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Pollution Prevention

Ambient Air Exposure Assessment for Formaldehyde

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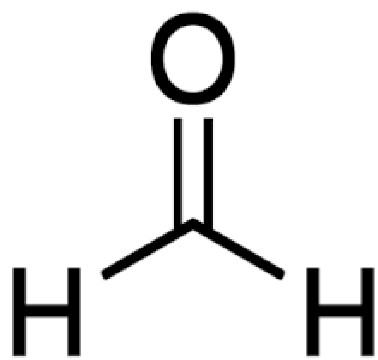

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Key Points: Ambient Air Exposure Assessment

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

- Formaldehyde is ubiquitous in ambient air. There are many different sources contributing to ambient concentrations of formaldehyde, including industrial facilities, secondary formation, natural (biogenic) sources, mobile sources, and others. Some of these sources are not subject to the Toxic Substances Control Act (TSCA).
- EPA considered both modeling and monitoring data in this ambient air exposure assessment to develop a comprehensive understanding of formaldehyde concentrations in ambient air from a variety of sources.
- Modeled daily average exposure concentrations resulting from maximum industrial release scenarios of formaldehyde that are primarily attributable to TSCA condition of uses (COUs) ranged from 0.0004 to 66 micrograms per cubic meter ($\mu g/m^3$) at 100 meters (m) from releasing facilities. Modeled daily average exposure concentrations resulting from industrial releases of formaldehyde that are primarily attributed to combustion ranged from 2 to 662 $\mu g/m^3$ at 100 m from releasing facilities.
- Modeled annual average exposure concentrations resulting from 95th percentile industrial releases of formaldehyde that are primarily attributable to TSCA COUs ranged from 0.0001 to 5.75 $\mu g/m^3$ within the 100 to 1,000 m area distance evaluated.
- Monitored formaldehyde concentrations extracted from EPA's Ambient Monitoring Technology Information Center (AMTIC) archive for the years 2015 through 2020 ranged from 0 to 60.1 $\mu g/m^3$ with a median of 1.6 $\mu g/m^3$.
- A case study of three high-resolution air monitoring sites in Houston, Texas, demonstrated consistent, year-round concentrations of formaldehyde up to 49 $\mu g/m^3$ with elevated concentrations consistent with the operating hours of the surrounding area's industrial, shipping, and chemical manufacturing sectors.
- *EPA has medium confidence in the Integrated Indoor/Outdoor Air Calculator (IIOAC)-modeled results used to characterize exposures in this ambient air assessment.* This is due to uncertainties related to input parameters and spatial and temporal differences seen across the multiple lines of evidence considered.

EXECUTIVE SUMMARY

Environmental releases of formaldehyde are reported for ambient air (U.S. EPA, 2024d). Although subject to direct and indirect photolysis in the ambient air, concentrations of formaldehyde are regularly measured (monitored) and reported in air. This assessment considers both measured and modeled formaldehyde concentrations in ambient air.

EPA used three different models to characterize outdoor air concentrations of formaldehyde. The IIOAC was used to estimate air concentrations of formaldehyde for individuals living either at 100 m or within 100 to 1,000 m (0.062–0.62 miles) of releasing facilities. These releases were quantified based on air emissions data reported to the Toxics Release Inventory (TRI) and the National Emissions Inventory (NEI). EPA also used results from the 2019 and 2020 AirToxScreen model to characterize total concentrations of formaldehyde in air due to biogenic and secondary formation. Lastly, EPA used the Human Exposure Model (HEM) to consider populations exposed and evaluate spatial distribution of formaldehyde concentrations across the United States.

IIOAC results varied based on the release amount, distance from the releasing facility, and expected source of formaldehyde. Modeled daily average exposure concentrations based on the maximum releasing facility within an industry sector and 95th percentile modeled concentrations (*e.g.*, downwind direction) at 100 m from a release point (*e.g.*, stack) that are primarily attributable to TSCA COUs ranged from 0.0004 to 66 μg/m^3. Modeled daily average exposure concentrations based on the maximum release and 95th percentile modeled concentration at 100 m from a release point that are primarily attributed to combustion (including airplanes, on-site vehicles, process heaters, turbines, and reciprocating internal combustion engines) ranged from 2 to 662 μg/m^3.

Outdoor annual average air concentrations based on the 95th percentile of facility releases by industry sector and 95th percentile modeled concentration within the 100 to 1,000 m area distance from a point of release range from 0.0001 to 5.75 μg/m3. To further characterize/contextualize these results, this ambient air exposure assessment uses data from AirToxScreen to understand how these modeled concentrations compare to concentrations from other sources of formaldehyde (*e.g.*, secondary formation, biogenic sources). For example, formaldehyde concentrations attributable to biogenic sources (*e.g.*, natural production like decaying organic material or breakdown of isoprenes) ranged from 0.13 to 1.8 μg/m^3 with a 95th percentile concentration of 0.28 μg/m^3 according to the AirToxScreen results. To better characterize the populations exposed to formaldehyde concentrations released from TSCA facilities, EPA used the HEM model.

Based on the modeled concentrations using IIOAC, the following TSCA COUs result in the highest daily exposure concentrations which EPA believes *are not* directly attributable to combustion releases of formaldehyde:

1. Processing-reactant-adhesive and sealants chemicals;
2. Processing-reactant-intermediate;
3. Processing-reactant-bleaching agent;
4. Processing-incorporation into an article-adhesives and sealants chemicals; and,
5. Recycling.

Based on the modeled concentrations using IIOAC, the following TSCA COUs result in the highest daily exposure concentration that EPA believes *are* primarily attributable to combustion releases of formaldehyde:

1. Manufacturing-importing;
2. Processing-incorporation into a formulation, mixture, reaction product-intermediate; and,
3. Processing-repackaging-sales to distributors for laboratory chemicals.

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

1. Processing – incorporation into an article-adhesives and sealant chemicals;
2. Processing as a reactant – intermediate; and,
3. Processing – incorporation into a formulation, mixture, or reaction product-intermediate.

The Agency used monitoring data extracted from EPA's AMTIC archive (U.S. EPA, 2022a). This information characterizes total exposures to formaldehyde from all contributing sources—including sources associated with TSCA COUs and other sources of formaldehyde.

Monitored formaldehyde concentrations extracted from AMTIC (2015–2020) ranged from 0 to 60.1 μg/m^3 with a median of 1.6 μg/m^3 across more than 300,000 monitored values. To understand some of the daily fluctuations in formaldehyde, EPA used 5-minute monitoring data from Houston, Texas.

Although these data were not tied to TSCA sources of formaldehyde, they generally demonstrated that formaldehyde concentrations in air regularly fluctuate but are somewhat stable throughout the year.

EPA has medium confidence in the IIOAC-modeled results used to characterize exposures in this ambient air assessment—due to uncertainties related to input parameters and spatial and temporal differences seen across the multiple lines of evidence considered. This assessment is a conservative assessment that is not site-specific. Similarly, the assessment was conducted independent of the size of the facility footprint, the precise location of the release, and the relative proximity of residences to the releasing facility/facilities. Additional modeling with HEM results provides context on the spatial variability of formaldehyde concentrations across the United States and an approximate understanding of populations exposed. EPA investigated the impact of several of the conservative inputs on overall exposure in a series of sensitivity analyses discussed in Appendix B.1. Findings from those sensitivity analyses found the impact from each sensitivity on overall findings was minimal. Impact of conservative inputs not investigated with a sensitivity analysis are unknown.

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 TSCA sections 3(2) (defining "chemical substance") and 3(4) (defining "conditions of use"). 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 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 document is illustrated with blue shading. In some cases, individual assessments were completed jointly under TSCA and FIFRA.

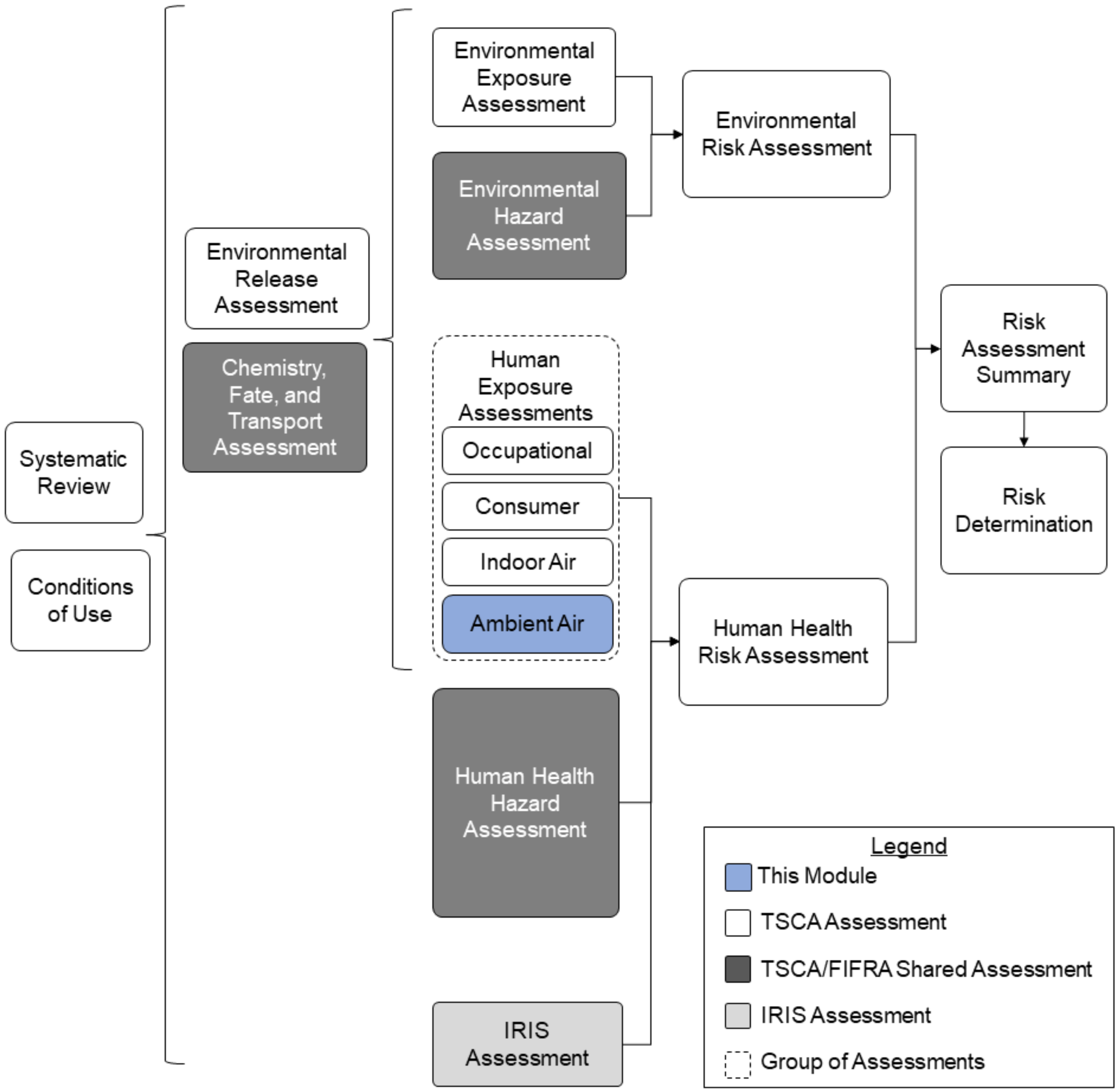

Figure 1-1. Risk Assessment Document Map Summary

Environmental releases of formaldehyde are reported for ambient air in the *Environmental Release Assessment for Formaldehyde* (U.S. EPA, 2024d). The *Chemistry, Fate, and Transport Assessment for Formaldehyde* (U.S. EPA, 2024b) and available monitoring data from EPA's AMTIC indicate formaldehyde is consistently present in the ambient air and represents a major pathway for exposure. Additional modeling from the 2019 and 2020 AirToxScreen supports the conclusion that formaldehyde is ubiquitous in ambient air from multiple sources, including TSCA sources and other sources. Considering these lines of evidence, EPA expects human exposure to formaldehyde via the ambient air to be common and therefore quantitatively estimates human exposure to formaldehyde via the ambient air pathway.

The scope of this ambient air exposure assessment focuses on exposures to formaldehyde resulting from industrial releases of formaldehyde to the ambient air that are primarily attributable to TSCA COUs. Detailed descriptions of TSCA COUs considered are included in the *Conditions of Use of the*

Formaldehyde Risk Evaluation (U.S. EPA, 2024c). In addition, this assessment considers exposure to formaldehyde resulting from industrial point source releases primarily attributed to combustion, including airplanes, on-site vehicles, process heaters, turbines, and reciprocating internal combustion engines. Other sources of formaldehyde in ambient air were not quantified for this ambient air exposure assessment, including mobile sources and other similar sources (off-road engines, etc.). Finally, this assessment acknowledges and describes biogenic production and secondary formation of formaldehyde in ambient air.

1.2 Revisions between Draft and the Revised Assessment

In response to the feedback received during peer review and public comment on the draft Ambient Air Exposure Assessment and draft Human Health Risk Assessment modules, EPA incorporated the following revisions into this completed Ambient Air Exposure Assessment for Formaldehyde:

- Daily average modeled formaldehyde exposure estimates primarily attributable to TSCA COUs previously included in the supplemental files are now summarized in the main body of this document (see Section 3.1.1.1);
- Daily average formaldehyde exposure estimates primarily attributed to combustion are now separately summarized from those attributable to TSCA COUs in Section 3.1.1.1 of this document. These estimates were previously in supplemental files.
- Comparison of release and exposure estimates previously reported in supplemental files for all industry sectors for both TRI and NEI release datasets are considered together and summarized in Sections 3.1.1.3. and 3.1.4;
- Section 3.1.4 now presents additional analyses comparing releases reported to TRI and NEI to determine if carrying NEI reported release data through quantitative assessment is expected to change conclusions reached for exposure to formaldehyde from TSCA COUs both individually and in aggregate when considering TRI release data alone (see Sections 3.1.1.3).
- A review of the latest, recently released, 2020 AirToxScreen results are available in Sections 2.1.4 and 3.1.2; and
- An examination of high frequency (5-minute) monitoring data from Texas is provided in Section 3.2.2 to further characterize possible peak/daily average exposures.
- The confidence in the overall ambient air assessment results has been lowered after further considerations of uncertainties in the assessment like the actual location of a release point, or whether 100 m falls on facility property rather than where people live.

1.3 Conceptual Exposure Model

EPA expects the ambient air to be one of the predominant human exposure pathways 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 of a stack) or controlled with a pollution control device (*e.g.*, scrubber or thermal oxidizer). Once released to the ambient air, formaldehyde may disperse off-site into the surrounding areas where people may be exposed through inhalation. This ambient air exposure assessment focuses on exposures to a subset of the general population living nearby industrial facilities releasing formaldehyde to the ambient air.

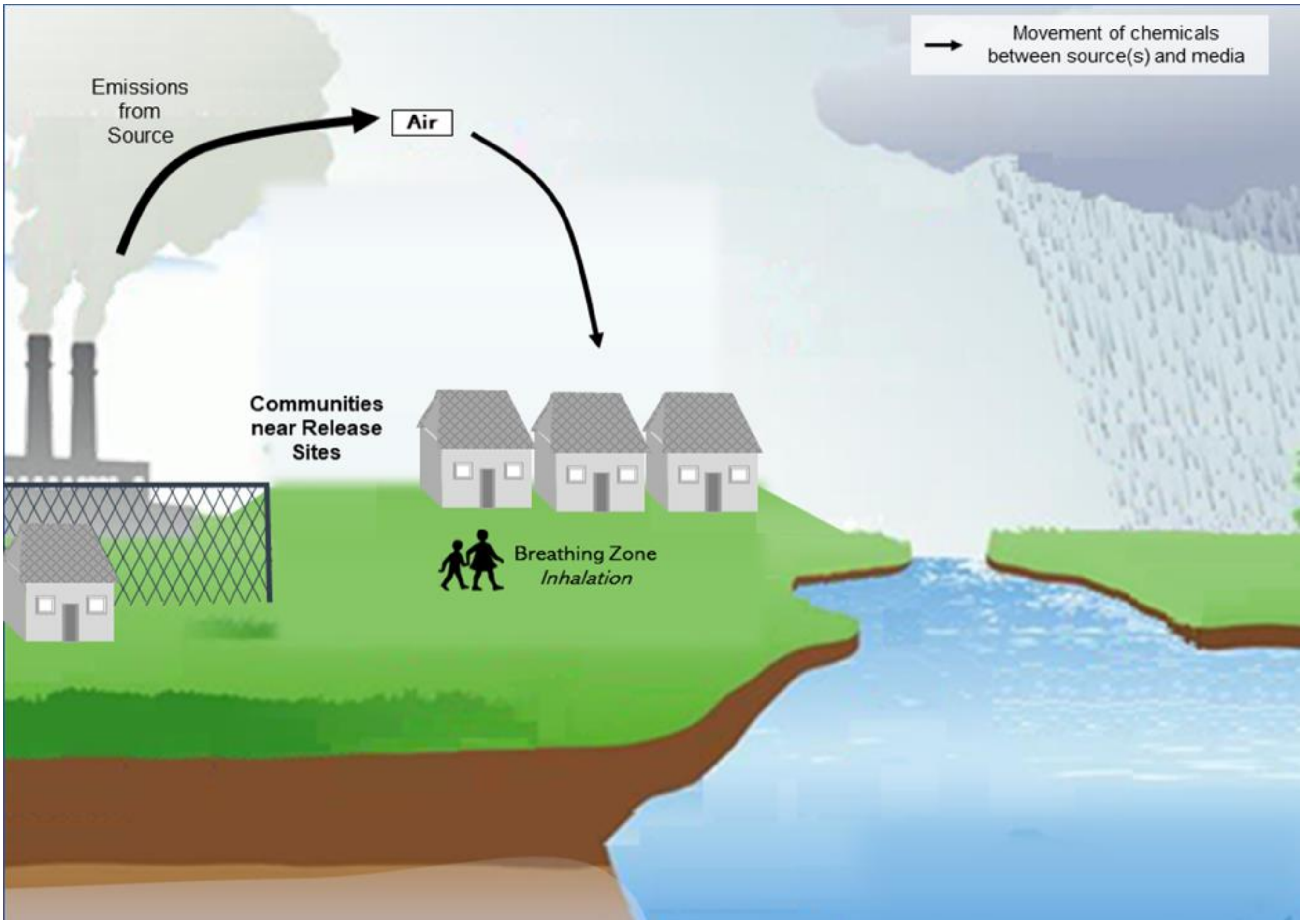

Figure 1-2. Industrial Releases to the Environment and Pathways by Which Exposures of the General Population to Formaldehyde May Occur

2 APPROACH AND METHODOLOGY

EPA considered both modeled and monitored formaldehyde concentrations for this ambient air exposure assessment for formaldehyde. The Agency's modeling estimated both daily average and annual average formaldehyde concentrations in ambient air for purposes of characterizing exposures. EPA considered reasonably available monitoring data from the AMTIC archive and State submitted data to further characterize national exposures. In addition, EPA considered more granular data in a case study of local monitoring data from Houston, Texas.

Given the complexities of assessing 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 presented in detail in the subsections that follow.

1. ***Estimated Formaldehyde Concentrations:*** This ambient air exposure assessment for formaldehyde uses EPA's Integrated Indoor/Outdoor Air Calculator Model (IIOAC)[1] to estimate formaldehyde concentrations near releasing facilities based on reported formaldehyde release data from two datasets (TRI and NEI). In addition, EPA's Human Exposure Model (HEM v4.2) is used to estimate geographically specific aggregate formaldehyde concentrations which are TSCA COU agnostic based on site-specific reported formaldehyde release information from TRI.
2. ***Relative Contributions of Formaldehyde Concentrations in Ambient Air:*** This ambient air exposure assessment for formaldehyde uses the 2019 Air Toxics Screening Assessment (AirToxScreen) results from EPA's Office of Air and Radiation to contextualize formaldehyde concentrations in ambient air 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 for formaldehyde 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 may be attributed to TSCA COUs).
3. ***Measured Formaldehyde Concentrations:*** This assessment summarizes monitoring data from EPA's AMTIC archive (U.S. EPA, 2022a) to understand aggregate or total formaldehyde concentrations in ambient air and to contextualize modeled concentrations of formaldehyde. EPA also conducted a case study of exposures in Texas based on 5-minute sampling data from a state monitoring program submitted through the AMTIC archive.

2.1 Modeling

EPA used three different models to estimate formaldehyde concentrations in outdoor air. These included the IIOAC Model, the HEM, and the AirToxScreen Assessment. Each model serves a different purpose in this assessment as described in the following subsections.

The IIOAC Model was used to estimate formaldehyde concentrations used to estimate exposures, derive risk estimates, and characterize risks. The HEM results expand on the IIOAC results by providing more site-specific exposure estimates and geospatial data for mapping and population analysis. The AirToxScreen assessment, a collection of models and results, was used to understand source attribution of formaldehyde concentrations from 37 source types including secondary formation, biogenic (natural)

[1] For further information see the IIOAC homepage.

production, and point sources. This allows EPA to place context around ambient air concentrations of formaldehyde from TSCA COUs.

2.1.1 Integrated Indoor/Outdoor Air Calculator Model (IIOAC)

EPA used the IIOAC Model to estimate daily-average and annual-average formaldehyde concentrations for a suite of exposure scenarios at three distances from facilities releasing formaldehyde to the ambient air. All results from the IIOAC modeling for both TRI and NEI release datasets are provided in the Ambient Air Exposure Assessment Results and Risk Calcs Supplement A (U.S. EPA, 2024a).

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).

EPA's IIOAC modeling evaluated releases reported by industry under statute which can be attributable to TSCA COUs. Four release statistics (maximum, 95th percentile, median, and minimum) were summarized for facilities by industry sector as described in the Environmental Release Assessment for Formaldehyde (U.S. EPA, 2024d) and used as direct inputs to EPA's IIOAC Model to estimate ambient air concentrations resulting from those industry sector releases. The same modeling was conducted for both the TRI and the NEI release datasets. Modeled results by industry sector are crosswalked to TSCA COUs when summarizing results in Section 3 of this assessment and when deriving risk estimates. Release and

2.1.1.1 Exposure Scenarios Evaluated

Modeled ambient air concentration outputs from IIOAC need to be converted to estimates of exposures to derive risk estimates. For this exposure assessment, EPA assumes the general population evaluated is continuously exposed (*i.e.*, 24 hours per day, 365 days per year) to outdoor ambient air concentrations. Therefore, daily average modeled ambient air concentrations are equivalent to daily average exposure concentrations, and annual average modeled ambient air concentrations are equivalent to annual average exposure concentrations used to derive risk estimates.

The release and dispersion scenarios evaluated for this ambient air exposure assessment for formaldehyde to obtain daily average and annual average modeled ambient air concentrations are summarized below with a more detailed discussion following.

- Distribution of formaldehyde releases within each industry sector (kg/site-day):
    - Maximum releasing facility
    - 95th percentile of releasing facilities
    - median
    - minimum
- Release Dataset:
    - 2016 to 2021 TRI
    - 2017 NEI
- Release Type:
    - Stack
    - Fugitive

[2] See AERMOD for further information.

- Distances Evaluated (m) from Release:
    - 100
    - 100 to 1,000
    - 1,000
- Meteorological Station (from IIOAC):
    - South (Coastal): Surface and Upper Air Stations at Lake Charles, Louisiana
- Operating Scenario:
    - 365 days per year; 7 days per week; 24 hours per day;
    - 250 days per year; 5 days per week; 8 hours per day
- Topography:
    - Urban
    - Rural
- Particle Size:
    - Vapor only

2.1.1.1.1 Environmental Releases Evaluated

As further discussed in the *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 included the most recent 6 years of release data available at that time in the TRI database and the most recent reporting year available for NEI. While more recent years of data are reported to TRI (2022–2023) and the 2020 NEI was just released at the time of publishing this exposure assessment, EPA is unable to integrate that data into the current exposure assessment analyses due to statutory time frames within TSCA. Nonetheless, EPA reviewed the most recent data and saw release trends remain relatively consistent across the years with higher releases captured within the datasets considered for this ambient air exposure assessment. In total, EPA identified approximately 810 facility level releases from TRI and nearly 150,000 process unit-level releases from NEI.

2.1.1.1.2 IIOAC Input Parameters

Based on the exposure scenarios described above, this assessment includes 32 exposure scenarios for each industry sector for both the TRI and NEI datasets.

EPA used certain default input parameters integrated within the IIOAC Model for both stack and fugitive releases 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

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

2.1.1.1.3 Meteorological Data

The parameterization of the IIOAC Model includes 5 years of meteorological data (2011–2015), which are integrated into the model itself and cannot be changed without updates to the model code. The meteorological data includes hourly readings of wind speed, wind direction, relative humidity, air temperature, air pressure, and other components. The IIOAC Model includes 14 real meteorological stations which represent different climate regions across the United States. Each of the 14 meteorological stations include both a surface station and upper-air station. Data from both surface and upper air stations are considered in and influence the dispersion modeling utilized for this ambient air exposure assessment for formaldehyde.

Modeling for this ambient air exposure assessment for formaldehyde used the meteorological data from the South (Coastal) climate region meteorological station integrated into the IIOAC Model. These data were obtained from the surface and upper-air stations located in Lake Charles, Louisiana. Use of this meteorological data results in the highest exposure concentrations compared to the other 13 meteorological climate regions which data are available for use in the IIOAC Model as demonstrated in the sensitivity analysis provided in Appendix B. The results from use of the Lake Charles, Louisiana, are only slightly higher than modeled concentrations for other locations. As such, use of these data streamlined this assessment by minimizing model simulations resulting in similar concentrations and is not expected to impact the overall assessment conclusions.

2.1.1.2 IIOAC Model Output Values

The IIOAC Model provides multiple output values as described in the IIOAC Users Guide (U.S. EPA, 2019b) and included in the supplemental files summarizing model outputs and results for this ambient air exposure assessment for formaldehyde. A description of select outputs relied upon for this assessment are provided below.

Fenceline Average: represents the daily and annual-average modeled concentrations at 100 m from a release point and a proxy for concentrations expected at the boundary of a generic facility.

Community Average: represents the daily and annual-average modeled concentrations within the area distance between 100 to 1,000 m from a release point and therefore a reasonable proxy for concentrations expected to be experienced by residents around a facility.

High-End, Daily-Average: represents the 95th percentile (*e.g.* downwind direction) daily-average concentration across the entire distribution of modeled concentrations at the respective distance(s) modeled. The daily-average concentrations represent the average of all hourly modeled concentrations across each 24-hour period (12:00 AM to 12:00 AM) within a 5-year period (each day for five years).

High-End, Annual-Average: represents the 95th percentile (*e.g.* downwind direction) annual-average concentration across the entire distribution of modeled concentrations at the respective distance(s) modeled. The annual-average concentrations represent the 365-day rolling, daily-average modeled concentrations within a 5-year period.

2.1.1.2.1 Estimated Daily Average Formaldehyde Concentrations

EPA uses the high-end, daily-average modeled concentration results from the following exposure scenario to assess daily average exposures. This daily average exposure assessment was added to the body of this ambient air assessment in response to SACC review and public comments. This addition utilizes a different exposure scenario than presented in the draft Ambient Air Exposure Assessment for

Formaldehyde which EPA believes is more representative for evaluating daily average exposures with the IIOAC Model.

Release Scenario: Maximum facility release reported by industry to either TRI or NEI for each industry sector.

This represents the highest actual reported annual release within each industry sector and therefore, would be expected to result in the highest or peak exposures to formaldehyde (which in turn may be a closer representation to a daily or peak exposure than a mean release and mean exposure concentration). For this ambient air exposure assessment, the maximum release values modeled came from both TRI and NEI datasets. Use of the maximum release within an industry sector enabled EPA to further parse out the reported maximum releases (and resulting exposures) primarily attributable to TSCA COUs and primarily attributed to combustion to further characterize exposure.

Modeled Concentration: High-end (95th percentile) modeled air concentrations at the 100-meter finite distance from the release point.

These modeled concentrations were selected for each industry sector because the values represent a national level, high-end air concentration that may occur near a releasing facility which are inclusive of sensitive and locally impacted populations. The 100-meter distance was selected based on EPA's consideration of the TSCA COUs evaluated for this assessment. EPA acknowledges there is some uncertainty around its use of the 100 m distance from the release point (*e.g.*, process unit/stack). For example, for larger facilities, 100 m from a release point may fall on facility property (where individuals within the general population do not live or frequent) and therefore would not be exposed to modeled concentrations 24 hours per day, 7 days per week, or 365 days per year. In contrast, for smaller facilities, there may be one or more individuals within the general population living 100 m away from the release point and therefore would be exposed continuously—although most individuals may not stay within their residences 24 hours per day, 7 days per week, 365 days per year. However, even with these uncertainties, in an effort to ensure exposure scenarios where to the general population who live or frequent an area at 100 m from a release point are not missed, 100 m was selected as a conservative, near facility exposure boundary distance for the general population.

Operating Scenario: 365 days per year, 7 days per week, 24 hours per day.

The daily release value (kilograms per site-day) used for modeling under this operating scenario assumes a steady-state operation and therefore releases occur continuously at the same daily rate over the course of a year. This assumption results in identical daily-average and annual-average concentrations estimates because the annual-average is the average of all daily-average concentrations.

2.1.1.2.2 Estimated Annual Average Formaldehyde Concentrations

EPA uses the high-end annual average modeled concentration results from the following exposure scenario to assess annual average exposures.

Release Scenario: Ninety-fifth percentile of releasing facilities calculated for either TRI or NEI datasets for each industry sector.

This represents the 95th percentile releases calculated across the entire distribution of releases reported to either TRI or NEI within each industry sector. While this still represents a conservative release value, it considers potential variability within reported releases within each industry sector (which in turn may be a closer representation of annual average exposures occurring every day across the year) and variability in releases year after year. Therefore, the 95th percentile release is more representative of a national level high end release value. For this ambient air exposure assessment, the 95th percentile release values modeled came from both TRI and NEI datasets.

Although for the maximum release scenario (which involves a single facility maximum release) EPA was able to distinguish combustion sources from TSCA COUs, this unit-process granularity is not available for the 95th percentile release scenario. This is because the 95th percentile release values are calculated values across the entire distribution of releases within an industry sector which includes both releases attributable to TSCA COUs and releases attributable to combustion. Therefore, EPA acknowledges uncertainty in the reported releases (and resulting exposures) primarily attributable to specific TSCA COUs.

Modeled Concentration: High-end (95th percentile) modeled air concentrations at the 100 to 1,000 m area distance from the release point.

These modeled concentrations were selected for each industry sector because they represent a national level, high-end air concentration that may occur near a releasing facility. The 100 to 1,000 m area distance was selected based on EPA's consideration of the TSCA COUs evaluated for this assessment and an effort to capture an area distance where a larger community is more likely to reside and experience potential exposures. The annual-average concentration also represents the 95th percentile across the entire distribution of modeled concentrations throughout the area distance (both upwind and downwind concentrations) and therefore are more representative of a national level, normalized average exposure.

Operating Scenario: 365 days per year, 7 days per week, 24 hours per day.

This operating scenario was selected because industrial facilities evaluated for this ambient air exposure assessment generally operate on a continuous basis under the TSCA COUs evaluated. Therefore this operating scenario is reasonable and representative for a national level assessment.

2.1.2 Human Exposure Model (HEM)

EPA used the Human Exposure Model (HEM 4.2) to obtain geospatial data for mapping and population analysis. HEM was run to estimate annual average formaldehyde concentrations on a site-specific basis at multiple distances from releasing facilities, based on site-specific maximum releases reported to TRI. 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 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 the same set of conservative default parameters integrated into the IIOAC Model for comparability (Table 2-2).

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

Release Type	Release Parameters	Value
Stack	Stack height (m)	10
Stack	Stack diameter (m)	2
Stack	Exit velocity (m/sec)	5
Stack	Exit temperature (°K)	300
Fugitive	Length (m)	10
Fugitive	Width (m)	10
Fugitive	Angle (degrees)	0
Fugitive	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 individual site-specific maximum annual release reported to TRI from 2016 to 2021 for modeling. While using this approach, the Agency recognizes any given site-specific maximum annual release may occur during a different year than another maximum site-specific release. (*e.g.*, Facility A's highest release and modeled exposure may occur in 2016 while Facility B's highest release and modeled exposure may occur in 2018). Therefore, combining the two modeled exposures from two different years as a single year aggregate exposure will not provide an actual exposure for either year, but rather a hypothetical maximum aggregate exposure assuming any combination of years of maximum exposure occur at the same time. Therefore, the estimated aggregated annual exposures from releases to air from industrial facilities may be overestimated.

HEM was run in a configuration with 11 rings of exposed individuals 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 discretely models and estimates annual average concentrations at census block centroids within 3 km of a source. Between 3 and 50 km, 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.

HEM also 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), as described in the *Human Health Risk*

Assessment for Formaldehyde (U.S. EPA, 2024e). Although HEM calculates this aggregate Census block concentration internally, only the MIR value for each block is reported in the output files. To evaluate the aggregate concentrations estimated for each Census block, 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 within each census block are the summed stack and fugitive modeled concentrations from all nearby industrial releasers reporting releases to TRI and impacting that census block within the distances evaluated. In some cases, this represents an aggregate exposure from multiple facilities releasing formaldehyde to the ambient air that are in proximity. In other cases, there may only be a single facility impacting a given census block and therefore there is no aggregated exposure from multiple facilities in proximity. Nonetheless, the single facility impact is still reflected in the HEM results. The census block-specific concentration results represent the expected annual-average ambient air concentration attributable from all site-specific modeled TRI releases attributable to TSCA COUs which impact that census block. The 2020 Census block population estimates included in the HEM Census database associated with modeled blocks are summarized nationally to evaluate the magnitude of the exposed population to various levels of concentrations.

2.1.3 Release and Exposure Concentration Comparison Between TRI and NEI

In response to public and peer review comments, EPA compared the magnitudes and distributions of releases reported in the TRI and NEI datasets as well as associated IIOAC-modeled exposures for TRI and NEI. This comparison was conducted both across individual facilities and by binning releases by industry sector. The industry sector level analysis was a side-by-side comparison of the maximum individual facility reported within TRI and NEI and the 95th percentiles of reported releases across facilities in each sector. These comparison releases were modeled under the annual average exposure scenario (95th percentile modeled concentrations at 100–1,000 m area distance).

The site-specific analysis of releases and aggregate releases utilized individual facility release data to screen and compare the magnitudes of annual release values. Screening release values allows EPA to evaluate where NEI facility release data—either by individual facilities or with aggregated nearby facilities—may result in exposures beyond those already modeled. For this comparison, EPA summed the process-level releases reported to NEI by facility, to create facility total releases that could be compared to TRI facility total releases. Additionally, EPA estimated aggregate release totals from process-level releases located near one another, following methodology previously peer reviewed by SACC and put out for public comment in 2022. The goal of this analysis was to assess whether aggregated releases from nearby facilities reported in the NEI dataset could result in exposure scenarios not otherwise represented in the individual facility modeling based on TRI data and IIOAC modeling results.

EPA reviewed and summarized all 2017 NEI reported release data for formaldehyde from industrial sources. EPA calculated a 100-meter buffer ring around each process-level release point and analyzed where one or more buffers overlapped. If any release overlapped with any other release within that buffer ring, EPA added the release values to obtain a maximum aggregate release for that 100-meter area. This screening exercise focused on the aggregation of release amounts (in kg/year) rather than modeled environmental concentrations, as a means of screening to assess and compare the magnitude of releases. Where aggregate or individual facility releases from the NEI dataset were identified that exceeded the releases already modeled from the TRI dataset, EPA conducted a brief land use analysis by inspecting satellite imagery of the facility and surrounding areas to identify whether residential exposures would be expected.

2.1.4 Air Toxics Screening Assessment (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 using release data from the NEI database. In the 2019 AirToxScreen referenced in this assessment, EPA estimated annual average concentrations are calculated by census tracts. The Agency used information from the 2019 AirToxScreen, which relied upon 2019 NEI reported releases, to characterize the relative relationship of formaldehyde concentrations in ambient air resulting from all known sources of hazardous air pollutants in ambient air. These AirToxScreen results allow EPA to differentiate, to a limited degree, relative modeled emissions from various source categories (*e.g.*, point sources, biogenic sources, and secondary formation) to the overall concentrations of formaldehyde in the ambient air.

EPA used results from the 2019 AirToxScreen in the present assessment to estimate the 95th percentile annual average concentration of formaldehyde from modeled biogenic sources. This estimate represents a concentration that is reasonably expected to occur without human contributions. The 95th percentile estimate is presented along with other formaldehyde sources in Section 3.1.2.. While this value is a percentile derived from the entirety of AirToxScreen data there may be locations where biogenic sources are not prevalent or where biogenic sources are prevalent. In industrialized locations where the presence of biogenic sources may not be prevalent (large forests, national parks, etc.), but where industrial facilities releasing formaldehyde into the ambient air may be predominant formaldehyde sources, the AirToxScreen value from biogenic sources may overestimate the true contribution of biogenic sources to the ambient concentrations of formaldehyde at those locations. By association, this in turn would result in underestimating the relative contribution of formaldehyde resulting from industrial releases of formaldehyde attributable to TSCA COUs when compared to the biogenic contribution.

In 2024, EPA's Office of Air and Radiation published a 2020 AirToxScreen assessment (U.S. EPA, 2024f). Several changes/updates were implemented in this latest analysis including averaging modeled concentrations at the census block level rather than the census tract level. The census block level averaging brings the results more in line with aggregated concentrations modeled with HEM in this Ambient Air Exposure Assessment for Formaldehyde.

2.2 Monitoring

EPA identified and summarized monitoring data for formaldehyde from EPA's AMTIC archive (U.S. EPA, 2022a). The monitoring data are used to understand aggregate or total formaldehyde concentrations from all sources in ambient air. The AMTIC data are also used along with model estimates to characterize concentrations of formaldehyde with recognition that these two difference sources of information provide different information. Finally, EPA used AMTIC archive data from three high-frequency sampling locations to understand the temporal variability of formaldehyde concentrations.

2.2.1 Ambient Monitoring Technology Information Center (AMTIC)

Ambient air concentration data was pulled in July 2023 from EPA's Ambient Air Monitoring Group (AAMG) AMTIC archive for ambient formaldehyde air concentration monitoring data from January 2015 through December 2020. The formaldehyde AMTIC monitoring data had a total of approximately 234,000 entries from 20 monitoring programs covering 187 census tracts in 36 states. Samples were collected using the Fluxsense sampling system (83% of samples), 2,4-dinitrophenylhydrazine (DNPH) silica cartridge (17%), or by pressurized canister (<1%). Samples collected using Flux sense collected 5-minute composite samples while the DNPH silica collection and pressurized canister methods collected 3-, 6-, 8-, and 24-hour duration composite samples. EPA used the AMTIC monitoring data for formaldehyde to assess the geographic distribution of formaldehyde in ambient air across the United States.

EPA also further analyzed the AMTIC monitoring dataset specifically focusing on characterization of exposures for a case-study in the Houston, Texas, area, based on comprehensive 5-minute sampling duration monitoring data submitted by the Houston Department of Health. This dataset consists of 184,307 5-minute composite samples collected in 2019 and 2020 from 3 locations around Buffalo Bayou (Clinton Drive, Lynchburg Ferry, and Haden Road) as it converges with Trinity Bay. The surveyed region is a mixed-use area, including both industrial and residential populations. The sampling sites are surrounded by industrial facilities including chemical plants, William P. Hobby airport, the Port of Houston, shipbuilding ports, and oil and gas refineries intertwined with residential neighborhoods. As such, the measured formaldehyde concentrations represent an aggregate concentration and likely include combustion sources.

These data are used as a case study to assess formaldehyde concentrations because of the high temporal resolution in a highly industrial area. These data can be directly associated with general population exposures that may not be adequately captured from longer-duration or less frequent air sampling. These data are not expected to represent formaldehyde concentrations in other locations but offer insight into the temporal variability of formaldehyde concentrations and are expected to be the best available data to assess formaldehyde exposure concentrations in this specific location.

3 RESULTS

EPA considered both modeled and monitored formaldehyde concentrations for this ambient air exposure assessment. EPA presents results from three different models used to estimate formaldehyde concentrations in ambient air. These include the IIOAC Model (Section 2.1.1), the HEM (Section 2.1.2), and the AirToxScreen assessment (Section 2.1.4) as previously described, and each model serves a different purpose in this assessment. The results for these analyses are provided below.

3.1 Modeling

3.1.1 Integrated Indoor/Outdoor Air Calculator Model (IIOAC)

Results for the IIOAC modeling in this assessment include estimated concentrations from all reported formaldehyde releases from industrial facilities. EPA separately presents results for sites with releases primarily attributable to TSCA COUs and results for sites where the source of the release is primarily attributed to combustion.

3.1.1.1 Daily Average Exposures

The 95th percentile modeled daily average exposure concentrations primarily attributable to TSCA COUs range from 0.0004 to 66 µg/m^3 and are based on the maximum release reported to TRI or NEI as described in Section 2.1.1.1. The highest modeled exposure concentrations from either TRI or NEI are presented in Figure 3-1. There are several instances where the modeling results represent multiple TSCA COUs. This occurs because modeling was done across an industry sector (Section 2.1.1) and several industry sectors cross-walk to multiple TSCA COUs as described in the *Environmental Release Assessment for Formaldehyde* (U.S. EPA, 2024d) and seen in the *Ambient Air Exposure Assessment Results and Risk Calcs Supplement B and C* (U.S. EPA, 2024a). The five highest modeled concentrations linked to TSCA COUs are provided in Table 3-1. Because some industry sectors cross walk to the same TSCA COU, some concentrations included in Table 3-1 may not be reflected in Figure 3-1.

The first two columns in Table 3-1 include information on the industry sector and the industry sector crosswalk to TSCA COUs. The release dataset column notes the source of the reported data, either TRI or NEI. The fugitive and stack columns provide the industry reported source apportioned release values which were used as direct inputs to the IIOAC Model. The concentration column presents the sum of the exposure results modeled for fugitive and stack releases modeled at 100 m from a release point.

Figure 3-1. Daily Average Exposure Concentrations by TSCA COU

Table 3-1. Five Highest 95th Percentile Daily Average Exposure Concentrations Attributable to TSCA COUs

Industry Sector	COUs	Maximum Release Value (kg/year)			Concentration ($\mu g/m^3$ at 100 m)
		Release Dataset	Fugitive	Stack	
Wood Product Manufacturing	Commercial use – chemical substances in automotive and fuel products – automotive care products; Lubricants and greases; Fuels and related products	NEI	9,774	157,547	66
	Processing – incorporation into an article – adhesives and sealant chemicals				
	Processing – reactant – adhesives and sealant chemicals				
	Processing – reactant – bleaching agent				
	Processing – reactant – intermediate				
	Recycling				
Paper Manufacturing	Commercial use – Chemical substances in automotive and fuel products – automotive care products; Lubricants and greases; Fuels and related products	NEI	11,585	23,929	58
	Processing – incorporation into an article – adhesives and sealant chemicals				
	Processing – reactant – intermediate				
	Recycling				
All Other Basic Organic Chemical Manufacturing	Commercial use – Chemical substances in automotive and fuel products – Automotive care products; Lubricants and greases; Fuels and related products	NEI	11,036	9,053	53
	Processing – incorporation into a formulation, mixture, or reaction product				
	Processing – incorporation into a formulation, mixture, or reaction product – Intermediate				
	Processing – Reactant – Adhesives and Sealant Chemicals				
	Processing – reactant – intermediate				
	Processing – reactant – processing aids, specific to petroleum production				

Industry Sector	COUs	Maximum Release Value (kg/year)			Concentration (µg/m³ at 100 m)
		Release Dataset	Fugitive	Stack	
Textiles, Apparel, and Leather Manufacturing	Commercial use – chemical substances in automotive and fuel products – automotive care products; Lubricants and greases; Fuels and related products Commercial use – chemical substances in furnishing treatment/care products – floor coverings; … Processing – incorporation into a formulation, mixture, or reaction product – bleaching agents Processing – incorporation into article – finishing agents	TRI	9,347	18,644	46
Pesticide, Fertilizer, and Other Agricultural Chemical Manufacturing	Commercial use – chemical substances in automotive and fuel products – automotive care products; lubricants and greases; Fuels and related products Processing – incorporation into a formulation, mixture, or reaction product – agricultural chemicals (nonpesticidal) Processing – reactant – intermediate	TRI	8,922	15,588	44

Formaldehyde 95th percentile daily average exposure concentrations attributable to releases where the primary source is combustion ranged from 2 to 662 μg/m^3 based on the maximum release reported to TRI or NEI. The highest modeled exposure concentrations from either TRI or NEI are presented in Table 3-2.

The first three columns in Table 3-2 include information on the industry sector, site reporting the fugitive and stack releases, and the major process unit source(s) from which those releases came. The remaining 4 columns present the same information as described for Table 3-1.

As described previously and shown in Table 3-2, all of the maximum releases within each of the top five industry sectors are from combustion sources such as airplanes, on-site vehicles, process heaters, turbines, and RICE.3.1.4 These estimates are substantially higher than all monitoring data available for formaldehyde (see Section 3.2).

EPA further considered the representativeness of each industry sector's maximum releasing facility by comparing the reported maximum release to the calculated 95th percentile release for that industry sector. For each industry sector presented in Table 3-2, the maximum release was approximately one to two orders of magnitude higher than the calculated 95th percentile release for that same industry sector, indicating that the releases from these individual facilities are likely not representative within their respective industry sectors. This data further supports the large spatial variability in formaldehyde ambient air concentrations. Detailed description of this comparison can be found in Sections 3.1.1.3 and 3.1.4.

Table 3-2. Five Highest 95th Percentile Daily Average Exposure Concentrations Attributable to Combustion

Industry Sector	Facility (County, State)	Major Process Unit Source(s)	Maximum Release Value (kg/year)			Concentration ($\mu g/m^3$ at 100 m)
			Release Dataset	Fugitive	Stack	
Wholesale and Retail Trade	Columbus AF Base (Lowndes, MS)	Aircrafts	NEI	138,205		662
	Transcontinental Gas Pipeline Company, LLC (Henry, GA)	RICE, Turbines			95,159	
Oil and Gas Drilling, Extraction, and Support Activities	Chevron USA Inc. (Kern, CA)	Process heaters, RICE, Turbines	NEI	22,742		334
	Frenchie Draw Central Compressor Station (Fremont, WY)	RICE			1,412,023	
Non-Metalic Mineral Product Manufacturing	Cemex Black Mountain Quarry Plant (San Bernardino, CA)	On-Site Vehicles	NEI	41,190		198
	Thermafiber Inc (Wabash, IN)	Not reported			36,492	
Services	Pope Airforce Base (Cumberland, NC)	Aircrafts	NEI	34,155		169
	Seneca Energy LFGTE Facility (Seneca, NY)	RICE			63,483	
Utilities	Lorain County LFG Power Station (0247100968) (Lorain, OH)	RICE	NEI	10,108		61
	Basin Creek Power Services (Silver Bow, MT)	RICE			101,968	

3.1.1.2 Annual Average Exposures

Formaldehyde annual average exposure concentrations attributable to TSCA COUs range from 0.0001 to 5.7 μg/m^3 based on modeling the 95th percentile releasing facility reported to TRI or NEI. The highest modeled exposure concentrations from either TRI or NEI are presented in Figure 3-2. There are instances where a single modeled concentration represents multiple TSCA COUs.

Figure 3-2. Annual-Average Exposure Concentrations Attributable to TSCA COU

Table 3-3. Five Highest 95th Percentile Annual Average Exposure Concentrations Attributable to TSCA COUs

Industry Sector	COUs	Maximum 95th Percentile Release Value (kg/year)			Concentration (µg/m³) (between 100–1,000 m area distance)
		Release Dataset	Fugitive	Stack	
Non-metallic Mineral Product Manufacturing	Commercial use – chemical substances in automotive and fuel products – automotive care products; Lubricants and greases; Fuels and related products	TRI	8,407	27,961	6
	Processing – incorporation into a formulation, mixture, or reaction product – intermediate				
	Processing – incorporation into an article – adhesives and sealant chemicals				
	Processing – reactant – intermediate				
Textiles, Apparel, and Leather Manufacturing	Commercial use – chemical substances in automotive and fuel products – automotive care products; Lubricants and greases; Fuels and related products	TRI	8,042	3,315	5
	Commercial use – chemical substances in furnishing treatment/care products – floor coverings; Foam seating and bedding products; Furniture and furnishings.				
	Processing – incorporation into a formulation, mixture, or reaction product – bleaching agents				
	Processing – incorporation into article – finishing agents				
Transportation Equipment Manufacturing	Commercial use – chemical substances in automotive and fuel products – automotive care products; Lubricants and greases; Fuels and related products	TRI	3,146	40,823	5
	Industrial use – chemical substances in industrial products – paints and coatings; Adhesives and sealants; Lubricants				
	Processing – incorporation into an article – paint additives and coating additives				

Industry Sector	COUs	Maximum 95th Percentile Release Value (kg/year)			Concentration (µg/m³) (between 100–1,000 m area distance)
		Release Dataset	Fugitive	Stack	
Oil and Gas Drilling, Extraction, and Support Activities	Commercial use – chemical substances in automotive and fuel products – automotive care products; Lubricants and greases; Fuels and related products	NEI	4,117	7,265	3
	Industrial use – non – incorporative activities – processing aids				
	Processing – incorporation into a formulation, mixture, or reaction product – intermediate				
	Processing – incorporation into a formulation, mixture, or reaction product – processing aids, specific to petroleum production				
	Processing – reactant – functional fluid				
Wood Product Manufacturing	Commercial use – chemical substances in automotive and fuel products – automotive care products; Lubricants and greases; Fuels and related products	NEI	3,807	7,9601	2
	Processing – incorporation into an article – adhesives and sealant chemicals				
	Processing – reactant – adhesives and sealant chemicals				
	Processing – reactant – bleaching agent				
	Processing – reactant – intermediate				
	Recycling				

3.1.1.3 IIOAC Release and Exposure Results Comparison between TRI and NEI

Table 3-4 presents the highest releases reported to either TRI or NEI for each industry sector for both the maximum and 95th percentile release scenarios evaluated in this ambient air exposure assessment. When the highest release value is reported in the NEI dataset it is bolded.

There are a total of 35 industry sectors captured by the TRI dataset which reported formaldehyde releases. There are 46 industry sectors captured by the NEI dataset which reported formaldehyde releases. There are 11 industry sectors captured by NEI, and not captured by TRI, which are bolded and italicized in Table 3-4.

Table 3-4. Reported Release Comparison of TRI and NEI

Industry Sector	Highest Total Releases (kg/yr) (between TRI and NEI)			
	Maximum Release Scenario		95th Percentile Release Scenario	
	Fugitive	Stack	Fugitive	Stack
Adhesive Manufacturing	**170**	457	65	455
Agriculture, Forestry, Fishing and Hunting	656	3,285	9	213
All Other Basic Inorganic Chemical Manufacturing	**121**	**13,879**	33	4,562
All Other Basic Organic Chemical Manufacturing	**11,036**	**9,054**	**673**	1,975
All Other Chemical Product and Preparation Manufacturing	2,605	6,804	316	990
All Other Petroleum and Coal Products Manufacturing	2,355	672	899	455
Asphalt Paving, Roofing, and Coating Materials Manufacturing	711	**6,895**	526	1,434
Computer and Electronic Product Manufacturing	**261**	**979**	131	536
Construction	198	11,047	68	675
Custom Compounding of Purchased Resin	321	590	321	560
Electrical Equipment, Appliance, and Component Manufacturing	117	1,594	10	99
Explosives Manufacturing	195	39	185	33
Fabricated Metal Product Manufacturing	**4,445**	28,360	132	2,858
Furniture and Related Product Manufacturing	6,008	**2,150**	3,917	468
Industrial Gas Manufacturing	**398**	**1,679**	192	615
Machinery Manufacturing	3,357	13,428	2,611	10,424
Manufacturing of Formaldehyde	6,949	17,690	2,736	10,645
Mining (except Oil and Gas) and Support Activities	**497**	**103,180**	**57**	381
Miscellaneous Manufacturing	340	32,400	340	31,651
"Nonmetallic Mineral Product Manufacturing (includes clay, glass, cement, concrete,	**41,190**	36,902	8,407	27,961

Industry Sector	Highest Total Releases (kg/yr) (between TRI and NEI)			
	Maximum Release Scenario		95th Percentile Release Scenario	
	Fugitive	Stack	Fugitive	Stack
lime, gypsum, and other nonmetallic mineral product manufacturing)"				
Oil and Gas Drilling, Extraction, and Support Activities	22,742	1,412,023	4,117	7,265
Organic Fiber Manufacturing	376	**2,317**	362	**2,147**
Paint and Coating Manufacturing	2,948	1,343	2,948	969
Paper Manufacturing	**11,585**	**23,929**	**1,658**	13,502
Pesticide, Fertilizer, and Other Agricultural Chemical Manufacturing	8,922	15,588	1,852	6,473
Petrochemical Manufacturing	**4,434**	20,563	2,177	13,637
Petroleum Lubricating Oil and Grease Manufacturing	10	49	8	24
Petroleum Refineries	**6,525**	**136,723**	**1,856**	10,889
Photographic Film Paper, Plate, and Chemical Manufacturing	48	56	45	51
Plastic Material and Resin Manufacturing	3,040	13,892	958	4,775
Plastics Product Manufacturing	**4,625**	8,552	2,983	8,024
Primary Metal Manufacturing	**5,169**	**6,231**	**101**	1,629
Printing and Related Support Activities	23	450	3	15
Printing Ink Manufacturing	0	5	0	4
Rubber Product Manufacturing	**9**	**991**	**7**	**40**
Services	**34,155**	**63,483**	524	361
Soap, Cleaning Compound, and Toilet Preparation Manufacturing	4,295	**4,385**	1,162	884
Synthetic Dye and Pigment Manufacturing	**5,250**	1,343	2,889	1,343
Synthetic Rubber Manufacturing	3	3,342	3	482
Textiles, apparel, and leather manufacturing	9,347	18,644	8,042	3,315
Transportation Equipment Manufacturing	3,298	44,906	3,146	40,823
Utilities	**10.108**	**101,968**	468	25,877
Wholesale and Retail Trade	**138,205**	**95,159**	**546**	**9,345**
Wood Product Manufacturing	**9,774**	158,757	**3,807**	24,724
Bolded release numbers represent NEI reported releases which are greater than TRI reported releases for that industry sector ***Bolded and italicized*** industry sectors represent industry sectors captured by NEI but not TRI.				

As shown in Table 3-4, the TRI dataset tends to capture higher releases of formaldehyde compared to NEI dataset when considering the calculated 95th percentile releases across industry sectors. However, in some cases, facilities within certain industry sectors report higher formaldehyde releases in NEI than TRI. While those NEI releases are higher, in those industry sectors the TRI and NEI datasets were similar (*i.e.*, fell within the same estimated distribution range). In addition, the overall observed release and exposure findings do not change substantially when the NEI dataset is included with the TRI dataset. When there is a substantial difference between TRI and NEI reported releases, EPA found that those are generally due to combustion sources which are captured by NEI but not TRI. The high-end exposure profiles for both TRI and NEI datasets are compared in Figure 3-3**.** More information on TRI and NEI releases and additional analysis of releases at the site-specific level and in aggregate are described in Section 3.1.4.

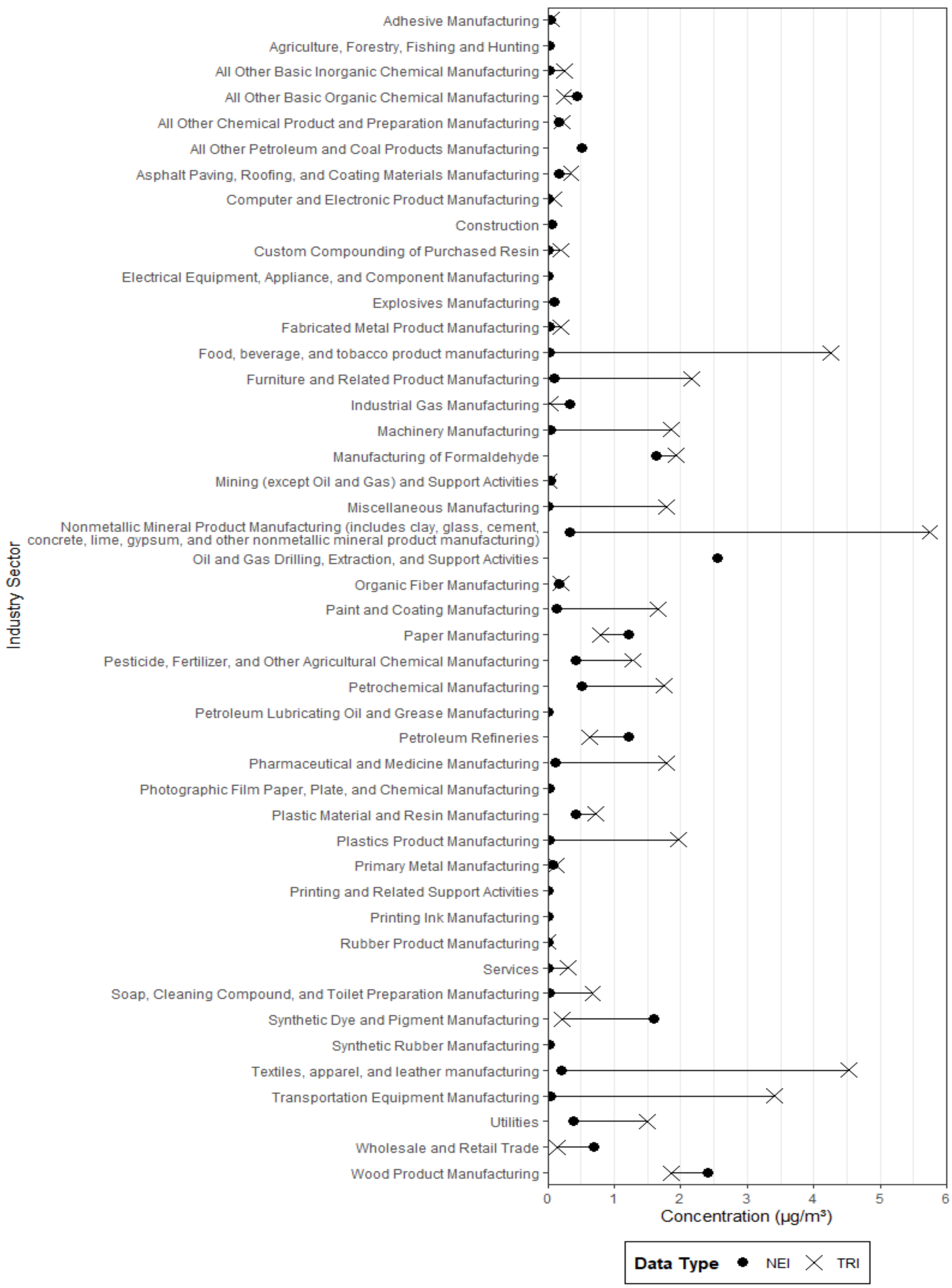

Figure 3-3. High-End (95th Percentile) Exposure Concentration Comparison by Industry Sector Between TRI and NEI at 100 to 1,000 Meters Based on 95th Percentile Release Scenario NEI Release Screening and Comparison with TRI (Site-Specific)

3.1.2 AirToxScreen

Figure 3-4 presents the range of modeled formaldehyde concentrations across biogenic sources, secondary sources, and point sources. These results are not specific to a finite distance like the IIOAC or

HEM modeled concentrations. Rather, the 2019 AirToxScreen results are modeled at the census tract level, which is a large area of land rather than a finite distance from a TSCA COU specific release point. Regarding population, census tracts may range from 1,200 to 8,000 people and can be as small as a few city blocks or as large as several square miles. These sources are a subset of the 38 different sources available in the 2019 dataset. AirToxScreen formaldehyde concentrations range from 0.11 to 9.38 μg/m^3 with secondary production contributing the most. Secondary production of formaldehyde was estimated to range between 0.085 to 1.80 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 as well as other chemicals regulated under TSCA such as 1,3-butadiene. Point source contributions to total formaldehyde concentrations range from 0.0 to 0.88 μg/m^3. Point sources are expected to include contributions from TSCA COUs; however, AirToxScreen results are not TSCA COU-specific. The lower concentrations estimated by 2019 AirToxScreen, relative to the IIOAC-modeled concentrations is expected because 2019 AirToxScreen is averaged across a census tract rather than at a finite distance from a release point. Biogenic sources of formaldehyde also significantly contribute to the total concentrations of formaldehyde. These emissions are from trees, plants, and soil microbes and ranged from 0.0014 to 0.62 μg/m^3. The Agency used the 95th percentile of biogenic sources of formaldehyde or 0.28 μg/m^3 to understand how other modeled and monitored air concentrations compare to natural sources of formaldehyde.

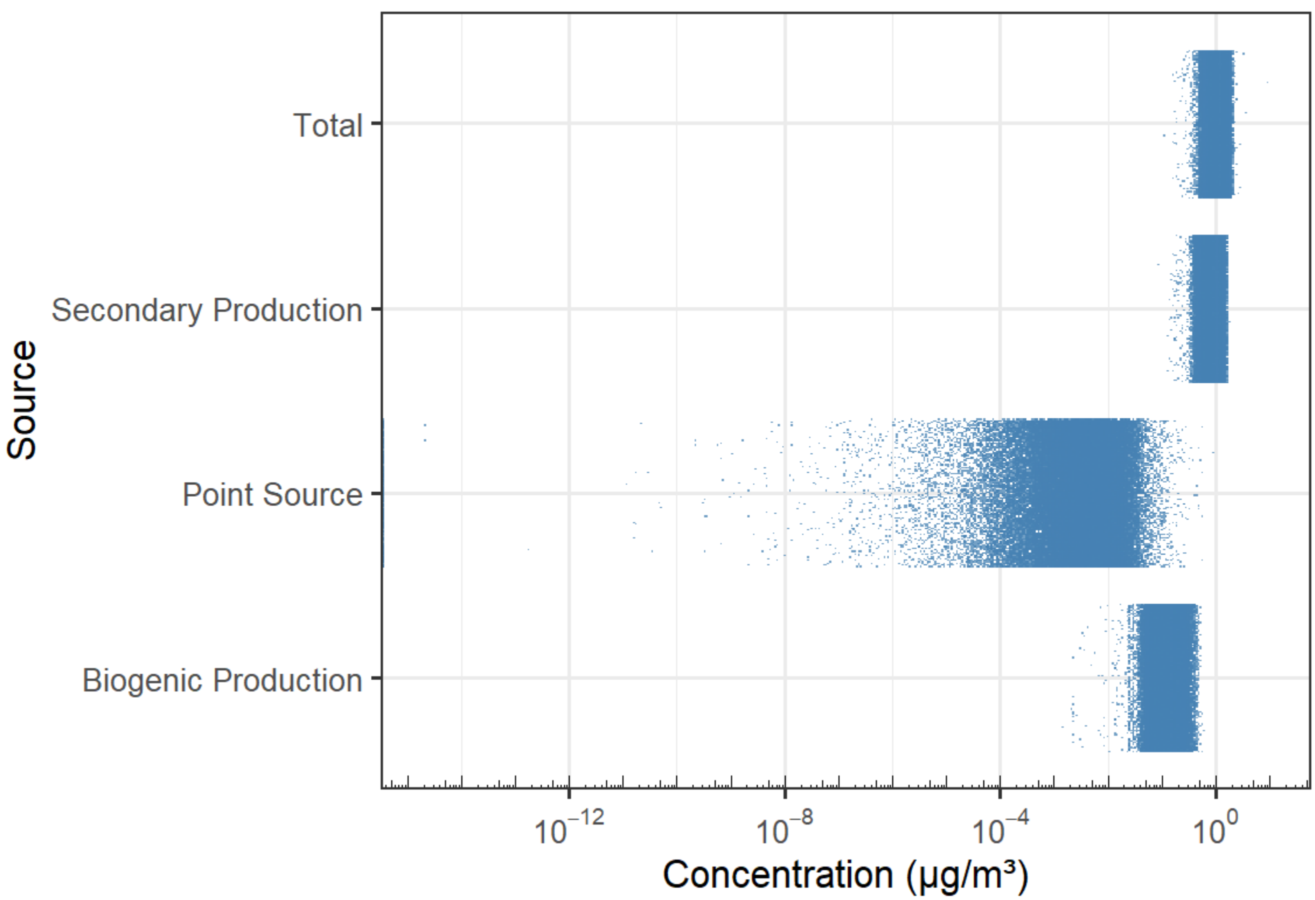

Figure 3-4. 2019 AirToxScreen Results for Total, Secondary Production, Point Source, and Biogenic Production Modeled Concentrations

After the *Draft Risk Evaluation for Formaldehyde* was released, results from the 2020 AirToxScreen assessment were released by the Office of Air and Radiation (https://www.epa.gov/AirToxScreen/2020-airtoxscreen-assessment-results). These results are shown in Figure 3-5. Total formaldehyde concentrations range from 0 to 17.2 μg/m^3, which has a higher max compared to the 2019 AirToxScreen results. This difference may be attributed to the scale of the model. As mentioned, the 2019 results are at the census tract scale. The 2020 results are modeled at the census block scale which is much smaller and provides less area for estimating ambient air concentrations. Several areas with elevated concentrations of formaldehyde were present in Oregon (max 17.2 μg/m^3), Puerto Rico (max 9.7 μg/m^3), Texas (max 9.6 μg/m^3), and Colorado (max 9.1 μg/m^3). These maximum concentrations estimated by 2020 AirToxScreen are 2 to 3 times higher than the IIOAC 95th percentile annual average modeled concentrations based on the 95th percentile releases and an order of magnitude lower than the highest IIOAC 95th percentile annual average modeled concentrations based on the maximum release scenarios (which as described above are primarily attributable to combustion sources). While some general conclusions may be attempted when comparing 2019 to 2020 AirToxScreen results, the results are not directly comparable between 2019 and 2020. Nontheless, both results show that secondary formation, biogenic production, and point sources are the largest contributors to total ambient air concentrations of formaldehyde.

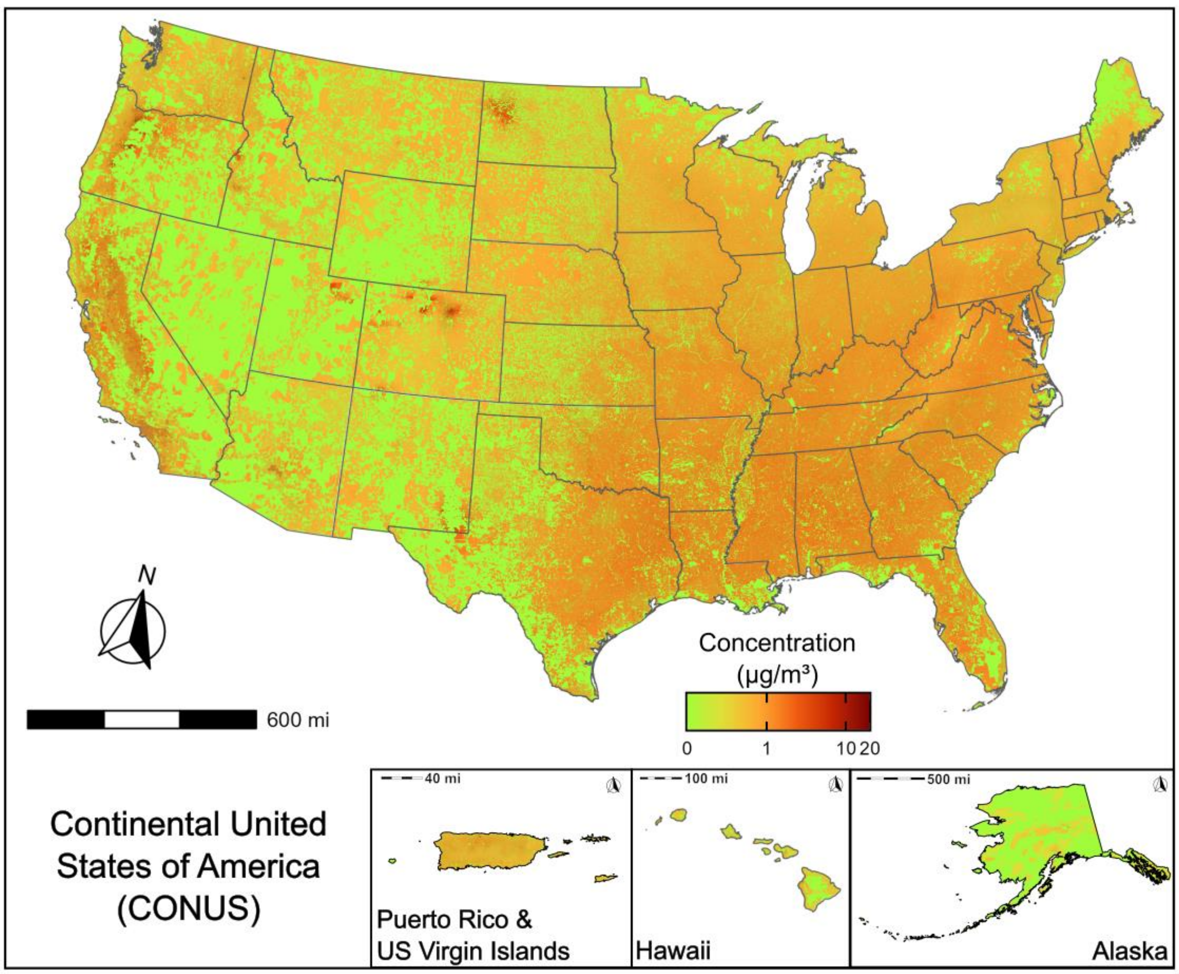

Figure 3-5. 2020 AirToxScreen-Modeled Formaldehyde Concentrations Throughout the Continental United States of America

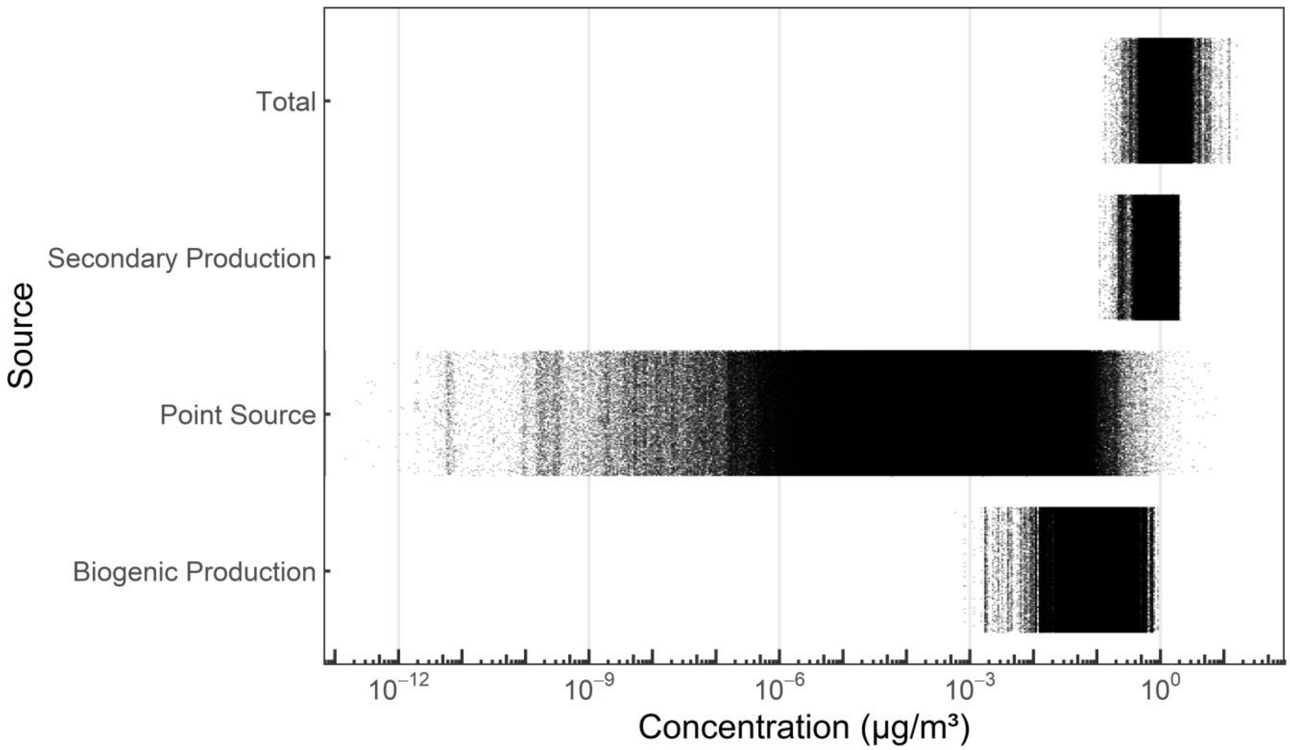

Figure 3-6. 2020 AirToxScreen Results for Total, Secondary Production, Point Source, and Biogenic Production Modeled Concentrations

3.1.3 Human Exposure Model (HEM)

Annual average formaldehyde 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 3-7). Resulting concentrations ranged from 0 to 8.9 µg/m³, with the greatest concentrations nearby industrial facilities. Census blocks with modeled concentrations below a concentration of 0.28 µg/m³ are presented in gray. This value is associated with the estimated national 95th percentile concentration from biogenic/natural sources of formaldehyde. Blue dots show Census blocks with concentrations ranging from 1 to 5 times 0.28 µg/m³, purple dots show concentrations from 5 to 10 times 0.28 µg/m³, and pink dots show values greater than 10 times 0.28 µg/m³. Across the nation, a total population of approximately one-hundred-thousand people (based on 2020 Census data) live in the Census blocks with modeled ambient concentrations from TRI sources exceeding 0.28 µg/m³.

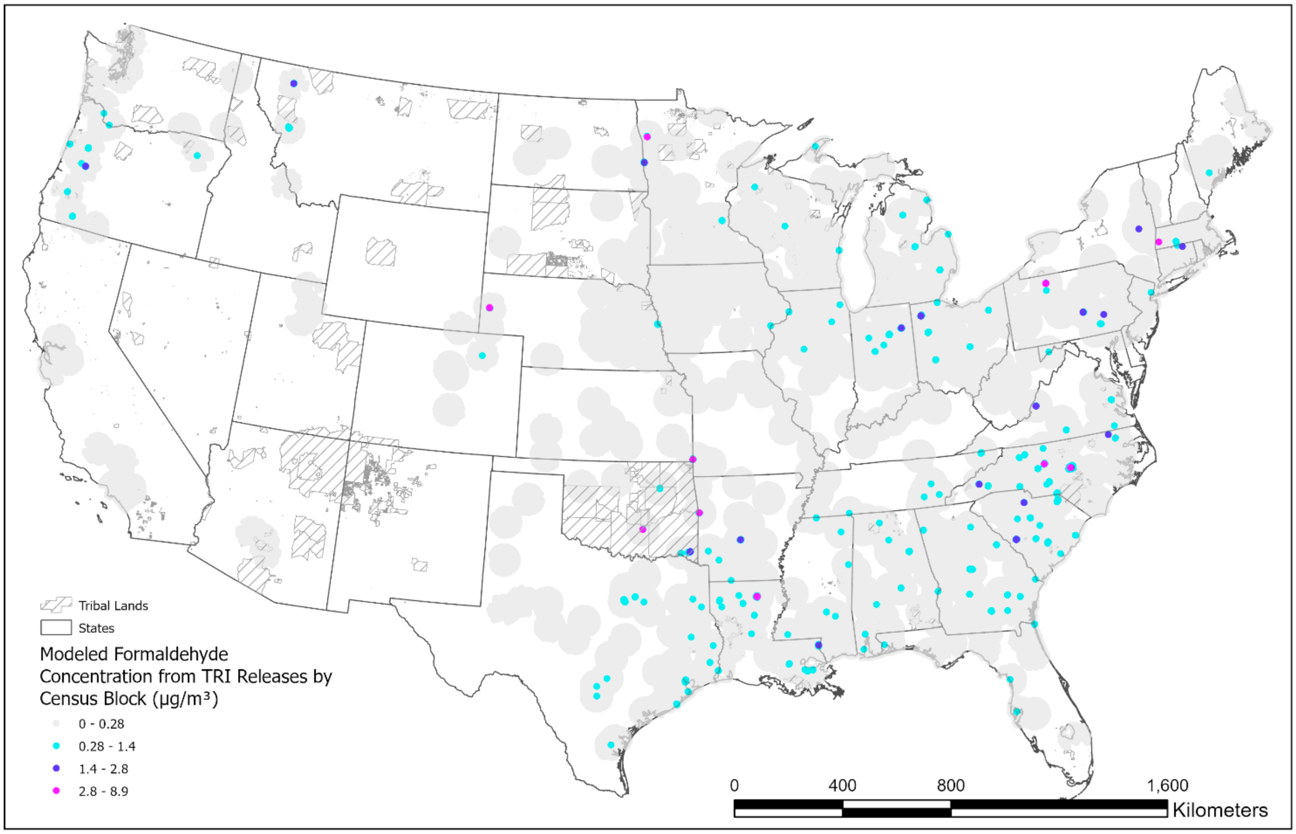

Figure 3-7. Map of Contiguous United States with HEM Model Results for TRI Releases Aggregated and Summarized by Census Block

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 release point were examined (Figure 3-8). 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 release point, 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 release point. 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. Maximum modeled ambient air concentrations approaching 100 µg/m³ at the 100-meter distance and approaching 10 µg/m³ at the 10-meter distance are consistent with the IIOAC results discussed in Section 3.1.1.

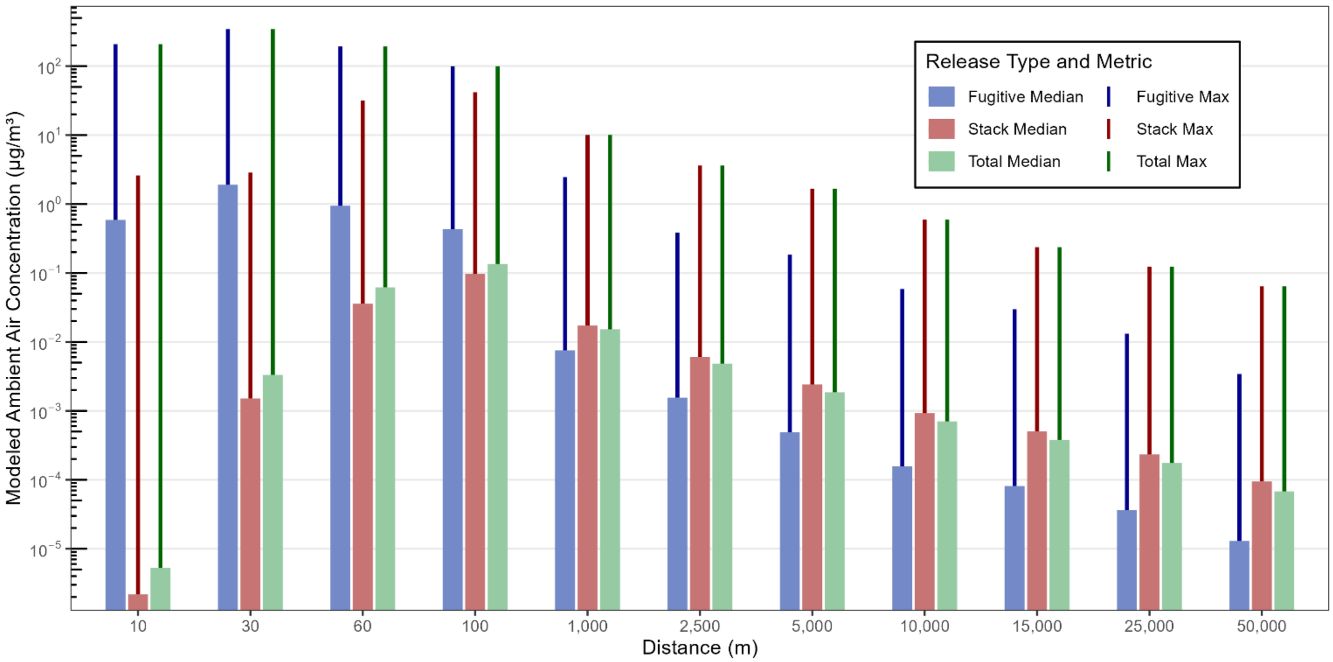

Figure 3-8. Median and Maximum Downwind Concentrations (Fugitive, Stack, and Total Emissions) across the 11 Discrete Distance Rings Modeled in HEM

3.1.4 NEI Release Screening and Comparison with TRI (Site-Specific)

EPA modeled NEI releases using IIOAC and presents a comparison with the releases reported to TRI in Section 3.1.1.3. As a further analysis, to assess the potential value added from HEM modeling of NEI release data, EPA screened the release values of NEI against TRI releases, both from individual facilities, and as aggregate releases from nearby facilities in Section 3.1.4.1.

The overall distribution of facility total formaldehyde releases to air were plotted as histograms, with the NEI releases presented in Figure 3-9 and TRI releases presented in Figure 3-10. Prior to analysis, the process-level release records from NEI were summed to create facility totals, which represented a combination of fugitive and stack releases. Generally, the bulk of the distribution of releases reported to TRI tend to be higher overall, relative to NEI reported releases, aside from a few of the maximum releases reported from NEI, with the median TRI facility release falling at approximately 900 kg/yr, and the median NEI release approximately 1.3 kg/yr. The distribution of the facility releases reported via NEI is heavily skewed toward lower releases; approximately 64 percent of NEI facility release totals are less than 1 kg/yr (9,431 facilities) and approximately 87 percent of NEI facility release totals are less than 100 kg/yr (12,943 facilities).

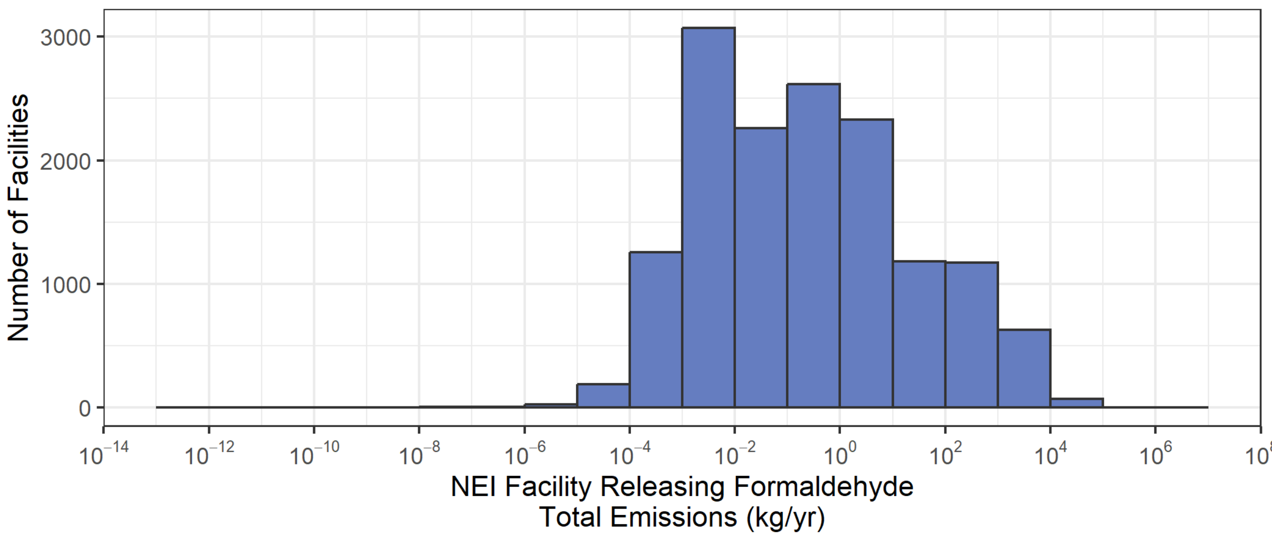

Figure 3-9. Histogram of Facility Totals of Annual Formaldehyde Emissions from the 2017 NEI Dataset

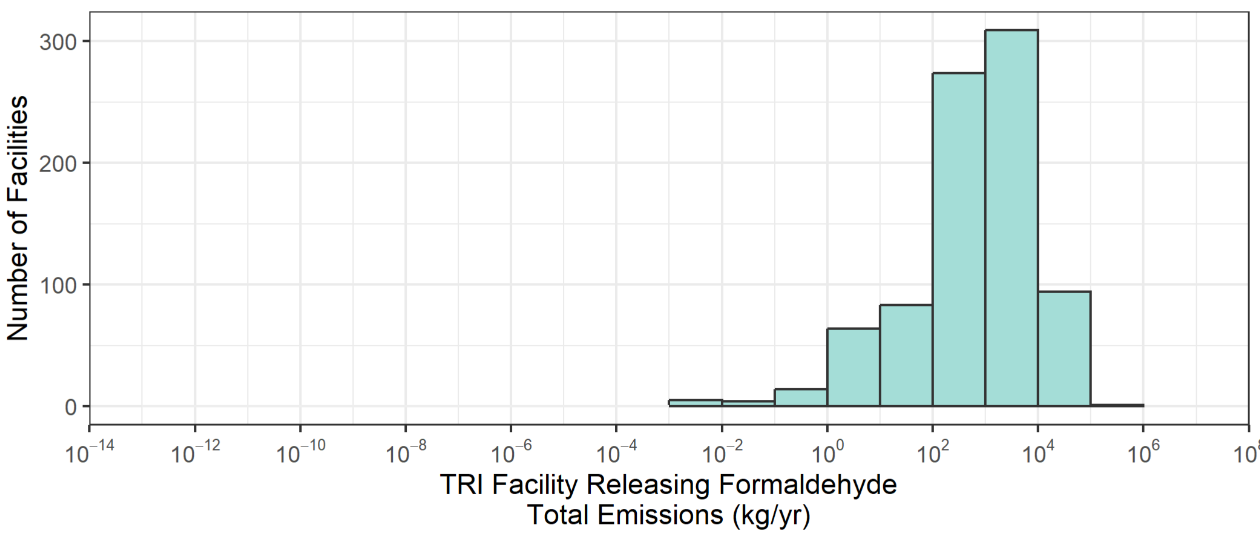

Figure 3-10. Histogram of the Maximum Annual Facility Total Emissions of Formaldehyde from TRI

The NEI dataset has two facilities with higher releases than those represented in TRI. These are in Fremont County, Wyoming, and are part of the Oil and Gas Drilling, Extraction, and Support Activities sector. The third-highest facility reporting to NEI, in Chatham County, North Carolina, is also included in TRI and represented in the HEM modeling already conducted by EPA for the Formaldehyde Risk Evaluation. Beyond the third-highest facility, NEI does not contain any other facilities reporting individual facility total release amounts greater than those reported in the TRI dataset and modeled in HEM.

Table 3-5. Top-10 Facility Total Formaldehyde Air Releases Reported to the 2017 NEI

EIS ID	TRI ID	County	State	Total Emissions[a] (kg/yr)	IS Description
14554311	98632WYR HS3401I	Fremont	WY	1,412,023	Oil and Gas Drilling, Extraction, and Support Activities
16678611		Fremont	WY	580,664	Oil and Gas Drilling, Extraction, and Support Activities
7998311	27559WYR HSSTATE[b]	Chatham	NC	158,809	Wood Product Manufacturing
11307011		Lowndes	MS	138,205	Wholesale and Retail Trade
8222511		Crawford	IL	136,723	Petroleum Refineries
12132011		Virginia Beach City	VA	116,347	Wholesale and Retail Trade
6927911		St. Louis	MN	103,180	Mining (except oil and gas) and Support Activities
6371211		Lorain	OH	101,968	Utilities
2681611		Cook	IL	99,301	Wholesale and Retail Trade
9076711		Tarrant	TX	97,926	Wholesale and Retail Trade

[a] The total emissions reported in this table are sum totals of the individual process-level release data associated with the facility reported to NEI.
[b] Denotes the facility present in the top-10 releases from both TRI and NEI.

Table 3-6. Top-10 Facility Total Formaldehyde Air Releases Reported to TRI and Included in HEM Modeling

TRI ID	County	State	Total Air Release of Formaldehyde (kg/year)
27559WYRHSSTATE[a]	CHATHAM	NC	158,756
29512FLKBR579WI	MARLBORO	SC	48,771
46783GMCTR12200	ALLEN	IN	45,442
46992SGNTRMILLS	WABASH	IN	36,896
56716MRCNCHIGHW	POLK	MN	34,547
59802LSNPC3300R	MISSOULA	MT	33,330
29059SNTCMSCHWY	ORANGEBURG	SC	32,678
17547RMSTRROUTE	LANCASTER	PA	32,638
28345PRGRSNCSR1	RICHMOND	NC	30,839
59912PLMCRPOBOX	FLATHEAD	MT	28,494

[a] Denotes the facility present in the top 10 releases from both TRI and NEI.

The two highest-releasing facilities from NEI, which are not represented in the TRI dataset, are both oil- and gas-related and located in Wyoming far from residential areas. General population exposures are not expected for these two facilities. No residential communities were observed from visual inspection of the areas surrounding the facilities as shown below in Figure 3-11 and Figure 3-12.

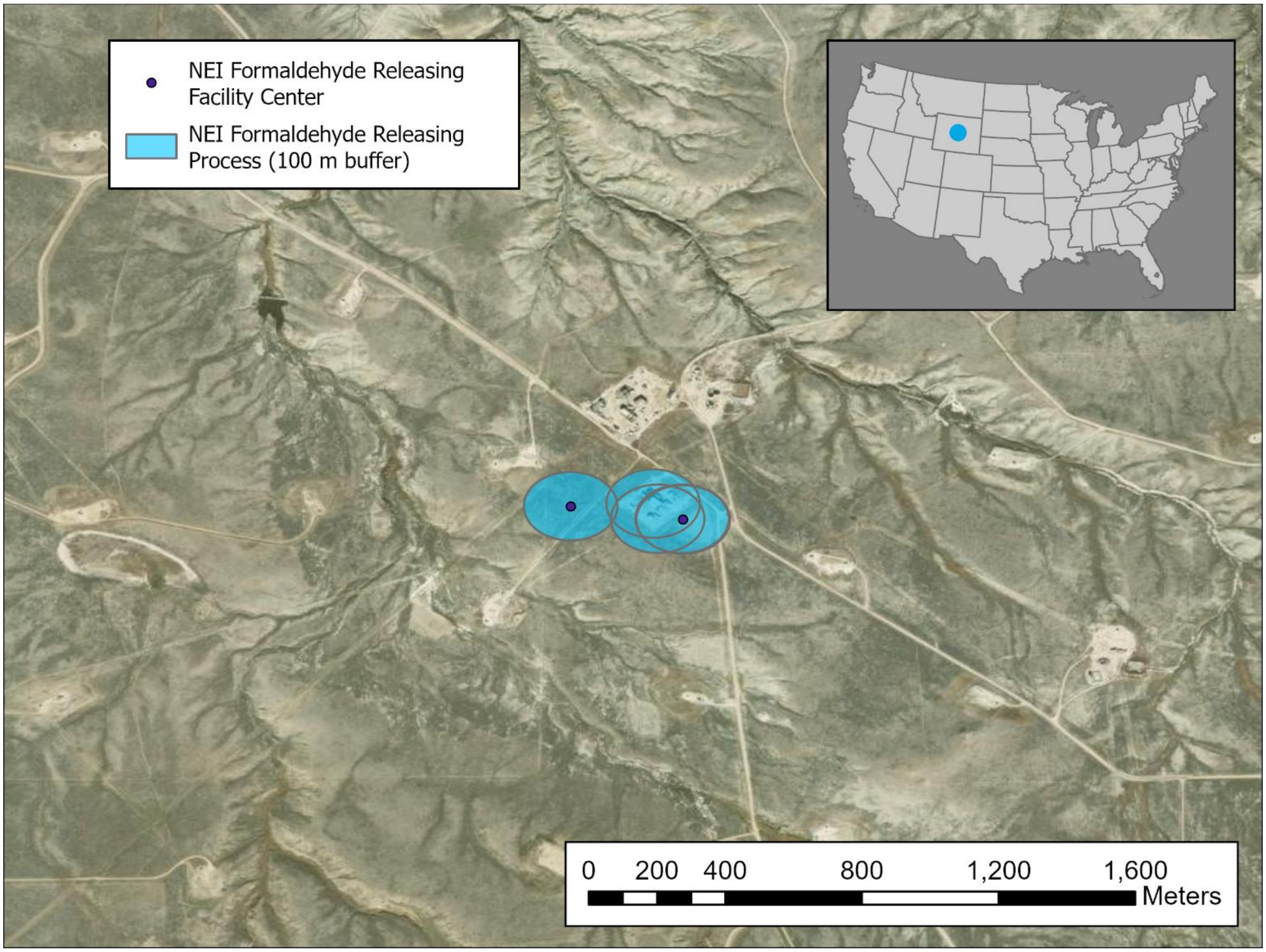

Figure 3-11. The Highest Releasing Facility from NEI

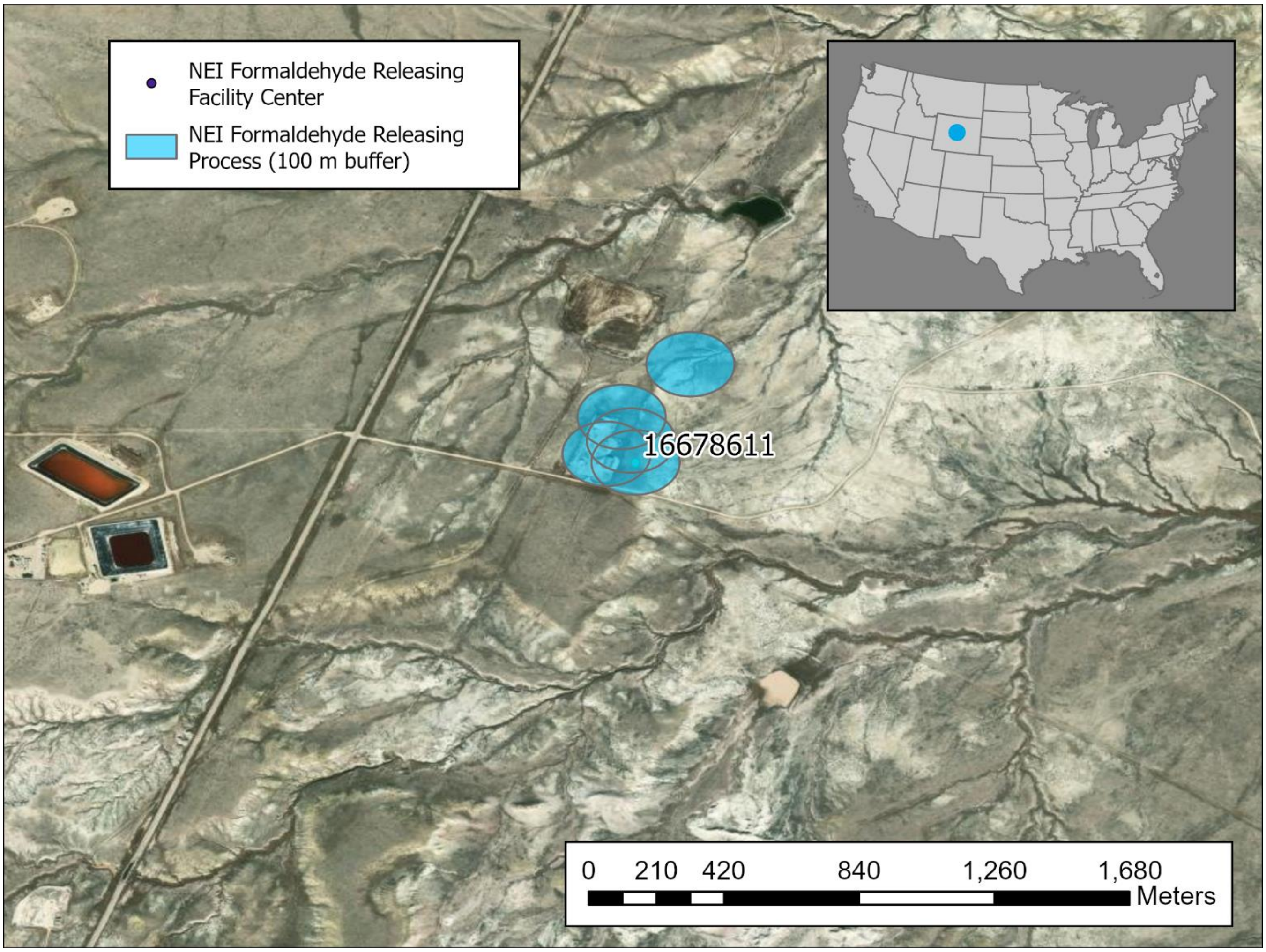

Figure 3-12. The Second-Highest Releasing Facility from NEI

On an individual facility basis—these comparisons of the range of the datasets demonstrate little value added by modeling NEI facilities in HEM, when compared to the TRI releases already evaluated. EPA has already accounted for releases of the magnitude represented in NEI, and the individual facility maximum release amounts have already been accounted for in the IIOAC modeling presented in Section 3.1.1.3.

3.1.4.1 NEI Aggregate Release Screening (Site-Specific)

An analysis of the potential aggregate releases from nearby facilities was also conducted to assess potential value added from modeling NEI releases in HEM. The upper end of the distribution of aggregated releases reported in the 2017 NEI (where release points had overlapping 100-meter buffers) tended to be entirely made up of pairs of releasing facilities. By visual inspection, these aggregate release scenarios were typically larger industrial properties which included multiple facilities, with the aggregated release typically composed of a larger release aggregated with a smaller release from a nearby facility. In this typical scenario, the aggregate scenario represented a total release that did not differ greatly from the individual facility release at the same location.

The highest aggregated release includes the highest individual facility release as shown in Figure 3-11. The second-highest aggregated release is shown in Figure 3-12 and includes a pair of facilities releasing a combined 54,427 kg/year. With all other aggregated releases falling below this total release amount, the potential for aggregate releases at the 100-meter distance are far outweighed by the individual facility releases already accounted for in the modeling (with the highest TRI release reported as 158,756 kg/yr). This facility is shown in Figure 3-13.

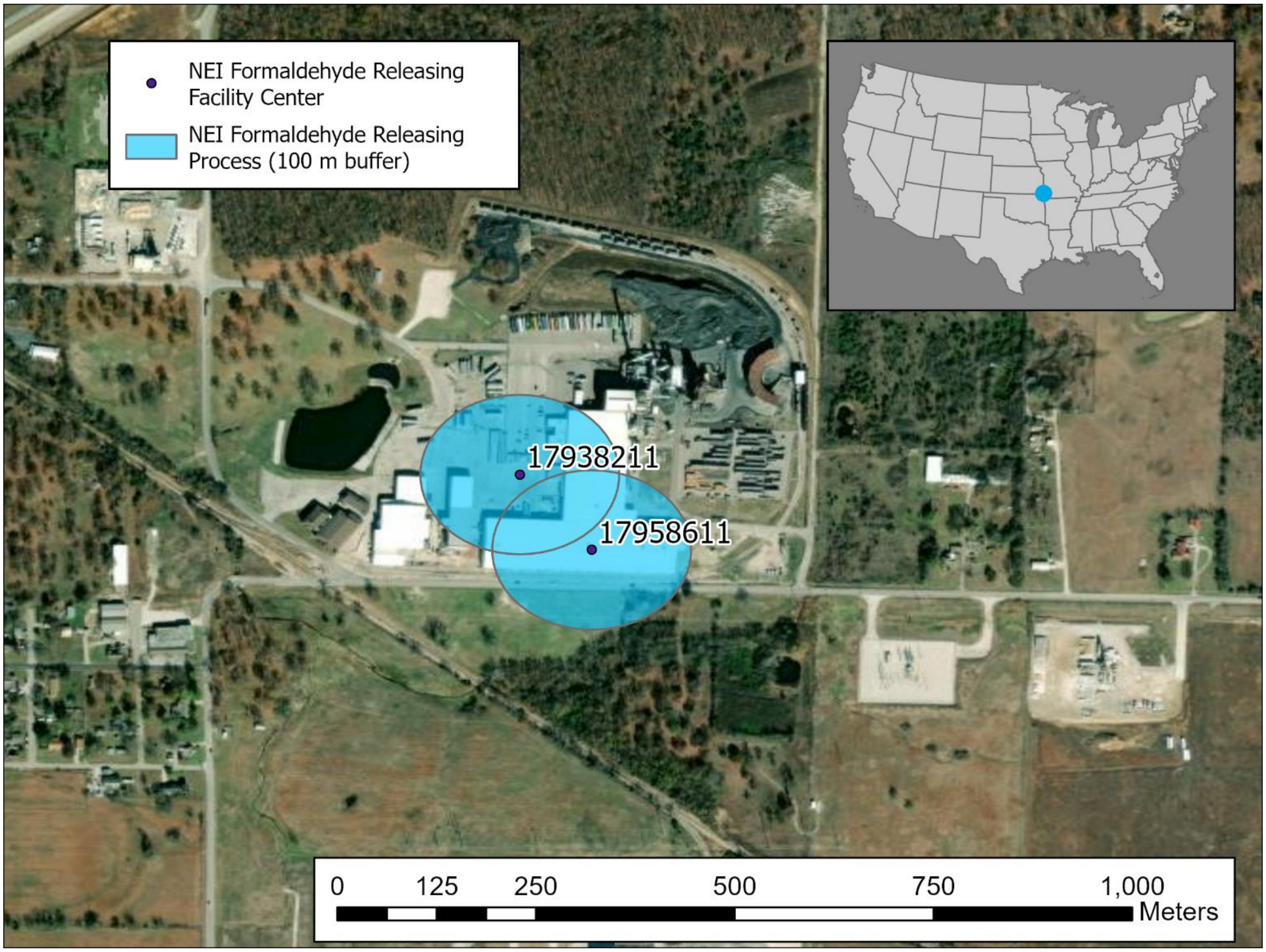

Figure 3-13. Example of High-End Aggregate Release of Two Facilities within 100 m of Each Other with a Combined Release of 54,427 kg/yr

While the highest aggregated release amounts come from pairs of nearby facilities, such as those pictured in Figure 3-13. The NEI dataset includes areas where many facilities intersect at the 100 m distance. An example of one of the highest density locations is in San Francisco, California (Figure 3-14), where most of the releases are attributed to combustion processes. Despite the high number of facilities, and the high amount of overlap at the 100 m distance, the largest aggregated release in this area is approximately 100 kg/yr—and not notably higher than the largest individual facility release in the area. Individual facility generic modeling conducted in IIOAC therefore provides a more conservative and protective estimate of exposures than a more nuanced analysis of such a site-specific scenario.

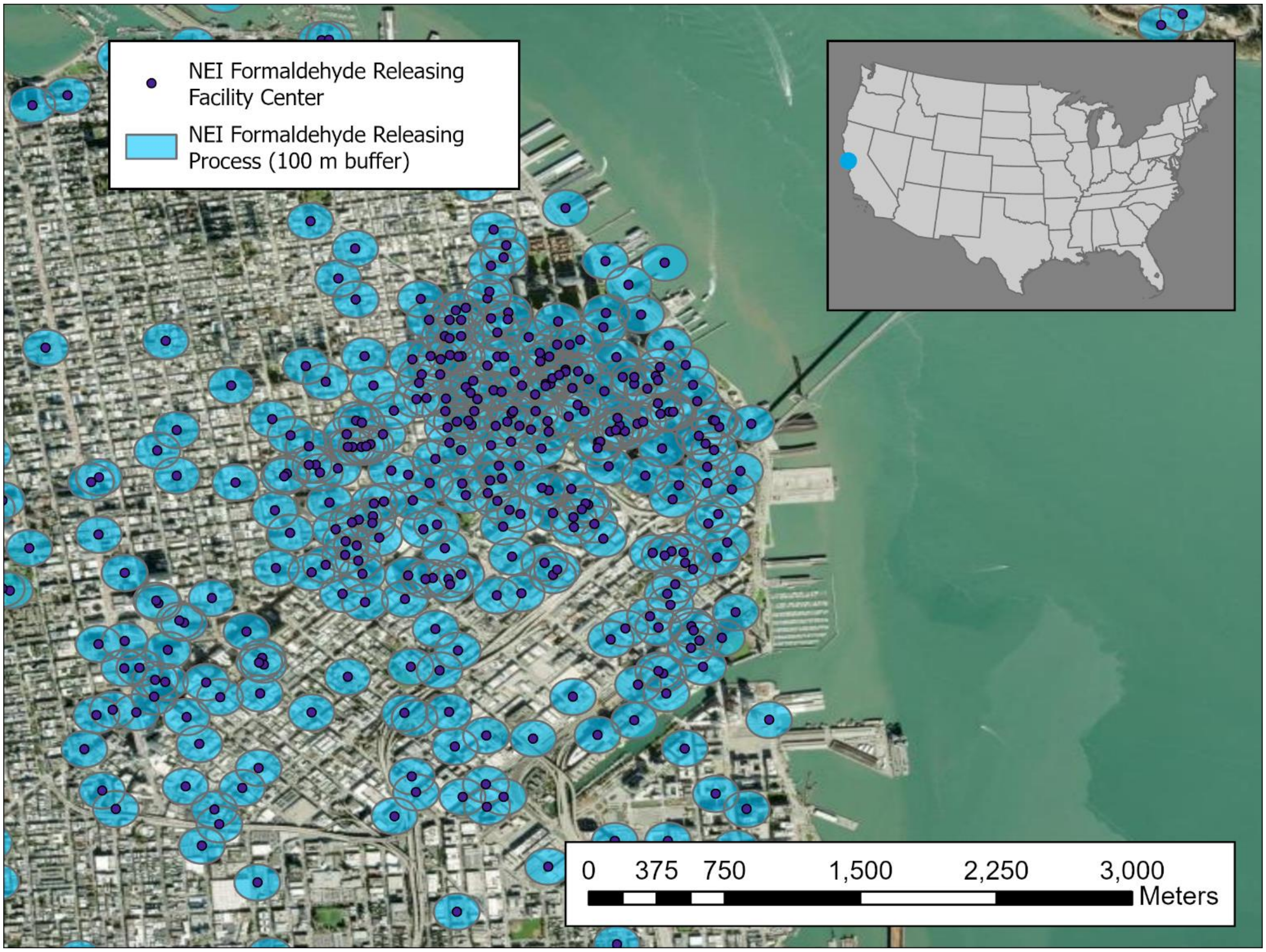

Figure 3-14. Example of a Higher Density of Nearby Releases
Note: Due to the low individual release values for each facility, the largest aggregated release amount at 100 m is approximately 100 kg/yr.

The potential for nearby releases is greater in the NEI dataset, due to the greater numbers of facilities reporting. However, the skew of the dataset toward lower release values results in aggregate releases which do not suggest that notably higher exposures are occurring on a national scale than those considered in the individual facility analyses. In contrast to the 10 highest individual facility releases, the highest aggregated releases at the 100-meter distance are presented in Table 3-7. Generally, the greater release amounts from individual facilities demonstrate aggregation of NEI releases via HEM modeling would not suggest risk beyond the exposures already estimated by the IIOAC modeling presented in Section 3.1.1.3.

Table 3-7. The Highest Aggregated Facility Release Amounts at the 100-Meter Distance

2017 NEI Aggregated Facility Releases at 100 m (kg/yr)	County	State
1,412,023	Fremont	WY
54,427	Jasper	MO
37,345	Latimer	OK
34,559	Hansford	TX
28,558	Defiance	OH
25,350	St. Mary	LA
24,041	Anchorage	AK
23,333	Heard	GA
17,531	Mohave	AZ
16,626	Galveston	TX

3.2 Monitoring

3.2.1 Ambient Monitoring Technology Information Center (AMTIC) Archive

EPA considered approximately 234,000 samples from a total of 306,529 samples pulled from the AMTIC archive (U.S. EPA, 2024a). Incomplete sample cases were filtered out from the complete sample set if they were missing key metadata or otherwise incomplete (*i.e.*, failure to report units, concentration, collection or analysis methodology, or collection date, time, or geographic location). Samples were collected from June 01, 2015, through December 31, 2020. EPA found 24 percent of entries were omitted due to missing or incomplete concentration, duration, or methodology data. Fifteen percent of samples fell below the standard method detection limit (MDL). The overall monitoring dataset had concentrations ranging from 0 to 60 $\mu g/m^3$ with a median concentration of 1.6 $\mu g/m^3$ and a mean concentration of 2.1 ± 2.2 $\mu g/m^3$. Annual summary statistics are provided in Figure 3-15. Figure 3-16 shows the location and concentration of formaldehyde at each formaldehyde monitoring site.

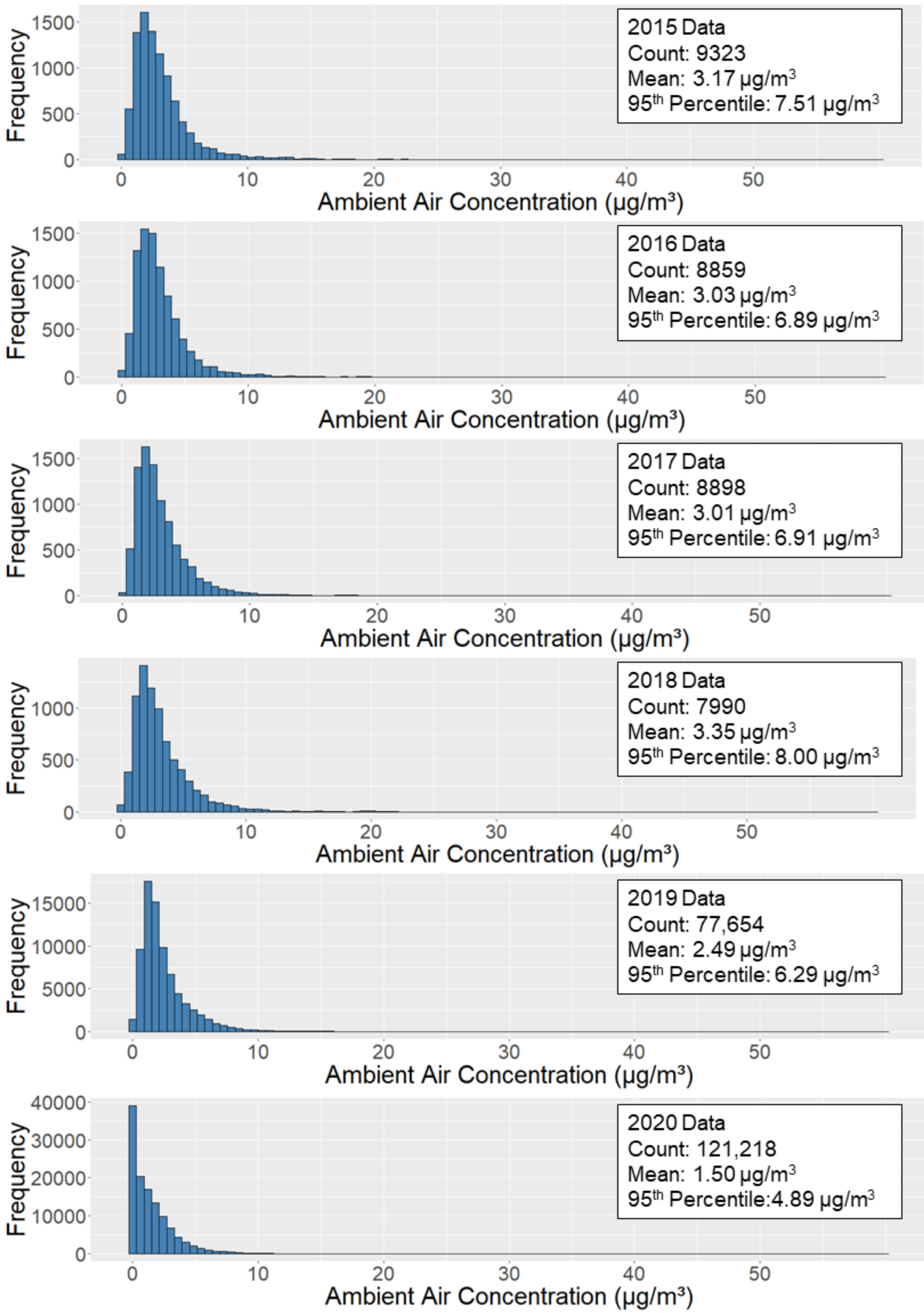

Figure 3-15. Histograms of Ambient Air Concentrations (µg/m³) of Formaldehyde across Contiguous United States from 2015 to 2020 (All Collection Methods, All Collection Durations)

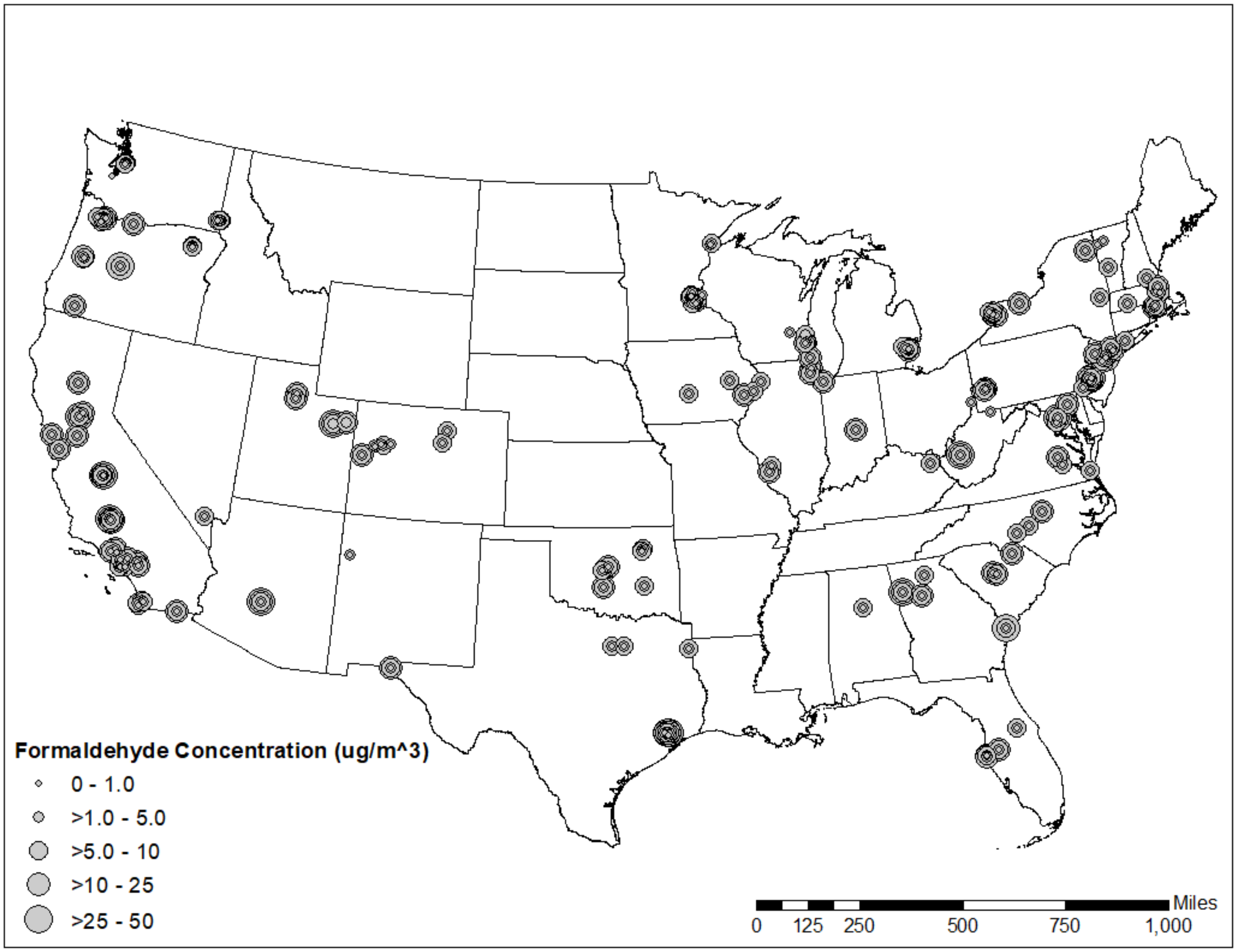

Figure 3-16. Map of Monitoring Sites for Formaldehyde across the Contiguous United States

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 EPA pre-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. Five-minute sample duration had a lower median (1.3 µg/m^3) and mean (1.6 µg/m^3) compared to the longer duration composite sample median (2.3–3.7 µg/m^3) and mean (2.8–4.4 µg/m^3). The 5-minute samples were taken continuously over the 24-hour period, which would include peak and off-peak times.

Table 3-8. Formaldehyde Summary Statistics from AMTIC Dataset (2015–2020)

Monitored Concentration Statistics (µg/m^3)									
Method Code	Description	Entry Count	Minimum	Non-zero Minimum	Median	Mean	Standard Deviation	Maximum	Collection Details
	All Samples	233,961	0	0.00012	1.6	2.1	2.2	60	
Group: Collection Duration									**Collection Methods**
A	5 Minutes[1]	184,307	0	0.00012	1.3	1.8	2.0	49	*d*
B	3 Hours[2]	5,870	0	0.0083	3.7	4.4	3.3	45	*abce*
C	6 Hours[3]	1	3.4	3.4	3.4	3.4	–	3.4	*e*
D	8 Hours	4,155	0.0055	0.0055	3.6	4.1	2.8	24	*bce*
E	12 Hours	340	0.50	0.50	3.6	3.8	1.7	9.0	*e*
F	24 Hours	39,288	0	0.0015	2.3	2.8	2.1	60	*bce*
Group: Collection Method									**Collection Durations**
a	6-L Pressurized Canister	67	3.5	3.5	11	14	7.9	42	*B*
b	Cartridge DNPH On Silica, Heated O_3 Denuder	6,671	0	0.020	2.3	2.7	1.8	46	*BDF*
c	Cartridge- DNPH -On-Silica	10,115	0	0.024	3.1	3.7	2.6	60	*BDF*
d	Fluxsense	184,307	0	0.00012	1.3	1.8	2.0	49	*A*
e	Silica- DNPH -Cart-Ki O_3 Scrub	32,801	0	0.0015	2.5	3.0	2.3	45	*BCDEF*

Notes: The Alternate Methods outline the list of collection methods (in the case of Group: Collection Duration) and collection duration (in the case of Group: Collection Methods) used for each row in the Table. For example, the 8-hour sample group row has alternative methods bce indicating that the 8-hour samples were collected using the Cartridge DNPH On Silica, Heated O3 Denuder, Cartridge- DNPH -On-Silica, and Silica- DNPH -Cart-Ki O_3 Scrub collection methods.

3.2.2 AMTIC Archive: Houston Case Study

Three high-resolution monitoring sites, 482010803 (N = 42,560), 482011015 (N = 70,126), and 482011035 (N = 71,621), around the Port of Houston were selected for more in-depth site-specific analysis. All three sites collected 5-minute composite air samples continuously using a mobile lab equipped with a FluxSense air monitoring system in highly industrial regions focusing on oil and chemical refining intertwined with residential areas located north-east of William Hobby International Airport (Figure 3-17).

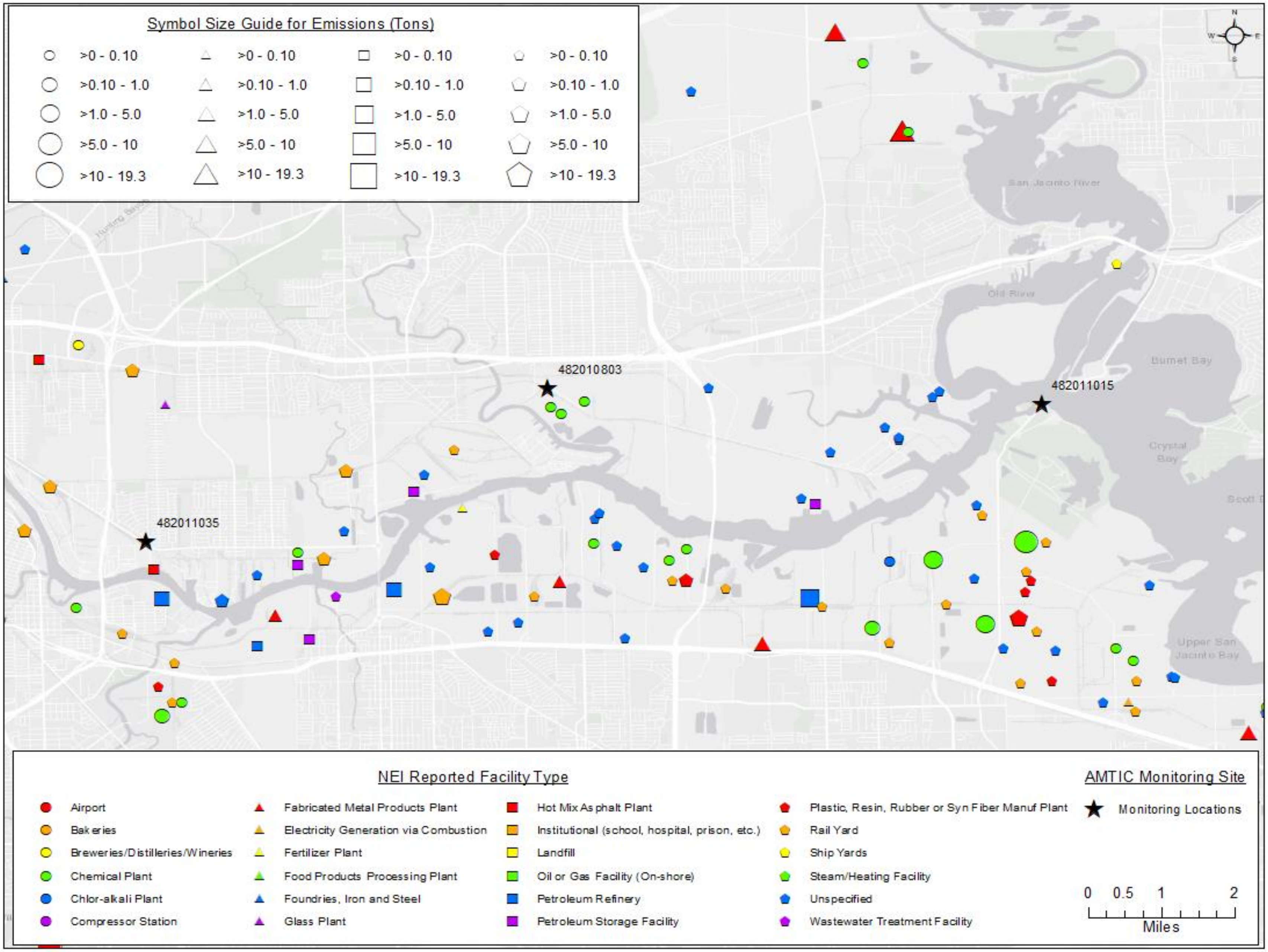

Figure 3-17. High-Resolution Monitoring Locations in Houston, Texas

The lowest 5-minute average concentrations of formaldehyde for all three sites fell below the detection limits while the highest 5-minute concentrations of formaldehyde ranged from 23.8 to 49.0 µg/m^3. Median values ranged from 1.0 to 2.2 µg/m^3 with slightly higher mean 5-minute concentrations of 1.3 to 2.9 µg/m^3 with a slight positive skew meaning there is a higher quantity of higher-concentration samples than would be expected in a standard normal distribution (Figure 3-18). Approximately 0.5 to 18 percent of measurements fell below the reported 0.159 µg/m^3 method detection limit. The limited data available showed no seasonal effects during the year of recording. During the twelve-month monitoring period, there were no significant changes in ambient formaldehyde concentration. Ambient formaldehyde concentrations appear to be stable throughout the monitoring period indicating that formaldehyde in ambient air is generally representative of an ongoing concentration to which the general population may be routinely exposed in day-to-day life (Figure 3-19). Ambient air concentration of formaldehyde does experience periodic increases and decreases in concentration that largely align with the 24-hour day which may align with the working conditions of nearby industrial facilities (Figure 3-20). Concentration of formaldehyde peaked in the afternoon and evening between the hours of 12:00 p.m. and 7:00 p.m. during the day and the lowest concentrations of formaldehyde were typically in the early morning between 12:00 a.m. and 8:00 a.m. (Figure 3-20).

Given the industrialized areas of Houston from which the samples were collected (Figure 3-17), and the daily trends identified in Figure 3-20, it is possible that the 5-minute median and mean values do not capture the influence of short-lived peak concentrations. However, this information may be captured in the max values shown in Figure 3-18 and Figure 3-19. Longer composite samples likely capture peak emission events within the composite sample and, in combination with the daytime collection and fewer sample count, may result in a positive skew in the median and mean concentration statistics. Histograms and summary statistics of annual data are shown in Table 3-8.

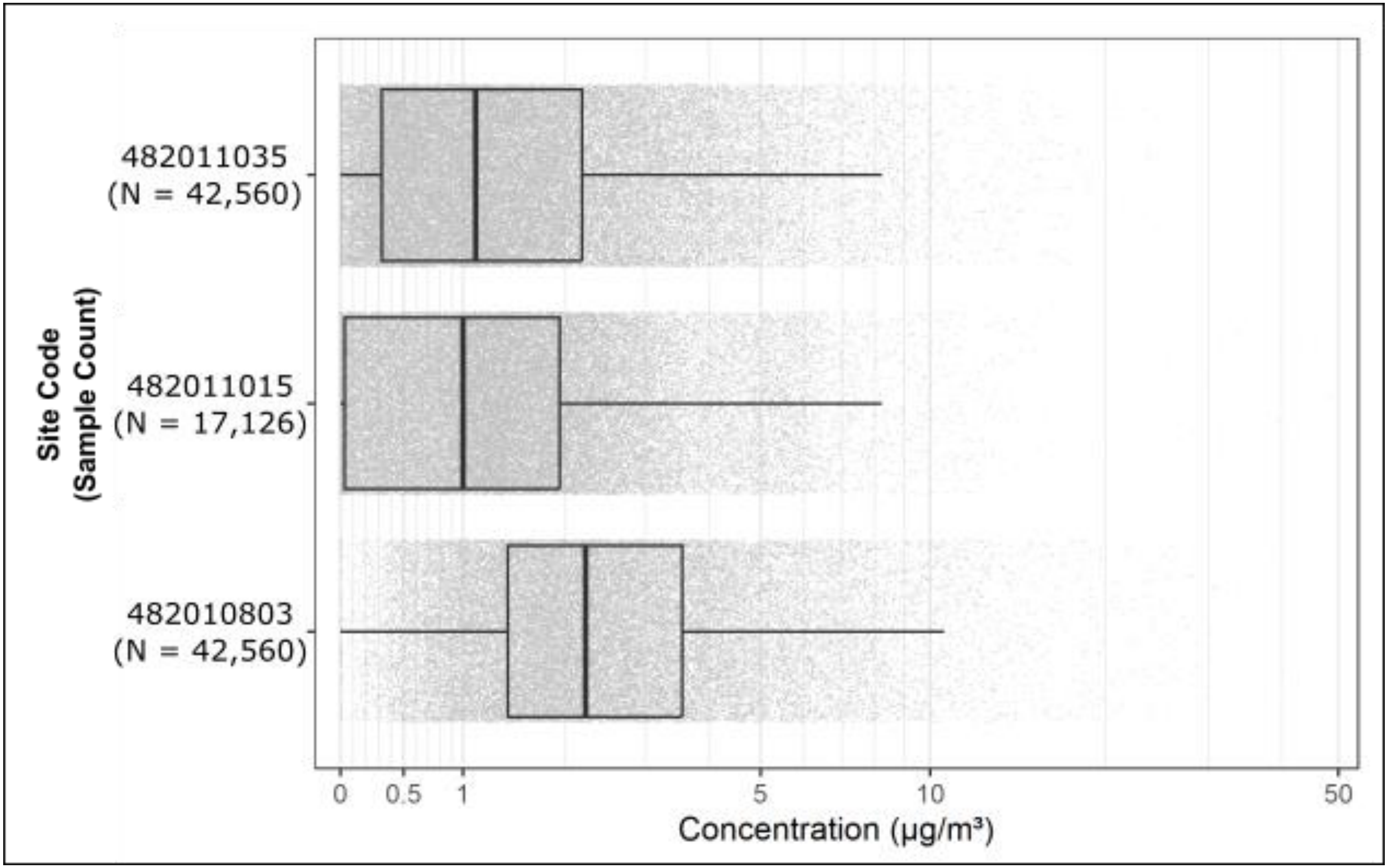

Figure 3-18. Formaldehyde Air Concentrations from the Three High Frequency Monitoring Locations in Houston, Texas

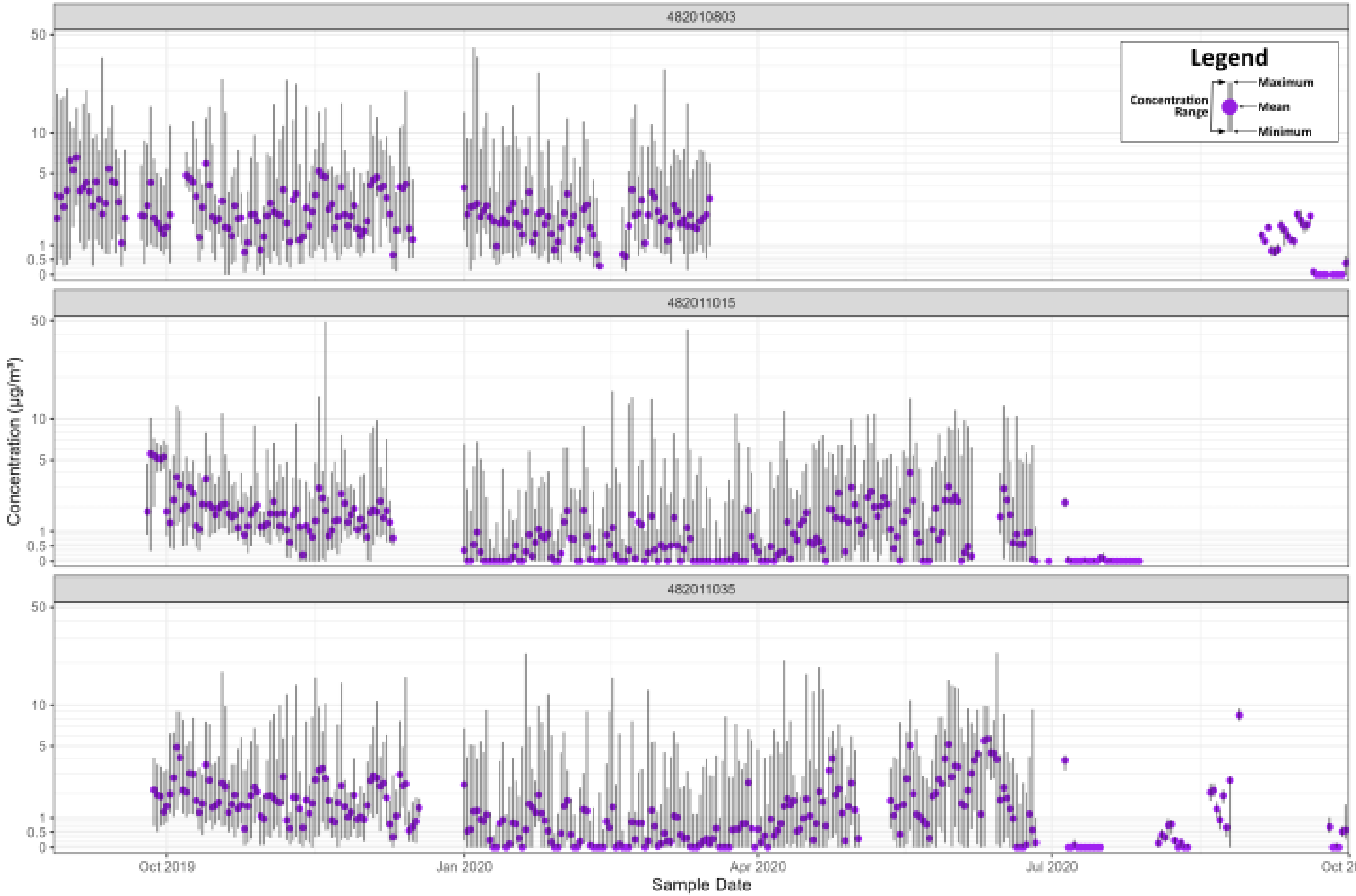

Figure 3-19. Houston Area Formaldehyde Concentration Time Series (5-Minute Sites)

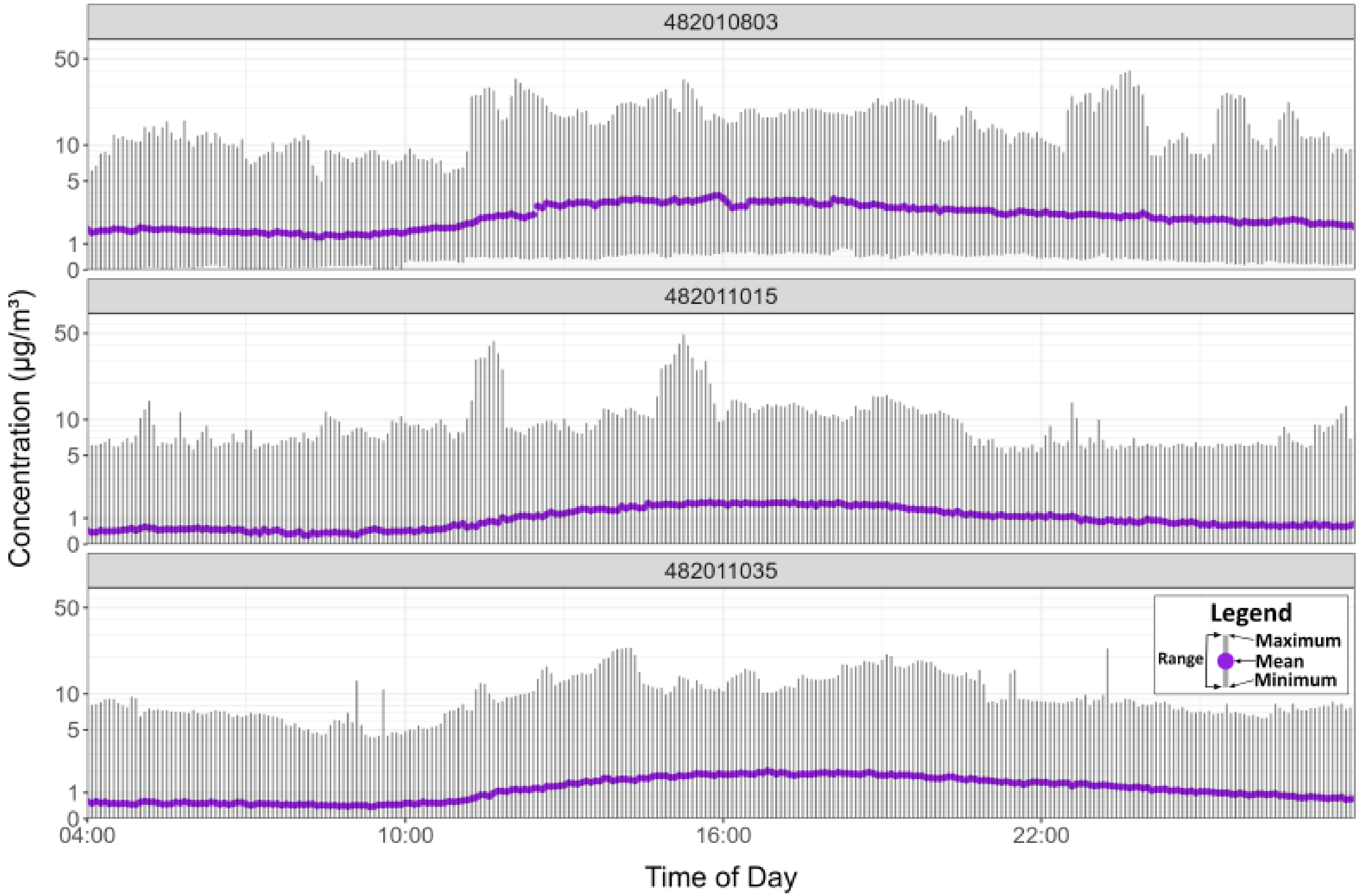

Figure 3-20. Houston Area Sites 5-Minute Concentration Data Aggregated by Time of Day

3.3 Data Integration of Various Sources of Formaldehyde

Monitoring data from AMTIC, modeled exposures calculated from IIOAC, and data from AirToxScreen were compiled to understand how exposures from TSCA COUs fit into the broader context of available information on formaldehyde. Figure 3-21 shows the overlapping distributions of data from these datasets. At the national scale, populations are exposed to many different sources of formaldehyde (TSCA COUs, secondary, biogenic, etc.) Monitoring data from AMTIC represents the aggregate concentration of formaldehyde in the ambient air from all sources, while IIOAC-modeled concentrations represent local exposures attributable to TSCA COUs at select distances near a releasing facility. The 2019 AirToxScreen data presented in Figure 3-21 represent the contribution of 38 different sources of formaldehyde to ambient air averaged across census tracts, as described in Section 3.1.2.
Figure 3-21

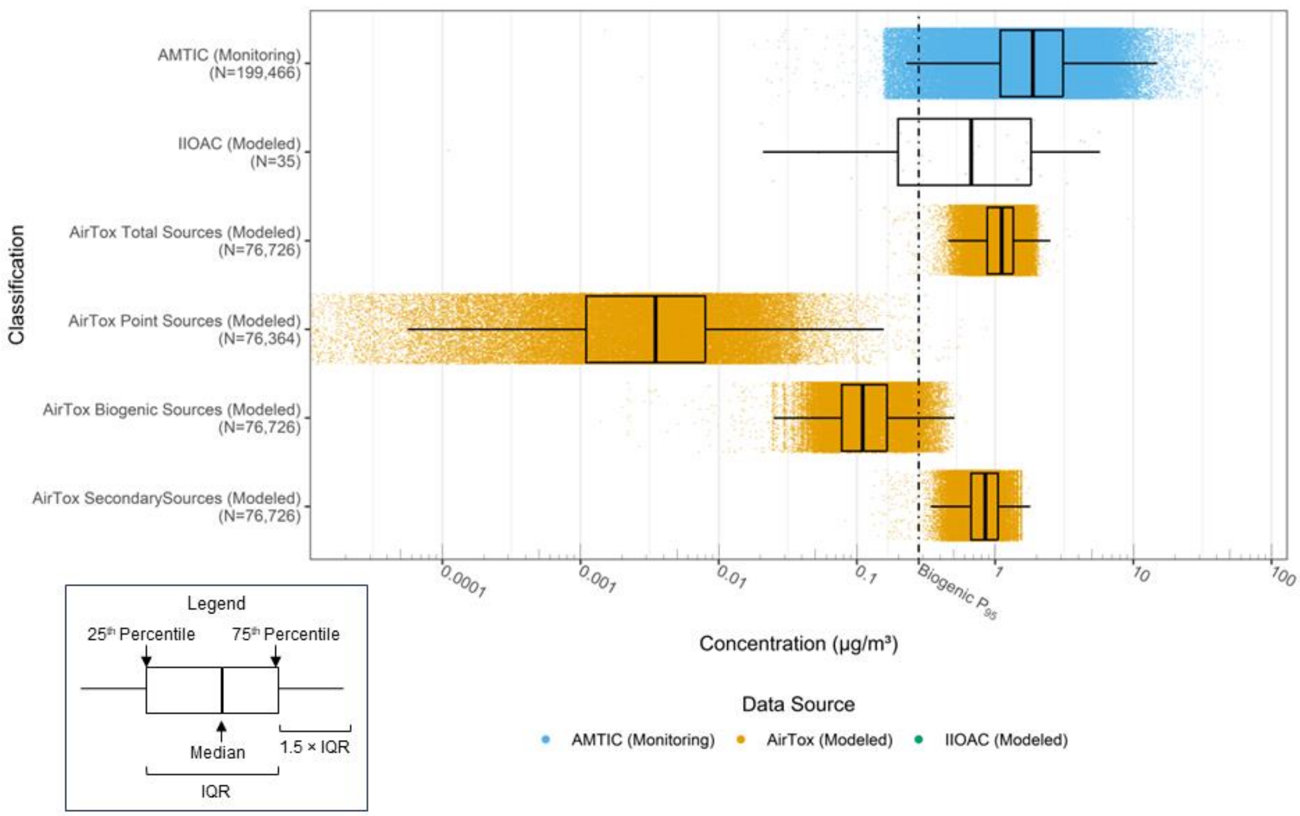

Figure 3-21. Distributions of AMTIC Monitoring Data, IIOAC-Modeled Data, and 2019 AirToxScreen Modeled Data[a]

The "n" values in the Y-axis represent the number of data points used for each of the six plots identified on the Y-axis.

EPA recognizes that the datasets presented in Figure 3-21 may not be directly comparable to each other, due to spatial and temporal differences across the data. For example, spatially, the IIOAC results in Figure 3-21 represent the 95th percentile annual average modeled concentrations between 100 to 1,000 m from the release point (~0.3 square miles). In contrast, the 2019 AirToxScreen point source concentrations are annual concentrations averaged at the centroid of census tracts which can range from a few city blocks to as large as several square miles. Similarly, 2020 AirToxScreen data are averaged across census blocks which, although smaller than census tracts, are generally larger areas than the area distance evaluated with IIOAC. In addition, the AMTIC data are collected at discrete locations of varying distance from release points. Temporally, the IIOAC-modeled data and AirToxScreen data are both estimated annual average concentrations across 365 days per year, while the AMTIC data are monitored (measured) values based on short-term sampling periods (5 minutes to 24 hours).

The case study of three high-resolution air monitoring sites in Houston, Texas from the AMTIC archive data demonstrated consistent, year-round concentrations of formaldehyde being as high as 49 µg/m ^{3} which supports EPA's modeling assumptions that releases are continuous and relatively consistent day to day throughout the year. Elevated concentrations within the case study data were consistent with the operating hours of the surrounding areas industrial, shipping, and chemical manufacturing sectors; but, the monitoring locations were not adjacent to TSCA industries and may not represent potential peak concentrations for those facilities.

Although the spatial and temporal differences between the different datasets in Figure 3-21 may not be directly comparable, taken together the totality of integrated data can and do allow for a characterization of general population exposures but has some uncertainty.

3.4 Summary of Results

EPA relies upon the IIOAC daily and annual average modeled concentrations described in this ambient air exposure assessment to characterize exposures needed to derive risk estimates attributable to TSCA COUs presented in the *Human Health Risk Evaluation for Formaldehyde*. IIOAC daily average modeled concentrations for short-term exposure attributable to TSCA COUs range from 0.0004 to 66 µg/m^3 at 100 m from the release point. IIOAC daily average modeled concentrations for short-term exposure attributable to combustion range from 2 to 662 µg/m^3 at 100 m from the release point. The high concentrations are based on release information from the NEI dataset, and are attributable to combustion sources (*e.g.*, airplanes, on-site vehicles, process heaters, turbines, and reciprocating internal combustion engines). IIOAC annual average modeled concentrations for long-term exposure attributable to TSCA COUs range from 0.0001 to 5.75 µg/m^3 within the 100 to 1,000 m area distance evaluated.

HEM modeling results allowed EPA to account for populations exposed to ambient formaldehyde concentrations from industrial releases attributable to TSCA COUs. Annual average formaldehyde concentrations resulting from TRI facility releases modeled by HEM ranged from 0 to 8.9 µg/m^3, with the greatest concentrations nearby industrial facilities. 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.

Monitored formaldehyde concentrations extracted from EPA's AMTIC archive for the years 2015 through 2020 range from 0 to 60.1 µg/m^3 with a median of 1.6 µg/m^3. These data represent an aggregate exposure from all formaldehyde sources and cannot be attributed to TSCA COUs in this exposure assessment. Results of the case-study AMTIC data (5-minute measured concentrations) from the Houston, Texas, area ranged from below detection limit to 49.0 µg/m^3. Median values ranged from 1.0 to 2.2 µg/m^3. The limited data available showed no seasonal effects during the year of recording. During the 12-month monitoring period, there were no significant changes in ambient formaldehyde concentration.

2019 AirToxScreen formaldehyde concentrations from all sources combined range from 0.11 to 9.38 µg/m^3 with secondary production contributing the most. Secondary production of formaldehyde was estimated to range between 0.085 to 1.80 µg/m^3 and represents the atmospheric formation of formaldehyde from naturally occurring and manmade compounds. This can include the degradation of isoprene to formaldehyde as well as other chemicals regulated under TSCA such as 1,3-butadiene, but cannot be attributed to TSCA COUs. Point source contributions to total formaldehyde concentrations range from 0.0 to 0.88 $\mu g/m^3$ based on the 2019 AirToxScreen data. Point sources are expected to include contributions from TSCA COUs; however, AirToxScreen results are not TSCA COU-specific. Biogenic sources of formaldehyde ranged from 0.0014 to 0.62 $\mu g/m^3$. Biogenic emissions represent natural production of formaldehyde from trees, plants, and soil microbes and are not attributable to TSCA COUs.

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

The approaches and methodologies presented in this ambient air exposure assessment utilize previously peer reviewed approaches and methods. The approaches and methodologies also incorporate several additional components recommended by peer reviewers during earlier peer reviews of other ambient air exposure assessments as well as peer review of the *Draft Ambient Air Exposure Assessment for Formaldehyde*.

4.1 Integrated Indoor/Outdoor Air Calculator Model (IIOAC)

A strength of the IIOAC modeling includes use of environmental release data from multiple databases across multiple years (including data that are required by law to be reported by industry). These databases undergo repeatable quality assurance and quality control reviews (U.S. EPA, 2024d). These release data are used as direct inputs to EPA's peer-reviewed IIOAC Model to estimate concentrations at several distances from releasing facilities where individuals may 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 by the reporter as described in the *Environmental Release Assessment for Formaldehyde* (U.S. EPA, 2024d) allowing for a more direct association of exposures from industrial releases to TSCA COUs.

However, the use of annual release data to estimate daily average concentrations introduces uncertainty in modeling outputs estimated. Because both TRI and NEI report a single annual release value (for stack and fugitive emissions) from each release point, EPA assumes operations are continuous and releases are the same every day of operation in order to calculate daily average concentrations. These assumptions may result in modeled concentrations missing true peak releases (and associated exposures) and therefore may underestimate peak exposures. However, as described in Sections 2.2 and 3.2, the case study 5-minute average monitoring data supports EPA's assumption of relatively steady state concentrations of formaldehyde in ambient air over the course of a year.

Assumptions made when choosing input parameters for IIOAC modeling introduce uncertainty in model estimates, likely resulting in an overestimation of exposure. The maximum stack and fugitive releases for each industry sector were used as input values for IIOAC modeling. However, the maximum stack and fugitive releases within an industry sector are not necessarily associated with the same facility, and it is unknown how likely it is for the maximum stack and fugitive releases to be occurring at a single facility. This conservative approach introduces uncertainty in the concentration estimates modeled, which likely represent an overestimation of exposure. There is additional conservatism built into the IIOAC modeling including using the maximum and 95th percentile releases modeled and relied upon for the exposure concentrations, stack parameters representing a low, slow moving, non-buoyant plume, and the meteorological station within IIOAC used for the ambient air exposure assessment representing a high-end station which leads to higher overall estimated concentrations.

Limitations of the IIOAC modeling approaches and methods used include the fact that 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. Default input parameters include stack parameters, 2011 to 2015 meteorological data, and the lack of site-specific information like building dimensions, stack heights, elevation, and land use. To characterize the impact of the default input parameters, EPA conducted a series of sensitivity analyses described in Appendix B.1. Generally, the Agency found that although the limitations identified above have some impact on overall modeled results, the impact is not substantial and does not change the overall characterization of exposures from industrial releases.

Lastly, a limitation of the exposure estimates presented in this assessment are that they do not consider population data alongside IIOAC modeling estimates of ambient air concentrations. The land area occupied by the facility itself (*i.e.*, distance from release point to the fenceline) and the distance of residential areas from the release point for each facility is unknown. Therefore, the assumption that ambient air concentrations are equivalent to exposure estimates neglects the consideration of whether individuals actually reside in a particular location.

An additional limitation and uncertainty impacting modeling is the use of annual release data to estimate daily average concentrations. Since both TRI and NEI report a single annual release value (for stack and fugitive emissions) from each release point, EPA divides the annual reported releases by the number of operating days to obtain a daily emission rate needed for any of the ambient air models used for this assessment. This requires the Agency to assume operations are continuous and releases are the same every day of operation. These assumptions may result in modeled concentrations missing true peak releases (and associated exposures/risks) and therefore underestimate true exposures and associated risks. However, as described in Sections 2.2 and 3.2, the case study 5-minute average monitoring data supports EPA's assumption of relatively steady state concentrations of formaldehyde in ambient air.

4.2 AirToxScreen

AirToxScreen has been previously reviewed by EPA's Science Advisory Board (SAB). As, such EPA has 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, Version 1.0: A Generic TSCA Systematic Review Protocol with Chemical-Specific Methodologies* (U.S. EPA, 2021b). However, note that the NEI point source emissions are largely dependent on state-reported emissions inventories to which HAP emission data are voluntarily reported. Furthermore, biogenic emissions are modeled estimates and are likely less certain than point source emission estimates.

The strengths of the AirToxScreen data included in this exposure assessment are that they show the contributions of formaldehyde to the ambient air from all sources of formaldehyde in the contiguous United States. However, the use of AirToxScreen is limited due to the inability to isolate contributions from TSCA COUs. EPA's use of these results provides strength to this assessment because the AirToxScreen data are used to contextualize IIOAC-modeled annual average concentrations of formaldehyde relative to other large contributing sources to the ambient air.

4.3 Human Exposure Model (HEM)

The base dispersion model run by HEM 4.2 is EPA's AERMOD. AERMOD is EPA's regulatory model which has been peer reviewed as part of the regulatory model process described in "Appendix W" to 40 CFR Part 51. As such, EPA has high confidence in the modeling methods based on HEM's reliance on the Agency's regulatory model. For a discussion of strengths, limitations, and uncertainties of environmental release data used as input to HEM (see Section 4.1). In addition, there may be uncertainty in census population data used as input to HEM for specific locations and populations. A limitation of the HEM model is the exclusion of consideration of photodegradation processes within the AERMOD sub-routines, which may be relevant to modeling ambient air concentrations of formaldehyde since it is known to undergo photolysis within 4 hours in sunlight.

4.4 Ambient Monitoring Technology Information Center (AMTIC) Archive

EPA has high confidence in the AMTIC archive data set (U.S. EPA, 2022a). The AMTIC archive dataset received a high-quality rating from EPA's systematic review process. (U.S. EPA, 2021a). Additionally, the AMTIC archive dataset undergoes review and verification by AMTICs Ambient Air Monitoring Group. This review and verification process includes multiple quality assurance steps to ensure data quality and certification in accordance with 40 CFR 58.15. There is also added value from the AMTIC archive monitoring data set because they are real measured data which reflect concentrations to which the general population would be exposed to in the time and space the sample was taken.

The primary limitations of the AMTIC are that it represents a diverse collection of sampling durations (none of which are annual averages) that are not directly comparable to either IIOAC or AirToxScreen results. 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. Additional limitations of the AMTIC data include the wide variety of monitoring locations represented, which may include sites both near-to and far-from facility release points associated with TSCA COUs.

4.5 Weight of Scientific Evidence

There are many sources of formaldehyde which contribute to exposures to the general population. This ambient air exposure assessment for formaldehyde considers multiple lines of evidence including measured (monitored) and modeled formaldehyde concentrations to characterize exposures. Overall, this ambient air exposure assessment finds that the general population living near industrial facilities releasing formaldehyde to the ambient air experience both short- and long-term inhalation exposure to formaldehyde attributable to TSCA COUs. While individual lines of evidence may not be directly comparable, taken together the data and results support EPA's use of IIOAC daily and annual average modeled concentrations to characterize exposures.

EPA has medium confidence in the IIOAC-modeled results used to characterize exposures in this ambient air exposure assessment. Several inputs used for the IIOAC Model are generally conservative, including the maximum and 95th percentile releases modeled and relied upon for the exposure concentrations, stack parameters representing a low, slow moving, non-buoyant plume, and the meteorological station within IIOAC used for this assessment representing a high-end station which leads to higher overall estimated concentrations. In addition, in assuming that ambient air concentrations are equivalent to exposure, an assumption is made that an individual lives at the same location for their entire lifetime, spending the entirety of their day, each day, at that location. EPA investigated the impact of IIOAC meteorological input parameters and stack height in a series of sensitivity analyses discussed in Appendix B.1. Findings from those sensitivity analyses found the impact of changes in these input parameters on overall findings was minimal. The impact of the other conservative inputs and assumptions on risk estimates is unknown.

In addition to the above, there are uncertainties in model outputs due to assumptions made when choosing input parameters which supports the overall confidence of medium. These include the use of annual average releases to calculate daily releases and the use of default parameters within IIOAC. There is additional uncertainty because IIOAC does not consider the location of residential areas relative to the 100-meter distance from release points of industrial facilities associated with TSCA COUs. Further, the assessment was conducted independent of the size of the facility footprint, the precise location of the release, and the relative proximity of residences to the releasing facility/ies. For example, for larger facilities, 100 m from a release point may fall on facility property (where individuals within the general population do not live or frequent) and therefore would not be exposed to modeled concentrations 24 hours per day, 7 days per week, or 365 days per year. In contrast, for smaller facilities, there may be one or more individuals within the general population living 100 m away from the release point and therefore would be exposed continuously, although most individuals may not stay within their residences 24 hours per day, 7 days per week, 365 days per year. Additional modeling with HEM results provides context on the spatial variability of formaldehyde concentrations across the United States and an approximate understanding of populations exposed.

Additional lines of evidence provide context for the use of IIOAC modeling results. Monitoring data from AMTIC represent the aggregate concentration of formaldehyde in the ambient air from all sources, while IIOAC-modeled concentrations represent local exposures attributable to TSCA COUs at select distances near a releasing facility. AirToxScreen data provide further context for contributions from multiple sources including biogenic, secondary, TSCA COUs and other sources. HEM results provide additional context on the spatial variability of formaldehyde concentrations across the United States. While the individual lines of evidence provide context, the individual datasets are not directly comparable to each other, due to spatial and temporal differences. Further, formaldehyde concentrations are highly variable based on geographic location (*e.g.*, HEM results show elevated concentrations in the Southeastern United States), nearby releases, and contributions from other sources of formaldehyde. Taken together, the totality of integrated data can and do allow for a characterization of general population exposures but has some uncertainty.

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APPENDICES

Appendix A LIST OF SUPPLEMENTAL DOCUMENTS

- IIOAC Assessment Results and Risk Calcs for Formaldehyde Supplement A
- IIOAC Assessment Results and Risk Calcs for Formaldehyde Supplement B
- IIOAC Assessment Results and Risk Calcs for Formaldehyde Supplement C

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.

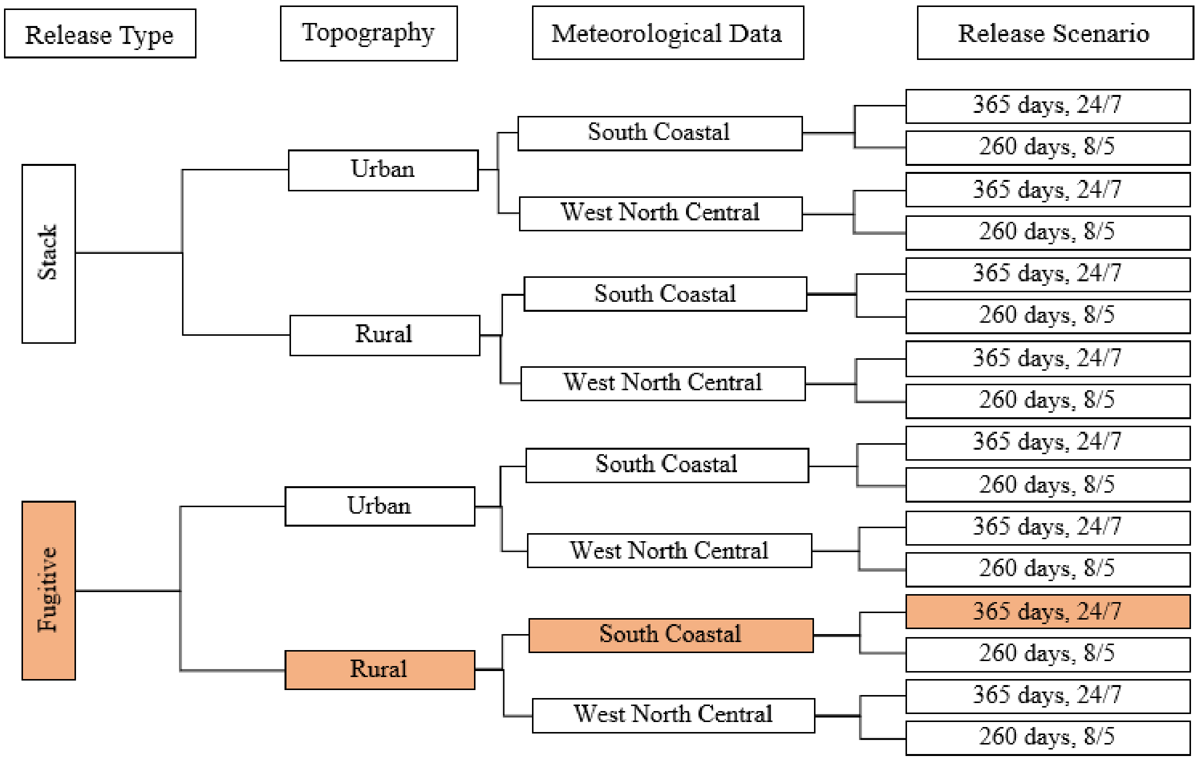
Based on these findings, EPA has high confidence in the modeled exposure concentrations from each model. As such, the Agency uses both models in this general population risk assessment to inform exposures and take advantage of certain model capabilities to better characterize exposures for TSCA COUs, 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 High-End and Central Tendency 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 (CT) and high-end (HE) 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 (2011–2015) 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 High-End Exposure Scenario in IIOAC

IIOAC is capable of modeling a variety of release types, topography, meteorological conditions, and release scenarios. Because 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 (2011–2015). 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 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. The Agency also recognizes the 10-meter stack height, and other stack parameters integral to IIOAC, represent a low, slow moving, non-buoyant plume. Therefore, this 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 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.

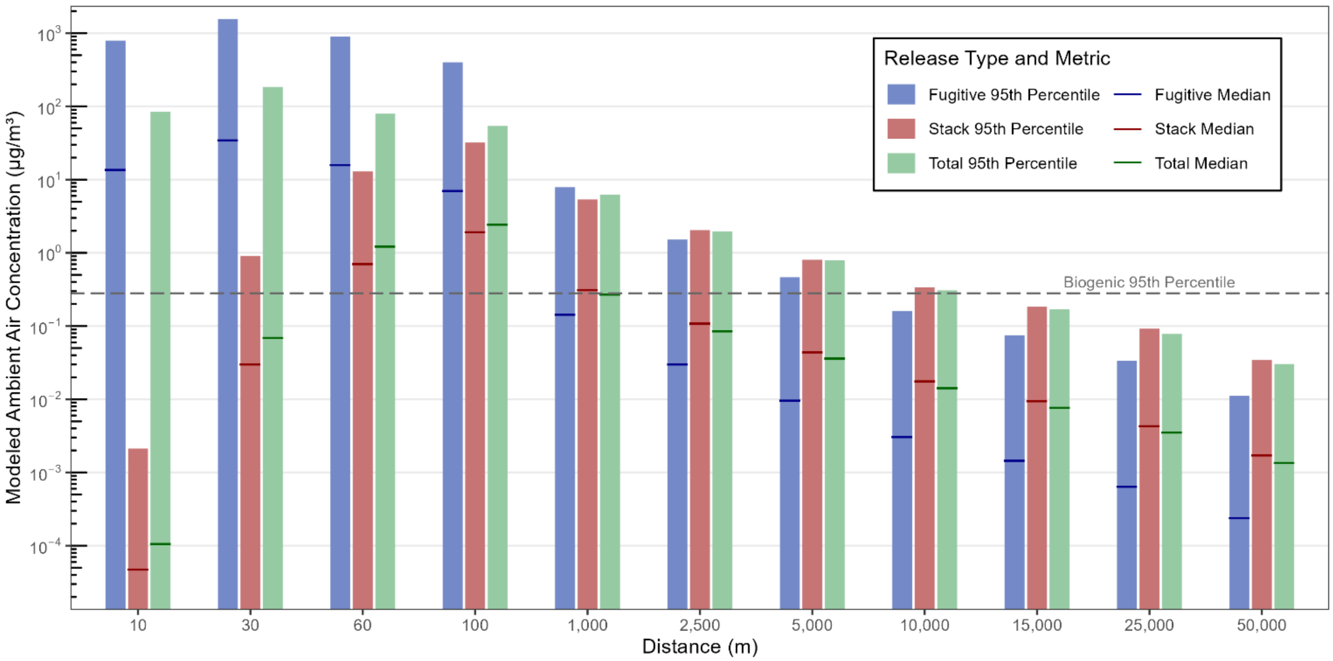
As expected, EPA found the 25-meter stack height allowed for additional dispersion prior to a plume reaching the breathing zone of individuals at the distances evaluated and where exposure occurs. Generally, the 25-meter stack height resulted in slightly lower modeled concentrations at the distances 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 evaluation. 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 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