present on the article surfaces. EPA identified one relevant source for this OES during data extraction and evaluation. These data include a total of 12 8-hour TWA area samples. Based on this data, EPA decided to not quantitatively assess worker exposures for commercial use of plastic and rubber products containing TBBPA, as the low concentrations provided by these samples are not expected to generate considerable exposure and risk to workers. Based on this information, EPA has concluded that the weight of scientific evidence for this assessment is moderate.
Industrial and Commercial Laboratory Chemical Use	For this OES, EPA did not identify site-specific data for the number of facilities in the United States for this OES. EPA had inhalation data provided via a test order submission from the ACC, which included processors and users of TBBPA. Inhalation data from the SEG "Laboratory technicians" were used in this assessment. EPA considered the assessment approach, the quality of the data, and uncertainties in assessment results to determine the weight of scientific evidence conclusion for the 8-hour TWA inhalation exposure estimates. The primary strength of these data are that they are PBZ and capture many tasks that are expected to occur in a commercial laboratory setting. There were 4 data points for laboratory technicians in Group 2, and 5 data points for laboratory technicians in Group 3. This amounts to a total of 9 data points from 3 sites in the ACC test order data used for this OES. The data source has a high data quality rating from the systematic review process. The primary limitations include: (1) the data are for laboratory technicians in a manufacturing/processing setting, rather than a commercial setting, and so the representativeness of the dataset for workers in a commercial setting is uncertain; and (2) the lack of data for ONUs. Additionally, EPA assumed 250 exposure days per year based on TBBPA exposure each working day for a typical worker schedule; it is uncertain whether this captures actual worker schedules and exposures. Based on these strengths and limitations, EPA has concluded that the weight of scientific evidence for this assessment is moderate-to-robust.

OES	Weight of Scientific Evidence Conclusion in Occupational Inhalation Exposure Estimates
Disposal	For this OES, EPA identified 11 sites for this OES based on TRI data. EPA used EPA's PNOR Model (U.S. EPA, 2021b) data for NAICS sector 56 (Administrative and Support and Waste Management and Remediation Services) to assess inhalation exposures. EPA considered the assessment approach, the quality of the data, and the uncertainties in the assessment results to determine the weight of scientific evidence conclusion for the inhalation exposure estimates. A strength of the assessment is that the assessed TBBPA inhalation exposure concentrations are based on the subset of EPA's PNOR model data that consisting of total dust 8-hour TWA PBZ worker inhalation exposure concentration measurements for workers at facilities associated with various NAICS codes encompassed by NAICS code 56 as presented in Section 3.12.3. These are measurements for a broadly specified group of NAICS codes and are therefore very likely to encompass values that equal total dust concentrations at facilities at which TBBPA containing wastes are disposed of. The limitations of the assessment are as follows: 1. The data of EPA's PNOR Model (U.S. EPA, 2021b) are surrogate data because these data are based on concentrations of total dust measurements made by OSHA in connection with OSHA's PEL for PNOR. 2. The assessed TBBPA 8-hour TBBPA TWA concentrations were calculated by multiplying the relevant central tendency and high-end total dust concentrations of EPA's PNOR Model (U.S. EPA, 2021b) with the greatest mass fraction of TBBPA in products containing TBBPA that are used commercially or by consumers. That is, EPA assumed dust is generated at disposal facilities as the result of the disposal of a single type of products which are those that contain TBBPA. But the dust that workers are exposed to results from the disposal of waste that contains a variety of products and not just products that contain TBBPA. 3. The assessed exposures are not applicable in the case of disposal of waste material that are generated in industrial facilities such as neat TBBPA because such wastes are contained in containers such as filter bags and EPA does not expect the disposal of such containers to result in occupational inhalation exposure to TBBPA. 4. The assessed exposures are not applicable in the case of the disposal of articles that are made using TBBPA reactively because EPA does not expect the disposal of such articles to result in worker inhalation exposure because the concentration of TBBPA in such articles is either nil or very low. The uncertainties of the assessment are as follows: 1. There is uncertainty about the accuracy of the assessed TBBPA 8-hour TWA concentrations. 2. The monitoring dataset does not contain information about worker activities, and therefore there is uncertainty about whether the data are applicable for ONUs; accordingly, the central tendency of the dataset was used to assess ONU exposure. 3. EPA assumed 8 exposure hours per day and 250 exposure days per year based on continuous TBBPA exposure during each working day for a typical worker schedule. It is uncertain whether this assumption captures actual worker schedules and exposures. Based on these strengths and limitations, EPA has concluded that the weight of scientific evidence for this assessment is slight but the Agency has high confidence that the assessment results overestimate actual exposures, especially in the case of the high-end estimate.
NAICS = North American Industry Classification System; OES = occupational exposure scenario; OEL = occupational exposure limit; ONU = occupational non-user; OSHA = Occupational Safety and Health Administration; PBZ = personal breathing zone; PEL = permissible exposure limit; PNOR = Particulates Not Otherwise Regulated; SEG = similar exposure group	

5 OCCUPATIONAL EXPOSURE ASSESSMENT CONCLUSIONS

EPA considered all reasonably available information identified through its systematic review process under TSCA (U.S. EPA, 2026j) to characterize the occupational exposure of TBBPA. TBBPA has a total PV in the United States between 10 and 50 million lb of TBBPA from the 2024 CDR reporting period. It is primarily used as a flame retardant in various plastics material and resin manufacturing. Secondary uses include incorporation into formulations such as adhesives and incorporation into articles such as building and construction materials and electronics.

EPA evaluated occupational exposures for each OES, which are developed based on a set of occupational activities and conditions such that similar occupational exposures are expected from the use(s) covered under each OES. The Agency provided occupational exposure results for each OES, which are expected to be representative of the population of workers and sites for the given OES in the United States. EPA used inhalation monitoring data, including directly applicable data obtained through test orders or literature, to evaluate intermediate and chronic exposures to workers and ONUs for 8 of the 14 OESs. EPA used surrogate data from the test order for one OES and the PNOR Model for four OESs where no monitoring data were found. One OES was assessed qualitatively. Inhalation exposures to TBBPA are highest during manufacturing and repackaging.

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APPENDICES

Appendix A ESTIMATING NUMBER OF WORKERS AND OCCUPATIONAL NON-USERS

This appendix summarizes the methods that EPA used to estimate the number of workers who are potentially exposed to TBBPA in each OES evaluated under TSCA. The method consists of the following steps:

1. Identify the (NAICS codes for the industry sectors associated with each COU.
2. Estimate total employment by industry/occupation combination using the BLS Occupational Employment Statistics data (U.S. BLS, 2023a).
3. Refine the Occupational Employment Statistics estimates where they are not sufficiently granular by using the SUSB data on total employment by 6-digit NAICS (U.S. Census Bureau, 2017).
4. Estimate the percentage of employees likely to be using TBBPA instead of other chemicals (*i.e.,* the market penetration of TBBPA in the OES).
5. Estimate the number of sites and number of potentially exposed employees per site.
6. Estimate the number of potentially exposed employees within the OES.

Step 1: Identifying Affected NAICS Codes
As a first step, EPA identified NAICS industry codes associated with each OES. EPA generally identified NAICS industry codes for an OES by:

- Querying the U.S. Census Bureau's NAICS Search tool (U.S. Census Bureau, 2022) using keywords associated with each COU to identify NAICS codes with descriptions that match the COU.
- Referencing EPA GSs and OECD ESDs for a COU to identify NAICS codes cited by the GS or ESD.
- Reviewing CDR data for the chemical, identifying the industrial sector codes reported for downstream industrial uses, and matching those industrial sector codes to NAICS codes using Table D-2 provided in the CDR reporting instructions (U.S. EPA, 2016).

Each OES section in the main body of this draft assessment/TSD identifies the NAICS codes EPA identified for the respective OES.

Step 2: Estimating Total Employment by Industry and Occupation
BLS's Occupational Employment Statistics data provide employment data for workers in specific industries and occupations (U.S. BLS, 2023a). The industries are classified by NAICS codes that were previously identified, and occupations are classified by SOC codes (U.S. BLS, 2018).

Among the relevant NAICS codes (identified previously), EPA reviewed the occupation description and identified those occupations (SOC codes) where workers are potentially exposed to TBBPA. Table_Apx A-1 shows the SOC codes by NAICS codes EPA classified as occupations potentially exposed to TBBPA for an example associated with 4-digit NAICS code 562200 – Waste Treatment and Disposal. These occupations are classified as workers (W) and occupational non-users (O) by NAICS code. All relevant SOC codes by NAICS codes combinations can be found in supplemental file *Draft Estimates of Number of Workers and ONUs Model for 4,4'-(1-Methylethylidene)bis[2,6-dibromophenol] (TBBPA)* (U.S. EPA, 2026d) under the "Affected SOCs" tab and all other SOC codes by NAICS codes combinations are assumed to represent occupations where exposure is unlikely.

After identifying relevant NAICS and SOC codes, EPA used BLS data to determine total employment by industry and by occupation based on the NAICS and SOC combinations. For example, there are 1,033 employees associated with 4-digit NAICS 562200 (Waste Treatment and Disposal) and SOC 51-8030 (Water and Wastewater Treatment Plant and System Operators).

Using a combination of NAICS and SOC codes to estimate total employment provides more accurate estimates for the number of workers than using NAICS codes alone. Using only NAICS codes to estimate number of workers typically result in an overestimate, because not all workers employed in that industry sector will be exposed. However, in some cases, BLS only provides employment data at the 4-digit or 5-digit NAICS level; therefore, further refinement of this approach may be needed (see next step).

Step 3: Refining Employment Estimates to Account for Lack of NAICS Granularity

The third step in EPA's methodology was to further refine the employment estimates by using total employment data in the U.S. Census Bureau's SUSB (U.S. Census Bureau, 2017). In some cases, BLS Occupational Employment Statistics' occupation-specific data are only available at the 4- or 5-digit NAICS level, whereas the SUSB data are available at the 6-digit level (but are not occupation-specific). Identifying specific 6-digit NAICS will ensure that only industries with potential TBBPA exposure are included. As an example, Occupational Employment Statistics data are available for the 4-digit NAICS 562200 Waste Treatment and Disposal, which includes several 6-digit NAICS:

- 562211 – Hazardous Waste Treatment and Disposal;
- 562212 – Solid Waste Landfill;
- 562213 – Solid Waste Combustors and Incinerators; and
- 562219 – Other Nonhazardous Waste Treatment and Disposal.

In this example, each of these 6-digit NAICS are of interest. However, the Census data allow EPA to calculate employment in the specific 6-digit NAICS of interest as a percentage of employment in the BLS 4-digit NAICS.

As an example, the 6-digit NAICS 562211 comprises 59.34% of total employment under the 4-digit NAICS 5622. This percentage can be multiplied by the occupation-specific employment estimates given in the BLS Occupational Employment Statistics data to further refine the Agency's estimates of the number of employees with potential exposure. Table_Apx A-1 illustrates this granularity adjustment for NAICS 562211.

Table_Apx A-1. Estimated Number of Potentially Exposed Workers and ONUs Under NAICS 562211

NAICS	SOC CODE	SOC Description	Occupation Designation	Employment by SOC at 4-Digit NAICS Level	% of Total Employment	Estimated Employment by SOC at 6-Digit NAICS Level
562200	11-3050	Industrial Production Managers	O	170	59.3%	101
562200	11-9020	Construction Managers	O	71	59.3%	42
562200	11-9040	Architectural and Engineering Managers	O	51	59.3%	30
562200	17-2000	Engineers	O	801	59.3%	475

NAICS	SOC CODE	SOC Description	Occupation Designation	Employment by SOC at 4-Digit NAICS Level	% of Total Employment	Estimated Employment by SOC at 6-Digit NAICS Level
562200	17-3020	Engineering Technologists and Technicians, Except Drafters	O	150	59.3%	89
562200	19-2031	Chemists	O	600	59.3%	356
562200	19-2041	Environmental Scientists and Specialists, Including Health	O	110	59.3%	65
562200	19-4000	Life, Physical, and Social Science Technicians	O	1,142	59.3%	677
562200	47-4040	Hazardous Materials Removal Workers	W	5,545	59.3%	3,288
562200	49-1000	Supervisors of Installation, Maintenance, and Repair Workers	O	761	59.3%	451
562200	49-2000	Electrical and Electronic Equipment Mechanics, Installers, and Repairers	W	229	59.3%	136
562200	49-9000	Other Installation, Maintenance, and Repair Occupations	W	3,433	59.3%	2,036
562200	51-1000	Supervisors of Production Workers	O	880	59.3%	522
562200	51-8030	Water and Wastewater Treatment Plant and System Operators	W	1,742	59.3%	1,033
562200	51-8090	Miscellaneous Plant and System Operators	W	821	59.3%	487
562200	53-7061	Cleaners of Vehicles and Equipment	W	40	59.3%	24
562200	53-7080	Refuse and Recyclable Material Collectors	O	17,253	59.3%	10,231
Total Potentially Exposed Employees				**33,799**		**20,041**
Total Workers						**7,003**
Total ONUs						**13,038**

W = worker; O = occupational non-user
Note: numbers may not sum exactly due to rounding.
Source: U.S. Census Bureau (2017) and U.S. BLS (2023a)

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Step 4: Estimating the Percentage of Workers Using TBBPA Instead of Other Chemicals

In the final step, EPA accounted for the market share by applying a factor to the number of workers determined in Step 3. This accounts for the fact that TBBPA may be only one of multiple chemicals used for the applications of interest. EPA did not identify market penetration data for any OES. In the absence of market penetration data for a given OES, EPA assumed TBBPA may be used at up to all sites and by up to all workers calculated in this method as a bounding estimate. This assumes a market penetration of 100%.

Step 5: Estimating the Number of Workers and ONUs per Site

EPA calculated the number of workers and ONUs in each industry/occupation combination using the formula below (granularity adjustment is only applicable where SOC data are not available at the 6-digit NAICS level):

$$\begin{aligned} &\mathit{Number\ of\ Workers\ or\ ONUs\ in\ NAICS/SOC}\ (\mathit{Step}\ 2) \times \mathit{Granularity\ Adjustment\ Percentage}\ (\mathit{Step}\ 3) \\ &= \mathit{Number\ of\ Workers\ or\ ONUs\ in\ the\ Industry/Occupation\ Combination} \end{aligned}$$

EPA then estimated the total number of establishments by obtaining the number of establishments reported in the U.S. Census Bureau's SUSB (U.S. Census Bureau, 2017) data at the 6-digit NAICS level. In this example, there are 873 establishments associated with 6-digit NAICS code 562211 – Hazardous Waste Treatment and Disposal.

EPA then summed the number of workers and ONUs over all occupations within a NAICS code and divided these sums by the number of establishments in the NAICS code to calculate the average number of workers and ONUs per site.

Step 6: Estimating the Number of Workers and ONUs, and Sites for a COU

EPA estimated the number of workers and ONUs potentially exposed to TBBPA and the number of sites that use TBBPA in a given OES through the following steps:

- 6A. Obtaining the total number of establishments by:
  - i. Obtaining the number of establishments from SUSB at the 6-digit NAICS level (Step 5) for each NAICS code in the OES and summing these values; or
  - ii. Obtaining the number of establishments from the TRI, DMR, NEI, or literature for the OES.
- 6B. Estimating the number of establishments that use TBBPA by taking the total number of establishments from Step 6A and multiplying it by the market penetration factor from Step 4.
- 6C. Estimating the number of workers and ONUs potentially exposed to TBBPA by taking the number of establishments calculated in Step 6B and multiplying it by the average number of workers and ONUs per site from Step 5.

Appendix B EQUATIONS FOR CALCULATING INTERMEDIATE, AND CHRONIC (NON-CANCER) INHALATION AND DERMAL EXPOSURES

This draft TSD assessed TBBPA inhalation exposures to workers in occupational settings, presented as full-shift TWA. The full-shift TWA exposures are then used to calculate intermediate average daily concentrations (IADC) and average daily concentrations (ADC) for chronic non-cancer risks. This report also assesses TBBPA dermal exposures to workers in occupational settings, presented as a dermal APDR. The APDRs are then used to calculate the IADD and ADD.

This appendix presents the equations and input parameter values used to estimate each exposure metric.

B.1 Equations for Calculating Intermediate, and Chronic (Non-Cancer and Cancer) Inhalation Exposures

IADC is used to estimate workplace inhalation exposures for sub-chronic risks and is estimated as follows:

Equation_Apx B-1.

$$IADC = \frac{(C \times ED \times EF_{INT} \times BR)}{AT_{ADC\_I}}$$

Where:

$IADC$	=	Intermediate average daily concentration (ppm or mg/m^3)
C	=	Contaminant concentration in air (TWA) (ppm or mg/m^3)
ED	=	Exposure duration (hr/day)
EF_{Int}	=	Intermediate exposure frequency (day/yr)
BR	=	Breathing rate ratio (unitless)
AT_{ADC_I}	=	Averaging time (hr) for sub-chronic exposure

Equation_Apx B-2.

$$AT_{ADC\_I} = ID \times 24 \frac{hr}{day}$$

Where:

AT_{ADC_I}	=	Averaging time (hr) for sub-chronic exposure
ID	=	Days for sub-chronic duration (day)

ADC is used to estimate workplace exposures for non-cancer risks. This exposure is estimated as follows:

Equation_Apx B-3.

$$ADC = \frac{(C \times ED \times EF \times WY \times BR)}{AT_c}$$

Where:

ADC	=	Average daily concentration used for chronic non-cancer risk calculations
C	=	Contaminant concentration in air (TWA)
ED	=	Exposure duration (hr/day)
EF	=	Exposure frequency (day/yr)
WY	=	Working years per lifetime (yr)

BR = Breathing rate ratio (unitless)
AT_c = Averaging time (hr) for chronic, non-cancer risk

Equation_Apx B-4.

$$AT = WY \times 365 \frac{days}{yr} \times 24 \frac{hr}{day}$$

Where:
WY = Working years per lifetime (yr)
AT_c = Averaging time (hr) for chronic, non-cancer risk

B.2 Equations for Calculating Sub-Chronic and Chronic (Non-Cancer) Dermal Exposures

A sub-chronic dermal dose (SCDD) is used to estimate workplace dermal exposures for sub-chronic risks. and is estimated using Equation_Apx B-5.

Equation_Apx B-5.

$$IADD = \frac{(APDR \times EF_{int})}{(BW \times SCDD)}$$

Where:
$IADD$ = Intermediate average daily dose (mg/kg-day)
$APDR$ = Acute potential dose rate (mg/day)
EF_{int} = Intermediate exposure frequency (day/yr)
BW = Body weight (kg)
$SCDD$ = Sub-chronic dermal dose (mg/kg-day)

ADD is used to estimate workplace dermal exposures for non-cancer risks and is calculated using Equation_Apx B-6.

Equation_Apx B-6.

$$ADD = \frac{(APDR \times EF \times WY)}{\left(BW \times 365 \frac{days}{yr} \times WY\right)}$$

Where:
ADD = Average daily dose (mg/kg-day) [Note: WY is used in the denominator for ADD]
$APDR$ = Acute potential dose rate (mg/day)
EF = Exposure Frequency (days/yr)
WY = Working Years (years)
BW = Body weight (kg)

B.3 Intermediate and Chronic (Non-Cancer) Equation Inputs

The input parameter values in Table_Apx B-1 are used to calculate each of the above intermediate and chronic exposure estimates. Where multiple values are provided for ED, it indicates that EPA may have used different values for different OES. The EF and EF_{INT} used for each OES can differ, and the values used are described in the appropriate sections of this report. The maximum values used in the equations as well as a general summary for these differences are described below in this section.

Table_Apx B-1. Parameter Values for Calculating Inhalation and Dermal Exposure Estimates

Parameter Name	Symbol	Value	Unit
Exposure duration	ED	8, 12, or 12.5	hours/day
Breathing rate ratio	BR	2.04	unitless
Exposure frequency	EF	13–250[a]	days/yr
Exposure frequency, intermediate	EF_{INT}	14	days
Days for intermediate duration	ID	18	days
Working years	WY	31 (50th percentile) 40 (95th percentile)	years
Averaging time, intermediate	AT_{ACD_I}	432	hours
Averaging time, non-cancer	AT	271,560 (central tendency) [b] 350,400 (high-end) [c]	hours
Body weight	BW	80 (average adult worker)	kg

[a] Depending on OES.
[b] Calculated using the 50th percentile value for working years.
[c] Calculated using the 95th percentile value for working years.

B.3.1 Exposure Duration (ED)

EPA generally uses an exposure duration of the full-shift as specified by the data source for averaging full-shift exposures. This is typically 8 hours, but select OESs have different full-shift lengths.

B.3.2 Breathing Rate Ratio (BR)

EPA uses a BR, which is the ratio between the worker breathing rate and resting breathing rate, to account for the amount of air a worker breathes during exposure. The typical worker breathes about 10 m^3 of air in 8 hours, or 1.25 m^3/h while the resting breathing rate is 0.6125 m^3/h (U.S. EPA, 1991). The ratio of these two values is equivalent to 2.04.

B.3.3 Exposure Frequency (EF)

EPA generally used a maximum EF of 250 days per year based on the assumptions of daily exposure during each working day, 5 work days per week, and 2 weeks of vacation per year. The relevant sections of this report describe EPA's estimation of exposure frequency for each OES.

EF is expressed as the number of days per year a worker is exposed to the chemical being assessed. In some cases, it may be reasonable to assume a worker is exposed to the chemical on each working day. In other cases, it may be more appropriate to assume a worker's exposure to the chemical occurs during a subset of the worker's annual working days (AWD). The relationship between exposure frequency and annual working days can be described mathematically as follows:

Equation_Apx B-7.

$$EF = f \times AWD$$

Where:

EF = Exposure frequency, the number of days per year a worker is exposed to the chemical (day/yr)

f = Fractional number of annual working days during which a worker is exposed to the chemical (unitless)

AWD = Annual working days, the number of days per year a worker works (day/yr)

BLS provides data on the total number of work hours and total number of employees by each industry NAICS code (U.S. BLS, 2016). BLS provides these data from the 3- to 6-digit NAICS level (where 3-digit NAICS are less granular and 6-digit NAICS are the most granular). Dividing the total, annual hours worked by the number of employees yields the average number of hours worked per employee per year for each NAICS (U.S. BLS, 2023a).

EPA identified approximately 140 NAICS codes applicable to the multiple conditions of use for the first 10 chemicals that underwent risk evaluation. For each NAICS code of interest, EPA looked up the average hours worked per employee per year at the most granular NAICS level available (*i.e.,* 4-, 5-, or 6-digit). EPA converted the working hours per employee to working days per year per employee assuming employees work an average of eight hours per day. The average number of working days per year, or AWD, ranges from 169 to 282 days per year, with a 50th percentile value of 250 days per year. EPA repeated this analysis for all NAICS codes at the 4-digit level. The average AWD for all 4-digit NAICS codes ranges from 111 to 282 days per year, with a 50th percentile value of 228 days per year. Two hundred fifty days per year is approximately the 75th percentile of the distribution AWD for the 4-digit NAICS codes. In the absence of industry- and TBBPA-specific data, EPA assumed the parameter, f, is equal to 1 for all OESs.

B.3.4 Intermediate Exposure Frequency (EF_{INT})

For TBBPA, the timeframe for sub-chronic health effects is 18 days, which is the value used for ID. EPA estimated the maximum number of working days (subtracting weekends) within this timeframe to be 14 days, assuming 5 working days per week, for the value of EF_{INT}.

B.3.5 Intermediate Duration (ID)

EPA assessed an intermediate duration of 18 days based on the available health data.

B.3.6 Working Years (WY)

EPA developed a triangular distribution for number of lifetime working years using the following parameters:

- Minimum value: BLS CPS tenure data with current employer as a low-end estimate of the number of lifetime working years was 10.4 years;
- Mode value: The 50th percentile of the tenure data with all employers from Survey of Income and Program Participation (SIPP) as a mode value for the number of lifetime working years was 36 years; and
- Maximum value: The maximum of the average tenure data with all employers from SIPP as a high-end estimate on the number of lifetime working years was 44 years.

This triangular distribution has a 50th percentile value of 31 years and a 95th percentile value of 40 years. EPA uses these values to represent the central tendency and high-end number of working years in the ACC calculations.

BLS (2014) provides information on employee tenure with *current employer* obtained from the Current Population Survey (CPS). CPS is a monthly sample survey of about 60,000 households that provides information on the labor force status of the civilian non-institutional population ages 16 years and over. CPS data are released every two years. The data are available by demographic characteristics and by generic industry sectors, but not by NAICS codes.

The U.S. Census Bureau (2019b) SIPP provides information on *lifetime tenure with all employers*. SIPP is a household survey that collects data on income, labor force participation, social program participation and eligibility, and general demographic characteristics through a continuous series of national panel surveys of between 14,000 and 52,000 households (U.S. Census Bureau, 2019a; U.S. BLS, 2023b). EPA analyzed the 2008 SIPP Panel Wave 1, a panel that began in 2008 and covers the interview months of September 2008 through December 2008 (U.S. Census Bureau, 2019b). For this panel, lifetime tenure data are available by Census Industry Codes, which can be cross walked with NAICS codes.

SIPP data include fields that describe, for each surveyed worker, the industry in which they work (TJBIND1); their age (TAGE); and years of work experience *with all employers* over the surveyed individual's lifetime.[4] Census household surveys use different industry codes than the NAICS codes, so EPA converted these industry codes to NAICS using a published crosswalk (U.S. Census Bureau, 2012). EPA calculated the average tenure for the following age groups: (1) workers aged 50 (years) and older; (2) workers aged 60 (years) and older; and (3) workers of all ages employed at time of survey. The Agency used tenure data for age group "50 and older" to determine the high-end lifetime working years, because the sample size in this age group is often substantially higher than the sample size for age group "60 and older." For some industries, the number of workers surveyed, or the *sample size*, was too small to provide a reliable representation of the worker tenure in that industry. Therefore, EPA excluded data where the sample size was less than 5 from the analysis.

Table_Apx B-2 summarizes the average tenure for workers aged 50 years and older from SIPP data. Although the tenure may differ for any given industry sector, there is no significant variability between the 50th and 95th percentile values of average tenure across manufacturing and non-manufacturing sectors.

Table_Apx B-2. Overview of Average Worker Tenure from U.S. Census SIPP (Age Group 50+) (U.S. Census Bureau, 2019a)

Industry Sectors	Working Years			
	Average	50th Percentile	95th Percentile	Maximum
Manufacturing sectors (NAICS 31–33)	35.7	36	39	40
Non-manufacturing sectors (NAICS 42–81)	36.1	36	39	44
Note: Industries where the sample size <5 were excluded from this analysis.				

BLS CPS data provides the median years of tenure that wage and salary workers had been with their current employer. Table_Apx B-3 presents CPS data for all demographics (men and women) by age group from 2008 to 2012. To estimate the low-end value for number of working years, EPA used the most recent (2014) CPS data for workers aged 55 to 64 years, which indicates a median tenure of 10.4 years with their current employer. The use of this low-end value represents a scenario where workers are only exposed to the chemical of interest for a portion of their lifetime working years, as they may change jobs or move from one industry to another throughout their career.

[4] To calculate the number of years of work experience EPA took the difference between the year first worked (TMAKMNYEAR) and the current data year (*i.e.,* 2008). EPA then subtracted any intervening months when not working (ETIMEOFF).

Table_Apx B-3. Median Years of Tenure with Current Employer by Age Group (U.S. BLS, 2014)

Age	January 2008	January 2010	January 2012	January 2014
16+ years	4.1	4.4	4.6	4.6
16–17 years	0.7	0.7	0.7	0.7
18–19 years	0.8	1.0	0.8	0.8
20–24 years	1.3	1.5	1.3	1.3
25+ years	5.1	5.2	5.4	5.5
25–34 years	2.7	3.1	3.2	3.0
35–44 years	4.9	5.1	5.3	5.2
45–54 years	7.6	7.8	7.8	7.9
55–64 years	9.9	10.0	10.3	10.4
65+ years	10.2	9.9	10.3	10.3

B.3.7 Body Weight (BW)

EPA assumed a BW of 80 kg for average adult workers, per Chapter 8 of the *Exposure Factors Handbook* (U.S. EPA, 2011).

B.4 Calculating Aggregate Exposure

EPA combined the expected dermal and inhalation exposures for each OES and worker type into a single aggregate exposure to reflect the potential total dose from both exposure routes.

Equation_Apx B-8.

$$IADD_{aggregate} = IADD_{dermal} + IADD_{inhalation}$$

Where:

$IADD_{aggregate}$ = Aggregated intermediate absorbed dose (mg/kg-day)
$IADD_{dermal}$ = Dermal exposure intermediate retained dose (mg/kg-day)
$IADD_{inhalation}$ = Inhalation exposure intermediate retained dose (mg/kg-day)

ADD also follow the same approach for defining aggregate exposures.

Appendix C SAMPLE CALCULATIONS FOR CALCULATING INTERMEDIATE AND CHRONIC (NON-CANCER) OCCUPATIONAL EXPOSURES

Sample calculations for high-end and central tendency intermediate and chronic (non-cancer) doses for one OES, Manufacturing, are demonstrated below for an average adult worker. The explanation of the equations and parameters used is provided in Appendix B.

C.1 Example High-End IADC and ADC Calculations

Calculate $IADC_{HE}$:

$$IADC_{HE} = \frac{C_{HE} \times ED \times EF_I \times BR}{AT_{ADC_I}}$$

$$IADC_{HE} = \frac{2.8\, mg/m^3 \times 8\,\frac{hr}{day} \times 14\,\frac{days}{year} \times 2.04}{432\, hr} = 1.5\, mg/m^3$$

Calculate ADC_{HE}:

$$ADC_{HE} = \frac{C_{HE} \times ED \times EF \times WY \times BR}{AT}$$

$$ADC_{HE} = \frac{2.8\, mg/m^3 \times 8\,\frac{hr}{day} \times 250\,\frac{days}{year} \times 40\, years \times 2.04}{40\, years \times 365\,\frac{days}{yr} \times 24\,\frac{hr}{day}} = 1.3\, mg/m^3$$

C.2 Example Central Tendency IADC and ADC Calculations

Calculate $IADC_{CT}$:

$$IADC_{CT} = \frac{C_{CT} \times ED \times EF_I \times BR}{AT_{ADC_I}}$$

$$IADC_{CT} = \frac{0.80\, mg/m^3 \times 8\,\frac{hr}{day} \times 14\,\frac{days}{year} \times 2.04}{432\, hr} = 0.42\, mg/m^3$$

Calculate ADC_{CT}:

$$ADC_{CT} = \frac{C_{CT} \times ED \times EF \times WY \times BR}{AT}$$

$$ADC_{CT} = \frac{0.80\ mg/m^3 \times 8\frac{hr}{day} \times 250\frac{days}{year} \times 31\ years \times 2.04}{31\ years \times 365\frac{days}{yr} \times 24\frac{hr}{day}} = 0.37\ mg/m^3$$

Appendix D MODEL APPROACHES AND PARAMETERS

D.1 Inhalation Exposure to Total Particulates Model Approach and Parameters

The PNOR Model (U.S. EPA, 2021b) estimates worker inhalation exposure to respirable solid particulates using PBZ PNOR monitoring data from OSHA's Chemical Exposure Health Data (CEHD) dataset. The CEHD data provides PNOR exposures as 8-hour TWAs by assuming exposures outside the sampling time are zero, and the data also include facility NAICS code information for each data point. To estimate particulate exposures for relevant OESs, EPA used the 50th and 95th percentiles of respirable PNOR values for applicable NAICS codes as the central tendency and high-end exposure estimates, respectively.

Due to lack of data on the concentration of TBBPA in the particulates, EPA assumed TBBPA is present in particulates at the same mass fraction as in the bulk solid material, whether that is a plastic product or another solid article. Therefore, the Agency calculated the 8-hour TWA exposure to TBBPA present in dust and particulates using the following equation:

Equation_Apx D-1.

$$C_{TBBPA,8hr-TWA} = C_{PNOR,8hr-TWA} \times F_{TBBPA}$$

Where:

$C_{TBBPA,8hr-TWA}$	=	8-hour TWA exposure to TBBPA (mg/m^3)
$C_{PNOR,8hr-TWA}$	=	8-hour TWA exposure to PNOR (mg/m^3)
F_{TBBPA}	=	Mass fraction of TBBPA in PNOR (mg/mg)

Table_Apx D-1 provides a summary of the OESs assessed using the PNOR Model (U.S. EPA, 2021b) along with the associated NAICS code, PNOR 8-hour TWA exposures, TBBPA mass fraction, and TBBPA 8-hour TWA exposures assessed for each OES.

Table_Apx D-1. Summary of TBBPA Exposure Estimates for OESs Using the Generic Model for Exposure to PNOR

OES	NAICS Code Assessed	Total PNOR 8-Hour TWA from Model (mg/m^3)		TBBPA Mass Fraction Assessed	TBBPA 8-Hour TWA (mg/m^3)	
		Central Tendency	High-End		Central Tendency	High-End
Industrial and Commercial additive Use in Electrical and Electronic Articles	334 – Computer and Electronic Product Manufacturing	0.33	6.0	0.20	6.6E−02	1.2
Industrial and Commercial Use in Building and Construction materials[a]	23 – Construction	2.4	15.0	0.22	0.53	3.3
Use of Powder Coatings in	334 – Computer and Electronic Product	2.0	15.0	0.10	0.2	1.5

OES	NAICS Code Assessed	Total PNOR 8-Hour TWA from Model (mg/m³)		TBBPA Mass Fraction Assessed	TBBPA 8-Hour TWA (mg/m³)	
		Central Tendency	High-End		Central Tendency	High-End
Electronics[a]	Manufacturing; 335 – Electrical Equipment, Appliance, and Component Manufacturing; and 336 – Transportation Equipment Manufacturing					
Disposal[a]	56 – Administrative and Support and Waste Management and Remediation Services	2.5	15.0	0.22	5.5E−01	3.3

[a] To calculate central tendency and high-end value for multiple NAICS codes, EPA combined the CEHD data for the three codes, then calculated 50th and 95th percentile values of the entire dataset. The 95th percentile was above the OSHA PEL for total PNOR (dust) of 15 mg/m³, so the PEL was used as the high-end value.

Appendix E CONSIDERATION OF ENGINEERING CONTROLS AND PERSONAL PROTECTIVE EQUIPMENT

OSHA and NIOSH recommend employers utilize the hierarchy of controls to address hazardous exposures in the workplace. The hierarchy of controls strategy outlines, in descending order of priority, the use of elimination, substitution, engineering controls, administrative controls, and lastly PPE. The hierarchy of controls prioritizes the most effective measures first which is to eliminate or substitute the harmful chemical (*e.g.,* use a different process, substitute with a less hazardous material), thereby preventing or reducing exposure potential. Following elimination and substitution, the hierarchy recommends engineering controls to isolate employees from the hazard (*e.g.,* source enclosure, local exhaust ventilation systems), followed by administrative controls (*e.g.,* do not open machine doors when running), or changes in work practices (*e.g.,* maintenance plan to check equipment to ensure no leaks) to reduce exposure potential. Administrative controls are policies and procedures instituted and overseen by the employer to limit worker exposures. Under CFR 1910.1000, OSHA requires the use of engineering or administrative controls to bring exposures to the levels permitted under the air contaminants standard. The respirators do not replace engineering controls, and they are implemented in addition to feasible engineering controls (29 CFR 1910.134(a)(1)). PPE (*e.g.,* respirators, gloves) could be used as the last means of control when the other control measures cannot reduce workplace exposure to an acceptable level.

The remainder of this appendix discusses respiratory protection and glove protection, including protection factors (PFs) for various respirators and dermal protection strategies. EPA's estimates of occupational exposure presented in this document do not assume the use of engineering controls or PPE; however, the effect of respiratory and dermal PFs on the Agency's occupational exposure estimates can be explored under the "Risk Reduction" tab of the *Draft Risk Calculator for Occupational Exposures for 4,4'-(1-Methylethylidene)bis[2,6-dibromophenol] (TBBPA)* (U.S. EPA, 2026h).

E.1 Respiratory Protection

OSHA's Respiratory Protection Standard (29 CFR 1910.134) requires employers in certain industries to address workplace hazards by implementing engineering control measures and, if these are not feasible, provide respirators that are applicable and suitable for the purpose intended. Engineering and administrative controls must be implemented whenever employees are exposed above the PEL. If the engineering and administrative controls do not reduce exposures to below the PEL, respirators must be worn. Respirator selection provisions are provided in 29 CFR 1910.134(d) and require that appropriate respirators are selected based on the respiratory hazard(s) to which the worker will be exposed and workplace and user factors that affect respirator performance and reliability. Assigned protection factors (APFs) are provided in Table 1 under 29 CFR 1910.134(d)(3)(i)(A) (see below in Table_Apx E-1). Respirators must meet or exceed the required level of protection listed in Table_Apx E-1. Based on the APF, inhalation exposures may be reduced by a factor of 5 to 10,000 if respirators are properly worn and fitted.

For atmospheres that are immediately dangerous to life and health, workers must use a full facepiece pressure demand self-contained breathing apparatus (SCBA) certified by NIOSH for a minimum service life of 30 minutes or a combination full facepiece pressure demand supplied-air respirator (SAR) with auxiliary self-contained air supply. Respirators that are provided only for escape from an atmosphere that is immediately dangerous to life and health must be NIOSH-certified for escape from the atmosphere in which they will be used.

Table_Apx E-1. Assigned PFs for Respirators in OSHA Standard 29 CFR 1910.134

Type of Respirator	Quarter Mask	Half Mask	Full Facepiece	Helmet/ Hood	Loose-Fitting Facepiece
1. Air-purifying respirator	5	10	50	–	–
2. Power air-purifying respirator (PAPR)	–	50	1,000	25/1,000	25
3. Supplied-air respirator (SAR) or airline respirator					
• Demand mode	–	10	50	–	–
• Continuous flow mode	–	50	1,000	25/1,000	25
• Pressure-demand or other positive-pressure mode	–	50	1,000	–	–
4. Self-contained breathing apparatus (SCBA)					
• Demand mode	–	10	50	50	–
• Pressure-demand or other positive-pressure mode (*e.g.,* open/closed circuit)	–	–	10,000	10,000	–
Source: 29 CFR 1910.134(d)(3)(i)(A)					

NIOSH and BLS conducted a voluntary survey of U.S. employers regarding the use of respiratory protective devices between August 2001 and January 2002. The survey was sent to a sample of 40,002 establishments designed to represent all private sector establishments. The survey had a 75.5% response rate (NIOSH, 2003). A voluntary survey may not be representative of all private industry respirator use patterns as some establishments with low or no respirator use may choose to not respond to the survey. Therefore, results of the survey may potentially be biased towards higher respirator use.

NIOSH and BLS estimated about 619,400 establishments used respirators for voluntary or required purposes (including emergency and non-emergency uses). About 281,800 establishments (45%) were estimated to have had respirator use for required purposes in the 12 months prior to the survey. The 281,800 establishments estimated to have had respirator use for required purposes were estimated to be approximately 4.5% of all private industry establishments in the United States at the time (NIOSH, 2003).

The survey found that the establishments that required respirator use had the following respirator program characteristics (NIOSH, 2003):

- 59% provided training to workers on respirator use;
- 34% had a written respiratory protection program;
- 47% performed an assessment of the employees' medical fitness to wear respirators; and
- 24% included air sampling to determine respirator selection.

The survey report does not provide a result for respirator fit testing or identify if fit testing was included in one of the other program characteristics.

Of the establishments that had respirator use for a required purpose within the 12 months prior to the survey, NIOSH and BLS found the following (NIOSH, 2003):

- Non-powered air purifying respirators are most common, 94% overall and varying from 89 to 100% across industry sectors.
- Powered air-purifying respirators represent a minority of respirator use, 15% overall and varying from 7 to 22% across industry sectors.
- Supplied air respirators represent a minority of respirator use, 17% overall and varying from 4 to 37% across industry sectors.

Of the establishments that used non-powered air-purifying respirators for a required purpose within the 12 months prior to the survey, NIOSH and BLS found the following (NIOSH, 2003):

- A high majority use dust masks, 76% overall and varying from 56 to 88% across industry sectors.
- A varying fraction uses half-mask respirators, 52% overall and varying from 26 to 66% across industry sectors.
- A varying fraction uses full-facepiece respirators, 23% overall and varying from 4 to 33% across industry sectors.

Table_Apx E-2 summarizes the number and percentage of all private industry establishments and employees that used respirators for a required purpose within the 12 months prior to the survey and includes a breakdown by industry sector (NIOSH, 2003).

Table_Apx E-2. Number and Percentage of Establishments and Employees Using Respirators Within 12 Months Prior to Survey

Industry	Establishments		Employees	
	Number	Percentage of All Establishments (%)	Number	Percentage of All Employees (%)
Total Private Industry	281,776	4.5	3,303,414	3.1
Agriculture, Forestry, and Fishing	13,186	9.4	101,778	5.8
Mining	3,493	11.7	53,984	9.9
Construction	64,172	9.6	590,987	8.9
Manufacturing	48,556	12.8	882,475	4.8
Transportation and Public Utilities	10,351	3.7	189,867	2.8
Wholesale Trade	31,238	5.2	182,922	2.6
Retail Trade	16,948	1.3	118,200	0.5
Finance, Insurance, and Real Estate	4,202	0.7	22,911	0.3
Services	89,629	4.0	1,160,289	3.2

E.2 Glove Protection

OSHA's hand protection standard (29 CFR 1910.138) requires employers to select and require employees to use appropriate hand protection when expected to be exposed to hazards such as those from skin absorption of harmful substances, severe cuts or lacerations, severe abrasions, punctures, chemical burns, thermal burns, and harmful temperature extremes. Dermal protection selection provisions are provided in 29 CFR 1910.138(b) and require that appropriate hand protection is selected based on the performance characteristics of the hand protection relative to the task(s) to be performed, conditions present, duration of use, and the hazards to which employees will be exposed.

Unlike respiratory protection, OSHA standards do not provide PFs associated with various hand protection PPE, such as gloves, and data about the frequency of effective glove use—that is, the proper use of effective gloves—is very limited in industrial settings. Initial literature review suggests that there is unlikely to be sufficient data to justify a specific probability distribution for effective glove use for a chemical or industry. Instead, the impact of effective glove use is explored by considering different percentages of effectiveness.

Gloves only offer barrier protection until the chemical breaks through the glove material. Using a conceptual model, Cherrie et al. (2004) proposed a glove workplace PF as the ratio of estimated uptake through the hands without gloves to the estimated uptake though the hands while wearing gloves. This PF is driven by flux and thus varies with time. The European Centre for Ecotoxicology and Toxicology of Chemicals Targeted Risk Assessment (ECETOC TRA) Model represents the protection factor of gloves as a fixed, APF equal to 5, 10, or 20 (Marquart et al., 2017) where, similar to the APF for respiratory protection, the inverse of the PF is the fraction of the chemical that penetrates the glove. It should be noted that the described PFs are not based on experimental values or field investigations of PPE effectiveness, but rather professional judgments used in the development of the ECETOC TRA model. EPA did not identify reasonably available information on PPE usage to corroborate the PFs used in this model.

As indicated in Table_Apx E-3, use of PFs above 1 is recommended only for glove materials that have been tested for permeation against the TBBPA-containing liquids associated with the COU. EPA has not found information that would indicate specific activity training (*e.g.,* procedure for glove removal and disposal) for tasks where dermal exposure can be expected to occur in a majority of sites in industrial only OESs, so the PF of 20 would usually not be expected to be achieved.

Table_Apx E-3. Glove PFs for Different Dermal Protection Strategies from ECETOC TRA v3

Dermal Protection Characteristics	Affected User Group	Indicated Efficiency (%)	PF
a. Any glove/gauntlet without permeation data and without employee training	Both industrial and professional users	0	1
b. Gloves with available permeation data indicating that the material of construction offers good protection for the substance		80	5
c. Chemically resistant gloves (*i.e.,* as b. above) with "basic" employee training		90	10
d. Chemically resistant gloves in combination with specific activity training (*e.g.,* procedure for glove removal and disposal) for tasks where dermal exposure can be expected to occur	Industrial users only	95	20