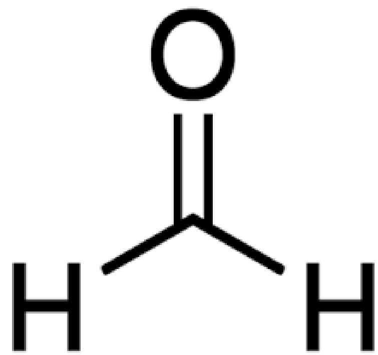
**United States
Environmental Protection Agency**

**March 2024
Office of Chemical Safety and
Pollution Prevention**

# Draft Ambient Air Exposure Assessment for Formaldehyde

## CASRN 50-00-0



***March 2024***

# TABLE OF CONTENTS

# LIST OF TABLES



# LIST OF FIGURES



# LIST OF APPENDIX TABLES



# LIST OF APPENDIX FIGURES

**Key Points: Ambient Air Exposure Assessment**

The following bullets summarize the key points of this draft ambient air exposure assessment:

- Formaldehyde is ubiquitous and consistently present in the ambient air and therefore EPA quantitatively assesses human exposure to formaldehyde via the ambient air pathway.
- Recognizing the ubiquity of formaldehyde in ambient air is due to contributions from many different sources, EPA considers and presents measured and modeled concentrations of formaldehyde from multiple lines of evidence, data, and analyses in this ambient air exposure assessment to evaluate and contextualize formaldehyde exposures in ambient air due to Toxic Substances Control Act (TSCA) conditions of use (COU).
- EPA considered the last five years (2015 to 2020) of monitored formaldehyde concentrations extracted from EPA's Ambient Monitoring Technology Information Center (AMTIC) dataset for this exposure assessment. EPA acknowledges this ambient monitoring data is generally representative of a total aggregate concentration from all formaldehyde sources (both TSCA and non-TSCA sources) but taken together with other data sources allows EPA to contextualize modeled concentrations from IIOAC relative to the monitored concentrations from AMTIC.
- Additional analyses considered or conducted for this exposure assessment include 2019 AirToxScreen data [a screening analysis representing formaldehyde contributions from 37 different sources (including biogenic sources and secondary formation)], and additional modeling using EPA's Human Exposure Model (HEM) [to evaluate national scale population impacts of and exposures to industrial releases of formaldehyde]
- Acute and chronic exposures from industrial releases of formaldehyde which can be attributed to TSCA COUs based on the IIOAC modeling range from 0.0001 to 5.75 micrograms per cubic meter ($\mu g/m^3$) with a median of 0.62 $\mu g/m^3$ within the 100 to 1,000 m area distance evaluated.
- Monitored formaldehyde concentrations extracted from AMTIC between 2015 and 2020 ranged from 0 to 60.1 $\mu g/m^3$ with a median of 1.6 $\mu g/m^3$.
- When contextualizing modeled concentrations from EPA's IIOAC modeling in relation to the other data sources considered, EPA found modeled concentrations generally fall within the lower quartile range of the AMTIC monitoring data and within the same range of concentrations attributed to secondary formation sources from the 2019 AirToxScreen dataset. Contributions from biogenic sources of formaldehyde from the 2019 AirToxScreen dataset generally fall within the lower quartile range of the IIOAC modeled concentrations.
- Overall, EPA's IIOAC results show 21 of 29 TSCA COUs have modeled concentrations greater than the 95th percentile concentration of 0.28 ug/m3 attributable to biogenic/natural sources (from 2019 AirToxScreen data). Eighteen TSCA COUs are greater than five times the 95th percentile concentration attributable to biogenic sources and seven TSCA COUs are greater than ten times the 95th percentile concentration attributable to biogenic sources of formaldehyde.
- EPA is confident in the characterization of exposures to formaldehyde via the ambient air pathway-inhalation route in this ambient air assessment resulting from industrial facilities releasing formaldehyde to the ambient air. The greatest uncertainty is associated with the contribution of formaldehyde to the total ambient monitoring data due to secondary formation and as a byproduct of combustion.

# EXECUTIVE SUMMARY

Environmental releases of formaldehyde are reported to occur into the ambient air (U.S. EPA, 2024d). Although subject to direct and indirect photolysis in the ambient air, formaldehyde is ubiquitous and has consistently been found to be present in air based on testing and ambient monitoring implemented under multiple EPA programs.

EPA's assessment of the ambient air pathway considers both measured (monitored) and modeled formaldehyde concentrations in ambient air. Modeling for this ambient air exposure assessment used EPA's Integrated Indoor/Outdoor Air Calculator (IIOAC) model to estimate air concentrations to which people, including locally impacted and more sensitive populations, are exposed. The modeling for this ambient air assessment focused specifically on exposures to individuals living nearby (within 100 to 1,000 meters (0.062 to 0.62 miles)) industrial facilities reporting releases of formaldehyde to the ambient air which are associated with TSCA COUs. Exposures presented in this ambient air exposure assessment were quantified from Toxic Release Inventory (TRI) reported release data across 35 industry sectors representing 29 TSCA COUs. Exposures were also quantified from National Emissions Inventory (NEI) reported release data and, while not summarized in this ambient air exposure assessment, are included in the Draft IIOAC Assessment Results and Risk Calcs Supplement A to this ambient air exposure assessment.

The Agency used monitoring data extracted from EPA's AMTIC (U.S. EPA, 2022a) from 2015 through 2021 to contextualize modeled values as well as characterize total aggregate exposures to formaldehyde from all possible contributing sources—including sources associated with TSCA COUs and other sources out of scope for this assessment and not associated with TSCA COUs (*e.g.*, biogenic sources (decay of organic matter), secondary formation, combustion byproduct formation, other byproduct formation, mobile sources, and others). EPA also considered existing modeled data from 2019 AirToxScreen to show how different sources (*e.g.*, point sources, biogenic sources, and secondary formation) contribute to total ambient air concentrations of formaldehyde. The Agency also used the 2019 AirToxScreen data to contextualize how formaldehyde concentrations in the ambient air associated directly with TSCA COUs compare to contributions from other sources not associated with TSCA COUs like biogenic-sourced formaldehyde.

Modeled results for acute and chronic exposures to populations living near industrial facilities releasing formaldehyde to the ambient air ranged from 0.0001 to 5.75 $\mu g/m^3$. Monitored formaldehyde concentrations extracted from AMTIC (2015 to 2020) ranged from 0 to 60.1 $\mu g/m^3$ with a median of 1.6 $\mu g/m^3$ across more than 300,000 monitored values. Monitoring data from select monitoring sites located near industrial releasing facilities showed comparable formaldehyde concentrations to modeled concentrations from those same releasing facilities (within the same order of magnitude). Formaldehyde concentrations attributable to biogenic or secondary production based on AirToxScreen range from 0.13 to 1.8 $\mu g/m^3$.

Taken together, these data and results show modeled formaldehyde concentrations using IIOAC are generally in the same range as monitored formaldehyde concentrations in ambient air as well as contributions of formaldehyde to the ambient air from biogenic and secondary production. However, to characterize exposures associated with TSCA COUs it is necessary to recognize modeled concentrations may contribute to some part of the total concentrations captured by monitored data but are independent and exclusive of non-TSCA sources like biogenic sources or secondary formation. Therefore, while modeled concentrations are in the same range as biogenic and secondary formation, the exposures resulting from TSCA COUs are representative of actual exposures from TSCA COUs alone, and not a subset of the biogenic or secondary formation data. To contextualize this, actual exposures occurring at a given location from both TSCA COUs and biogenic or secondary formation would be an additive exposure receiving the full contribution of formaldehyde from TSCA COUs as well as the full contribution of formaldehyde from biogenic sources.

Based on the modeled concentrations using IIOAC, the following TSCA COUs result in the highest formaldehyde concentrations:

- Processing – incorporation into an article-adhesives and sealant chemicals;
- Processing as a reactant – intermediate;
- Processing – incorporation into a formulation, mixture, or reaction product-intermediate;
- Processing – incorporation into article-finishing agent;
- Processing – incorporation into a formulation, mixture, or reaction product-bleaching agents;
- Processing – incorporation into an article-paint additives and coating additives; and
- Industrial use – chemical substances in industrial products-paints and coatings; adhesives and sealants, lubricants.

When IIOAC modeled concentrations associated with TSCA COUs are compared to the 95th percentile concentration attributable to biogenic sources in the ambient air, EPA found 21 of 29 TSCA COUs are greater than the 95th percentile concentration attributable to biogenic sources. Eighteen TSCA COUs are greater than five times the 95th percentile concentration attributable to biogenic sources and 7 TSCA COUs are greater than ten times the 95th percentile concentration attributable to biogenic sources,

EPA has high confidence in the overall characterization of exposures for this ambient air exposure assessment. Exposure results relied upon direct reported releases, which can be tied to TSCA COUs and peer-reviewed models to derive exposure concentrations at distances from releasing facilities where individuals within the general population typically reside for many years. Additionally, monitoring data from locations near industrial releasing facilities show comparable formaldehyde concentrations in the ambient air and therefore provide added confidence to EPA’s use of modeled results to characterize human exposures to formaldehyde via the ambient air pathway.

# 1 INTRODUCTION

Formaldehyde is a naturally occurring aldehyde produced during combustion, decomposition of organic matter, and in the human body as a normal part of metabolism. Formaldehyde is also released into the ambient air by industrial operations involved with manufacturing, processing, formulation, disposal, and other practices (U.S. EPA, 2024d). It may be distributed as a mixture known as formalin or as a solid known as paraformaldehyde. This assessment focuses on formaldehyde after it has been released to air as a gas (U.S. EPA, 2024b). Due to the previously mentioned natural occurrences and continuous releases from industrial facilities, formaldehyde is ubiquitous in the outdoor environment.

Formaldehyde is a high priority chemical undergoing the TSCA risk evaluation process for existing chemicals following passage of the Frank R. Lautenberg Chemical Safety for the 21st Century Act in 2016. It is concurrently undergoing a risk assessment under the Federal Insecticide, Fungicide, Rodenticide Act (FIFRA) and EPA's Integrated Risk Information System (IRIS) programs. This ambient air exposure assessment considers TSCA COUs, as defined by the TSCA section 3(2) definition of "chemical substance." This TSCA-specific document serves to support risk management needs by the Office of Pollution Prevention and Toxics (OPPT) and is one of many documents included within the Draft Formaldehyde Risk Evaluation package.

## 1.1 Risk Evaluation Scope

The TSCA risk evaluation of formaldehyde comprises several human health, environmental, fate, and exposure assessment modules and two risk assessment documents—the environmental risk assessment and the human health risk assessment. A diagram showing the layout of these modular assessments and the relationships between assessments is provided in Figure 1-1. This ambient air exposure assessment is shaded blue. In some cases, individual assessments were completed jointly under TSCA and FIFRA. These modules are shown in dark gray.

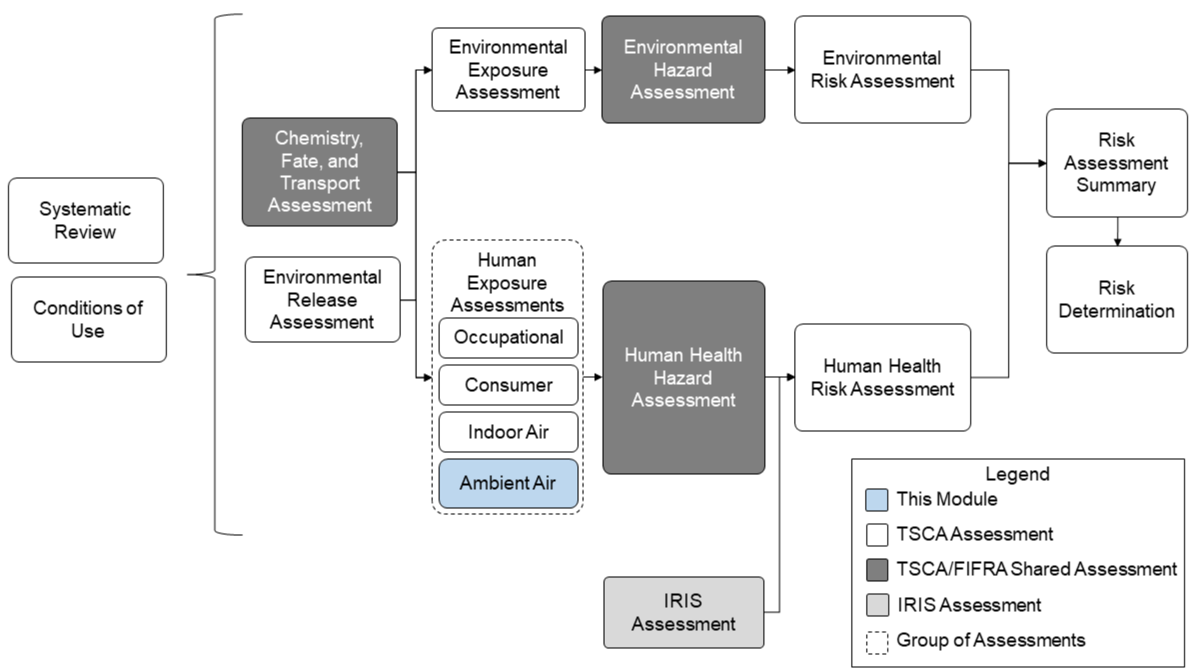



**Figure 1-1. Risk Assessment Document Map Summary**

Environmental releases of formaldehyde are reported for ambient air in the *Draft Environmental Release Assessment for Formaldehyde* (U.S. EPA, 2024d). The *Draft Chemistry, Fate, and Transport Assessment for Formaldehyde* (U.S. EPA, 2024b) and available monitoring data from EPA's AMTIC indicate formaldehyde is ubiquitous and consistently present in the ambient air. Additional modeling and data from the 2019 AirToxScreen support the ubiquity of formaldehyde in ambient air from multiple sources, including non-TSCA sources. Considering these lines of evidence and the ubiquity of formaldehyde in ambient air, EPA expects human exposure to formaldehyde via the ambient air to be common and therefore quantitatively assesses human exposure to formaldehyde via the ambient air pathway.

The scope of this ambient air exposure assessment focuses on human exposures to formaldehyde resulting from industrial releases of formaldehyde to the ambient air that are associated with TSCA COUs. Detailed descriptions of TSCA COUs considered are included in the *Conditions of Use for the Draft Formaldehyde Risk Evaluation* (U.S. EPA, 2024c). Certain uses are considered out of scope for this human health risk assessment, including combustion byproducts, mobile sources, biogenic sources, secondary formation, and other non-TSCA sources. The Draft Conditions of Use Module also includes discussion around those COUs that are considered out of scope.

Considering the ubiquity of formaldehyde in ambient air—while biogenic sources, secondary formation, and other non-TSCA sources are out of scope—EPA considers the contributions of these sources to ambient concentrations of formaldehyde to contextualize the relative contributions resulting from TSCA COUs. However, for TSCA purposes, the Agency can only regulate formaldehyde resulting from TSCA COUs, and to do so in a manner that could be complied with and enforced, needs to distinguish exposure resulting from TSCA COUs from exposures resulting from other non-TSCA sources.

## 1.2 Summary of the Chemistry, Fate, and Transport Assessment

Formaldehyde is a colorless, flammable gas at room temperature and has a strong odor. As noted in the *Draft Chemistry, Fate, and Transport Assessment for Formaldehyde* (U.S. EPA, 2024b), formaldehyde is subject to direct and indirect photolysis and chemical transformation processes in the ambient air. In direct sunlight, studies indicate formaldehyde has a half-life up to 4 hours, although in the absence of direct sunlight formaldehyde has a half-life up to 114 hours. Formaldehyde transformations in the ambient air include, for example, hydrolysis in humid or moist air to formic acid. Formaldehyde also reacts with ozone, nitrates, and hydroxy radicals to form other chemicals in the ambient air. Formaldehyde can also be formed in ambient air from parent compounds such as 1,3-butadiene, or through other secondary formation paths as described in "Sensitivity of Ambient Atmospheric Formaldehyde and Ozone to Precursor Species and Source Types Across the United States" (Luecken et al., 2018).

## 1.3 Conceptual Exposure Model

EPA expects the ambient air pathway to be the predominant human exposure pathway to formaldehyde in the outdoor environment as shown in Figure 1-2. In summary, formaldehyde is released from industrial facilities as uncontrolled fugitive releases (*e.g.*, process equipment leaks, process vents, building windows, building doors, roof vents) and stack releases that may be either uncontrolled (*e.g.*, direct releases out a stack) or controlled with pollution control device (*e.g.*, baghouse, scrubber, thermal oxidizer). Once released to the ambient air, formaldehyde may move off-site into the surrounding areas where humans may be exposed through inhalation. This draft ambient air exposure assessment focuses on exposures to a subset of the general population living nearby industrial facilities releasing formaldehyde to the ambient air.

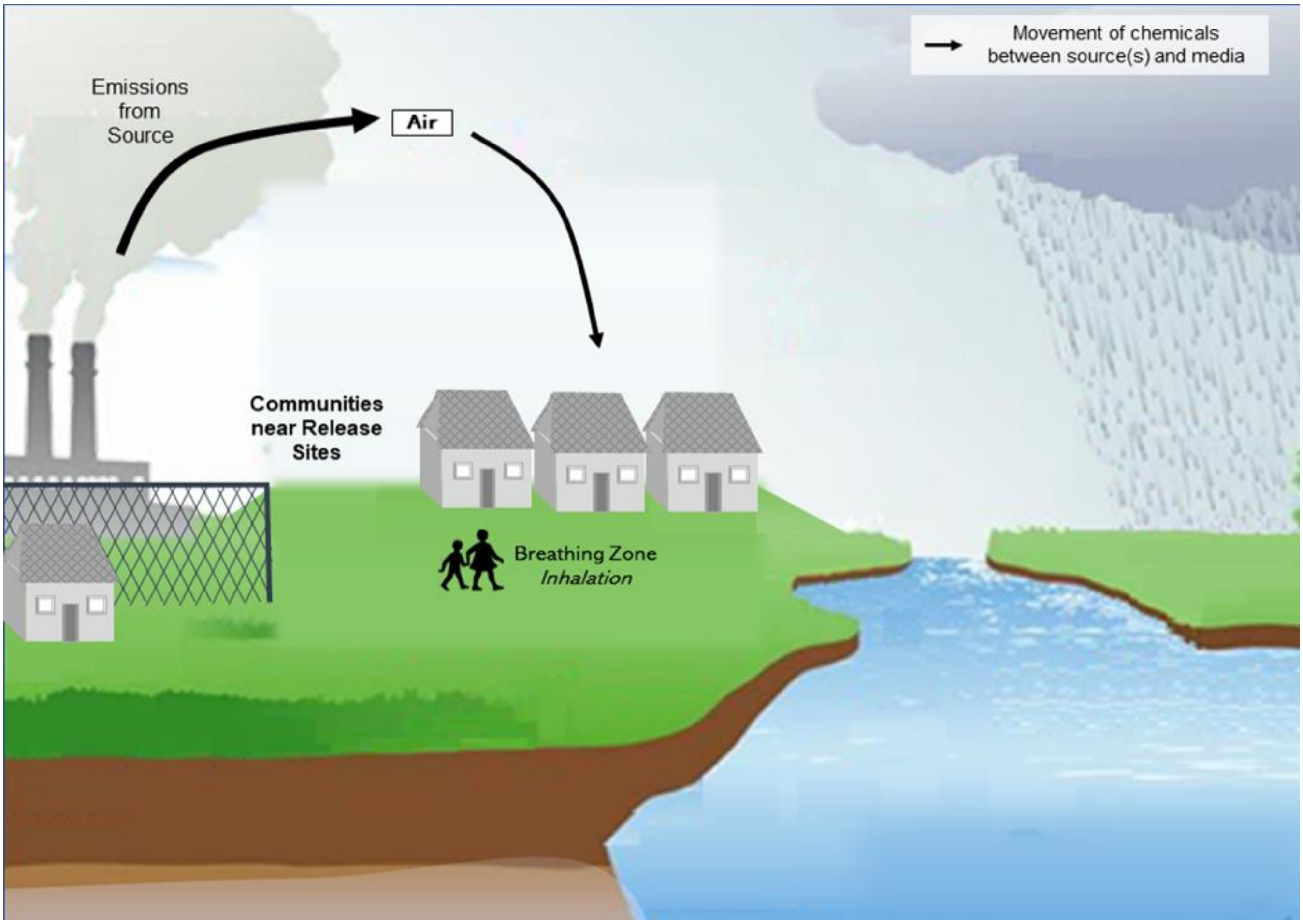



**Figure 1-2. Industrial Releases to the Environment and Pathways by Which Exposures of the General Population to Formaldehyde May Occur**

# 2 APPROACH AND METHODOLOGY

EPA considered both modeled and monitored formaldehyde concentrations in the ambient air for this draft ambient air exposure assessment. EPA estimated both short-term (daily-averaged) and long-term (annual-averaged) formaldehyde concentrations in ambient air for purposes of characterizing exposures in this ambient air exposure assessment and deriving acute and chronic risk estimates for comparison to human health hazard data in the *Draft Human Health Risk Assessment for Formaldehyde* (U.S. EPA, 2024e).

Given the complexities of the exposure assessment of formaldehyde in ambient air as previously described, multiple yet complimentary lines of evidence were considered to understand and contextualize the ambient air concentrations of formaldehyde resulting from TSCA COUs. These evidence streams are summarized below and detailed in the following subsections.

1. ***Estimated Formaldehyde Concentration from Formaldehyde TSCA COUs:*** This draft assessment uses EPA's Integrated Indoor/Outdoor Air Calculator Model (IIOAC)[1] to estimate formaldehyde concentrations near releasing facilities based on reported formaldehyde release data for TSCA COUs. In addition, EPA's Human Exposure Model (HEM v4.2) is used to estimate geographically specific formaldehyde concentrations based on site-specific reported formaldehyde release information for formaldehyde TSCA COUs.
2. ***Relative Contributions of Formaldehyde Concentrations in Ambient Air:*** This draft assessment uses the 2019 Air Toxics Screening Assessment Tool (AirToxScreen) to contextualize formaldehyde concentrations in ambient air resulting from all known sources of hazardous air pollutants (including formaldehyde). While there are multiple sources of formaldehyde to the ambient air, this ambient air exposure assessment includes consideration of several larger sources contributing formaldehyde to the ambient air including biogenic sources (natural production), secondary formation (formed through chemical transformations like breakdown of isoprene to formaldehyde), and point sources (stationary sources including industrial facilities with releases of formaldehyde that can be attributed to TSCA-COUs).
3. ***Measured Formaldehyde Concentrations:*** This assessment summarizes monitoring data from EPA's AMTIC (U.S. EPA, 2022a) to understand aggregate or total formaldehyde concentrations in ambient air and to characterize modeled concentrations of formaldehyde.

## 2.1 Modeling

As described above, EPA uses multiple approaches to understand formaldehyde concentrations as well as the relative contributions of those concentrations in ambient air.

### 2.1.1 Integrated Indoor/Outdoor Air Calculator Model (IIOAC)

EPA used the IIOAC Model to estimate daily-averaged and annual-averaged formaldehyde concentrations for a suite of exposure scenarios at three predefined distances from a facility releasing formaldehyde to the ambient air. EPA's modeling evaluated industrial releases of formaldehyde which are associated with TSCA COUs from two separate databases: Toxic Release Inventory (TRI) and National Emissions Inventory (NEI). While releases from both databases were evaluated, EPA compared releases and modeled concentrations from the two databases and found results were similar (*i.e.*, fell within the same estimated distribution range). Therefore, to provide a clearer picture of findings, EPA only presents results from the TRI dataset in this ambient air exposure assessment.

[1] For further information see the IIOAC homepage.

Nonetheless, results from all exposure scenarios and datasets evaluated are provided in the "Draft Ambient Air Exposure Assessment Results and Risk Calcs Supplement A."

IIOAC is a spreadsheet-based tool that estimates indoor and outdoor air concentrations using pre-run results from a suite of dispersion scenarios in a variety of meteorological and land-use settings within EPA's American Meteorological Society/Environmental Protection Agency Regulatory Model (AERMOD).[2] As such, IIOAC is limited by the parameterizations utilized for the pre-run scenarios within AERMOD (meteorologic data, stack heights, distances, exposed population, etc.). Additional information on IIOAC can be found in the user guide (U.S. EPA, 2019b).

#### 2.1.1.1 Environmental Releases Evaluated

As further discussed in *Draft Environmental Release Assessment for Formaldehyde* (U.S. EPA, 2024d), EPA developed the air release estimates included in this assessment using the 2016 through 2021 reporting years for TRI (U.S. EPA, 2022b) and 2017 NEI (U.S. EPA, 2019a). These databases were queried in 2022 and include the most recent 6 years available at that time in the TRI database and the most recent reporting year available for NEI (2017) and received a high-quality rating under EPA's systematic review process. NEI provides emission data at the process unit level and incorporates a larger database of site emission data. In total, EPA identified more than 150,000 separate emission data records (including unit-level estimates) for formaldehyde across both databases.

Due to the substantial available release information, EPA used site-level emission data and developed a new industrial-sector approach to categorize the release data. The Agency uses the primary North American Industry Classification System (NAICS) codes reported by the reporting facility to group facilities by their primary industry sector. By taking an industry sector approach in this TSCA ambient air exposure assessment, EPA can more directly map exposures to industrial TSCA COUs (U.S. EPA, 2024e). This, in turn, informed which TSCA COUs are contributing to human exposures to formaldehyde via the ambient air. From these industry sectors, EPA calculated from the distribution (non-zero) of site-specific releases from each database across all years (*e.g.*, 2015 to 2020 for TRI data and separately 2017 for NEI data): and extracted: (1) the maximum reported release, (2) the 95th percentile release, (3) the median release, and (4) the minimum release for each industrial sector. These industrial sectors are then used to characterize TSCA COUs. The emissions described herein were used as direct inputs to EPA's IIOAC Model to estimate ambient air concentrations of formaldehyde for each sector from each database.

The *Draft Environmental Release Assessment for Formaldehyde* (U.S. EPA, 2024d) and associated supplemental files provide detailed descriptions of the methods used to extract release data, calculate the emission statistics described above, and all releases considered for this ambient air exposure assessment. To summarize, the TRI database included 810 reporting facilities across the 6 years of reporting data queried. Fugitive releases ranged from $4.5\times10^{-5}$ kg/year (minimum) to 14,272 kg/year (maximum), while stack releases ranged from $7.1\times10^{-5}$ kg/year (minimum) to 158,757 kg/year (maximum). The NEI database included nearly 150,000 reported releases from the 2017 reporting year. Fugitive releases ranged from $1\times10^{-14}$ kg/year (minimum) to 138,205 kg/year (maximum), while stack releases ranged from $1\times10^{-11}$ kg/year (minimum) to 1,412,022 kg/year (maximum). Although the formaldehyde release amounts reported in both databases vary, the variability within an individual database is due to facility size, process rates, and several other factors, while variability across the two databases is due to differences in the criteria for reporting between the programs. Neither is reflective of uncertainty in the reported releases themselves.

[2] See AERMOD for further information.

#### 2.1.1.2 Exposure Scenario

IIOAC can model a variety of user defined input parameters and exposure scenarios, including varying release scenarios/patterns, release types, release durations, urban and rural settings (topography), and meteorological conditions. EPA modeled stack and fugitive releases separately, each using the default release parameters integrated within the IIOAC Model along with a user-defined length and width for fugitive releases as listed in Table 2-1

**Table 2-1. IIOAC Input Parameters for Stack and Fugitive Air Releases**

| Stack Release Parameters | Value |
|---|---|
| Stack height (m) | 10 |
| Stack diameter (m) | 2 |
| Exit velocity (m/sec) | 5 |
| Exit temperature (°K) | 300 |
| **Fugitive Release Parameters** | **Value** |
| Length (m) | 10 |
| Width (m) | 10 |
| Angle (degrees) | 0 |
| Release height (m) | 3.05 |

For this ambient air exposure assessment, EPA categorized reporting industrial facilities into 35 industry sectors (associated with 29 TSCA COUs) for the TRI dataset and 46 industry sectors for the NEI dataset. For each industry sector, results presented in this draft ambient air exposure assessment are based on

1. The 95th percentile release value reported by industry sector (mapped to respective TSCA COUs for the TRI dataset) assuming the total annual reported releases are continuous and equally distributed across all days of operation.
2. The 95th percentile modeled daily- and annual-averaged air concentrations from the IIOAC output files at a distance of 100 to 1,000 m from the release point to characterize exposures.
3. An operating scenario representing industrial facilities releasing formaldehyde to the ambient air operating 24 hours/day, 7 days/week, 365 days/year.

This exposure scenario was selected to represent a national level exposure estimate inclusive of sensitive and locally impacted populations. The 95th percentile release scenario and modeled concentrations were used to represent a more national level exposure estimate based on actual reported releases. The 100 to 1,000 m area distance is selected because it represents an area distance where a larger community may reside and be exposed rather than a smaller number of individuals who may reside at a given finite distance ring. The operating scenario used for this assessment was selected because it is representative of typical operating conditions under which industrial facilities involved with formaldehyde manufacturing, processing, etc. operate. While this scenario is representative of a high-end exposure scenario which is inclusive of more sensitive and locally impacted populations, it is not a maximum worst-case exposure scenario and thus considered more representative of an overall community or nationally representative exposure scenario.

The scenario further represents exposed residents experiencing a lifetime continuous exposure to the total formaldehyde release based on reasonably conservative assumptions about release and stack parameters based on two separate sets of sensitivity analyses described in Appendix B.1. Because of the exposure scenario used, the daily-averaged modeled concentration and annual-averaged modeled concentration output values from the IIOAC model are the same. Results from this exposure scenario are summarily presented independently in the “Draft Ambient Air Exposure Assessment Results and Risk Calcs Supplement B.”

In addition to the exposure scenario described above, EPA assessed a suite of additional exposure scenarios including the consideration of stack and fugitive releases, urban and rural topography, and a second industrial operating scenarios (250 days/year, 8 hours/day, 5 days/week) for both the TRI and NEI datasets. All exposure scenarios modeled used the south coastal meteorological data, which represents a more conservative meteorological region within the IIOAC model in relation to the other 13 regional meteorological stations included within the IIOAC model. In total, the IIOAC output results represent 32 exposure scenarios for each industry sector for both the TRI and NEI datasets. While not presented directly in this ambient air exposure assessment, all results for these additional exposure scenarios are included in the Draft Ambient Air Exposure Assessment Results and Risk Calcs Supplement A.

#### 2.1.1.3 IIOAC Model Output Values

The IIOAC Model provides multiple output values including daily-averaged and annual-averaged high-end (95th percentile) and mean air concentrations of formaldehyde at three pre-defined distances (100, 100 to 1,000, and 1,000 m) from releasing facilities. Daily-averaged concentrations are the average of all modeled hourly concentrations at each modeled exposure point for each day of operation modeled within IIOAC. For the two finite distances (100 and 1,000 m), IIOAC considers a polar grid of 16 modeled exposure points placed equidistance around each distance ring and 5 years of meteorological data. Since the exposure scenario modeled assumes 365 days of operation each year (366 for a leap year), this results in a total of 29,216 separate daily-averaged concentrations at each of the three distances evaluated. The 95th percentile daily-averaged concentration for the 100 and 1,000 meter distances therefore represents the 95th percentile daily-averaged concentration across the entire distribution of 29,216 daily-averages modeled within IIOAC. The 95$^{t}$h percentile generally represents a downwind concentration at a modeled exposure point where a resident lives downwind of the industrial release, taking into account a non, site-specific estimate for dispersion and dilution.

For the area distance of 100 to 1,000 m, IIOAC considers a cartesian grid of 456 receptors placed at 100 m intervals across the entire area distance. The daily-averaged concentrations then represent the arithmetic average of all daily-averaged concentrations across all 456 receptors for each day. Since IIOAC considers 5 years of meteorological data and our exposure scenario assumes 365 days of operation each year (366 for a leap year), this results in a total of 2,191 separate daily-averaged concentrations. The 95th percentile daily-averaged concentration for the 100 to 1,000 m area distance therefore represents the 95th percentile daily-averaged concentration across the entire distribution of 2,191 daily-averaged concentrations modeled within IIOAC.

Annual-averaged concentrations are the 5-year average of all modeled daily-averaged concentrations at each modeled exposure point within IIOAC. Since IIOAC considers 16 modeled exposure points and one 5-year average modeled concentration, 16 annual-averaged concentrations are produced at each distance evaluated for the 100 and 1,000 m finite distances. For the 100 to 1,000 m area distance, IIOAC considers the arithmetic average of all modeled daily-averaged concentrations and a single modeled exposure point, the 95th percentile annual-averaged concentration is the 95th percentile modeled concentration across the entire distribution of 2,191 modeled daily-averaged concentrations within IIOAC and generally represents a downwind concentration at a modeled exposure point where to which a resident living approximately downwind of the industrial release, taking into account a non, site-specific estimate for dispersion and dilution.

Based on the IIOAC users guide, the Fenceline average represents the daily-averaged and annual-averaged concentrations at 100 m distance from releasing facilities. The community average represents the daily-averaged and annual-averaged concentrations within the area distance of 100 to 1,000 m from releasing facilities. Lastly, the outer-boundary average represents the daily- and annual-averaged concentrations at 1,000 m distance from releasing facilities.

##### 2.1.1.3.1 Estimated Short-Term Formaldehyde Concentrations

EPA uses the downwind daily-averaged concentration (95th percentile) output values from the IIOAC model to evaluate short-term exposures to formaldehyde in this ambient air assessment. These downwind daily-averaged air concentrations are the basis for estimating acute exposures (acute concentrations) as described in Section 2.1.1.4.

##### 2.1.1.3.2 Estimated Long-Term Formaldehyde Concentrations

EPA uses the downwind annual-averaged air concentration (95th percentile) output values from the IIOAC model to evaluate long-term exposure to formaldehyde in this ambient air assessment. These downwind annual-averaged air concentrations are the basis for calculating chronic exposure concentrations (average daily concentrations [ADC] and lifetime average daily concentrations [LADC]) as described in Section 2.1.1.4.

#### 2.1.1.4 Exposure Calculations

To compare the modeled air concentrations from the IIOAC Model, outputs to the human health hazard data (U.S. EPA, 2024e) for purposes of deriving risk estimates, the modeled air concentration outputs from IIOAC need to be adjusted to reflect the exposure evaluated. Because available formaldehyde hazard data include acute, chronic, and cancer inhalation hazard values, EPA adjusted modeled air concentrations from IIOAC for both acute exposure concentrations (AC) and chronic (non-cancer [ADC] and cancer [LADC]) exposures as described in Sections 2.1.1.4.1 and 2.1.1.4.3.

##### 2.1.1.4.1 Acute Concentrations (AC)

The AC is defined as the daily air concentration adjusted for exposure duration and averaging time. For purposes of this ambient air exposure assessment, EPA uses the downwind daily-averaged air concentration output from IIOAC and adjusts it for a 24-hour exposure duration and a 24-hour averaging time to calculate the AC using Equation 2-1.

**Equation 2-1.**

$$AC = \frac{(C \times ED)}{AT}$$

Where:

| | | |
|---|---|---|
| $AC$ | = | Acute concentration (µg/m$^3$) |
| $C$ | = | Daily-averaged air concentration (µg/m$^3$) [IIOAC output] |
| $ED$ | = | Exposure duration (24 hours) |
| $AT$ | = | Averaging time (24 hours) |

The calculated AC is used for comparison with acute human hazard data[3] to calculate acute non-cancer risk estimates as described in the *Draft Human Health Risk Assessment for Formaldehyde* (U.S. EPA, 2024e).

##### 2.1.1.4.2 Average Daily Concentration (ADC)

The ADC is defined as the mean amount of an agent to which an individual is exposed on a daily basis often averaged over a definitive period of time. For purposes of this ambient air exposure assessment, EPA uses the downwind annual-averaged air concentration output from IIOAC and adjusts it for exposure time, exposure frequency, exposure duration, and averaging time associated with the exposure scenario to calculate the ADC using Equation 2-2.

**Equation 2-2.**

$$ADC = \frac{(C \times ET \times EF \times ED)}{AT}$$

Where:

$ADC$ = Average daily concentration (µg/m$^3$)
$C$ = Annual-averaged air concentration (µg/m$^3$)
$ET$ = Exposure time (24 h/day)
$EF$ = Exposure frequency (365 days/yr)
$ED$ = Exposure duration (1 yr)
$AT$ = Averaging Time, 1 yr × 365 days/yr × 24 hr/day

The calculated ADC is used for comparison with chronic human hazard data to calculate chronic non-cancer risk estimates as described in the *Draft Human Health Risk Assessment for Formaldehyde* (U.S. EPA, 2024e).

##### 2.1.1.4.3 Lifetime Daily Average Concentration (LADC)

The LADC is defined as the average daily concentration adjusted for an individuals expected residency time and average lifetime. For purposes of this ambient air exposure assessment, EPA uses the downwind annual-averaged air concentration output from IIOAC and adjusts it for exposure time, exposure frequency, exposure duration, and averaging time associated with the exposure scenario to calculate the LADC using Equation 2-3.

**Equation 2-3.**

$$LADC = \frac{(C \times ET \times EF \times ED)}{AT}$$

Where:

$LADC$ = Lifetime average daily concentration (µg/m$^3$)
$C$ = Annual-averaged air concentration (µg/m$^3$)
$ET$ = Exposure time (24 h/day)
$EF$ = Exposure frequency (365 days/yr)
$ED$ = Exposure duration (78-year resident); number of years resident assumed to reside in a residential location where exposure occurs
$AT$ = Averaging Time (78-year × 365 days/yr × 24 hr/day); number of years a receptor

[3] For context, while EPA uses the daily-averaged air concentration (24-hour average) to calculate the AC, the acute inhalation hazard value available for formaldehyde reflects a 15-minute peak exposure window.

is assumed to live (years) (from EPA's *Exposure Factors Handbook*) (U.S. EPA, 2011, 7485096)

The calculated LADC is used for comparison with cancer human hazard data to calculate cancer risk estimates as described in the *Draft Human Health Risk Assessment for Formaldehyde* (U.S. EPA, 2024e). The LADC is intended to represent the population within the community that experiences exposure over a full 78-year lifetime. Since formaldehyde is ubiquitous in the ambient air, EPA assumes a residency time of 78-years because even if a resident moves to another location, exposure to formaldehyde is expected to continuously occur.

### 2.1.2 Human Exposure Model (HEM)

EPA used the Human Exposure Model (HEM 4.2) to estimate formaldehyde concentrations on a site-specific basis at multiple distances from releasing facilities. HEM 4.2 has two components: (1) an atmospheric dispersion model, AERMOD, with included regional meteorological data; and (2) U.S. Census Bureau population data at the Census block level. The current HEM version utilizes 2020 Census data—including all 50 states, the District of Columbia, Puerto Rico, and the U.S. Virgin Islands. AERMOD estimates the magnitude and distribution of chemicals concentrations in ambient air in the vicinity of each releasing facility within a user-defined radial distances out to 50 km (about 30 miles). HEM also provides chemical concentrations in ambient air at the centroid of over 8 million census blocks across the United States. The model is also able to combine the estimated chemical's concentrations with hazard data to estimate cancer risks and noncancer hazards, and the population data to inform cancer incidence, and other risk measures. HEM automatically utilizes regional meteorological data for each release point, as well as local topographic information, to inform the release dispersion model. Refer to the HEM v4.2 User Guide for more details about these and other capabilities.

EPA evaluated site-specific releases from 810 TRI facilities directly reporting to TRI with Form R using HEM v4.2. EPA expects TRI emissions to be a sub-set of the larger NEI point source database and incorporate the larger release sites associated with TSCA COUs. Facilities must meet TRI reporting criteria for the number of full-time employees, specific NAICS codes and a chemical threshold of manufacturing and processing (>25,000 lb) or otherwise using formaldehyde (>10,000 lb). A bulk run of all facilities reporting air releases of formaldehyde to TRI was conducted to obtain aggregated location-specific air concentrations at a national scale. Stack and fugitive releases were modeled as distinct sources, each using a generic set of parameters (Table 2-2).

**Table 2-2. HEM Input Parameters for Stack and Fugitive Air Releases**

| Stack Release Parameters | Value |
|---|---|
| Stack height (m) | 10 |
| Stack diameter (m) | 2 |
| Exit velocity (m/sec) | 5 |
| Exit temperature (°K) | 300 |
| **Fugitive Release Parameters** | **Value** |
| Length (m) | 10 |
| Width (m) | 10 |

| Stack Release Parameters | Value |
|---|---|
| Angle (degrees) | 0 |
| Release height (m) | 3.05 |

The exposure scenario modeled with HEM is identical to the scenario modeled with IIOAC and assumed each facility operates 24 hours/day, 7 days/week and 365 days/year. However, for the HEM modeling, EPA utilized the site-specific maximum annual release reported to TRI from 2016 to 2021 for modeling.

HEM was run in a configuration with 11 rings of receptors placed at varying radial distances from the facility center: 10, 30, 60, and 100 m; 1, 2.5, 5, 10, 15, 25, and 50 km. Each ring is made up of 16 evenly spaced modeled exposure points. The HEM results were applied to consider concentrations at discrete distances, compare the impact of fugitive and stack releases at discrete distances, and to compare with IIOAC results. HEM calculates resulting annual average concentrations at each modeled exposure point among the rings, and then processes the results to aggregate concentrations at a Census block scale. The resulting output data is both tabular and geographic, capable of being mapped to physical locations. The model results associated with Census geometry can then be compared to populations and demographics associated with ranges of modeled ambient air conditions.

An additional analysis was conducted to evaluate the locations and populations where modeled facility releases resulted in concentrations above the 95th percentile biogenic formaldehyde concentrations in AirToxScreen modeling data (see Section 3.2). HEM calculates an aggregated risk value, called the maximum individual risk (MIR) for each Census block within the model domain. This risk value is calculated by multiplying the aggregate Census block concentration by the inhalation unit risk (IUR). An IUR of $6.4 \times 10^{-6}$ $m^3/\mu g$ was applied for formaldehyde in this modeling approach. Because this aggregated result across Census blocks is only presented as a risk quotient, the bulk MIR output by Census block was converted to concentrations by dividing by the IUR. The resulting aggregate mean annual concentrations were then mapped to visualize the spatial distribution of modeled concentrations. These aggregated concentrations are the summed stack and fugitive release concentrations, which can include the summation of multiple adjacent facilities, at specific locations. The site-specific concentration results represent the expected annual average ambient air concentration attributable from all modeled TRI releases of TSCA COUs, in some census blocks accounting for concentrations from multiple releasing facilities. The 2020 Census block population estimates included in the HEM Census database for modeled blocks were applied to evaluate the magnitude of the exposed population to various levels of concentrations.

### 2.1.3 Air Toxics Screening Assessment Tool (AirToxScreen)

AirToxScreen uses the chemical transport model (CMAQ) and the dispersion model (AERMOD) to estimate average annual outdoor ambient air concentrations across the United States. EPA used data from the 2019 AirToxScreen to contextualize the relative relationship of formaldehyde concentrations in ambient air resulting from all known source of hazardous air pollutants in ambient air.The tool uses release data from the NEI database. These AirToxScreen data allow EPA to differentiate among modeled emissions from various source categories (*e.g.*, point sources, biogenic sources, and secondary formation.

In this draft assessment, EPA used data from AirToxScreen to estimate a 95th percentile concentration of census tract concentrations of formaldehyde from all modeled biogenic sources. This estimate captures concentrations that are reasonably expected to occur without human contributions. EPA used this estimate for comparison to concentrations from other formaldehyde sources, including those that are expected from formaldehyde TSCA COUs. While this value is a percentile derived from the entirety of AirToxScreen data, it should be noted there may be locations where biogenic sources are not prevalent. As such, in some locations which may be highly industrialized (with industrial facilities releasing formaldehyde into the ambient air), this value may overestimate the true contribution of biogenic sources to the ambient concentrations of formaldehyde.

## 2.2 Monitoring

EPA identified and summarized monitoring data for formaldehyde from EPA's AMTIC (U.S. EPA, 2022a). EPA also identified and summarized monitoring data that were included in EPA's systematic review process (U.S. EPA, 2023).

### 2.2.1 Ambient Monitoring Technology Information Center (AMTIC)

AMTIC oversees ambient air quality monitoring data collected for high priority air pollutants overseen by the EPA Ambient Air Monitoring Group (AAMG). AMTIC maintains a database of submitted air quality monitoring data that meet the collection and quality assurance criteria set by AMTIC.

Ambient air concentration data was pulled in July of 2023 capturing monitoring data from 2015 to 2020. The formaldehyde AMTIC monitoring data used comprised 234,000 entries by 20 monitoring programs covering 36 states and 187 census tracts. Dates of sample collection ranged from January 2015 through December 2020. Samples were collected using the Fluxsense sampling system (83% of samples), DNPH silica cartridge (17%), or by pressurized canister (<1%). Samples collected using Flux sense had a 5-minute collection period while DNPH silica included 3-, 6-, 8-, and 24-hour collection durations. The resulting formaldehyde concentrations were converted to $\mu g/m^3$. Samples with concentrations below the reported limit of detection were filtered out (15 percent of samples). The remaining concentrations ranged from 0.0015 to 60.1 $\mu g/m^3$ with a 95th percentile ranging from 0.382 to 6.2 $\mu g/m^3$ and median concentration of 1.88 $\mu g/m^{3.}$

EPA used the AMTIC monitoring data for formaldehyde to assess the geographic distribution of formaldehyde in ambient air across the United States. These data allowed the EPA to identify the influence of specific facilities reporting the emissions of formaldehyde falling under the TSCA conditions of use on formaldehyde concentrations in air. The data were also used to identify regions with elevated ambient formaldehyde concentrations for more in-depth investigations. These data were also used to compare the results of the AirToxScreen and IIOAC models to field monitoring data for model validation and quality assurance.

# 3 RESULTS

## 3.1 Modeling

### 3.1.1 Integrated Indoor/Outdoor Air Calculator Model (IIOAC)

As noted in Section 2.1.1.2, EPA modeled a suite of exposure scenarios with IIOAC including releases from two separate datasets (TRI and NEI). These results are provided in the "Draft Ambient Air Exposure Assessment Results and Risk Calcs Supplement A" to this ambient air exposure assessment.

As described in Section 2.1.1.3, for this ambient air exposure assessment, EPA utilized the 95th percentile of annual release by industry sector reported to TRI, and the downwind modeled daily-averaged and annual-averaged air concentrations from the IIOAC output file at an area distance of 100 to 1,000 m from the releasing facility, to calculate exposure concentrations (see Section 2.1.1.4) for each industry sector. The industry sector results are then mapped to associated TSCA COUs for purposes of presenting the data in this ambient air exposure assessment. Use of these TRI-based results represent exposures resulting from actual reported releases tied to TSCA COUs.

Results for acute and chronic exposure concentrations across all industry sectors and associated COUs ranged from 0.0001 to 5.7 $\mu g/m^3$ for the exposure scenario described above. Results are presented for each TSCA COU in Figure 3-1; the distribution is shown in Figure 3-2. These results represent the highest exposure concentration across each industry sector associated with the respective formaldehyde TSCA COU. A Table summarizing all industry sectors, the associated mapping to TSCA COU, and the modeled exposure concentration for the scenario presented and summarized in this ambient air exposure assessment is provided in Appendix C.


**Figure 3-1. Exposure Concentrations by TSCA COU for the 95th Percentile Release Scenario and 95th Percentile Modeled Concentration between 100 and 1,000 m from Industrial Facilities Releasing Formaldehyde to the Ambient Air**

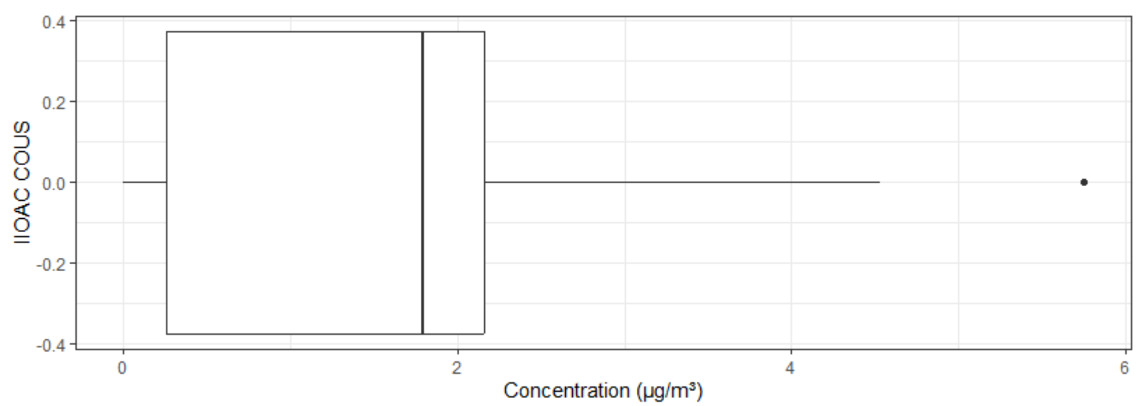



**Figure 3-2. Distribution of Exposure Concentrations Modeled by IIOAC**

A total of 810 TRI reporting facilities reported releases of formaldehyde to the ambient air. These facilities represented 35 industry sectors, which were evaluated in this ambient air exposure assessment and are associated with 29 formaldehyde TSCA COUs, as shown in the Figure 3-1. Across all 29 TSCA COUs evaluated, 19 (65.5 percent) have calculated exposure concentrations greater than 1 µg/m$^3$; 7

(24.1 percent) have calculated exposure concentrations between 0.1 and 1 µg/m$^3$; 2 (6.9 percent) have calculated exposure concentrations between 0.01 and 0.1 µg/m$^3$; and 1 has a calculated exposure concentration of 0.0001 µg/m$^3$.

Recognizing the ubiquity of formaldehyde in ambient air occurs from multiple sources including non-TSCA sources like biogenic/natural sources and secondary formation, EPA compared modeled concentrations from IIOAC to the 95th percentile concentration of 0.28 µg/m$^3$ attributable to biogenic sources (from the 2019 AirToxScreen data described in Sections 3.1.2). Across all 29 TSCA COUs evaluated, 21 TSCA COUs have IIOAC modeled concentrations (ranging from 0.3 to 5.75 µg/m$^3$) greater than the 95th percentile concentration attributable to biogenic sources. Twenty TSCA COUs have IIOAC modeled concentrations (ranging from 0.7 to 5.75 µg/m$^3$) greater than twenty percent of the 95th percentile concentration attributable to biogenic sources (0.34 µg/m$^3$). Eighteen TSCA COUs have IIOAC modeled concentrations (ranging from 1.65 to 5.75 µg/m$^3$) greater than five times the 95th percentile concentration attributable to biogenic sources (1.4 µg/m$^3$). Seven TSCA COUs have IIOAC modeled concentrations (ranging from 3.4 to 5.75 µg/m$^3$) greater than ten times the 95th percentile concentration attributable to biogenic sources (2.8 µg/m$^3$). Eight TSCA COUs have IIOAC modeled concentrations less than the 95th percentile concentration attributable to biogenic sources.

The following three industry sectors had the highest calculated exposure concentrations relative to the other calculated exposure concentrations evaluated:

- Non-metallic Mineral Product Manufacturing (5.7 µg/m$^3$);
- Textiles, Apparel, and Leather Product Manufacturing (4.5 µg/m$^3$); and
- Transportation Equipment Manufacturing (3.4 µg/m$^3$).

Together, these three industry sectors are associated with seven formaldehyde TSCA COUs:

- Processing – incorporation into an article-adhesives and sealant chemicals (5.7 µg/m$^3$);
- Processing as a reactant – intermediate (5.7 µg/m$^3$);
- Processing – incorporation into a formulation, mixture, or reaction product-intermediate (5.7 µg/m$^3$);
- Processing – incorporation into article-finishing agent (4.5 µg/m$^3$);
- Processing – incorporation into a formulation, mixture, or reaction product-bleaching agents (4.5 µg/m$^3$);
- Processing – incorporation into an article-paint additives and coating additives (3.4 µg/m$^3$); and
- Industrial use – chemical substances in industrial products-paints and coatings; adhesives and sealants, lubricants (3.4 µg/m$^3$).

Although a single industry sector can represent multiple formaldehyde TSCA COUs (as shown above where Non-metallic Mineral Product Manufacturing is associated with the first three TSCA COUs), it is also possible that multiple industry sectors are associated with an individual formaldehyde TSCA COU. Therefore, in addition to the maximum values plotted in Figure 3-1, there may be additional exposure estimates for each formaldehyde TSCA COU that better represent individual industry processes. For example, the exposure concentration for the TSCA COU "Industrial use – non-incorporative activities – oxidizing/reducing agent; processing aids, not otherwise listed" is plotted as 0.20 µg/m$^3$; however, the exposure concentrations for this COU ranged from 0.09 to 0.2 µg/m$^3$ across four industry sectors as listed below:

- Organic Fiber Manufacturing (0.2 µg/m$^3$);
- Computer and Electronic Part Manufacturing (0.09 µg/m$^3$);
- Fabricated Metal Product Manufacturing (0.19 µg/m$^3$); and

- Primary Metal Manufacturing (0.12 µg/m$^3$).

A table of results for all the industry sectors and the associated industrial TSCA COUs is provided in Appendix C for reference. Some TSCA industrial COUs were associated with industry sectors not captured within the TRI database, EPA used ambient air results from the NEI data in those cases. These results are provided in the "Draft Ambient Air Exposure Assessment Results and Risk Calcs Supplement A."

### 3.1.2 AirToxScreen

EPA used 2019 AirToxScreen to understand the relative formaldehyde concentration contributions of non-TSCA sources compared to TSCA-COUs. These data are shown in Figure 3-3, which presents the range of concentrations across all sources of formaldehyde, as well as contributions from biogenic sources, secondary sources, and point sources. Results from the 2019 AirToxScreen national-scale analysis are attributable to 38 different emission source categories (including point source, secondary production, biogenic, on/off-road, etc.).

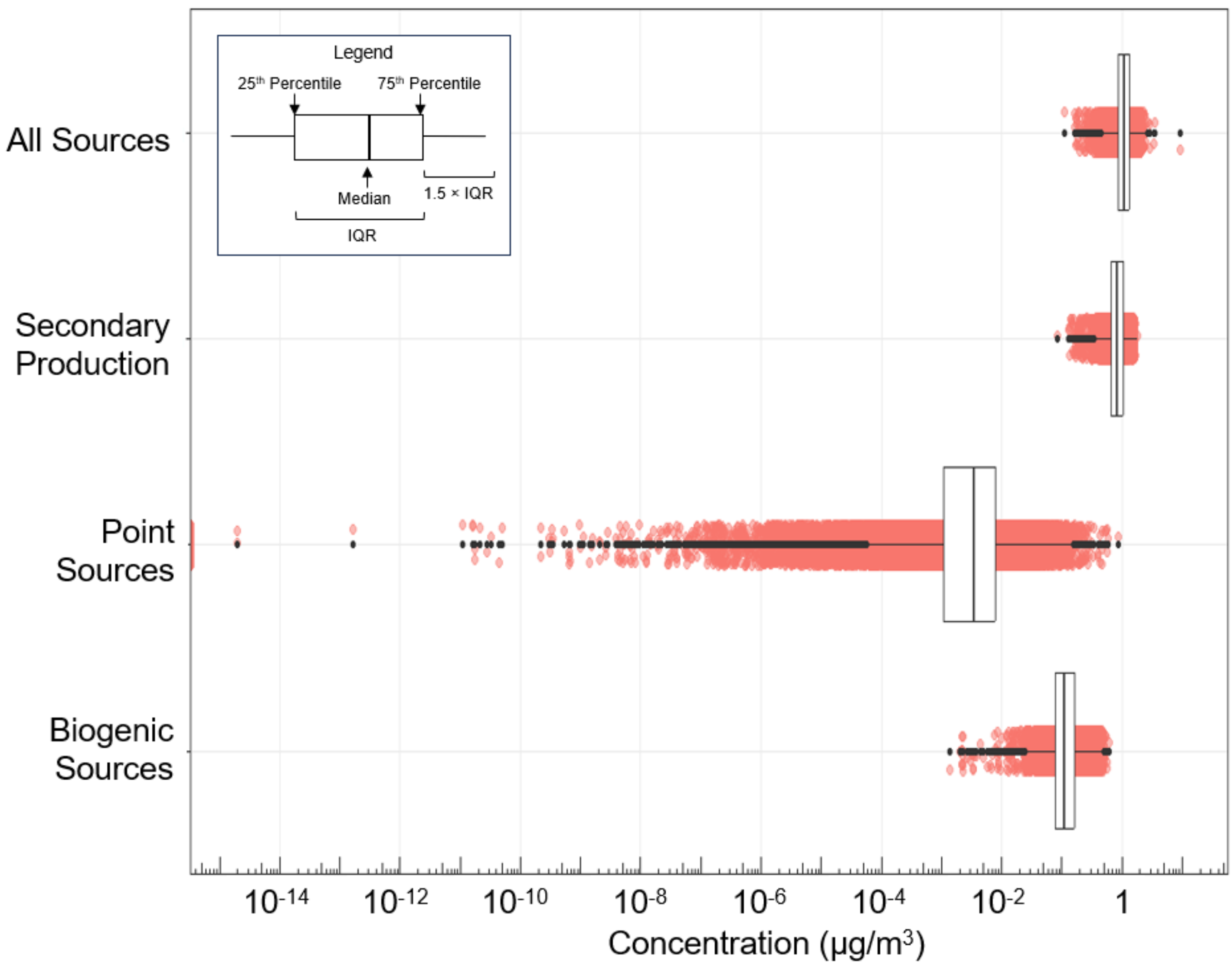



**Figure 3-3. 2019 AirToxScreen Results**

Secondary production of formaldehyde is the largest contributor of formaldehyde to ambient air concentrations ranging from 0.085 to 1.8 µg/m$^3$ (mean ± 1 SD: 0.86 ± 0.25 µg/m$^3$). Secondary production is the atmospheric formation of formaldehyde from naturally and manmade compounds. This can include the degradation of isoprene (a compound naturally produced by animals and plants) to formaldehyde. AirToxScreen is not able to source apportion relative contributions from different secondary sources. Biogenic sources also significantly contribute to total concentration with a range of 0.0014 to 0.67 μg/m$^3$ (mean ± 1 SD: 0.13 ± 0.072 μg/m$^3$) and a 95th percentile calculated concentration of 0.28 μg/m$^3$. Biogenic sources are those emissions from trees, plants, and soil microbes. Notably, these data do not show any TSCA-specific data but do show relative distributions of various sources; however, the point sources estimates are expected to include contributions from TSCA COUs. Point sources contributions to total formaldehyde concentrations range from 0.0 to 0.88 μg/m$^3$ (mean ± 1SD: 0.0070 ± 0.014 μg/m$^3$). Although Figure 3-3 does not include AirToxScreen data for on-road sources, near-road sources, off-road sources, wildfire sources, etc., these sources would be captured in the results shown for all sources.

### 3.1.3 Human Exposure Model (HEM)

Concentrations resulting from TRI facility releases modeled by HEM were aggregated and summarized at the Census block level, allowing visualization of the geographic distribution of results (Figure 3-4). Resulting concentrations ranged from 0 to 8.9 μg/m$^3$, with the greatest concentrations nearby industrial facilities. Census blocks with modeled total concentrations below a concentration of 0.28 μg/m$^3$ associated with biogenic/natural sources of formaldehyde are presented in gray. Blue dots show Census blocks with concentrations ranging from 1 to 5 times 0.28 μg/m$^3$, purple dots show concentrations from 5 to 10 times 0.28 μg/m$^3$, and pink dots show values greater than 10 times 0.28 μg/m$^3$. Across the nation, a total population of 105,463 people (based on 2020 Census data) live in the Census blocks shown with ambient are concentrations above 0.28 μg/m$^3$.

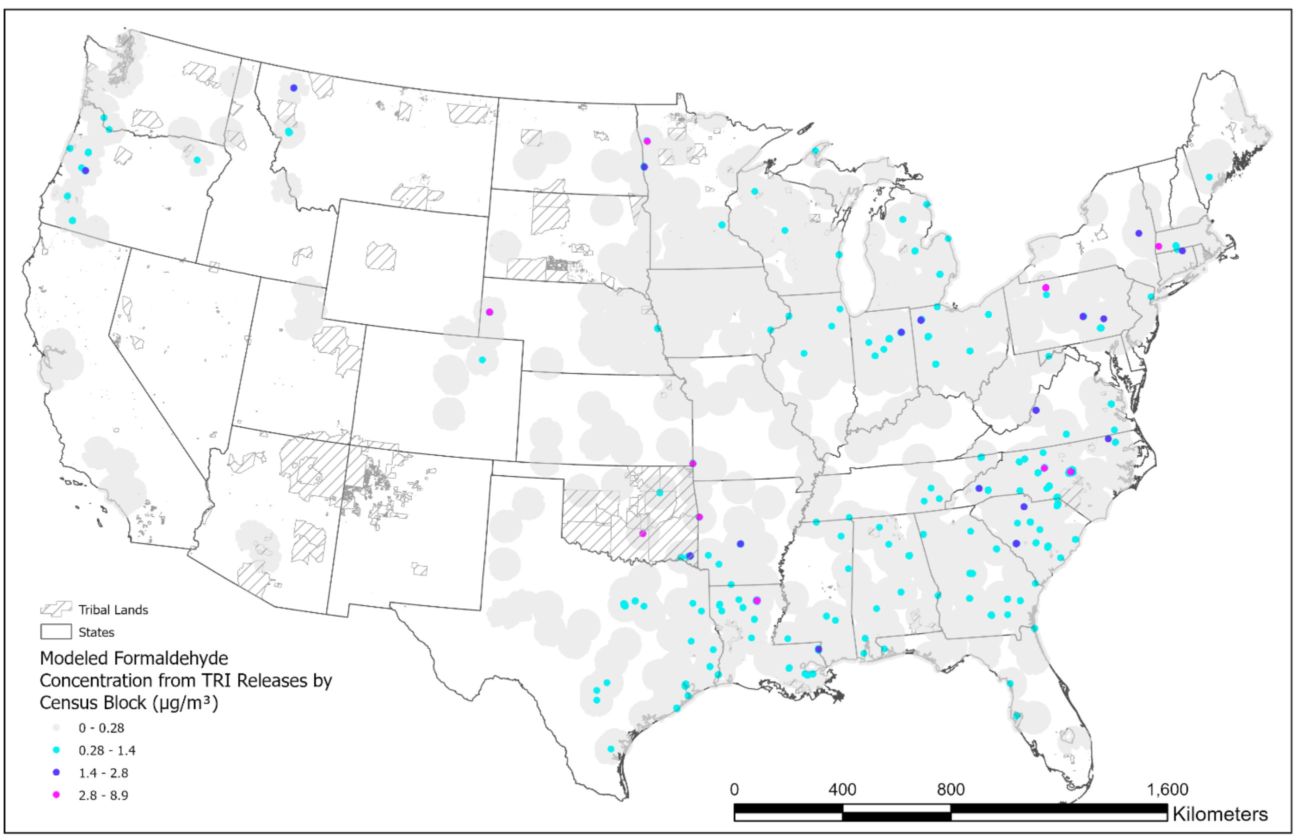


**Figure 3-4. Map of Contiguous United States with HEM Model Results for TRI Releases Aggregated and Summarized by Census Block**

Elevated ambient air concentrations of formaldehyde from industrial releases appear most densely concentrated in the southeastern United States. Census blocks with elevated concentrations are found throughout the nation, with some regions showing fewer overall TRI facilities, and fewer releases resulting in elevated air concentrations.

Patterns in the relative contribution of stack and fugitive releases, and the distribution of results at varying radial distances from the releasing facility were examined (Figure 3-5). The concentration results across all facilities and COUs were pooled for this analysis to visualize general trends across all TRI facilities reporting formaldehyde releases. Each vertical bar and maximum line indicate the shape of the distribution of concentrations by release type for individual facilities. These results indicate that concentrations resulting from fugitive emissions are greater than those from stack emissions closer to the releasing facility, but concentrations from stack emissions tend to become greater at further distances. As many facilities report only a single release type (either fugitive or stack), the total concentration distributions represent a greater number of facilities than the corresponding fugitive and stack distributions and the median values tend to fall somewhere between the fugitive and stack values. Total modeled concentrations tend to reach their maximum within 1,000 m of a facility. Values represented in this analysis are directly modeled at the radial receptor points, rather than Census block centroids, and can therefore be located much closer to the releasing facility and represent much higher concentrations. These points are not associated with population estimates, and in some cases the modeled distances may still be within a facility property boundary.

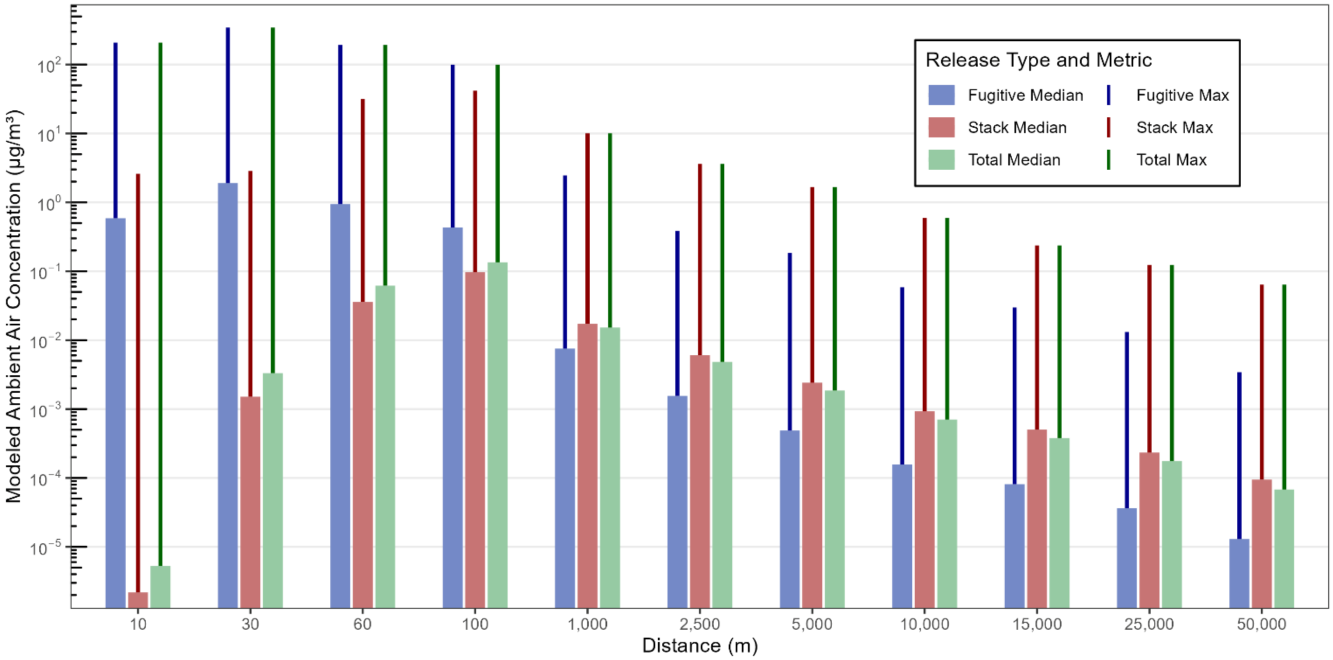



**Figure 3-5. Median and Maximum Downwind Concentrations (Fugitive, Stack, and Total Emissions) across the 11 Discrete Distance Rings Modeled in HEM**

## 3.2 Monitoring

### 3.2.1 Ambient Monitoring Technology Information Center (AMTIC)

EPA considered a total of 306,529 samples from the AMTIC database (U.S. EPA, 2024a). The Agency computed summary statistics for all samples, as well as samples by state, census tract, monitoring site, monitoring site and year, and monitoring site and year and quarter. Sample collection durations ranged from 5 minutes to 24 hours using one of five approved collection methods. No data was omitted based on collection duration or method. Entries with concentrations reported below the self-reported limit of detection or contained invalid concentration data (*i.e.*, NULL, NA) were omitted from the final data set. Formaldehyde concentrations were converted to µg/m$^3$ for consistency across sample analysis methods but were not otherwise normalized by sample collection duration or methodology. EPA used the overall statistics across all samples to characterize exposures, derive risk estimates, and characterize risks to the general population (see Table 3-1). Histograms and summary statistics of annual data are shown in Figure 3-6.

**Table 3-1. Overall Monitored Method Detection Limits (MDL) of Formaldehyde from AMTIC Dataset (2015 to 2020)**

| Monitored Concentration Statistics (µg/m³) | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Group** | **Entry Count** | **Minimum** | **Non-zero Minimum** | **Median** | **Mean** | **Standard Deviation** | **Maximum** |
| Grouped by: all samples | | | | | | | |
| All | 233,961 | 0 | 0.00012 | 1.6 | 2.1 | 2.2 | 60 |
| Grouped by: collection duration description | | | | | | | |
| 12 Hours | 340 | 0.50 | 0.50 | 3.6 | 3.8 | 1.7 | 9.0 |
| 24 Hours | 39,288 | 0 | 0.0015 | 2.3 | 2.8 | 2.1 | 60 |
| 3 Hours | 5,870 | 0 | 0.0083 | 3.7 | 4.4 | 3.3 | 45 |
| 5 Minutes | 184,307 | 0 | 0.00012 | 1.3 | 1.8 | 2.0 | 49 |
| 6 Hours | 1 | 3.4 | 3.4 | 3.4 | 3.4 | – | 3.4 |
| 8 Hours | 4,155 | 0.0055 | 0.0055 | 3.6 | 4.1 | 2.8 | 24 |
| Grouped by: collection method description | | | | | | | |
| 6-L Pressurized Canister | 67 | 3.5 | 3.5 | 11 | 14 | 7.9 | 42 |
| Cartridge Dnph On Silica, Heated O3 Denuder | 6,671 | 0 | 0.020 | 2.3 | 2.7 | 1.8 | 46 |
| Cartridge-Dnph-On-Silica | 10,115 | 0 | 0.024 | 3.1 | 3.7 | 2.6 | 60 |
| Fluxsense | 184,307 | 0 | 0.00012 | 1.3 | 1.8 | 2.0 | 49 |
| Silica-Dnph-Cart-Ki O3 Scrub | 32,801 | 0 | 0.0015 | 2.5 | 3.0 | 2.3 | 45 |

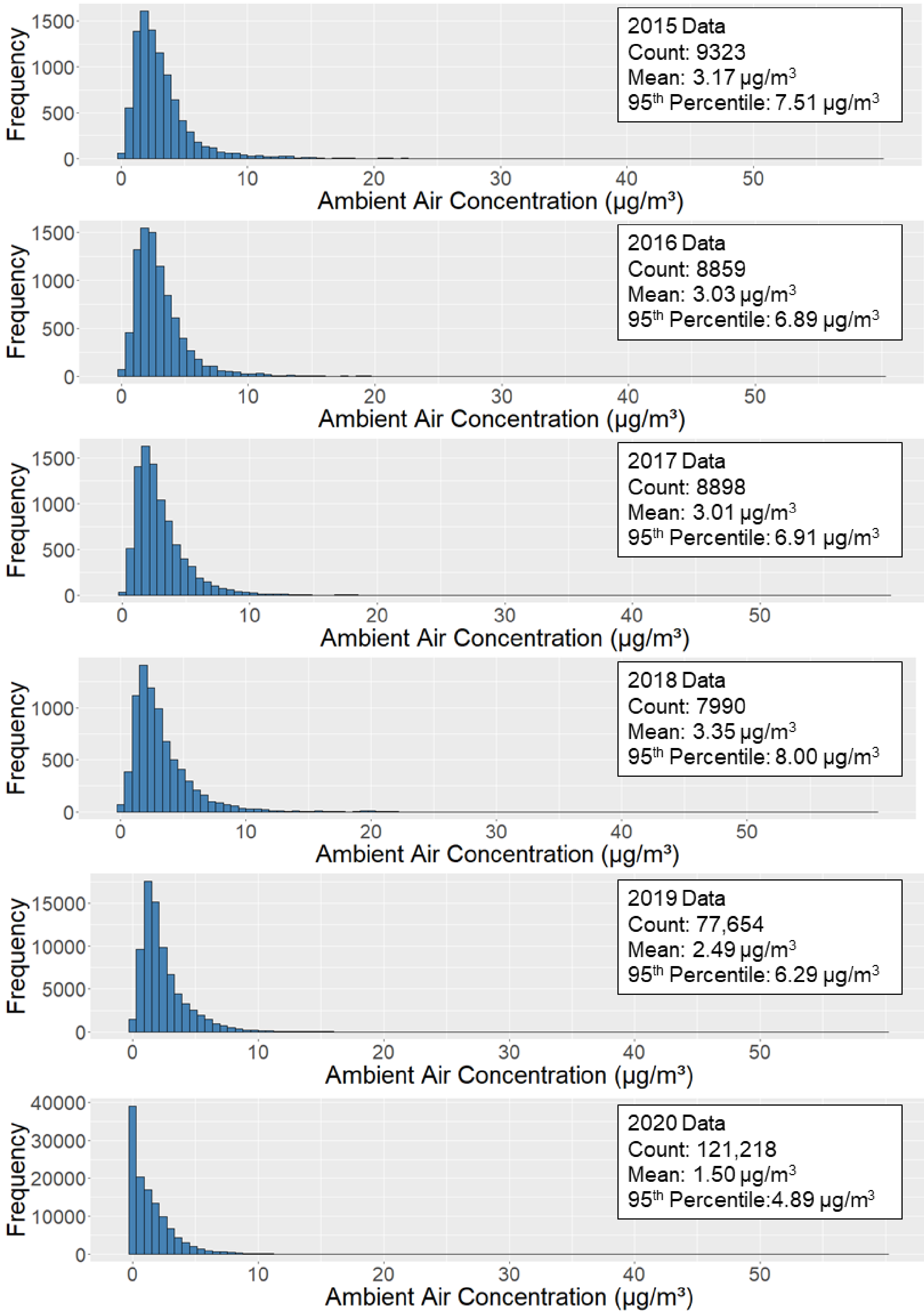



**Figure 3-6. Histograms of Ambient Air Concentrations (μg/m$^3$) of Formaldehyde across Contiguous United States from 2015 to 2020**

From the overall AMTIC dataset, samples were collected from June 01, 2015, through December 31, 2020. Within this dataset, EPA found 24 percent of entries lacked standardized concentration data. EPA also found 15 percent of samples fall below the standard method detection limit (MDL) with a mean standardized formaldehyde concentration of 2.1 ± 2.2 μg/m$^3$. The overall monitoring dataset had concentrations ranging from 0 to 60 μg/m$^3$ with a median value of 1.6 μg/m$^3$. Figure 3-7 shows the location and relative concentration of formaldehyde at each formaldehyde monitoring site.

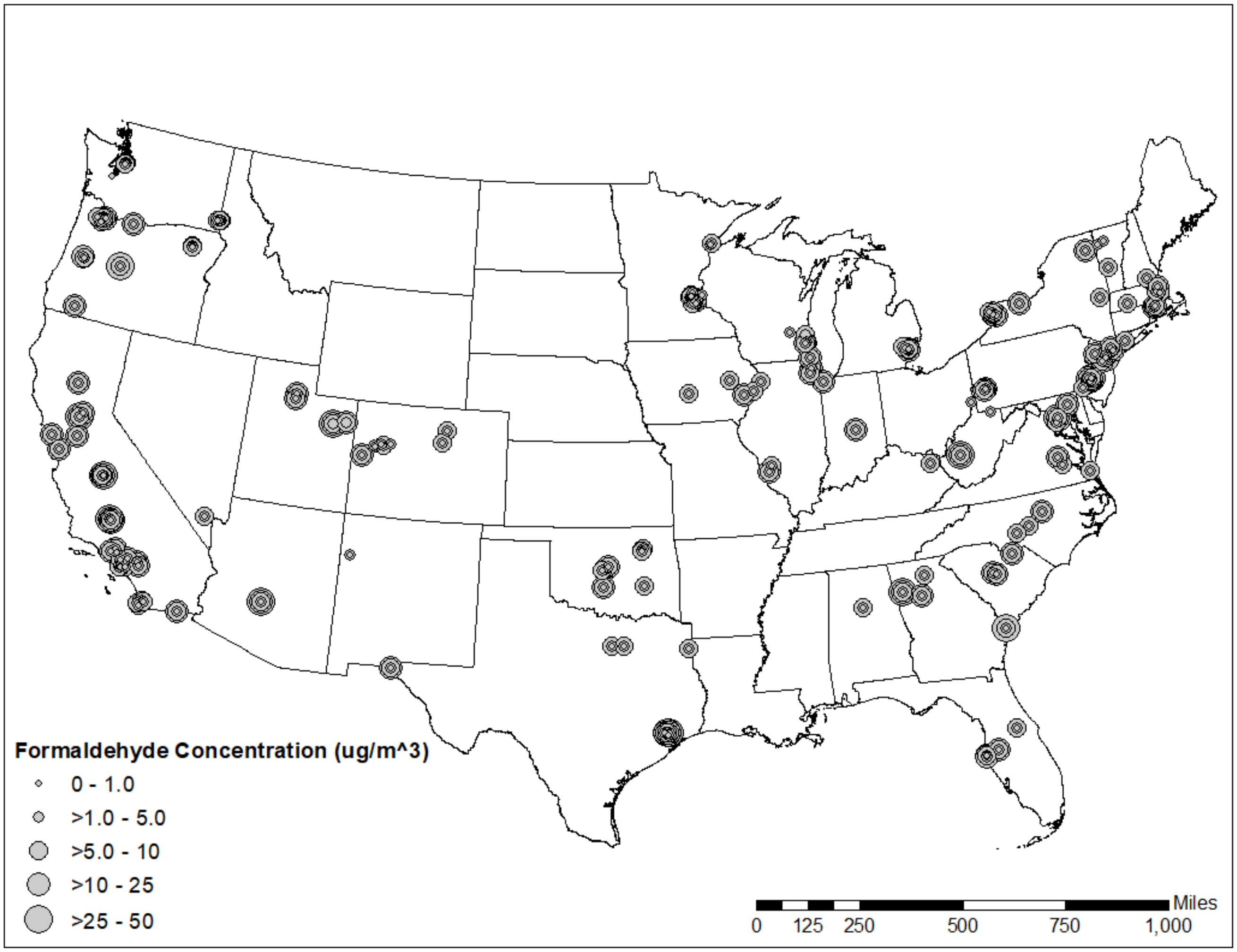



**Figure 3-7. Map of Monitoring Sites for Formaldehyde across the Contiguous United States**

## 3.3 Data Integration of Various Sources of Formaldehyde

Monitoring data from AMTIC, modeled exposures calculated from IIOAC by COU, and modeled data from AirToxScreen were compiled to understand how TSCA COUs fit into the broader context of available information on formaldehyde. Figure 3-8 shows the distributions of data from these datasets. This image shows that the calculated concentrations of formaldehyde resulting from formaldehyde TSCA COUs falls within the range of concentrations that are expected to occur from naturally occuring sources including biogenic and secondary production of formaldehyde. Furthermore, modeled exposures calculated from IIOAC fall within the range of measured concentration values.

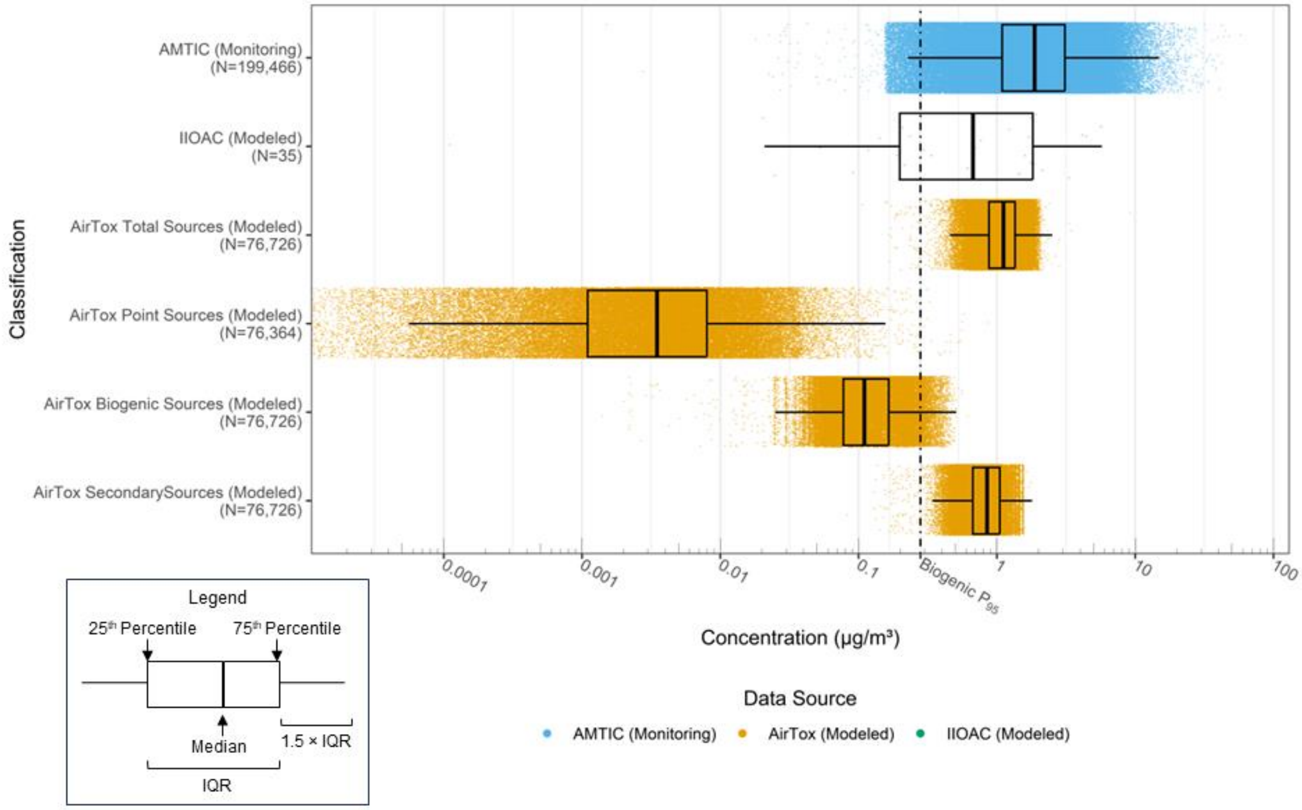



**Figure 3-8. Distributions of AMTIC Monitoring Data, IIOAC Modeled Data, and AirToxScreen Modeled Data**

EPA recognizes that the different model estimates are not directly comparable. For example, the IIOAC results represent a downwind annual average concentration between 100 to 1,000 m from the release point. In contrast, AirToxScreen concentrations represent annual average concentrations averaged across census tracts. Only point source data may include concentrations resulting from formaldehyde TSCA COUs, but again AirToxScreen point source data is averaged across census tracts and not directly comparable to the IIOAC results. Given the spatial scale difference, it is expected that AirToxScreen results could underestimate concentrations on a smaller scale (*i.e.*, near facilities) or have lower concentration estimates than IIOAC because the IIOAC estimates represent distances closer to the release point. None-the-less, considering these multiple data sources, even across mixed temporal data, can help contextualize contributions of formaldehyde concentrations from TSCA COUs relative to other non-TSCA sources.

Furthermore, the AMTIC data represent a range of formaldehyde samples collected at various locations and represent a total exposure from all formaldehyde sources and cannot be attributed to TSCA COUs. Additionally, collection durations for AMTIC are much shorter than a year (5 minutes to 24 hours). Similarly, sampling method may significantly affect concentration (see Figure 3-9). Samples collected using 6-liter pressurized canisters tend to be higher than all other sampling methods.

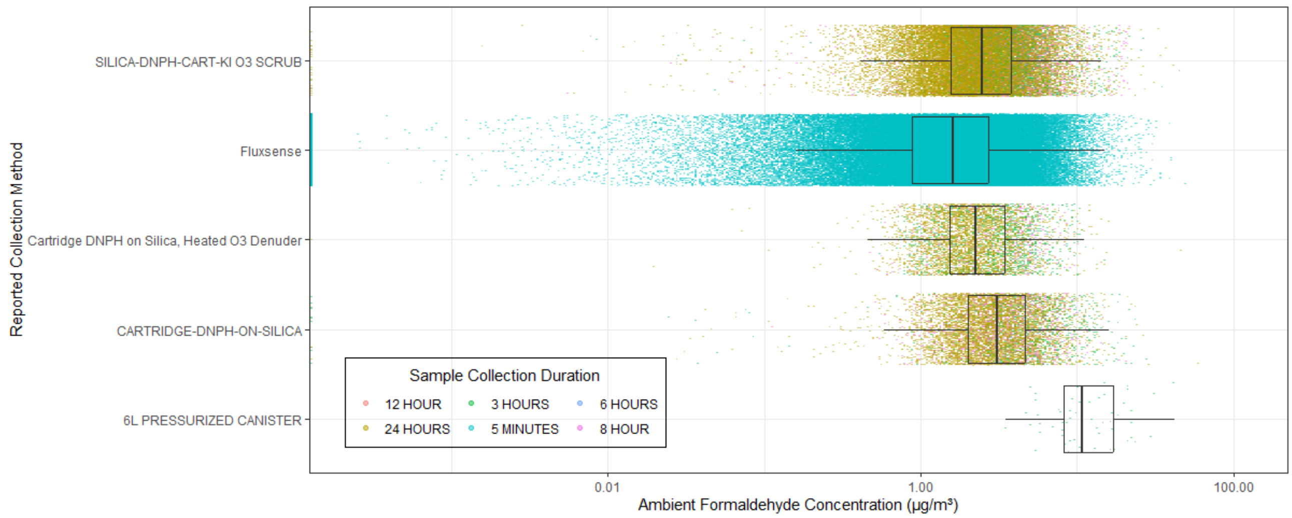



**Figure 3-9. Ambient Air Formaldehyde Concentrations by Sample Duration and Sampling Technique**

Taken together, these data and results show modeled formaldehyde concentrations using IIOAC are generally in the same range as monitored formaldehyde concentrations in ambient air as well as contributions of formaldehyde to the ambient air from biogenic and secondary production. However, to characterize exposures associated with TSCA COUs it is necessary to recognize modeled concentrations may contribute to some part of the total concentrations captured by monitored data but are independent and exclusive from non-TSCA sources. Therefore, while modeled concentrations are in the same range as biogenic and secondary formation, the exposures resulting from TSCA COUs are representative of actual exposures from TSCA COUs alone, and not a subset of the biogenic or secondary formation data. To contextualize this, actual exposures occurring at a given location from both TSCA COUs and biogenic or secondary formation would be an additive exposure receiving the full contribution of formaldehyde from TSCA COUs as well as the full contribution of formaldehyde from biogenic sources.

# 4 STRENGTHS AND LIMITATIONS, ASSUMPTIONS, UNCERTAINTY, AND CONFIDENCE STATEMENT

## 4.1 Integrated Indoor/Outdoor Air Calculator Model (IIOAC)

The approach and methodology presented in this ambient air exposure assessment replicates previously peer reviewed approaches and methods, and incorporates several additional components recommended by peer reviewers to provide a more comprehensive exposure assessment. As such, EPA has high confidence in the IIOAC modeling and use of the results to characterize exposures and derive risk estimates for individuals living nearby releasing facilities.

Strengths of this ambient air exposure assessment include use of environmental release data from multiple databases across multiple years which are reported by industry, as required by statute, and undergoes repeatable quality assurance quality control reviews (U.S. EPA, 2024d). These release data are used as direct inputs to EPA's peer reviewed IIOAC to estimate concentrations at several distances from releasing facilities where individuals reside for many years. Additionally, all reported releases within each database are categorized by industry sector based on NAICS codes reported to the respective database allowing for a more direct association of exposures from industrial releases to TSCA COUs.

Use of additional peer-reviewed models (AirToxScreen and HEM), along with monitoring data (AMTIC) to contextualize ambient air concentrations of formaldehyde, present a consistent picture of exposures when compared to IIOAC results. They also provide added strength and confidence to the approaches and methods used in this draft ambient air exposure assessment.

Limitations of the approaches and methods used for modeling are generally associated with overall limitations of IIOAC. For example, IIOAC modeling is based on pre-run scenarios within AERMOD. As such, default input parameters for IIOAC are confined to those input parameters utilized for those pre-run AERMOD scenarios and cannot be changed, including default stack parameters, 2011 to 2015 meteorological data, and the lack of site-specific information like building dimensions, stack heights, elevation, and land use.

However, to alleviate concerns around these limitations and impacts on the overall confidence in the IIOAC modeled results, EPA conducted a series of sensitivity analyses to address some of the concerns. These sensitivity analyses are described in Appendix B.1 and provide a brief discussion of EPA's findings. Generally, the Agency found that although the limitations identified above have some impact on overall modeled results, the impact is not substantial in terms of overall modeled concentrations and do not change the overall characterization of exposures from industrial releases. Additionally, EPA found that while exposure scenarios and default stack parameters may represent a more conservative estimate of exposures to individuals living near releasing facilities, the findings are not overly conservative and generally represent a more health protective, but still realistic exposure.

## 4.2 AirToxScreen

AirToxScreen has been previously reviewed by EPA's Science Advisory Board (SAB). As, such EPA has high confidence in the modeled data. Similarly, these data are based on the NEI, which has been rated as a high-quality data source according to the *Draft Systematic Review Protocol Supporting TSCA Risk Evaluations for Chemical Substances* (U.S. EPA, 2021b).

The strengths of these data are that they show the various potential sources of formaldehyde in the conterminous United States. The limitations of these data are that they cannot be directly compared to TSCA COUs as they are not representative of facility-scale releases and subsequent ambient air concentrations. A key assumption of AirToxScreen is that it cannot provide a precise exposure and risk for a specific person. Instead, these results are best applied to understand differences in potential sources of formaldehyde. Thus, using summary statistics is an appropriate application.

## 4.3 Human Exposure Model (HEM)

The HEM 4.2 dispersion calculations are handled by EPA's AERMOD, which has undergone review and evaluation as part of the regulatory models process. A description of its promulgation as a regulatory model is included in "Appendix W" to 40 CFR Part 51. Due to its regular application in assessments to inform regulatory decisions, EPA has high confidence in the modeling results. A limitation of the model is the exclusion of photodegradation processes, which may be relevant to ambient air concentrations of formaldehyde. Without modeled decreases in concentration due to photodegradation, the results presented in this document are more conservative (protective).

## 4.4 Ambient Monitoring Technology Information Center (AMTIC) Dataset

AMTIC data has been previously reviewed and verified by the AMTICs Ambient Air Monitoring Group, which has taken various quality assurance steps to ensure data quality and has been certified in accordance to 40 CFR Part 58.15. EPA has high confidence in the AMTIC ambient air data set (U.S. EPA, 2022a), which received a high-quality rating from EPA's systematic review process. (U.S. EPA, 2021a).

The primary limitations of the AMTIC data are as presented in this ambient air exposure assessment, the data has not been annualized and therefore represents a diverse collection of sampling durations (none of which are annual averages) that are not directly comparable to either IIOAC or AirToxScreen data. Additionally, because monitored data represents a total aggregate concentration from all sources of formaldehyde contributing to ambient air concentrations, the AMTIC data cannot be associated with TSCA COUs for purposes of characterizing exposures from TSCA COUS.

## 4.5 Weight of Scientific Evidence

EPA has high confidence in the overall characterization of exposures for this ambient air exposure assessment as it relies upon direct reported releases from databases that received a high-quality rating from EPA's systematic review process and peer-reviewed models to derive exposure concentrations at distances from releasing facilities where individuals reside for many years. Use of additional peer-reviewed models (AirToxScreen and HEM) along with monitoring data (AMTIC) to further contextualize ambient air concentrations of formaldehyde, which also present a consistent picture of exposures when compared to IIOAC results, provide added strength and confidence to the approaches and methods used in this draft ambient air exposure assessment. This confidence statement is consistent with the *Draft Systematic Review Protocol Supporting TSCA Risk Evaluations for Chemical Substances* (U.S. EPA, 2021b).

The use of release data from multiple databases across multiple years of data provide a more comprehensive ambient air exposure assessment and ensure higher release years are not missed. Furthermore, use of actual reported releases minimizes uncertainties around estimated releases using theoretical distributions and provides added confidence that modeled concentrations and exposures are real and not hypothetical.

Additionally, while the approaches and methods used in this ambient air exposure assessment use more conservative assumptions and default model inputs may be viewed as a limitation and uncertainty, sensitivity analyses around several of these inputs found that while they have some impact on overall modeled results, the impact is (1) not substantial in terms of overall modeled concentrations, and (2) does not change the overall characterization of exposures from industrial releases. Additionally, EPA found that although exposure scenarios and default stack parameters may represent a more conservative estimate of exposures to individuals living near releasing facilities, the findings are not overly conservative and generally represent a more health protective, yet still realistic exposure.

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# APPENDICES

## Appendix A LIST OF SUPPLEMENTAL DOCUMENTS

Draft IIOAC Assessment Results and Risk Calcs for Formaldehyde Supplement A

Draft IIOAC Assessment Results and Risk Calcs for Formaldehyde Supplement B

# Appendix B DATA SOURCES AND INFORMATION

## B.1 Sensitivity Analyses Conducted to Inform Modeling for Formaldehyde

EPA conducted a series of model sensitivity analyses to identify some key input parameters to be considered for this ambient air exposure assessment along with impact of select parameters on the overall modeling results.

***Compare IIOAC to HEM***

Both IIOAC and HEM rely upon EPA's AERMOD as the base model from which estimated ambient air concentrations are derived. Although both IIOAC and HEM use the same underlying model, slight differences in inputs, capabilities, and outputs warrant a sensitivity analysis to determine overall comparability of the modeled results. EPA conducted a sensitivity analysis using both models and identical input and exposure scenarios and found estimated concentrations, associated exposures, and associated risks were generally well within a magnitude of each other across multiple chemicals.

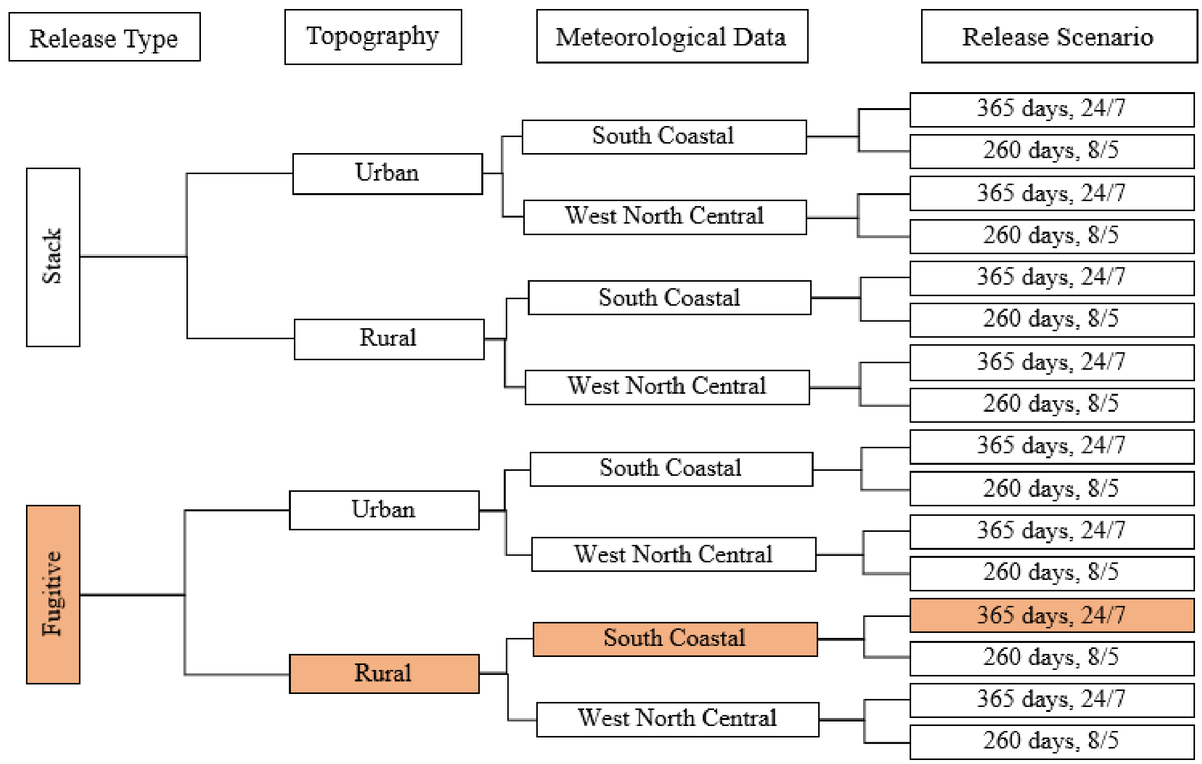
Based on these findings, EPA has high confidence in the modeled exposure concentrations from each model. As such, EPA uses both models in this general population risk assessment to inform exposures and take advantage of certain model capabilities to better characterize exposures for TSCA COUs, varying inputs, and other fit-for-purpose needs for this general population risk assessment. IIOAC is used for the screening and national level analyses as it is easier to use and faster to run. HEM has added flexibility to consider more than three pre-defined distances, additional meteorological stations, and other factors so HEM is used for the site-specific analysis to both target local population impacts as well as estimate concentrations at 11 finite distances away from each releasing facility, including 100 and 1,000 m that can be compared to outputs from IIOAC. HEM is not readily set up to consider area distances, so the area distance between 100 and 1,000 m is not evaluated with HEM. EPA takes advantage of HEM's flexibilities allowing user defined inputs to characterize findings for sensitivity analyses related to impact on modeled concentrations from different stack heights and different distances.

***Identifying HE and CT Met Stations in IIOAC***

IIOAC includes 14 pre-defined climate regions (each with a surface station and upper-air station). Since release data used for the screening and national level analyses are not location-specific, EPA conducted a sensitivity analysis to identify 2 of the 14 climate regions within IIOAC which represent a central tendency and high-end climate region. This analysis looked at the average concentration and deposition predictions from each of the 14 climate regions under a set of identical release and exposure scenarios using 5 years of meteorological data (2011 to 2015) for all source types. EPA then ranked the modeled results from largest to smallest and found the highest air concentration estimate (considered high-end for this sensitivity analysis) occurred with the South (Coastal) climate region and refers to the Lake Charles, Louisiana, surface station within IIOAC. The 6th highest air concentration estimate (considered central tendency for this sensitivity analysis) occurred with the West North Central climate region and refers to the Sioux Falls, South Dakota, surface station within IIOAC.

***Identifying HE Exposure Scenario in IIOAC***

IIOAC is capable of modeling a variety of release types, topography, meteorological conditions, and release scenarios. Since release data used for the screening and national level analyses are not location-specific, EPA previously developed and conducted a sensitivity analysis using IIOAC across multiple chemicals to evaluate a series of exposure scenarios presented in Figure_Apx B-1. The goal of this sensitivity analysis was to identify which exposure scenario, of those evaluated, tended to result in higher air concentration estimates relative to the other scenarios across multiple chemicals. The results of this sensitivity analysis found the scenario highlighted in orange in Figure_Apx B-1 tended to result in the higher concentration estimates relative to the other scenarios evaluated.




**Figure_Apx B-1. Sensitivity Analysis Conceptual Model for Exposure Scenarios Modeled for Max and Mean Release Using IIOAC Model**

***Impact of Different Years of Meteorologic Data***

IIOAC considers 5 years of meteorological data (2011 to 2015). EPA previously received comment around this being older data and recommendations to consider more recent years of meteorological data in our ambient air exposure assessments. To alleviate concerns about the use of older meteorological data, EPA conducted a sensitivity analysis across different years of meteorologic data within AERMOD to see what the impacts on the estimated concentrations are. Because AERMOD is the base model within which pre-run scenarios were run to develop IIOAC, any findings from this sensitivity analysis in AERMOD would extend to IIOAC. The results from this sensitivity analysis within found that, although different years of meteorological data may result in small differences in estimated concentrations, results are well within the same order of magnitude across different years of meteorological data, indicating minimal impact on the estimated concentrations. Therefore, these findings support EPA's ongoing use of the current meteorological data within IIOAC.

***Impact of Different Stack Heights in HEM***

IIOAC includes a default stack height of 10 m for a point-source stack release. This stack height is based on a national average stack height across the United States for processes that are not higher-temperature incinerators or hazardous waste incinerators. The default stack height of 10 m is inherent to the pre-run AERMOD scenarios from which IIOAC is built, are integrated into the IIOAC model directly, and cannot be changed.

Although 10 m represents a national average stack height, EPA recognizes actual stack heights may vary (higher or lower) from facility-to-facility. EPA also recognizes the 10-meter stack height, and other stack parameters integral to IIOAC, represent a low, slow moving, non-buoyant plume and therefore results in a more conservative concentration estimate at the distances evaluated. Additionally, EPA recognizes a higher stack height under normal conditions can provide for additional dispersion prior to a plume reaching the breathing level of individuals within the general population who are then exposed to pollutants within the plume.

EPA developed and conducted a sensitivity analysis to more thoroughly explore the impacts of different stack heights on modeled ambient air concentrations at multiple distances from releasing facilities. HEM is relied upon for this sensitivity analysis because of its added flexibilities to allow user defined stack parameters (including stack height), distances, and meteorological stations. This particular sensitivity analysis explored and compared modeled ambient air concentrations resulting from two stack heights (10- and 25-meters) at 11 finite distances under identical exposure scenarios.

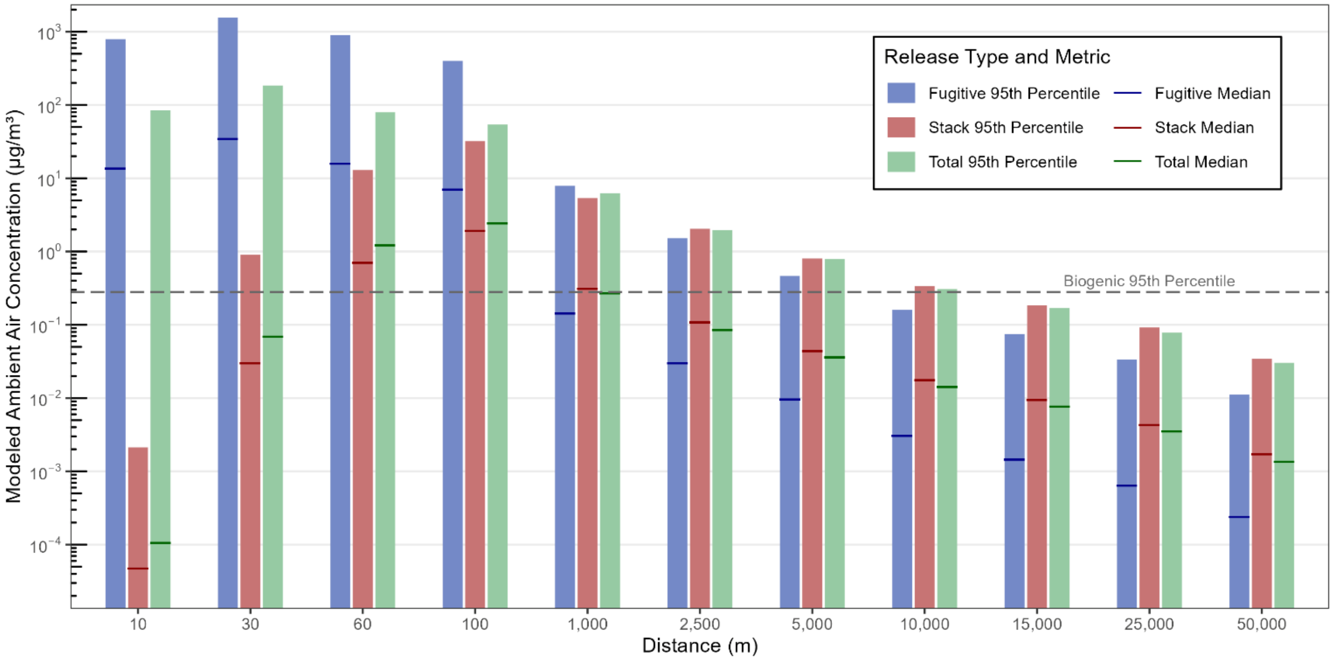
As expected, EPA found the 25-meter stack height allowed for additional dispersion prior to a plume reaching the breathing zone of individuals at the distances evaluated and where exposure occurs. Generally, the 25-meter stack height resulted in slightly lower modeled concentrations at the distances evaluated when compared to the 10-meter stack height at the same distances. Additionally, the greatest impact from the 25-meter stack height generally occurred at the 1,000 m finite distance from the releasing facilities while the greatest impact from the 10-meter stack height occurred at the 100 m finite distance from the releasing facilities. Based on these findings, EPA determined that while there are differences between estimated concentrations from different stack heights, the impacts are minimal. Therefore, EPA retains use of the 10-meter stack height and relies upon the IIOAC default stack parameters to provide a more conservative concentration estimate for this ambient air exposure assessment.

***Fugitive Impact Distances vs. Stack Impact Distances Using HEM***

Fugitive and stack type releases are modeled separately in air dispersion models like IIOAC and HEM. Both models model fugitive releases as an area source with a user defined "area of source" and stack releases as a point source. Each then provides source apportioned results of estimated concentrations for each release type at each distance evaluated. EPA utilized these source apportioned results from HEM in a sensitivity analysis designed to explore two concepts associated with exposures.

1. Which release type has the greatest impact on exposures at each distance evaluated?
2. At what distance, of those evaluated, does each release type have the greatest impact on exposure?

Results from this sensitivity analysis are shown in Figure_Apx B-2 and can inform exposure, risk estimates, risk determinations, and risk management rulemaking decisions around a fit-for-purpose national level risk evaluations. Generally, EPA found fugitive releases have greater overall impacts on exposures at distances less than 100 m. At distances farther than 100 m, fugitive releases tend to have similar impacts to modeled concentrations as stack releases. Stack releases, in contrast, have greater overall impacts on exposures at distances at distances between 60 and 1,000 m followed by a moderate decline in modeled concentrations beyond 1,000 m. Although these findings align with statements made in previous work by EPA, this sensitivity analysis specifically explored these findings to inform the relative impacts of fugitive and stack releases on exposures to individuals residing near industrial facilities releasing formaldehyde to the ambient air.




**Figure_Apx B-2. Median and 95th Percentile Concentrations (Fugitive, Stack, and Total Emissions) across the 11 Discrete Distance Rings Modeled in HEM**

# Appendix C IIOAC RESULTS BY COU

**Table_Apx C-1. Crosswalk of Industry Sector to COU along with Modeled Exposure Concentrations by Industry Sector for 95th Percentile Release Scenario and 95th Percentile Modeled Concentration at 100 to 1,000 m from Industrial Facilities Releasing Formaldehyde to Ambient Air**

| Industry Sector | Associated TSCA COU(s) | Exposure Concentrations (µg/m$^3$) | | |
|---|---|---|---|---|
| | | AC | ADC | LADC |
| Petroleum Refineries | Commercial use | 0.63 | 0.63 | 0.63 |
| Utilities | Commercial use | 1.50 | 1.50 | 1.50 |
| Industrial Gas Manufacturing | Disposal | 0.03 | 0.03 | 0.03 |
| Services | Disposal (services industrial sector includes waste management industry) | 0.30 | 0.30 | 0.30 |
| Manufacturing of formaldehyde | Domestic manufacturing | 1.93 | 1.93 | 1.93 |
| Transportation Equipment Manufacturing | Industrial use – chemical substances in industrial products- paints and coatings; adhesives and sealants, lubricants | 3.40 | 3.40 | 3.40 |
| Fabricated Metal Product Manufacturing | Industrial use – chemical substances in industrial products – paints and coatings; adhesives and sealants; lubricants | 0.19 | 0.19 | 0.19 |
| Furniture and Related Product Manufacturing | Industrial use – chemical substances in industrial products – paints and coatings; adhesives and sealants; lubricants | 2.16 | 2.16 | 2.16 |
| Organic Fiber Manufacturing | Industrial use – non-incorporative activities – oxidizing/reducing agent; processing aids, not otherwise listed | 0.20 | 0.20 | 0.20 |
| Computer and Electronic Product Manufacturing | Industrial use – non-incorporative activities – oxidizing/reducing agent; processing aids, not otherwise listed (*e.g.,* electroless copper plating) | 0.09 | 0.09 | 0.09 |
| Fabricated Metal Product Manufacturing | Industrial use – non-incorporative activities – oxidizing/reducing agent; processing aids, not otherwise listed (*e.g.,* electroless copper plating) | 0.19 | 0.19 | 0.19 |
| Primary Metal Manufacturing | Industrial use – non-incorporative activities – oxidizing/reducing agent; processing aids, not otherwise listed (*e.g.,* electroless copper plating) | 0.12 | 0.12 | 0.12 |
| Furniture and Related Product Manufacturing | Industrial use – non-incorporative activities – used in: construction | 2.16 | 2.16 | 2.16 |

| Industry Sector | Associated TSCA COU(s) | Exposure Concentrations (µg/m³) | | |
|---|---|---|---|---|
| | | AC | ADC | LADC |
| Wholesale and Retail Trade | Manufacturing – importing | 0.14 | 0.14 | 0.14 |
| Food, beverage, and tobacco product manufacturing | Non-TSCA | 4.27 | 4.27 | 4.27 |
| Pharmaceutical and Medicine Manufacturing | Non-TSCA | 1.79 | 1.79 | 1.79 |
| All Other Chemical Product and Preparation Manufacturing | Non-TSCA; processing – incorporation into a formulation, mixture, or reaction product – other: preservative | 0.21 | 0.21 | 0.21 |
| Custom Compounding of Purchased Resin | Processing as a reactant – intermediate | 0.20 | 0.20 | 0.20 |
| Fabricated Metal Product Manufacturing | Processing as a reactant – intermediate | 0.19 | 0.19 | 0.19 |
| Industrial Gas Manufacturing | Processing as a reactant – intermediate | 0.03 | 0.03 | 0.03 |
| Nonmetallic Mineral Product Manufacturing (includes clay, glass, cement, concrete, lime, gypsum, and other nonmetallic mineral product manufacturing) | Processing as a reactant – intermediate | 5.75 | 5.75 | 5.75 |
| Primary Metal Manufacturing | Processing as a reactant – intermediate | 0.12 | 0.12 | 0.12 |
| Synthetic Dye and Pigment Manufacturing | Processing as a reactant – intermediate | 0.22 | 0.22 | 0.22 |
| Machinery Manufacturing | Processing – incorporation into a formulation, mixture, or reaction product | 1.86 | 1.86 | 1.86 |
| Petrochemical Manufacturing | Processing – incorporation into a formulation, mixture, or reaction product | 1.75 | 1.75 | 1.75 |
| All Other Basic Organic Chemical Manufacturing | Processing – incorporation into a formulation, mixture, or reaction product | 0.24 | 0.24 | 0.24 |
| Asphalt Paving, Roofing, and Coating Materials Manufacturing | Processing – incorporation into a formulation, mixture, or reaction product | 0.35 | 0.35 | 0.35 |
| Soap, Cleaning Compound, and Toilet Preparation Manufacturing | Processing – incorporation into a formulation, mixture, or reaction product | 0.67 | 0.67 | 0.67 |
| Synthetic Dye and Pigment Manufacturing | Processing – incorporation into a formulation, mixture, or reaction product | 0.22 | 0.22 | 0.22 |
| Pesticide, Fertilizer, and Other Agricultural Chemical Manufacturing | Processing – incorporation into a formulation, mixture, or reaction product – agricultural chemicals (nonpesticidal) | 1.28 | 1.28 | 1.28 |

| Industry Sector | Associated TSCA COU(s) | Exposure Concentrations (µg/m³) | | |
|---|---|---|---|---|
| | | AC | ADC | LADC |
| Plastic Material and Resin Manufacturing | Processing – incorporation into a formulation, mixture, or reaction product – intermediate | 0.72 | 0.72 | 0.72 |
| Paint and Coating Manufacturing | Processing – incorporation into a formulation, mixture, or reaction product – paint additives and coating additives not described by other categories | 1.65 | 1.65 | 1.65 |
| Plastic Material and Resin Manufacturing | Processing – incorporation into a formulation, mixture, or reaction product – paint additives and coating additives not described by other categories | 0.72 | 0.72 | 0.72 |
| Paint and Coating Manufacturing | Processing – incorporation into a formulation, mixture, or reaction product – solvents (which become part of a product formulation or mixture) | 1.65 | 1.65 | 1.65 |
| Plastic Material and Resin Manufacturing | Processing – incorporation into a formulation, mixture, or reaction product – surface active agents | 0.72 | 0.72 | 0.72 |
| Adhesive Manufacturing | Processing – incorporation into a formulation, mixture, or reaction product – adhesives and sealants chemicals | 0.05 | 0.05 | 0.05 |
| Textiles, apparel, and leather manufacturing | Processing – incorporation into a formulation, mixture, or reaction product – bleaching agents | 4.53 | 4.53 | 4.53 |
| All Other Chemical Product and Preparation Manufacturing | Processing – incorporation into a formulation, mixture, or reaction product – intermediate | 0.21 | 0.21 | 0.21 |
| Custom Compounding of Purchased Resin | Processing – incorporation into a formulation, mixture, or reaction product – intermediate | 0.20 | 0.20 | 0.20 |
| Fabricated Metal Product Manufacturing | Processing – incorporation into a formulation, mixture, or reaction product – intermediate | 0.19 | 0.19 | 0.19 |
| Nonmetallic Mineral Product Manufacturing (includes clay, glass, cement, concrete, lime, gypsum, and other nonmetallic mineral product manufacturing) | Processing – incorporation into a formulation, mixture, or reaction product – intermediate | 5.75 | 5.75 | 5.75 |
| Wholesale and Retail Trade | Processing – incorporation into a formulation, mixture, or reaction product – intermediate | 0.14 | 0.14 | 0.14 |
| Paint and Coating Manufacturing | Processing – incorporation into a formulation, mixture, or reaction product – ion exchange agents | 1.65 | 1.65 | 1.65 |

| Industry Sector | Associated TSCA COU(s) | Exposure Concentrations (µg/m$^3$) | | |
|---|---|---|---|---|
| | | AC | ADC | LADC |
| Adhesive Manufacturing | Processing – incorporation into a formulation, mixture, or reaction product – ion exchange agents | 0.05 | 0.05 | 0.05 |
| Adhesive Manufacturing | Processing – incorporation into a formulation, mixture, or reaction product – lubricant and lubricant additive | 0.05 | 0.05 | 0.05 |
| All Other Chemical Product and Preparation Manufacturing | Processing – incorporation into a formulation, mixture, or reaction product – plating agents and surface treating agents | 0.21 | 0.21 | 0.21 |
| All Other Basic Inorganic Chemical Manufacturing | Processing – incorporation into a formulation, mixture, or reaction product – processing aids, specific to petroleum production | 0.26 | 0.26 | 0.26 |
| All Other Chemical Product and Preparation Manufacturing | Processing – incorporation into a formulation, mixture, or reaction product – processing aids, specific to petroleum production | 0.21 | 0.21 | 0.21 |
| Miscellaneous Manufacturing | Processing – incorporation into a formulation, mixture, or reaction product – solid separation agents | 1.79 | 1.79 | 1.79 |
| Transportation Equipment Manufacturing | Processing – incorporation into an article – paint additives and coating additives | 3.40 | 3.40 | 3.40 |
| Rubber Product Manufacturing | Processing – incorporation into article – additive | 0.0001 | 0.0001 | 0.0001 |
| Nonmetallic Mineral Product Manufacturing (includes clay, glass, cement, concrete, lime, gypsum, and other nonmetallic mineral product manufacturing) | Processing – incorporation into article – adhesive and sealants | 5.75 | 5.75 | 5.75 |
| Paper Manufacturing | Processing – incorporation into article – adhesive and sealants | 0.79 | 0.79 | 0.79 |
| Wood Product Manufacturing | Processing – incorporation into article – adhesive and sealants | 1.85 | 1.85 | 1.85 |
| Textiles, apparel, and leather manufacturing | Processing – incorporation into article – finishing agents | 4.53 | 4.53 | 4.53 |
| Paint and Coating Manufacturing | Processing – reactant – adhesive and sealant chemicals | 1.65 | 1.65 | 1.65 |
| All Other Basic Organic Chemical Manufacturing | Processing – reactant – adhesive and sealant chemicals | 0.24 | 0.24 | 0.24 |
| Plastic Material and Resin Manufacturing | Processing – reactant – adhesive and sealant chemicals | 0.72 | 0.72 | 0.72 |
| Wood Product Manufacturing | Processing – reactant – adhesive and sealant chemicals | 1.85 | 1.85 | 1.85 |

| Industry Sector | Associated TSCA COU(s) | Exposure Concentrations (µg/m³) | | |
|---|---|---|---|---|
| | | AC | ADC | LADC |
| Wood Product Manufacturing | Processing – reactant – bleaching agent | 1.85 | 1.85 | 1.85 |
| Paper Manufacturing | Processing – reactant – intermediate | 0.79 | 0.79 | 0.79 |
| Pesticide, Fertilizer, and Other Agricultural Chemical Manufacturing | Processing – reactant – intermediate | 1.28 | 1.28 | 1.28 |
| Paint and Coating Manufacturing | Processing – reactant – intermediate | 1.65 | 1.65 | 1.65 |
| Adhesive Manufacturing | Processing – reactant – intermediate | 0.05 | 0.05 | 0.05 |
| All Other Basic Organic Chemical Manufacturing | Processing – reactant – intermediate | 0.24 | 0.24 | 0.24 |
| All Other Chemical Product and Preparation Manufacturing | Processing – reactant – intermediate | 0.21 | 0.21 | 0.21 |
| Petrochemical Manufacturing | Processing – reactant – intermediate | 1.75 | 1.75 | 1.75 |
| Plastic Material and Resin Manufacturing | Processing – reactant – intermediate | 0.72 | 0.72 | 0.72 |
| Plastics Product Manufacturing | Processing – reactant – intermediate | 1.96 | 1.96 | 1.96 |
| Rubber Product Manufacturing | Processing – reactant – intermediate | 0.0001 | 0.0001 | 0.0001 |
| Soap, Cleaning Compound, and Toilet Preparation Manufacturing | Processing – reactant – intermediate | 0.67 | 0.67 | 0.67 |
| Wood Product Manufacturing | Processing – reactant – intermediate | 1.85 | 1.85 | 1.85 |
| Plastics Product Manufacturing | Processing – recycling | 1.96 | 1.96 | 1.96 |
| Wood Product Manufacturing | Processing – recycling | 1.85 | 1.85 | 1.85 |
| Paper Manufacturing | Processing – recycling | 0.79 | 0.79 | 0.79 |
| Wholesale and Retail Trade | Processing – repackaging | 0.14 | 0.14 | 0.14 |
| Mining (except Oil and Gas) and Support Activities | | 0.02 | 0.02 | 0.02 |

1128

**Table_Apx C-2. Modeled Exposure Concentrations by COU for 95th Percentile Release Scenario and 95th Percentile Modeled Concentration at 100 to 1,000 m from Industrial Facilities Releasing Formaldehyde to Ambient Air**

| Condition of Use (COU) | Exposure Concentration (µg/m$^3$) |
|---|---|
| Disposal (services industrial sector includes waste management industry) | 3.0E–01 |
| Domestic manufacturing | 1.9E00 |
| Industrial use – non-incorporative activities – oxidizing/reducing agent; processing aids, not otherwise listed (*e.g.,* electroless copper plating) | 2.0E–02 |
| Industrial use – chemical substances in industrial products – paints and coatings; adhesives and sealants, lubricants | 3.4E00 |
| Processing – incorporation into a formulation, mixture, or reaction product | 1.9E00 |
| Processing – incorporation into a formulation, mixture, or reaction product – adhesive and sealant chemicals | 5.4E–02 |
| Processing – incorporation into a formulation, mixture, or reaction product – agricultural chemicals (nonpesticidal) | 1.3E00 |
| Processing – incorporation into a formulation, mixture, or reaction product - intermediate | 7.2E–01 |
| Processing – incorporation into a formulation, mixture, or reaction product – ion exchange agents | 1.7E00 |
| Processing – incorporation into a formulation, mixture, or reaction product – lubricant and lubricant additive | 5.4E–02 |
| Processing – incorporation into a formulation, mixture, or reaction product – other: preservative | 2.1E–01 |
| Processing – incorporation into a formulation, mixture, or reaction product – paint additives and coating additives not described by other categories | 1.7E00 |
| Processing – incorporation into a formulation, mixture, or reaction product – plating agents and surface treating agents | 2.1E–01 |
| Processing – incorporation into a formulation, mixture, or reaction product – processing aids, specific to petroleum production | 2.6E–01 |
| Processing – incorporation into a formulation, mixture, or reaction product – solid separation agents | 1.8E00 |
| Processing – incorporation into a formulation, mixture, or reaction product – solvents (which become part of a product formulation or mixture) | 1.7E00 |
| Processing – incorporation into a formulation, mixture, or reaction product – surface active agents | 7.2E–01 |
| Processing – incorporation into a formulation, mixture, or reaction product – bleaching agents | 4.5E00 |
| Processing – incorporation into article – additive | 1.1E–04 |
| Processing – incorporation into article – finishing agents | 4.5E00 |
| Processing – incorporation into a formulation, mixture, or reaction product | 2.4E–01 |

| Condition of Use (COU) | Exposure Concentration ($\mu g/m^3$) |
|---|---|
| Processing – incorporation into a formulation, mixture, or reaction product – intermediate | 1.4E–01 |
| Processing – incorporation into an article – paint additives and coating additives | 3.4E00 |
| Processing – incorporation into article –adhesive and sealants | 1.9E00 |
| Processing – reactant – adhesive and sealant chemicals | 1.7E00 |
| Processing – reactant – adhesives and sealants | 1.9E00 |
| Processing – reactant – bleaching agent | 1.9E00 |
| Processing – reactant – intermediate | 2.0E00 |
| Processing – repackaging | 1.4E–01 |