Appendix B1b

Technical support document for the development of emissions inventories for Maryland's nonpoint sources missing in EPA EMP 2022v1 for 2022

BREWERIES

A. Source Category Description

Breweries emit Volatile Organic Compounds (VOC), primarily ethanol, during the fermentation process. Although large-scale commercial breweries have been inventoried as point sources, there are microbreweries and brewpubs that emit lower levels of VOCs and therefore must be inventoried as area sources. These smaller breweries emit most of their VOCs from the fermentation room, not the brew kettle as is the case with the large breweries.

Table 1: 2023 Brewery SCC.

SCC	SCC Level 1	SCC Level 2	SCC Level 3	SCC Level 4
2302070001	Industrial Processes	Food and Kindred Products: SIC 20	Fermentation/Beverages	Breweries

B. Overview of Calculations

Brewery VOC emissions in the 2023 NEI are estimated using brew production and emission factors.

In the following sections, details are provided related to the collection of activity data (Section C), calculation of emissions factors (Section D), accounting for control programs (Section E), emissions (Section F), point source subtraction (Section G), and sample calculations (Section H).

C. Activity Data

Activity data is based on year-specific and county-level beer production from the Maryland's Alcohol, Tobacco and Cannabis Commission's *2023 Alcohol & Tobacco Tax Annual Report.*[1] The 2023 NEI uses 2023 beer production estimates, as shown in Table 2.

Table 2: 2023 County Level Beer Production.

County Name	State County FIPs	Total Beer Production FY 2023 (Barrels)
Allegany	24001	417
Anne Arundel	24003	5,553
Baltimore	24005	95,108
Calvert	24009	1,243
Caroline	24011	2
Carroll	24013	4,259
Cecil	24015	143
Charles	24017	0
Dorchester	24019	9,295
Frederick	24021	70,708
Garrett	24023	0
Harford	24025	5,241
Howard	24027	8,148
Kent	24029	8
Montgomery	24031	17,714

Prince Georges	24033	5,572
Queen Annes	24035	4,781
Saint Mary's	24037	19
Somerset	24039	0
Talbot	24041	186
Washington	24043	3,941
Wicomico	24045	10,000
Worcester	24047	564
Baltimore City	24510	21,966
Total		264,845

D. Emissions Factors

Emissions from the small breweries were calculated using an emission factor cited in a February 5, 1992 Technical Memorandum prepared by Radian Corporation for EPA.[2] This emission factor is 56.743 lbs. VOC per 1000 barrels produced.

VOC emission factors for brewery SCCs are listed in table 3 below.

Table 3. 2023 NEI VOC emissions factors for Breweries

SCC	Description	Pollutant Code	Emission Factor	Unit	Source
2302070001	Breweries	VOC	0.05674	lb/barrel	[3]

E. Controls

There are no controls available for this source category.

F. Emissions

Total VOC emissions from breweries are calculated by multiplying the activity data for the source category by the calculated emissions factor for that category.

$$E_{VOCc,s} = A_{c,s} \times EF_{VOC,s}$$

Where:

$E_{VOC,c,s}$ = Annual VOC emissions in county c for source category s, in tons per year
$A_{c,s}$ = Activity data for county c associated with source category s (Table 2)
$EF_{VOC,s}$ = Calculated VOC emissions factor for source category s (Table 3)

G. Point Source Subtraction

There are no point source specific SCCs for breweries; therefore point source subtraction is not performed for this category.

H. Sample Calculations

Sample calculations for VOC emissions from breweries in Anne Arundel County, Maryland are included in the table below.

Table 4. Sample Calculations of VOC emissions for Breweries (SCC 2302070001) in Anne Arundel County.

Eq. #	Equation	Values for Anne Arundel County	Result
1	$\boldsymbol{E_{VOCc,s} = A_{c,s} \times EF_{VOC,s}}$	$\left(5{,}533\ barrels\ \times 0.05674 \frac{lb/_{barrel}}{2000}\right)$	0.1570 tons of VOC in 2023

I. References

[1] Maryland Alcohol, Tobacco and Cannabis Commission: *2023 Alcohol & Tobacco Tax Annual Report*. Retrieved December 3, 2024 from https://atcc.maryland.gov/wp-content/uploads/sites/24/2024/08/Annual-Report-FY2023.pdf

[2] United States Environmental Protection Agency under Contract No. 68-D0-0125 to Radian Corporation. *VOC Emissions From Breweries*. February 5, 1992.

[3] United States Environmental Protection Agency under Contract No. 68-D0-0125 to Radian Corporation. *VOC Emissions From Breweries*. February 5, 1992.

COMMERCIAL/INSTITUTIONAL RESIDUAL OIL COMBUSTION

A. Source Category Description

Commercial and Institutional fuel consumption includes emissions from boilers, engines, and other combustion sources from the commercial and institutional sectors that are not reported as point sources.

Table 1. 2023 NEI Commercial/Institutional Residual Oil Combustion SCC

SCC	SCC Level 1	SCC Level 2	SCC Level 3	SCC Level 4
2103005000	Stationary Source Fuel Combustion	Commercial/ Institutional	Residual Oil	Total: All Boiler Types

B. Overview of Calculations

Commercial/institutional residual oil combustion emissions in the 2023 National Emissions Inventory (NEI) are estimated using fuel consumption by sector from the Energy Information Administration (EIA) State Energy Data System (SEDS),[1] commercial employment from the U.S. Census Bureau,[2] and emission factors.

In the following sections, details are provided related to the collection of activity data (Section C), calculation of emission factors (Section D), accounting for control programs (Section E), Emissions (Section F), point source subtraction (Section G), and sample calculations (Section H).

C. Activity Data

Activity data is based on year-specific state-level fuel consumption from SEDS, and county-level employment data from the U.S. Census Bureau.[2] County Business Pattern NAICS codes 2212//, 2213//, 42--, 44--, 51--, 52--, 53--,54--, 55--, 56--, 61--, 62--, 71--, 72--, and 81-- are used to apportion state-fuel to the county level based on the proportion of employment in the commercial sector to the total commercial sector state employment.

$$F_{f,c,x} = F_{f,x} \times \frac{a_{c,x}}{a_x}$$

Where:

$F_{f,c,x}$ = Consumption of fuel f in county c in sector x
$F_{f,x}$ = Consumption of fuel f in sector x
$a_{c,x}$ = Employment in county c in sector x
a_x = Employment in sector x

The NEI uses 2022 SEDS fuel consumption and 2021 employment to estimate county-level fuel consumption for commercial/institutional residual oil combustion, as shown in Table 2.

Table 2: 2023 County Level Fuel Consumption for Commercial/Institutional Residual Oil Combustion

County Name	State County FIPs	Employment	Employment Fraction	EIS SEDS Consumption (Thousand Barrels)	Fuel Consumption (Thousand Barrels)
Allegany	24001	17,202	0.009345	5	0.05
Anne Arundel	24003	184,662	0.100319		0.50
Baltimore	24005	268,865	0.146063		0.73
Calvert	24009	14,130	0.007676		0.04
Caroline	24011	4,452	0.002419		0.01
Carroll	24013	38,796	0.021076		0.11
Cecil	24015	18,302	0.009943		0.05
Charles	24017	26,723	0.014517		0.07
Dorchester	24019	5,476	0.002975		0.01
Frederick	24021	69,590	0.037805		0.19
Garrett	24023	7,909	0.004297		0.02
Harford	24025	57,571	0.031276		0.16
Howard	24027	153,119	0.083183		0.42
Kent	24029	4,715	0.002561		0.01
Montgomery	24031	376,651	0.204618		1.02
Prince Georges	24033	200,372	0.108853		0.54
Queen Annes	24035	8,945	0.004859		0.02
Saint Mary's	24037	29,658	0.016112		0.08
Somerset	24039	2,944	0.001599		0.01
Talbot	24041	14,621	0.007943		0.04
Washington	24043	42,376	0.023021		0.12
Wicomico	24045	28,706	0.015595		0.08
Worcester	24047	17,370	0.009436		0.05
Baltimore City	24510	247,596	0.134508		0.67

D. Emissions Factors

The emissions factors for Industrial, Commercial and Institutional (ICI) fuel consumption sectors are from AP-42[3] and a spreadsheet developed in 2010 by EPA and the Eastern Regional Technical Advisory Committee.[4]

SO2 and filterable PM emission factors are multiplied by the state sulfur content. In Maryland, the sulfur content for commercial/institutional residual oil combustion is either 1% or 2% depending on the county%.[5] Primary PM emissions are estimated by adding condensable and filterable PM.

The emissions factors for hazardous air pollutants from (HAP) are taken from EPA's 2002 NEI Documentation.[6]

Criteria air pollutant emissions factors for commercial/institutional residual oil are listed in table 3 below. HAP emissions factors for this source category are included in Appendix Table 1

Table 3: 2023 NEI Criteria Pollutant Emissions Factors for Commercial/Institutional Residual Oil Combustion

SCC	Description	Pollutant Code	Emission Factor	Unit	Source
2103005000	Commercial/Institutional Residual Oil	CO	210	LB/E3BBL	4
		NOX	2310		
		PM-CON	63		
		PM10-FIL	5.17(1.12*S+0.37)		
		PM10-PRI	PM10-FIL + PM-CON		
		PM25-FIL	1.92(1.12*S+0.37)		
		PM25-PRI	PM25-FIL + PM-CON		
		SO2	157S		
		VOC	47.46		

E. Controls

Emissions from residual commercial/institutional fuel combustion are controlled through Code of Maryland Regulations (COMAR) 26.11.09.07: Control of Sulfur Oxides from Fuel Burning Equipment.[7] COMAR 26.11.09.07 limits sulfur content in fuel burning equipment in Maryland to 1 or 2% depending on the county. Sulfur is limited to 1% in Baltimore City and Anne Arundel, Baltimore, Carroll, Harford, Howard, Montgomery, and Prince Georges counties. Sulfur is limited to 2% in the rest of the state.

F. Emissions

Emissions in each ICI sector are estimated by multiplying the county-level nonpoint source fuel consumption by the emission factors for that sector.

$$E_{p,f,c,x} = NPF_{f,c,x} \times EF_{p,f,x}$$

Where:

$E_{p,f,c,x}$ = Annual emissions of pollutant *p* from fuel type *f* in county *c* in sector *x*
$NPF_{f,c,x}$ = Nonpoint source consumption of fuel type *f* in county *c* in sector x (Table 2)
$EF_{p,f,x}$ = Emissions factor for pollutant *p,* fuel type *f*, and sector *x* (Table 3 & Appendix Table 1)

G. Point Source Subtraction

Since emissions from commercial/intuitional residual oil combustion occurs from both point and nonpoint SCCs, point source subtraction is required to ensure emissions from this sector are not double-counted.

To accomplish this task, MDE utilizes the point source registry to locate commercial/institutional residual oil combustion point sources to estimate the amount of fuel consumption to subtract from the SEDS total. Facility level annual CO2 emissions are divided by an emission factor[8], which yields the amount of fuel in the county associated with the point source emissions. The county-level fuel consumption is then adjusted downward by the amount of fuel consumed by point sources. Nonpoint emissions are then estimated using the point source adjusted fuel consumption. The resultant emissions represent emissions only associated with nonpoint activity.

The fuel adjustment for point source subtraction is calculated as follows:

$$NP_{f,c} = Ep_{CO2c,s} \times 2000 \, / \, EF_{CO2,s}$$

Where:

$NP_{f,c}$ = Nonpoint source fuel consumption in county c for source category s, in thousands of barrels per year

$Ep_{CO2,c,s}$ = Annual point CO_2 emissions for the identified point sources in county c for source category s, in tons per year

$EF_{CO2,s}$ = CO_2 emissions factor for source category s

The point source consumption estimates for commercial/institutional residual oil are outlined in Table 4 below.

Table 4: Point Source Consumption Adjustment for Commercial/Institutional Residual Oil Combustion

County Name	FIPS State and County Code	Fuel Consumption (Thousand Barrels)	Point Source Fuel Consumption Reduction (Thousand Barrels)	Point Source Adjusted Fuel Consumption (Thousand Barrels)
Allegany	24001	0.05	0.00	0.05
Anne Arundel	24003	0.50	0.46	0.05
Baltimore	24005	0.73	0.00	0.73
Calvert	24009	0.04	0.00	0.04
Caroline	24011	0.01	0.00	0.01
Carroll	24013	0.11	0.00	0.11
Cecil	24015	0.05	0.00	0.05
Charles	24017	0.07	0.00	0.07
Dorchester	24019	0.01	0.00	0.01
Frederick	24021	0.19	0.00	0.19
Garrett	24023	0.02	0.00	0.02
Harford	24025	0.16	0.00	0.16
Howard	24027	0.42	0.00	0.42
Kent	24029	0.01	8.03	0.00
Montgomery	24031	1.02	0.00	1.02
Prince George's	24033	0.54	0.00	0.54
Queen Anne's	24035	0.02	0.00	0.02
St. Mary's	24037	0.08	0.00	0.08
Somerset	24039	0.01	0.00	0.01
Talbot	24041	0.04	0.00	0.04
Washington	24043	0.12	0.00	0.12
Wicomico	24045	0.08	0.00	0.08
Worcester	24047	0.05	0.00	0.05
Baltimore City	24510	0.67	7.89	0.00

H. Sample Calculations

Sample calculations for VOC emissions from commercial/institutional residual oil combustion in Anne Arundel County, Maryland are included in the table below.

Table 5. Sample Calculations of VOC Emissions for Commercial/Institutional Residual Oil Combustion in Anne Arundel County.

Eq. #	Equation	Values for Anne Arundel County	Result
1	$\boldsymbol{E_{p,f,c,x} = NPF_{f,c,x} \times EF_{p,f,x}}$	$(0.05\ E3BBL\ \times 47.46\ lb/E3BBL)/2000$	0.001092 tons of VOC in 2023

I. References

[1] Energy Information Administration. 2024. State Energy Data System, 2022 data. https://www.eia.gov/state/seds/

[2] U.S. Census Bureau. 2024. 2021 County Business Patterns. https://www.census.gov/data/datasets/2021/econ/cbp/2021-cbp.html

[3] U.S. Environmental Protection Agency. 1996. Compilation of Air Pollutant Emission Factors, 5th Edition, AP-42, Volume I: Stationary Point and Area Sources. Research Triangle Park, North Carolina. https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emission-factors#5thed

[4] EPA and Eastern Regional Technical Advisory Committee. 2010. Excel file: state_comparison_ERTAC_SS_version7_5_Mar 16 2010.xls

[5] Code of Maryland Regulations (COMAR) 26.11.09.07: Control of Sulfur Oxides from Fuel Burning Equipment. https://dsd.maryland.gov/Pages/COMARSearch.aspx

[6] U.S. Environmental Protection Agency. 2017. Industrial, Commercial, and Institutional Fuel Consumption NEMO. https://gaftp.epa.gov/air/nei/2017/doc/supporting_data/nonpoint/ICI%20NEMO%20FINAL_4-2%20updated.docx.

[7] Code of Maryland Regulations (COMAR) 26.11.09.07: Control of Sulfur Oxides from Fuel Burning Equipment. https://dsd.maryland.gov/Pages/COMARSearch.aspx

[8] Energy Information Administration. Carbon Dioxide Emissions Coefficients. September 18, 2024. https://www.eia.gov/environment/emissions/co2_vol_mass.php

APPENDIX

Table 1 Emissions Factors for Residual Oil Combustion in the Commercial and Institutional Sectors

SCC	Pollutant Code	Name	Factor Numeric Value	Factor Unit Numerator	Factor Unit Denominator	Factor Numeric Value	Factor Unit Numerator	Factor Unit Denominator	Reference
2103005000	50000	Formaldehyde	0.033	LB	E3GAL	1.386	LB	E3BBL	3; Table 1.3-9
2103005000	53703	Dibenzo[a,h]Anthracene	1.67E-06	LB	E3GAL	7.01E-05	LB	E3BBL	3; Table 1.3-9
2103005000	56553	Benz[a]Anthracene	4.01E-06	LB	E3GAL	0.000168	LB	E3BBL	3 Table 1.3-9
2103005000	71432	Benzene	0.000214	LB	E3GAL	0.008988	LB	E3BBL	3; Table 1.3-9
2103005000	75070	Acetaldehyde	0.00525	LB	E3GAL	0.2205	LB	E3BBL	6; 2002 NEI Documentation
2103005000	83329	Acenaphthene	2.11E-05	LB	E3GAL	0.000886	LB	E3BBL	3; Table 1.3-9
2103005000	85018	Phenanthrene	1.05E-05	LB	E3GAL	0.000441	LB	E3BBL	3; Table 1.3-9
2103005000	86737	Fluorene	4.7E-06	LB	E3GAL	0.000197	LB	E3BBL	3; Table 1.3-9
2103005000	91203	Naphthalene	0.0013	LB	E3GAL	0.0546	LB	E3BBL	3; Table 1.3-9
2103005000	120127	Anthracene	1.22E-06	LB	E3GAL	5.12E-05	LB	E3BBL	3; Table 1.3-9
2103005000	129000	Pyrene	4.25E-06	LB	E3GAL	0.000179	LB	E3BBL	3; Table 1.3-9
2103005000	191242	Benzo[g,h,i,]Perylene	2.43E-06	LB	E3GAL	0.000102	LB	E3BBL	3; Table 1.3-9
2103005000	193395	Indeno[1,2,3-c,d]Pyrene	2.14E-06	LB	E3GAL	8.99E-05	LB	E3BBL	3; Table 1.3-9
2103005000	206440	Fluoranthene	4.84E-06	LB	E3GAL	0.000203	LB	E3BBL	3; Table 1.3-9
2103005000	208968	Acenaphthylene	2.11E-07	LB	E3GAL	8.86E-06	LB	E3BBL	3; Table 1.3-9
2103005000	218019	Chrysene	2.38E-06	LB	E3GAL	1E-04	LB	E3BBL	3; Table 1.3-9
2103005000	7439921	Lead	0.001233	LB	E3GAL	0.051786	LB	E3BBL	3; Table 1.3-10
2103005000	56832736	Benzofluoranthenes	1.48E-06	LB	E3GAL	6.22E-05	LB	E3BBL	3; Table 1.3-9
2103005000	CO	Carbon Monoxide	5	LB	E3GAL	210	LB	E3BBL	4
2103005000	NH3	Ammonia	0.8	LB	E3GAL	33.6	LB	E3BBL	4
2103005000	NOX	Nitrogen Oxides	55	LB	E3GAL	2310	LB	E3BBL	4
2103005000	PM10-FIL	PM10 Filterable	5.17(1.12*S+0.37)	LB	E3GAL	5.17(1.12*S+0.37)*42	LB	E3BBL	4
2103005000	PM10-PRI	PM10 Primary (Filt + Cond)		LB	E3GAL	PM10 Filterable+ PM Condensible	LB	E3BBL	4
2103005000	PM25-FIL	PM2.5 Filterable	1.92(1.12*S+0.37)	LB	E3GAL	1.92(1.12*S+0.37)*42	LB	E3BBL	4
2103005000	PM25-PRI	PM2.5 Primary (Filt + Cond)		LB	E3GAL	PM2.5 Filterable+PM Condensible	LB	E3BBL	4
2103005000	PM-CON	PM Condensible	1.5	LB	E3GAL	63	LB	E3BBL	4
2103005000	SO2	Sulfur Dioxide	157S	LB	E3GAL	157S*42	LB	E3BBL	4

2103005000	VOC	Volatile Organic Compounds	1.13	LB	E3GAL	47.46	LB	E3BBL	4
2103005000	7440382	Arsenic	0.00141	LB	E3GAL	0.05922	LB	E3BBL	3
2103005000	7440417	Beryllium	0.00003	LB	E3GAL	0.00126	LB	E3BBL	**7**
2103005000	7440439	Cadmium	0.00042	LB	E3GAL	0.01764	LB	E3BBL	**7**
2103005000	18540299	Chromium (VI)	0.000162	LB	E3GAL	0.006804	LB	E3BBL	**7**
2103005000	16065831	Chromium III	0.000738	LB	E3GAL	0.030996	LB	E3BBL	**7**
2103005000	7439965	Manganese	0.00315	LB	E3GAL	0.1323	LB	E3BBL	**7**
2103005000	7439976	Mercury	0.000122	LB	E3GAL	0.005103	LB	E3BBL	**7**
2103005000	7440020	Nickel	0.09	LB	E3GAL	3.78	LB	E3BBL	**7**
2103005000	7782492	Selenium	0.000735	LB	E3GAL	0.03087	LB	E3BBL	**7**

INDUSTRIAL RESIDUAL OIL COMBUSTION

A. Source Category Description

Industrial fuel consumption includes emissions from boilers, engines, and other combustion sources from the industrial sector that are not reported as point sources.

Table 1. 2023 NEI Commercial/Institutional Residual Oil Combustion SCC

SCC	SCC Level 1	SCC Level 2	SCC Level 3	SCC Level 4
2102005000	Stationary Source Fuel Combustion	Industrial	Residual Oil	Total: All Boiler Types

B. Overview of Calculations

Industrial residual oil combustion emissions in the 2023 National Emissions Inventory (NEI) are estimated using fuel consumption by sector from the Energy Information Administration (EIA) State Energy Data System (SEDS),[1] commercial employment from the U.S. Census Bureau,[2] and emission factors.

In the following sections, details are provided related to the collection of activity data (Section C), calculation of emission factors (Section D), accounting for control programs (Section E), Emissions (Section F), point source subtraction (Section G), and sample calculations (Section H).

C. Activity Data

Activity data is based on year-specific state-level fuel consumption from SEDS, and county-level employment data from the U.S. Census Bureau.[2] County Business Pattern NAICS codes 11--, 21--, 23--, 31--, 32-- and 33-- are used to apportion state-fuel to the county level based on the proportion of employment in the commercial sector to the total industrial sector state employment.

The total fuel consumption is adjusted to account for fuel used as an input to industrial processes where it is not combusted. Maryland assumes that 81.80% of industrial coal throughput is not combusted. This assumption is based on the EIA Manufacturing Energy Consumption Survey (MECS)[3], which reports both total fuel consumption and non-combustion use of fuel by Census region.

$$\boldsymbol{F_{f,c,x} = F_{f,x} \times \frac{a_{c,x}}{a_x} \times (1 - nc_{f,industrial})}$$

Where:

$F_{f,c,x}$ = Consumption of fuel *f* in county *c* in sector *x*
$F_{f,x}$ = Consumption of fuel *f* in sector *x*
$a_{c,x}$ = Employment in county *c* in sector *x*
a_x = Employment in sector *x*
$nc_{f,x}$ = Fraction of fuel f used as an industrial input and is not combusted in the industrial sector

The NEI uses 2022 SEDS fuel consumption and 2021 employment to estimate county-level fuel consumption for industrial residual oil combustion, as shown in Table 2.

Table 2: 2023 County Level Fuel Consumption for Industrial Residual Oil Combustion

County Name	State County FIPs	Employment	Employment Fraction	EIS SEDS Consumption (Thousand Barrels)	Non-Fuel Consumption	Fuel Consumption (Thousand Barrels)
Allegany	24001	2,886	0.011073	9	81.80%	0.0181
Anne Arundel	24003	33,165	0.127247			0.2084
Baltimore	24005	38,098	0.146174			0.2394
Calvert	24009	2,579	0.009895			0.0162
Caroline	24011	1,819	0.006979			0.0114
Carroll	24013	9,303	0.035694			0.0585
Cecil	24015	5,909	0.022672			0.0371
Charles	24017	3,827	0.014683			0.0241
Dorchester	24019	3,532	0.013552			0.0222
Frederick	24021	16,507	0.063334			0.1037
Garrett	24023	1,812	0.006952			0.0114
Harford	24025	10,313	0.039569			0.0648
Howard	24027	17,254	0.0662			0.1084
Kent	24029	1,161	0.004455			0.0073
Montgomery	24031	32,072	0.123054			0.2016
Prince Georges	24033	39,127	0.150122			0.2459
Queen Annes	24035	2,788	0.010697			0.0175
Saint Mary's	24037	2,271	0.008713			0.0143
Somerset	24039	688	0.00264			0.0043
Talbot	24041	1,673	0.006419			0.0105
Washington	24043	9,108	0.034946			0.0572
Wicomico	24045	3,923	0.015052			0.0247
Worcester	24047	1,642	0.0063			0.0103
Baltimore City	24510	19,177	0.073578			0.1205

D. Emissions Factors

The emissions factors for Industrial, Commercial and Institutional (ICI) fuel consumption sectors are from AP-42[4] and a spreadsheet developed in 2010 by EPA and the Eastern Regional Technical Advisory Committee.[5]

SO2 and filterable PM emission factors are multiplied by the state sulfur content. In Maryland, the sulfur content for industrial residual oil combustion is either 1% or 2% depending on the county.[6] Primary PM emissions are estimated by adding condensable and filterable PM.

The emissions factors for hazardous air pollutants from (HAP) are taken from EPA's 2002 NEI Documentation.[7]

Criteria air pollutant emissions factors for industrial residual oil are listed in table 3 below. HAP emissions factors for this source category are included in Appendix Table 1

Table 3: 2023 NEI Criteria Pollutant Emissions Factors for Industrial Residual Oil Combustion

SCC	Description	Pollutant Code	Emission Factor	Unit	Source
2102005000	Industrial Residual Oil	CO	210	LB/E3BBL	5
		NOX	2310		
		PM-CON	63		
		PM10-FIL	7.17(1.12*S+0.37)*42		
		PM10-PRI	PM10-FIL + PM-CON		
		PM25-FIL	4.67(1.12*S+0.37)*42		
		PM25-PRI	PM25-FIL + PM-CON		
		SO2	157S+42		
		VOC	11.76		

E. Controls

Emissions from residual industrial fuel combustion are controlled through Code of Maryland Regulations (COMAR) 26.11.09.07: Control of Sulfur Oxides from Fuel Burning Equipment.[8] COMAR 26.11.09.07 limits sulfur content in fuel burning equipment in Maryland to 1 or 2% depending on the county. Sulfur is limited to 1% in Baltimore City and Anne Arundel, Baltimore, Carroll, Harford, Howard, Montgomery, and Prince Georges counties. Sulfur is limited to 2% in the rest of the state.

F. Emissions

Emissions in each ICI sector are estimated by multiplying the county-level nonpoint source fuel consumption by the emission factors for that sector.

$$E_{p,f,c,x} = NPF_{f,c,x} \times EF_{p,f,x}$$

Where:

$E_{p,f,c,x}$ = Annual emissions of pollutant *p* from fuel type *f* in county *c* in sector *x*
$NPF_{f,c,x}$ = Nonpoint source consumption of fuel type *f* in county *c* in sector x (Table 2)
$EF_{p,f,x}$ = Emissions factor for pollutant *p,* fuel type *f*, and sector *x* (Table 3 & Appendix Table 1)

G. Point Source Subtraction

Since emissions from industrial residual oil combustion occurs from both point and nonpoint SCCs, point source subtraction is required to ensure emissions from this sector are not double-counted.

To accomplish this task, MDE utilizes the point source registry to locate industrial residual oil combustion point sources to estimate the amount of fuel consumption to subtract from the SEDS total. Facility level annual CO2 emissions are divided by an emission factor[9], which yields the amount of fuel in the county associated with the point source emissions. The county-level fuel consumption is then adjusted downward by the amount of fuel consumed by point sources. Nonpoint emissions are then estimated using the point source adjusted fuel consumption. The resultant emissions represent emissions only associated with nonpoint activity.

The fuel adjustment for point source subtraction is calculated as follows:

$$NP_{f,c} = Ep_{CO2c,s} \times 2000\ /\ EF_{CO2,s}$$

Where:

$NP_{f,c}$ = Nonpoint source fuel consumption in county *c* for source category *s*, in thousands of barrels per year

$Ep_{CO2,c,s}$ = Annual point CO_2 emissions for the identified point sources in county *c* for source category *s*, in tons per year

$EF_{CO2,s}$ = CO_2 emissions factor for source category *s*

The point source consumption estimates for industrial residual oil are outlined in Table 4 below.

Table 4: Point Source Consumption Adjustment for Industrial Residual Oil Combustion

County Name	FIPS State and County Code	Fuel Consumption (Thousand Barrels)	Point Source Fuel Consumption Reduction (Thousand Barrels)	Point Source Adjusted Fuel Consumption (Thousand Barrels)
Allegany	24001	0.0181	0.00	0.0181
Anne Arundel	24003	0.2084	0.00	0.2084
Baltimore	24005	0.2394	0.00	0.2394
Calvert	24009	0.0162	0.00	0.0162
Caroline	24011	0.0114	0.00	0.0114
Carroll	24013	0.0585	0.00	0.0585
Cecil	24015	0.0371	0.00	0.0371
Charles	24017	0.0241	0.00	0.0241
Dorchester	24019	0.0222	0.00	0.0222
Frederick	24021	0.1037	0.00	0.1037
Garrett	24023	0.0114	0.00	0.0114
Harford	24025	0.0648	0.00	0.0648
Howard	24027	0.1084	0.00	0.1084
Kent	24029	0.0073	0.00	0.0073
Montgomery	24031	0.2016	0.00	0.2016
Prince George's	24033	0.2459	0.00	0.2459
Queen Anne's	24035	0.0175	0.00	0.0175
St. Mary's	24037	0.0143	0.00	0.0143
Somerset	24039	0.0043	0.00	0.0043
Talbot	24041	0.0105	0.00	0.0105
Washington	24043	0.0572	0.00	0.0572
Wicomico	24045	0.0247	0.00	0.0247
Worcester	24047	0.0103	12.36	0.0000
Baltimore City	24510	0.1205	24.30	0.0000

H. Sample Calculations

Sample calculations for VOC emissions from industrial residual oil combustion in Anne Arundel County, Maryland are included in the table below.

Table 5. Sample Calculations of VOC Emissions for Industrial Residual Oil Combustion in Anne Arundel County.

Eq. #	Equation	Values for Anne Arundel County	Result
1	$\boldsymbol{E_{p,f,c,x} = NPF_{f,c,x} \times EF_{p,f,x}}$	$(0.2084\ E3BBL\ \times 11.76\ lb/E3BBL)/2000$	0.00122 tons of VOC in 2023

I. References

[1] Energy Information Administration. 2024. State Energy Data System, 2022 data. https://www.eia.gov/state/seds/

[2] U.S. Census Bureau. 2024. 2021 County Business Patterns. https://www.census.gov/data/datasets/2021/econ/cbp/2021-cbp.html

[3] Energy Information Administration. 2018. Manufacturing Energy Consumption Survey, 2014 data. https://www.eia.gov/consumption/manufacturing/

[4] U.S. Environmental Protection Agency. 1996. Compilation of Air Pollutant Emission Factors, 5th Edition, AP-42, Volume I: Stationary Point and Area Sources. Research Triangle Park, North Carolina. https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emission-factors#5thed

[5] EPA and Eastern Regional Technical Advisory Committee. 2010. Excel file: state_comparison_ERTAC_SS_version7_5_Mar 16 2010.xls

[6] Code of Maryland Regulations (COMAR) 26.11.09.07: Control of Sulfur Oxides from Fuel Burning Equipment. https://dsd.maryland.gov/Pages/COMARSearch.aspx

[7] U.S. Environmental Protection Agency. 2017. Industrial, Commercial, and Institutional Fuel Consumption NEMO. https://gaftp.epa.gov/air/nei/2017/doc/supporting_data/nonpoint/ICI%20NEMO%20FINAL_4-2%20updated.docx.

[8] Code of Maryland Regulations (COMAR) 26.11.09.07: Control of Sulfur Oxides from Fuel Burning Equipment. https://dsd.maryland.gov/Pages/COMARSearch.aspx

[9] Energy Information Administration. Carbon Dioxide Emissions Coefficients. September 18, 2024. https://www.eia.gov/environment/emissions/co2_vol_mass.php

APPENDIX

Table 1 Emissions Factors for Residual Oil Combustion in the Industrial Sector

SCC	Pollutant Code	Name	Original Factor Numeric Value	Original Factor Unit Numerator	Original Factor Unit Denominator	Factor Numeric Value	Factor Unit Numerator	Factor Unit Denominator	Reference
2102005000	129000	PYRENE	0.00000425	LB	E3GAL	0.0001785	LB	E3BBL	4; Table 1.3-9
2102005000	206440	FLUORANTHENE	0.00000484	LB	E3GAL	0.00020328	LB	E3BBL	4; Table 1.3-9
2102005000	50000	FORMALDEHYDE	0.033	LB	E3GAL	1.386	LB	E3BBL	4; Table 1.3-9
2102005000	71432	BENZENE	0.000214	LB	E3GAL	0.008988	LB	E3BBL	4; Table 1.3-9
2102005000	75070	ACETALDEHYDE	0.00525	LB	E3GAL	0.2205	LB	E3BBL	7
2102005000	85018	PHENANATHRENE	0.0000105	LB	E3GAL	0.000441	LB	E3BBL	4; Table 1.3-9
2102005000	86737	FLUORENE	0.0000047	LB	E3GAL	0.0001974	LB	E3BBL	4; Table 1.3-9
2102005000	91203	NAPHTHALENE	0.0013	LB	E3GAL	0.0546	LB	E3BBL	4; Table 1.3-9
2102005000	CO	CARBON MONOXIDE	5	LB	E3GAL	210	LB	E3BBL	5
2102005000	NH3	AMMONIA	0.8	LB	E3GAL	33.6	LB	E3BBL	5
2102005000	NOX	NITROGEN OXIDES	55	LB	E3GAL	2310	LB	E3BBL	5
2102005000	PM10-FIL	PRIMARY PM10, FILTERABLE PORTION ONLY	7.17(1.12S+0.37)	LB	E3GAL	7.17(1.12S+0.37)*42	LB	E3BBL	5
2102005000	PM10-PRI	PRIMARY PM10, PRIMARY	7.17(1.12S+0.37) +1.5	LB	E3GAL	(PM10 Filterable+ PM Condensible)	LB	E3BBL	5
2102005000	PM25-FIL	PRIMARY PM2.5, FILTERABLE PORTION ONLY	4.67(1.12S+0.37)	LB	E3GAL	4.67(1.12S+0.37)*42	LB	E3BBL	5
2102005000	PM25-PRI	PRIMARY PM2.5, PRIMARY	4.67(1.12S+0.37) +1.5	LB	E3GAL	(PM2.5 Filterable + PM Condensible)	LB	E3BBL	5
2102005000	PM-CON	PRIMARY PM CONDENSIBLE PORTION ONLY (ALL LESS THAN 1 MICRON)	1.5	LB	E3GAL	63	LB	E3BBL	5
2102005000	SO2	SULFUR DIOXIDE	157S	LB	E3GAL	157S*42	LB	E3BBL	5
2102005000	VOC	VOLATILE ORGANIC COMPOUNDS	0.28	LB	E3GAL	11.76	LB	E3BBL	5
2102005000	7439921	LEAD	0.001233	LB	E3GAL	0.051786	LB	E3BBL	4; Table 1.3-10
2102005000	83329	Acenaphthene	0.0000211	LB	E3GAL	0.0008862	LB	E3BBL	4; Table 1.3-9
2102005000	7782492	Selenium	0.000735	LB	E3GAL	0.03087	LB	E3BBL	4
2102005000	7440439	Cadmium	0.00042	LB	E3GAL	0.01764	LB	E3BBL	4
2102005000	7440417	Beryllium	0.00003	LB	E3GAL	0.00126	LB	E3BBL	4
2102005000	7440382	Arsenic	0.00141	LB	E3GAL	0.05922	LB	E3BBL	4

2102005000	7440020	Nickel	0.09	LB	E3GAL	3.78	LB	E3BBL	4
2102005000	7439976	Mercury	0.0001215	LB	E3GAL	0.005103	LB	E3BBL	4
2102005000	7439965	Manganese	0.00315	LB	E3GAL	0.1323	LB	E3BBL	4
2102005000	56832736	Benzofluoranthenes	0.00000148	LB	E3GAL	0.00006216	LB	E3BBL	4; Table 1.3-9
2102005000	56553	Benz[a]Anthracene	0.00000401	LB	E3GAL	0.00016842	LB	E3BBL	4; Table 1.3-9
2102005000	53703	Dibenzo[a,h]Anthracene	0.00000167	LB	E3GAL	0.00007014	LB	E3BBL	4; Table 1.3-9
2102005000	218019	Chrysene	0.00000238	LB	E3GAL	0.00009996	LB	E3BBL	4; Table 1.3-9
2102005000	208968	Acenaphthylene	0.000000211	LB	E3GAL	0.000008862	LB	E3BBL	4; Table 1.3-9
2102005000	193395	Indeno[1,2,3-c,d]Pyrene	0.00000214	LB	E3GAL	0.00008988	LB	E3BBL	4; Table 1.3-9
2102005000	191242	Benzo[g,h,i,]Perylene	0.000002426	LB	E3GAL	0.000101892	LB	E3BBL	4; Table 1.3-9
2102005000	18540299	Chromium (VI)	0.000162	LB	E3GAL	0.006804	LB	E3BBL	4
2102005000	16065831	Chromium III	0.000738	LB	E3GAL	0.030996	LB	E3BBL	4
2102005000	120127	Anthracene	0.00000122	LB	E3GAL	0.00005124	LB	E3BBL	4; Table 1.3-9

INDUSTRIAL ADHESIVES

A. Source Category Description

Industrial adhesives are the application of a liquid or powder substance, such as solvent type paints, varnishes, and lacquers to a surface for decorative or protective purposes. The substances can be applied by brushing, rolling, spraying, dipping or flow coating. VOCs are released into the air as the substance dries. Powder coatings are applied to a hot surface and then melted; VOCs are released as the powder melts and dries.

Table 1: 2023 NEI Industrial Adhesive SCC.

SCC	SCC Level 1	SCC Level 2	SCC Level 3	SCC Level 4
2440000000	Solvent Utilization	Miscellaneous Industrial	All Processes	Total: All Solvent Types

B. Overview of Calculations

Industrial Adhesives Volatile Organic Compound (VOC) emissions in the 2023 NEI are estimated using population and a controlled emission factor.

In the following sections, details are provided related to the collection of activity data (Section C), calculation of emission factors (Section D), accounting for control programs (Section E), emissions (Section F), point source subtraction (Section G), and sample calculations (Section H).

C. Activity Data

Activity data is based on year-specific county-level population data from the U.S. Census Bureau.[1] The 2023 NEI uses 2023 population estimates, as shown in Table 2.

Table 2: 2023 County Level Population

County Name	State County FIPs	Population for Inventory Year
Allegany	24001	67,273
Anne Arundel	24003	594,582
Baltimore	24005	844,703
Calvert	24009	94,728
Caroline	24011	33,593
Carroll	24013	176,639
Cecil	24015	105,672
Charles	24017	171,973
Dorchester	24019	32,879
Frederick	24021	293,391
Garrett	24023	28,423
Harford	24025	264,644
Howard	24027	336,001
Kent	24029	19,303
Montgomery	24031	1,058,474
Prince Georges	24033	947,430

Queen Annes	24035	52,508
Saint Mary's	24037	115,281
Somerset	24039	24,910
Talbot	24041	37,823
Washington	24043	155,813
Wicomico	24045	104,800
Worcester	24047	54,171
Baltimore City	24510	565,239
Total		6,180,253

D. Emissions Factors

MDE used a VOC emission factor of 1.10 lbs/capita/year developed by The California Air Resources Board (CARB) for adhesives and sealants. [2]

CARB's Determination of Reasonably Available Control Technology and Best Available Retrofit Control Technology (RACT/BART) estimated emission factor calculation for adhesives and sealants is estimated as:

> VOC = 45 tons/day estimated in 1994 * 365 days/year * 2000 lbs/ton / 29,760,021 capita where 45 tons/day is the estimated state-wide emissions for industrial adhesives in California, 2000 lbs/ton is a conversion factor, and 29,760,021 capita is the 1990 population of California. VOC Emf = 1.10 lbs/capita/year of industrial adhesives

E. Controls

VOC emissions from Industrial Adhesives are controlled through Code of Maryland Regulations (COMAR) 26.11.19.15: Paint, Resin, and Adhesive Manufacturing and Adhesive Application. The regulation achieves VOC reductions through two basic components: sale and manufacture restrictions that limit the VOC content of specified adhesives, sealants and primers sold in the state; and use restrictions that apply primarily to commercial/industrial applications. The regulation is similar to the one proposed by the Ozone Transport Commission (OTC).

CARB's Determination of Reasonably Available Control Technology and Best Available Retrofit Control Technology (RACT/BART) forms the basis of rule. In the years 1998-2001, the provisions of the CARB determination were adopted in regulatory form in various air pollution control districts in California including the Bay Area, Ventura County, Sacramento Metropolitan and San Joaquin Valley. CARB and OTC estimate a 64.4 percent reduction in emissions from the source category regulation that was fully implemented in Maryland in 2009.

F. Emissions

Total VOC emissions from solvent utilization are calculated by multiplying the activity data for the source category by the calculated emissions factor for that category.

$$\boldsymbol{E_{VOCc,s} = A_{c,s} \times EF_{VOC,s} \times [1 - RE \times RP \times CE]}$$

Where:

$E_{VOC,c,s}$ = Annual VOC emissions in county *c* for source category *s*, in tons per year
$A_{c,s}$ = Activity data for county *c* associated with source category *s* (Section C)
$EF_{VOC,s}$ = Calculated VOC emissions factor for source category *s*
RE = Rule Effectiveness with source category *s*
RP = Rule Penetration with source category *s*
CE = Control Efficiency with source category *s*

HAP emissions are estimated using the VOC emissions and HAP speciation factors (see Table 1 in Appendix). It should be noted that if a speciation profile normalized to Total Organic Gas (TOG) is used for HAP-augmentation, the TOG/VOC ratio must first be applied to the Speciation Factor.

$$\boldsymbol{E_{p,c,s} = E_{VOC,c,s} \times SF_{p,s}}$$

Where:

$E_{p,c,s}$ = Annual emissions of HAP *p* county *c* for source category *s*, in tons per year
$E_{VOC,c,s}$ = Annual VOC emissions in county *c* for source category *s*, in tons per year (Eqn. 1)
$SF_{p,s}$ = Speciation factor for HAP *p* for source category *s* (Appendix Table 1)

G. Point Source Subtraction

There are no point source-specific SCCs for Industrial Adhesives; therefore, point source subtraction is not performed for this category.

H. Sample Calculations

Sample calculations for VOC emissions from Industrial Adhesives in Anne Arundel County, Maryland are included in the table below.

Table 3: Sample Calculations of VOC emissions for Industrial Adhesives (SCC 2440000000) in Anne Arundel County.

Eq. #	Equation	Values for Anne Arundel County	Result
1	$\boldsymbol{E_{VOCc,s} = A_{c,s} \times EF_{VOC,s} \times [1 - RE \times RP \times CE]}$	$(1.10\ ^{lb}/_{capita} \times 594{,}582\ people)/2000) \times 1 - 0.644$	116.42 tons of VOC in 2023

I. Reference

[1] U.S. Census Bureau. Annual Estimates of the Resident Population for Counties: April 1, 2020 to July 1, 2023 (CO-EST2023-POP) U.S. Department of Commerce. Retrieved April 8, 2024 from https://www.census.gov/data/tables/time-series/demo/popest/2020s-counties-total.html#v2023.

[2] Air Resources Board. Determination of Reasonably Available Control Technology and Best Available Retrofit Control technology for Adhesives and Sealants. December 1998.

APPENDIX

Table 1. HAP speciation factors for Industrial Adhesives. For estimating HAPs, MDE will multiply the VOC emissions for each SCC by the appropriate speciation factor provided in this table.

SCC	Description	Pollutant Code	Pollutant Description	Speciation Factor	SPECIATE 5.2 Reference Profile
2440000000	Industrial Adhesives	107211	Ethylene Glycol	0.034647	3.2
2440000000	Industrial Adhesives	110543	Hexane	0.012144	3.2
2440000000	Industrial Adhesives	108101	Methyl Isobutyl Ketone	0.008692	3.2
2440000000	Industrial Adhesives	108883	Toluene	0.110966	3.2
2440000000	Industrial Adhesives	79016	Trichloroethylene	0.006906	3.2
2440000000	Industrial Adhesives	1330207	Xylenes (Mixed Isomers)	0.0381	3.2
2440000000	Industrial Adhesives	107211	Ethylene Glycol	0.034647	3.2
2440000000	Industrial Adhesives	110543	Hexane	0.012144	3.2

Note: The Speciation Factor has been adjusted to reflect the HAP to VOC ratio for each SPECIATE profile. SPECIATE typically houses information normalized to TOG.

LEAKING UNDERGROUND STORAGE TANKS

A. Source Category Description

Many underground storage tanks (USTs) are over 15 years old and are constructed of steel, which may rust over time. The underground piping connected to these tanks also has the potential to leak. Leaking USTs (leaking underground storage tank sites or LUST sites) are of concern because they may result in the contamination of drinking water, subsurface soils, and ground and surface water, and may emit toxic and/or explosive vapors.

Table 1: 2023 NEI Leaking Underground Storage Site SCC.

SCC	SCC Level 1	SCC Level 2	SCC Level 3	SCC Level 4
2660000000	Waste Disposal, Treatment, and Recovery	Leaking Underground Storage Tanks	Leaking Underground Storage Tanks	Total: All Storage Types

B. Overview of Calculations

Leaking underground storage tanks Volatile Organic Compound (VOC) emissions in the 2023 NEI are estimated using the number of LUST sites and emission factors. Hazardous Air Pollutant (HAP) emissions are estimated based on the composition of products and profiles using U.S. EPA's SPECIATE database[1].

In the following sections, details are provided related to the collection of activity data (Section C), calculation of emissions factors (Section D), accounting for control programs (Section E), emissions (Section F), point source subtraction (Section G), and sample calculations (Section H).

C. Activity Data

Activity data is based on year-specific state- and county-level LUST sites Maryland Department of the Environment's Oil Control Program.[2] The number of LUST sites is multiplied by an assumed 30-day remediation period during which it is assumed that emissions are released. The 2023 NEI uses 2023 LUST remediation events, as shown in Table 2.

Table 2: 2023 LUST Remediation Events

County Name	State County FIPs	2021 Count of LUST Sites	Remediation Event Time (Days)	Lust Remediation Events
Allegany	24001	7		210
Anne Arundel	24003	79		2370
Baltimore	24005	31		930
Calvert	24009	4		120
Caroline	24011	6		180
Carroll	24013	7		210
Cecil	24015	13		390
Charles	24017	15		450
Dorchester	24019	5		150
Frederick	24021	17	30	510

Garrett	24023	2		60
Harford	24025	14		420
Howard	24027	9		270
Kent	24029	2		60
Montgomery	24031	29		870
Prince Georges	24033	36		1080
Queen Annes	24035	8		240
Saint Mary's	24037	0		0
Somerset	24039	2		60
Talbot	24041	5		150
Washington	24043	10		300
Wicomico	24045	11		330
Worcester	24047	6		180
Baltimore City	24510	20		600

D. Emissions Factors

The emission factor used to estimate emissions from LUST sites is derived from the *Emissions Inventory Improvement Project Volume III: Area Source Category Method Abstract – Remediation of Leaking Underground Storage Tanks*.[3]

VOC emission factors for LUST site SCCs are listed in table 3 below.

Table 3. 2023 NEI VOC emissions factors for LUST Sites

SCC	Description	Pollutant Code	Emission Factor	Unit	Source
2660000000	Leaking Underground Storage Tanks	VOC	28	lb/day	[4]

E. Controls

There are no controls available for this source category.

F. Emissions

Total VOC emissions from LUST sites are calculated by multiplying the activity data for the source category by the calculated emissions factor for that category.

$$E_{VOCc,s} = A_{c,s} \times EF_{VOC,s}$$

Where:

$E_{VOC,c,s}$ = Annual VOC emissions in county *c* for source category *s*, in tons per year
$A_{c,s}$ = Activity data for county *c* associated with source category *s* (Table 2)
$EF_{VOC,s}$ = VOC emissions factor for source category *s*

HAP emissions are estimated using the VOC emissions and HAP speciation factors shown (see Table 1 in Appendix). It should be noted that if a speciation profile normalized to Total Organic Gas (TOG) is used for HAP-augmentation, the TOG/VOC ratio must first be applied to the Speciation Factor.

$$E_{p,c,s} = E_{VOC,c,s} \times SF_{p,s}$$

Where:

$E_{p,c,s}$ = Annual emissions of HAP p county c for source category s, in tons per year
$E_{VOC,c,s}$ = Annual VOC emissions in county c for source category s, in tons per year
$SF_{p,s}$ = Speciation factor for HAP p for source category s (Appendix Table 1)

G. Point Source Subtraction

There are no point source-specific SCCs for LUST sites; therefore, point source subtraction is not performed for this category

H. Sample Calculations

Sample calculations for VOC emissions from LUST sites in Anne Arundel County, Maryland are included in the table below.

Table 4. Sample Calculations of VOC emissions for LUST Sites (SCC 2660000000) in Anne Arundel County.

Eq. #	Equation	Values for Anne Arundel County	Result
1	$E_{VOCc,s} = A_{c,s} \times EF_{VOC,s}$	$\left(2{,}370\ days\ \times 28 \frac{lb/day}{2000}\right)$	33.18 tons of VOC in 2023

I. References

[1] U.S. Environmental Protection Agency: Final Report, SPECIATE Version 5.0, Database Development Documentation, Research Triangle Park, NC, EPA/600/R-19/988, 2019. https://www.epa.gov/air-emissions-modeling/speciate-50-final-report-and-addenda-speciate-51-53. Note: This is the final report for the SPECIATE database. There is an addendum for Version 5.2 at the same location.

[2] Maryland Department of the Environment Oil Control Program. https://mde.maryland.gov/programs/land/OilControl/Pages/index.aspx.

[3] U.S. Environmental Protection Agency: *Emissions Inventory Improvement Project Volume III: Area Source Category Method Abstract – Remediation of Leaking Underground Storage Tanks*, https://www.epa.gov/sites/default/files/2015-08/documents/ust2_dec2000.pdf

[4] U.S. Environmental Protection Agency: *Emissions Inventory Improvement Project Volume III: Area Source Category Method Abstract – Remediation of Leaking Underground Storage Tanks*, https://www.epa.gov/sites/default/files/2015-08/documents/ust2_dec2000.pdf

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APPENDIX

Table 1. HAP speciation factors for LUST Sites. For estimating HAPs, MDE will multiply the VOC emissions by the appropriate speciation factor provided in this table.

SCC	Description	Pollutant Code	Pollutant Description	Speciation Factor
2660000000	Leaking Underground Storage Tanks	91203	Naphthalene	0.000002700
2660000000	Leaking Underground Storage Tanks	98828	Cumene	0.000120000
2660000000	Leaking Underground Storage Tanks	100414	Ethyl Benzene	0.000530000
2660000000	Leaking Underground Storage Tanks	108883	Toluene	0.014000000
2660000000	Leaking Underground Storage Tanks	110543	n-Hexane	0.018000000
2660000000	Leaking Underground Storage Tanks	540841	2,2,4-Trimethylpentane	0.007500000
2660000000	Leaking Underground Storage Tanks	1330207	Xylenes	0.005600000

Note: The Speciation Factor has been adjusted to reflect the HAP to VOC ratio for each SPECIATE profile. SPECIATE typically houses information normalized to TOG.

OIL SPILLS

A. Source Category Description

Oil spills involve oil tanker accidents, tanker truck accidents, and spills and blowouts from oil rigs or pipelines in coastal and inland areas. Because a wide range of fuel types may be spilled, the nature and quantity of emissions can vary. Emissions are also influenced by the clean-up procedure and by dispersion and weathering processes.

Table 1: 2023 Oil Spill SCC.

SCC	SCC Level 1	SCC Level 2	SCC Level 3	SCC Level 4
2830000000	Miscellaneous Area Sources	Catastrophic/Accidental Releases	All Catastrophic/Accidential Releases	Total

B. Overview of Calculations

Oil spill Volatile Organic Compound (VOC) emissions in the 2023 NEI are estimated using county gallons of oil spilled and an emission factor.

In the following sections, details are provided related to the collection of activity data (Section C), calculation of emissions factors (Section D), accounting for control programs (Section E), emissions (Section F), point source subtraction (Section G), and sample calculations (Section H).

C. Activity Data

Activity data is based on year-specific and county-level gallons from oil spills collected from Maryland Department of the Environment's Oil Control's Emergency Response Program. The 2023 NEI uses 2017 gallons of oil spilled, as shown in Table 2.

Table 2: 2017 County Level Oil Spills.

County Name	State County FIPs	2017 Gallons of Oil Spilled
Allegany	24001	339
Anne Arundel	24003	5,344
Baltimore	24005	6,351
Calvert	24009	210
Caroline	24011	179
Carroll	24013	1,266
Cecil	24015	1,622
Charles	24017	1,703
Dorchester	24019	385
Frederick	24021	1,244
Garrett	24023	588
Harford	24025	12,556
Howard	24027	1,034
Kent	24029	27
Montgomery	24031	2,572
Prince Georges	24033	17,238

Queen Annes	24035	319
Saint Mary's	24037	1,160
Somerset	24039	269
Talbot	24041	409
Washington	24043	4,977
Wicomico	24045	428
Worcester	24047	204
Baltimore City	24510	7,560
Total		67,985

D. Emissions Factors

The emission factor used to estimate oil spill emissions are from E.H. Pechan and Associates, Inc, the contractor used by the Metropolitan Washington Council of Governments for the 1990 base year inventory. The emission factor is based on a California Air Resources Board (CARB) study of air emissions from large oil spills.

VOC emission factors for oil spill SCCs are listed in table 3 below.

Table 3. 2023 NEI VOC emissions factors for Oil Spills

SCC	Description	Pollutant Code	Emission Factor	Unit
2830000000	Oil Spill	VOC	0.0000925	ton/gallon

E. Controls

There are no controls available for this source category.

F. Emissions

Total VOC emissions from oil spills are calculated by multiplying the activity data for the source category by the calculated emissions factor for that category.

$$E_{VOCc,s} = A_{c,s} \times EF_{VOC,s}$$

Where:

$E_{VOC,c,s}$ = Annual VOC emissions in county *c* for source category *s*, in tons per year
$A_{c,s}$ = Activity data for county *c* associated with source category *s* (Table 2)
$EF_{VOC,s}$ = Calculated VOC emissions factor for source category *s* (Table 3)

G. Point Source Subtraction

There are no point source specific SCCs for oil spills; therefore point source subtraction is not performed for this category.

H. Sample Calculations

Sample calculations for VOC emissions from oil spills in Anne Arundel County, Maryland are included in the table below.

Table 4. Sample Calculations of VOC emissions for Oil Spill (SCC 2830000000) in Anne Arundel County.

Eq. #	Equation	Values for Anne Arundel County	Result
1	$\boldsymbol{E_{VOCc,s} = A_{c,s} \times EF_{VOC,s}}$	$\left(5{,}345\ gallons\ \times 0.0000925\ {}^{ton}/_{gallon}\right)$	0.4944 tons of VOC in 2023

STRUCTURE FIRES

A. Source Category Description

Accidental structure fires result from unintentional actions, arson, or natural events. This category includes emissions from the burning of residential or commercial structures and their contents. Building fires can produce short-term emissions of Volatile Organic Compounds (VOC), Nitrogen Oxides (Nox), Carbon Monoxide (CO), and Particulate Matter (PM).

Table 1: 2023 NEI Structure Fire SCC.

SCC	SCC Level 1	SCC Level 2	SCC Level 3	SCC Level 4
2810030000	Miscellaneous Area Sources	Other Combustion	Structure Fires	Unspecified

B. Overview of Calculations

Structure Fire emissions in the 2023 NEI are estimated using total structure fires per county, a fuel loading factor, and emission factors.

In the following sections, details are provided related to the collection of activity data (Section C), calculation of emissions factors (Section D), accounting for control programs (Section E), emissions (Section F), point source subtraction (Section G), and sample calculations (Section H).

C. Activity Data

Activity data is based on year-specific county-level count of structure fires from the Maryland State Fire Marshal's office and a fuel loading factor. Structural materials such as insulation and wood, and the contents of structures such as furniture, carpets, clothing, paper and plastics, can burn in a structure fire. Not all of the contents and structural materials burn in a fire, rather, the fire burns a portion of the contents and structural material in the rooms where the fire originates and spreads. The average total material burned (i.e. fuel loading) in a residential fire is estimated to be 1.67 tons.[1] The total amount of material burned is estimated as the number of fires multiplied by the fuel loading factor. The 2023 NEI uses the total fuel burned, as shown in Table 2.

Table 2: 2023 County Structure Fire Activity

County	FIPS State and County Code	Number of Fires in 2023	Fuel Loading Factor (Tons/Fire)	Total Burned (Tons)
Allegany	24001	95	1.67	158.65
Anne Arundel	24003	504		841.68
Baltimore	24005	323		539.41
Calvert	24009	51		85.17
Caroline	24011	58		96.86
Carroll	24013	134		223.78
Cecil	24015	123		205.41
Charles	24017	243		405.81
Dorchester	24019	49		81.83

Frederick	24021	260		434.2
Garrett	24023	63		105.21
Harford	24025	154		257.18
Howard	24027	84		140.28
Kent	24029	40		66.8
Montgomery	24031	487		813.29
Prince George's	24033	856		1429.52
Queen Anne's	24035	43		71.81
St. Mary's	24037	125		208.75
Somerset	24039	15		25.05
Talbot	24041	56		93.52
Washington	24043	197		328.99
Wicomico	24045	157		262.19
Worcester	24047	68		113.56
Baltimore City	24510	1317		2199.39

D. Emissions Factors

Emission factors for structure fires are adopted from Holder's *Hazardous air pollutant emissions estimates from wildland urban interface*[2] Emission factors for structure fires are listed in Table 3 below.

Table 3. 2023 NEI emissions factors for Structure Fires

SCC	Description	Pollutant Code	Emission Factor	Unit	Source
2810030000	Structure Fires	VOC	116.4	lb/ton	2
2810030000	Structure Fires	Nox	0.662	lb/ton	
2810030000	Structure Fires	CO	138	lb/ton	
2810030000	Structure Fires	PM10-PRI	78.6	lb/ton	
2810030000	Structure Fires	PM2.5-PRI	78.6	lb/ton	
2810030000	Structure Fires	Lead	0.022	lb/ton	

E. Controls

There are no controls available for this source category.

F. Emissions

Emissions from structure fires are calculated by multiplying the activity data for the source category by the emissions factor for that category.

$$E_{c,s} = A_{c,s} \times EF_s$$

Where:

$E_{c,s}$ = Annual emissions in county *c* for source category *s*, in tons per year
$A_{c,s}$ = Activity data for county *c* associated with source category *s* (Table 2)
EF_s = Emissions factor for source category *s* (Table 3)

G. Point Source Subtraction

There are no point source-specific SCCs for structure fires; therefore, point source subtraction is not performed for this category.

H. Sample Calculations

Sample calculations for VOC emissions from structure fires in Anne Arundel County, Maryland are included in the table below.

Table 4. Sample Calculations of VOC emissions for structure fires (SCC 2810030000) in Anne Arundel County.

Eq. #	Equation	Values for Anne Arundel County	Result
1	$\boldsymbol{E_{VOCc,s} = A_{c,s} \times EF_{VOC,s}}$	$\left((841.68\ tons\ \times \frac{116.4\ lb}{ton} / 2000\right)$	48.99 tons of VOC in 2023

I. References

1 U.S. Environmental Protection Agency. Wagon Wheel: 2023NEI_NEMO_Structure_MotorVehicle_Fires_16jul2024.

2 Holder, A.L., A. Ahmed, J.M. Vukovich, and V. Rao. Supplementary data Table S-2 PNAS Nexus, Volume 2, Issue 6, June 2023, pgad186. "Hazardous air pollutant emissions estimates from wildland urban interface", https://doi.org/10.1093/pnasnexus/pgad186.

VEHICLE FIRES

A. Source Category Description

Accidental vehicle fires result from unintentional actions, arson, or natural events. This category includes emissions from the burning of any commercial or private mode of transportation that is authorized for use on public roads. Vehicle fires can produce short-term emissions of Volatile Organic Compounds (VOC), Nitrogen Oxides (Nox), Carbon Monoxide (CO), and Particulate Matter (PM).

Table 1: 2023 NEI Vehicle Fires SCC.

SCC	SCC Level 1	SCC Level 2	SCC Level 3	SCC Level 4
2810050000	Miscellaneous Area Sources	Other Combustion	Motor Vehicle Fires	Unspecified

B. Overview of Calculations

Vehicle Fires emissions in the 2023 NEI are estimated using total vehicle fires per county, a fuel loading factor, and emission factors.

In the following sections, details are provided related to the collection of activity data (Section C), calculation of emissions factors (Section D), accounting for control programs (Section E), emissions (Section F), point source subtraction (Section G), and sample calculations (Section H).

C. Activity Data

Activity data is based on year-specific county-level count of vehicle fires from the Maryland State Fire Marshal's office and a fuel loading factor. Automobile components including upholstery, belts, hoses and tires can burn in a vehicle fire. Not all of the vehicle contents burn in a fire. The average total material burned (i.e. fuel loading) in a vehicle fire is estimated to be 1,016 lbs, or 0.508 tons.[1] The total amount of material burned is estimated as the number of fires multiplied by the fuel loading factor. The 2023 NEI uses the total fuel burned, as shown in Table 2.

Table 2: 2023 County Vehicle Fire Activity

County	FIPS State and County Code	Number of Fires in 2023	Fuel Loading Factor (Tons/Fire)	Total Burned (Tons)
Allegany	24001	54	0.508	27.432
Anne Arundel	24003	224		113.792
Baltimore	24005	321		163.068
Calvert	24009	24		12.192
Caroline	24011	22		11.176
Carroll	24013	57		28.956
Cecil	24015	70		35.56
Charles	24017	58		29.464
Dorchester	24019	15		7.62
Frederick	24021	108		54.864
Garrett	24023	19		9.652
Harford	24025	83		42.164

Howard	24027	70		35.56
Kent	24029	12		6.096
Montgomery	24031	193		98.044
Prince George's	24033	500		254
Queen Anne's	24035	21		10.668
St. Mary's	24037	41		20.828
Somerset	24039	10		5.08
Talbot	24041	23		11.684
Washington	24043	102		51.816
Wicomico	24045	63		32.004
Worcester	24047	28		14.224
Baltimore City	24510	205		104.14

D. Emissions Factors

Emission factors for vehicle fires are adopted from Holder's *Hazardous air pollutant emissions estimates from wildland urban interface*[2] and *Hazardous air pollutant emissions estimates from wildland urban interface*[2] and Holder's *Supplementary_Data_20240210.xlsx.*[3]

Emission factors for vehicle fires are listed in Table 3 below.

Table 3. 2023 NEI emissions factors for Vehicle Fires

SCC	Description	Pollutant Code	Emission Factor	Unit	Source
2810050000	Vehicle Fires	VOC	21.7	lb/ ton	3
2810050000	Vehicle Fires	NOx	8.6	lb/ ton	3
2810050000	Vehicle Fires	CO	96	lb/ ton	2
2810050000	Vehicle Fires	PM10-PRI	114.4	lb/ ton	2
2810050000	Vehicle Fires	PM2.5-PRI	114.4	lb/ ton	2
2810050000	Vehicle Fires	Lead	0.065	lb/ ton	2

E. Controls

There are no controls available for this source category.

F. Emissions

Emissions from vehicle fires are calculated by multiplying the activity data for the source category by the emissions factor for that category.

$$\boldsymbol{E_{c,s} = A_{c,s} \times EF_s}$$

Where:

$E_{,c,s}$ = Annual emissions in county *c* for source category *s*, in tons per year
$A_{c,s}$ = Activity data for county *c* associated with source category *s* (Table 2)
EF_s = Emissions factor for source category *s* (Table 3)

G. Point Source Subtraction

There are no point source-specific SCCs for structure fires; therefore, point source subtraction is not performed for this category.

H. Sample Calculations

Sample calculations for VOC emissions from vehicle fires in Anne Arundel County, Maryland are included in the table below.

Table 4. Sample Calculations of VOC emissions for vehicle fires (SCC 2810050000) in Anne Arundel County.

Eq. #	Equation	Values for Anne Arundel County	Result
1	$\boldsymbol{E_{VOCc,s} = A_{c,s} \times EF_{VOC,s}}$	$\left(113.792\ tons\ \times \frac{21.7\ lb}{ton} / 2000\right)$	1.23 tons of VOC in 2023

I. References

1 U.S. Environmental Protection Agency. Wagon Wheel: 2023NEI_NEMO_Structure_MotorVehicle_Fires_16jul2024.

2 Holder, A.L., A. Ahmed, J.M. Vukovich, and V. Rao. Supplementary data Table S-2 PNAS Nexus, Volume 2, Issue 6, June 2023, pgad186. “Hazardous air pollutant emissions estimates from wildland urban interface”, https://doi.org/10.1093/pnasnexus/pgad186.

3 Holder, A.L., 2024. Correction to Table S2, “Supplementary_Data_20240210.xlsx”

2020 National Emissions Inventory Technical Support Document: Miscellaneous Non-Industrial NEC: Cremation – Human and Animal

EPA-454/R-23-001cc
March 2023

2020 National Emissions Inventory Technical Support Document: Miscellaneous Non-Industrial NEC: Cremation – Human and Animal

U.S. Environmental Protection Agency
Office of Air Quality Planning and Standards
Air Quality Assessment Division
Research Triangle Park, NC

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29 Miscellaneous Non-Industrial NEC: Cremation – Human and Animal

29.1 Sector Descriptions and Overview

The cremation of human remains results in emissions of particulate matter, SO_2, NOx, VOC, CO, and HAPs. It is a significant source of mercury emissions, due to mercury in dental fillings, as well as mercury in blood and tissues. In 2020, human cremation resulted in the emissions of approximately 2.3 tons of mercury.

The cremation of animals also results in emissions of CAPs and HAPs, though it emits less mercury than human cremation. In 2020, animal cremation resulted in the emissions of approximately 2.4 lbs. of mercury.

SCCs for human and animal cremation are provided in Table 29-1.

Table 29-1: Human and animal cremation SCCs

SCC	SCC Level 1	SCC Level 2	SCC Level 3	SCC Level 4
2810060100	Miscellaneous Area Sources	Other Combustion	Cremation	Humans
2810060200	Miscellaneous Area Sources	Other Combustion	Cremation	Animals

A list of agencies that submitted human and/or animal cremation emissions is provided in Section 6.2.3.

29.2 EPA-developed estimates

The calculations for estimating emissions from human cremation involve estimating the number of deaths in each age group in each county, using data from the Centers for Disease Control and Prevention. The number of deaths is multiplied by the average weight by age group and the state-level cremation rate from the National Funeral Directors Association to estimate the total amount of cremations in each county in terms of mass. This number is multiplied by an emissions factor to estimate the emissions of CAPs and HAPs. Emissions of mercury include emissions from mercury in fillings in teeth and in blood and tissues. The emissions from mercury in fillings are estimated based on data on the number of filled teeth per person in each age group and assumptions about the proportion of fillings that contain mercury and the amount of mercury in each filling.

The calculations for estimating emissions from animal cremation involve determining the number of cremated animals nationally and distributing this number to each county based on population. The number of cremated animals is multiplied by average weights for cats and dogs to determine the amount of cremations in each county in terms of mass. This number is multiplied by an emissions factor to estimate the emissions of CAPs and HAPS.

29.2.1 Activity data

<u>Human Cremation</u>

The activity data for human cremation is based on the number of deaths in each county in 13 age groups, from the Centers for Disease Control and Prevention WONDER database [ref 1]. Data for some counties are withheld in the WONDER database. These gaps are filled using the data on the total number of deaths by age group in each state (which includes the number of deaths that are withheld at the county level). First, the sum of the reported county-level number of deaths in each age group and state is subtracted from the reported state-level number of deaths in each age group to determine the total number of deaths withheld at the county level in each state and age group.

$$Deaths\_withheld_{s,a} = Deaths\_state_{s,a} - \sum Deaths\_county_{s,a} \quad \text{(H1)}$$

Where:

Deaths_withheld$_{s,a}$ = Total number of withheld deaths in state *s* in age group *a*
Deaths_state$_{s,a}$ = Total number of deaths reported at the state level in state *s* in age group *a*
Deaths_county$_{s,a}$ = Total number of deaths reported at the county level in state *s* in age group *a*

The total number of withheld deaths are distributed to the counties based on the proportion of population in those counties to the total state population.

$$Pop\_ratio_c = \frac{Pop_c}{Pop_s} \quad \text{(H2)}$$

Where:

Pop_ratio$_c$ = The population ratio used to distribute withheld deaths in state *s* to county *c*
Pop$_c$ = The total population of county *c*
Pop$_s$ = The total population of state *s*

The number of withheld deaths in each state is multiplied by the county population ratio to distribute the withheld deaths to the counties. Note that this step is only performed for counties where county-level data on number of deaths is withheld; this step is not performed where county-level data on deaths is reported.

$$Deaths_{c,a} = Deaths\_withheld_{s,a} \times Pop\_ratio_c \quad \text{(H3)}$$

Where:

Deaths$_{c,a}$ = The number of deaths in county *c* in age group *a*
Deaths_withheld$_{s,a}$ = Total number of withheld deaths in state *s* in age group *a*, from equation H1
Pop_ratio$_c$ = The population ratio used to distribute withheld deaths in state *s* to county *c*, from equation H2

The total number of deaths in each county (either reported directly in the CDC WONDER database or estimated using equation H3) is multiplied by a state-level cremation rate, reported by the National Funeral Directors Association (NFDA) [ref 2], shown in Table 29-2. It is assumed that the state-level cremation rate applies to all counties within the state.

$$Cremations_{c,a} = Deaths_{c,a} \times Cremation\_rate_s \quad \text{(H4)}$$

Where:

Cremations$_{c,a}$ = The number of human cremations in county *c* in age group *a*
Deaths$_{c,a}$ = The number of deaths in county *c* in age group *a*
Cremation_rate$_s$ = The rate of human cremations in state *s*, from Table 29-2 [ref 2]

Table 29-2: Human cremation rate by state

State	Cremation Rate
Alabama	35%
Alaska	71.7%
Arizona	67.9%
Arkansas	45.3%
California	66.4%
Colorado	74%
Connecticut	60.8%
Delaware	56.7%
District of Columbia	53.3%
Florida	69.1%
Georgia	48.7%
Hawaii	75.6%
Idaho	66.5%
Illinois	53.6%
Indiana	49.2%
Iowa	55.8%
Kansas	57.8%
Kentucky	37.2%
Louisiana	39.2%
Maine	78.8%
Maryland	50.4%
Massachusetts	52.4%
Michigan	64%
Minnesota	63.3%
Mississippi	29.5%
Missouri	52.4%
Montana	77.9%
Nebraska	55.6%
Nevada	80.7%
New Hampshire	77.2%
New Jersey	50.4%
New Mexico	66%
New York	49.8%
North Carolina	51.7%
North Dakota	51.7%
Ohio	52.8%
Oklahoma	51.6%
Oregon	78.8%
Pennsylvania	54.7%
Rhode Island	52.6%
South Carolina	48.6%
South Dakota	48.1%
Tennessee	41.2%
Texas	49.1%
Utah	40.2%
Vermont	75.7%
Virginia	47.3%
Washington	80.4%
West Virginia	42.8%
Wisconsin	63.9%
Wyoming	73%

The CDC provides estimates of the average weight of individuals in each age group [ref 3]. This number is multiplied by the number of cremations in each county in each age group and then summed across all age groups to estimate the total amount of cremations in tons in each county.

$$Cremations\_tons_c = \sum_{a=1}^{A} Cremations_{c,a} \times W_a \times \frac{1\ ton}{2{,}000\ lbs} \quad \text{(H5)}$$

Where:

Cremations_tons$_c$= The weight of humans cremated in county *c*, in tons
Cremations$_c$ = The number of human cremations in county *c*, from equation H4
W_a = The average weight of individuals from age group *a*

<u>Animal Cremation</u>

The Pet Loss Professionals Alliance (PLPA) conducted a survey that estimated that there were 1,840,965 pet cremations in 2012, and that 99 percent of deceased pets are cremated [ref 4]. In addition, the Humane Society of the United States estimates that there are 2,700,000 adoptable dogs and cats euthanized in animal shelters each year [ref 5]. It is assumed that all of these shelter animals are cremated. Therefore, there are a total of approximately 4,540,965 animal creations each year. Note that this estimate does not double count the number of animal cremations, because the PLPA study counts the number of cremations of pets—i.e. animals that are owned by people—whereas the Humane Society estimates are for animals in shelters that were not adopted.

The population of cats and dogs is approximately 52.5 percent cats and 48.5 percent dogs [ref 5]. Using this percentage and the total number of pets and shelter animals cremated annually, a total number of cats and a total number of dogs cremated annually can be calculated.

$$Cremations_{c/d,US} = Ratio_{c/d} \times (Cremations\_pets_{US} + Cremations\_shelter_{US}) \quad \text{(A1)}$$

Where:

Cremations$_{c/d}$ = Total cats, *c*, or dogs, *d*, cremated annually in the United States
Ratio$_{c/d}$ = Ratio of cats, *c*, or dogs, *d*, in the pet population
Cremations_pets$_{,US}$ = Total number of pets cremated annually in the United States
Cremations_shelter$_{,US}$ = Total number of shelter animals cremated annually in the United States

The average weight of a domestic cat is approximately 4.5 kg (9.9 pounds) [ref 6]. The average weight of a dog is difficult to determine due to large differences in breeds, but an average across breeds is 48.5 pounds [ref 7]. Note that this is a straight average of the average adult weight for male and female dogs across breeds. It is not a weighted average that takes into account the popularity of different breeds in the United States. To calculate the weight, in tons, of both cats and dogs cremated annually, the average weight values are multiplied by the total number of cats and total number of dogs cremated annually.

$$Cremations\_tons_{c/d} = Cremations_{c/d} \times Weight_{c/d} \times \frac{1\ ton}{2{,}000\ pounds} \quad \text{(A2)}$$

Where:

$Cremations\_tons_{c/d,US}$ = Total weight, in tons, of cats, *c*, or dogs, *d*, cremated annually in the United States
$Cremations_{c/d,US}$ = Total cats, *c*, or dogs, *d*, cremated annually in the United States
$Weight_{c/d}$ = Average weight per animal, in pounds, of cats, *c*, or dogs, *d*

Once the weight of cats and weight of dogs cremated annually has been calculated, these values can be summed to derive a total weight of animals cremated annually.

$$Cremations\_tons_{animal} = Cremations\_tons_c + Cremations\_tons_d \quad \text{(A3)}$$

Where:

$Cremations\_tons_{animal,US}$ = Total weight of animals cremated annually in the United States, in tons
$Cremations\_tons_{c,US}$ = Total weight of cats, *c*, cremated annually in the United States, in tons
$Cremations\_tons_{d,US}$ = Total weight of dogs, *d*, cremated annually in the United States, in tons

29.2.2 Allocation procedure

Human Cremation

The number of deaths is reported by the CDC at the county level. Therefore, these data do not need to be allocated. For counties with withheld data on the number of deaths, the total number of withheld deaths is distributed to counties based on the proportion of population in those counties, as described in equations H1-H3.

Animal Cremation

The estimated national-level total weight of animals cremated are allocated to the county level based on the ratio of population in each county to the total national population.

$$Cremations\_tons_{animal,c} = Cremations\_tons_{animal,US} \times \frac{Pop_c}{Pop_{US}} \quad \text{(A1)}$$

Where:

$Cremations\_tons_{animal,c}$ = Total weight of animals cremated in county *c*, in tons
$Cremations\_tons_{animal,US}$ = Total weight of animals cremated annually in the United States, in tons, from equation A3
Pop_c = The total population of county *c*
Pop_{US} = The total population of the United States

29.2.3 Emission factors

Human and Animal Cremation – Blood and Tissues

The emissions factors for human and animal cremation for CAPs are from AP-42 [ref 8], and a report by EPA on emissions tests of a crematory [ref 9] and are in units of pounds of emissions per ton cremated. The emission factors for CAPs are also provided in the "Wagon Wheel Emission Factor Compendium" on the 2020 NEI Supporting Data and Summaries site. The emissions factors for most HAPs are a report from the California Air Resources Board [ref 10], as well as from the EPA emissions test of a crematory. The VOC HAPs are computed in EIS using HAP Augmentation factors available in the zip file "HAPAugmentation_Nonpoint_28jan2023", on the 2020 NEI Supplemental data FTP site. The mercury emissions factor is from a review of multiple studies [ref 11]. These emission factors do not include emissions from dental fillings. As shown in Table 29-3, EPA uses the same emissions factors for emissions from cremation of blood and tissues for both humans and animals.

Table 29-3: Emissions factors for the cremation of human and animal blood and tissues

Pollutant	Pollutant Code	Emission Factor (lbs/ton)	Source
Carbon Monoxide	CO	2.947	8
Lead	7439921	0.009	9
Nitrogen Oxides	NOX	3.560	8
PM10 Primary	PM10-PRI	3.036	8 (65% of total PM)
PM2.5 Primary	PM25-PRI	2.022	8 (43.3% of total PM)
Sulfur Dioxide	SO2	2.173	8
Volatile Organic Compounds	VOC	0.299	8
Acenaphthene	83329	1.303E-06	10
Acenaphthylene	208968	8.971E-07	10
Acetaldehyde	75070	9.269E-04	10
Anthracene	120127	2.389E-06	10
Arsenic	7440382	5.097E-04	10
Benzo(a)anthracene	56553	1.166E-07	10
Benzo(a)pyrene	192972	4.720E-07	10
Benzo(b)fluoranthene	205992	1.737E-07	10
Benzo(g,h,i)perylene	191242	5.874E-07	10
Benzo(k)fluoranthene	207089	1.486E-07	10
Beryllium	7440417	1.760E-05	10
Cadmium	7440439	2.940E-03	9
Chromium (VI)	18540299	1.829E-04	10
Chrysene	218019	2.880E-07	10
Cobalt	7440484	8.869E-05	10
Dibenz(a,h)anthracene	53703	1.349E-07	10
Fluoranthene	206440	1.337E-06	10
Fluorene	86737	3.760E-06	10
Formaldehyde	50000	2.469E-04	10
Hydrogen Chloride	7647010	3.595E+00	9
Hydrogen Fluoride	7664393	8.651E-03	10
Indeno(1,2,3-cd)pyrene	193395	1.440E-07	10
Mercury	7439976	1.324E-04	10

Pollutant	Pollutant Code	Emission Factor (lbs/ton)	Source
Naphthalene	91203	7.520E-04	10
Nickel	7440020	4.149E-04	10
Phenanthrene	85018	1.531E-05	10
Pyrene	129000	1.474E-06	10
Selenium	7782492	4.971E-04	10

Human Cremation – Dental Mercury

In addition to mercury emitted from the cremation of blood and tissues, mercury is also emitted due to the cremation of dental fillings. The Bay Area Air Quality Management District (BAAQMD) issued a report in 2012 estimating the average amount of mercury in teeth per person for ten age groups, based on data from CDC's National Health and Nutrition Examination Survey [ref 12]. Table 29-4 shows the estimated amount of material in restored teeth by age group from the BAAQMD study [ref 12], which is matched to the age groups used by the CDC Wonder database, which is the source of data on deaths by age group.

The BAAQMD memorandum is used to estimate that 31.6 percent of filled teeth in the 5-24 age groups contain amalgam. According to the American Dental Association (ADA 1998) more than 75 percent of restorations before the 1970s used dental amalgam, which declined to 50 percent by 1991. Using these numbers, it is assumed that 50 percent of the filled teeth for 25-44 age groups contain amalgam, 62.5 percent of filled teeth in the 45-64 age group, and 75 percent of filled teeth for people over 65. The Food and Drug Administration has discouraged the use of dental amalgam in children under 6 [ref 13]. While EPA does not have data on the percent of fillings containing dental amalgam for the 1-4 age group, it is assumed that this age group has approximately half the dental amalgam of the other age groups under 20 years old. It is also assumed that children under the age of 1 have no dental mercury. The analysis also assumes that 45 percent of all amalgam-containing fillings are mercury, based on information from the Food and Drug Administration [ref 13].

Table 29-4: Estimated amount of material in restored teeth

Age Groups in CDC WONDER Database	Age Groups in BAAQMD Memorandum	Avg. Material in Restored Teeth (g)	% of Fillings Containing Mercury
< 1 year	0-4 years^{+}	0.000	0.0%
1-4 years		0.160	15.8%
5-9 years	5-14 years	0.720	31.6%
10-14 years			
15-19 years	15-24 years	1.070	31.6%
20-24 years			
25-34 years	25-34 years	2.230	50.0%
35-44 years	35-44 years	3.290	50.0%
45-54 years	45-54 years	4.310	62.5%
55-64 years	55-64 years	4.320	62.5%
65-74 years	65-74 years	3.780	75.0%

Age Groups in CDC WONDER Database	Age Groups in BAAQMD Memorandum	Avg. Material in Restored Teeth (g)	% of Fillings Containing Mercury
75-84 years	75-84 years	3.650	75.0%
85+ years	85+ years	2.960	75.0%

The emissions factor for mercury in teeth is calculated by multiplying the average amount of material in restored teeth per person by the percentage of fillings containing mercury in each age group and the proportion of mercury in dental amalgam (approximately 45 percent).

$$EF\_teeth_{Hg,a} = Material_a \times ContainHg_a \times HgProportion \times 0.0022 \frac{lb}{g} \tag{H6}$$

Where:

$EF\_teeth_{Hg,a}$ = Emission factor for mercury emissions from teeth due to cremation for age group *a*, in lbs. per cremation
$Material_a$ = The average amount of material in restored teeth for age group *a*, in grams, from Table 29-4
$ContainHg_a$ = The proportion of people in age group *a* with fillings that contain mercury, from Table 29-4
HgProportion = The proportion of dental amalgam that is mercury (approximately 45 percent)

29.2.4 Controls

There are no controls assumed for this source category.

29.2.5 Emissions

<u>Human Cremation</u>

To estimate the emissions of CAPs from human cremation, the total number of human cremations in each county, in tons, is multiplied by the emissions factor for each pollutant, from Table 29-3.

$$Emissions_{p,c} = Cremation\_tons_c \times EF_p \tag{H7}$$

Where:

$Emissions_{p,c}$ = Emissions of pollutant *p* from human cremation in county *c*, in pounds
$Cremations\_tons_c$ = The number of human cremations in county *c*, in tons
EF_p = Emissions factor for pollutant *p* from human cremation, in lbs. per ton

The emissions from mercury in teeth are estimated based on the number of cremations rather than the weight. To estimate the emissions of mercury from teeth during human cremation, the number of cremations in each age group is multiplied by the emissions factor for each age group and then summed across age groups.

$$Emissions\_teeth_{Hg,c} = \sum_{a=1}^{A} Cremations_{c,a} \times EF\_teeth_{Hg,a} \tag{H8}$$

Where:

$Emissions\_teeth_{Hg,c}$ = Emissions of mercury in teeth from human cremation in county *c*, in pounds
$Cremations_{c,a}$ = The number of human cremations in county *c* in age group *a*
$EF\_teeth_{Hg,a}$ = Emissions factor for mercury emissions from teeth due to cremation for age group *a*, in lbs. per cremation

The emissions from mercury from blood and tissues are estimated by multiplying the total number of cremations in each county, in tons, by the emissions factor for mercury from blood and tissues.

$$Emissions\_tissue_{Hg,c} = Cremations\_tons_c \times EF\_tissue_{Hg} \quad \text{(H9)}$$

Where:

$Emissions\_tissue_{Hg,c}$ = Emissions of mercury in tissues from human cremation in county *c*, in pounds
$Cremations\_tons_c$ = The number of human cremations in county *c*, in tons
$EF\_tissue_{Hg,a}$ = Emissions factor for mercury emissions from blood and tissues due to cremation for in lbs. per ton

The total emissions of mercury from cremation in each county is calculated by adding the emissions of mercury from teeth and the emissions of mercury from tissues.

$$Emissions_{Hg,c} = Emissions\_teeth_{Hg,c} + Emissions\_tissue_{Hg,c} \quad \text{(H10)}$$

Where:

$Emissions_{Hg,c}$ = Emissions of mercury from human cremation in county *c*, in pounds
$Emissions\_teeth_{Hg,c}$ = Emissions of mercury in teeth from human cremation in county *c*, in pounds
$Emissions\_tissue_{Hg,c}$ = Emissions of mercury in tissues from human cremation in county *c*, in pounds

Animal Cremation

$$Emissions_{p,c} = Cremation\_tons_c \times EF_p \quad \text{(A5)}$$

Where:

$Emissions_{p,c}$ = Emissions of pollutant *p* from animal cremation in county *c*, in pounds
$Cremations\_tons_c$ = The number of animal cremations in county *c*, in tons
EF_p = Emissions factor for pollutant *p* from animal cremation, in lbs. per ton

29.2.6 Sample calculations

Table 29-5 lists the sample calculations for estimating mercury emissions from human cremation in the 85+ age group and animal cremation of cats. To estimate the total emissions in a county, these steps would be repeated to estimate emissions from all age groups and from cremation of dogs. The values in these equations are demonstrating program logic and are not representative of any specific NEI year or county

Table 29-5: Sample calculations for mercury emissions from human cremation for the 85+ age group and cremation of cats

Eq. #	Equation	Values	Result
H1	$Deaths\_withheld_{s,a} = Deaths\_state_{s,a} - \sum Deaths\_county_{s,a}$	$4{,}013\ state\ level\ deaths - 3{,}997\ total\ county\ level\ deaths$	16 withheld deaths in the state
H2	$Pop_{ratio_c} = \frac{Pop_c}{Pop_s}$	$\frac{873\ people\ in\ the\ county}{1{,}975\ total\ population\ of\ counties\ with\ withheld\ deaths}$	0.442 population ratio
H3	$Deaths_{c,a} = Deaths_{withheld_{s,a}} \times Pop_{ratio_c}$	$16\ withheld\ deaths\ \times 0.442\ population\ ratio$	7 deaths in the county
H4	$Cremations_{c,a} = Deaths_{c,a} \times Cremation_{rate_s}$	$7\ deaths\ \times 56.8\%\ cremation\ rate$	4 cremations in the county
H5	$Cremations\_tons_c = \sum_{a=1}^{A} Cremations_{c,a} \times W_a \times \frac{1\ ton}{2{,}000\ lbs}$	$4\ cremations\ \times 158.25\ lbs\ per\ person\ in\ 85 + age\ group\ \div 2000\ lbs\ per\ ton$	0.3165 tons cremations in the county
H6	$EF\_teeth_{Hg,a} = Material_a \times ContainHg_a \times HgProportion \times 0.0022 \frac{lb}{g}$	$2.96\ g\ mercury\ \times 75\ \%\ with\ mercury\ \times 45\%\ of\ fillings\ are\ mercury\ \times 0.0022$	0.0022 lbs. mercury per cremation
H7	$Emissions_{p,c} = Cremation_{tons_c} \times EF_p$	N/A	Completed in equation H9 for mercury
H8	$Emissions_{teeth_{Hg,c}} = \sum_{a=1}^{A} Cremations_{c,a} \times EF_{teeth_{Hg,a}}$	$4\ cremations \times 0.0022\ lbs\ per\ cremation$	0.0088 lbs. mercury from teeth in 85+ age group in the county

Eq. #	Equation	Values	Result
H9	$Emissions_{tissue_{Hg,c}} = Cremations_{tons_c} \times EF_{tissue_{Hg}}$	$0.3165\ tons\ cremations \times 0.0015\ lbs\ per\ ton$	0.00047 lbs. mercury from tissues in 85+ age group in the county
H10	$Emissions_{Hg,c} = Emissions_{teeth_{Hg,c}} + Emissions_{tissue_{Hg,c}}$	$0.0088\ lbs\ from\ teeth + 0{,}00047\ lbs.\ from\ tissues$	0.0093 lbs. mercury from cremation of 85+ age group in the county
A1	$Cremations_{c/d,US} = Ratio_{c/d} \times (Cremations\_pets_{US} + Cremations\_shelter_{US})$	$52.5\%\ of\ cats\ in\ pet\ population \times (1{,}840{,}965\ pet\ cremations + 2{,}700{,}000\ shelter\ animal\ cremations)$	2,384,006 cremated cats in the U.S.
A2	$Cremations_{tons_{\frac{c}{d}}} = Cremations_{\frac{c}{d}} \times Weight_{\frac{c}{d}} \times \frac{1\ ton}{2{,}000\ pounds}$	$2{,}384{,}006\ cremated\ cats \times 9.9\ lbs\ per\ cat \div 2000\ lbs\ per\ ton$	11,800 tons of cremated cats in the U.S.
A3	$Cremations_{tons_{animal}} = Cremations_{tons_c} + Cremations_{tons_d}$	N/A	Cremations of dogs are not estimated in this sample calculation
A4	$Cremations\_tons_{animal,c} = Cremations\_tons_{animal,US} \times \frac{Pop_c}{Pop_{US}}$	$11{,}800\ cremated\ cats \times \frac{873\ people\ in\ the\ county}{329{,}164{,}967\ people\ in\ US}$	0.03 tons cats cremated in the county
A5	$Emissions_{p,c} = Cremation_{tons_c} \times EF_p$	$0.03 \times 0.0015\ lbs\ per\ ton$	0.000045 lbs. mercury emissions from cremation of cats in the county

29.2.7 Improvements/Changes in this NEI

There are no significant changes from the methodology used to calculate the previous NEI emissions.

29.2.8 Puerto Rico and U.S. Virgin Islands

Since insufficient data exists to calculate emissions from human cremation for the counties in Puerto Rico and the US Virgin Islands, emissions are based on two proxy counties in Florida: 12011, Broward County for Puerto Rico and 12087, Monroe County for the US Virgin Islands. The total emissions in tons for these two Florida counties are divided by their respective populations creating a tons per capita emissions factor. For each Puerto Rico and US Virgin Island county, the tons per capita emissions factor is multiplied by the county population (from the same year as the inventory's activity data) which served as the activity data. In these cases, the throughput (activity data) unit and the emissions denominator unit are "EACH".

Emissions from animal cremation are based on county population; therefore, the emissions from animal cremation in Puerto Rico and the Virgin Islands are calculated using the method described for the rest of the counties.

29.3 References

1. CDC. 2020 WONDER Database. Table 2, last accessed December 2021.
2. National Funeral Directors Association (NFDA). 2020. The NFDA Cremation and Burial Report: Research, Statistics and Projections, last accessed December 2021.
3. CDC 2016. Anthropometric Reference Data for Children and Adults: United States, 2011-2014. Vital Health Statistics, Series 3, Number 29, last accessed August 2018.
4. Pet Loss Professionals Alliance (PLPA). 2013. Pet Loss Professionals Alliance Releases Finding of Inaugural Professional Survey, last accessed August 2018.
5. Humane Society of the United States. 2014. Pets by the Numbers, last accessed August 2018.
6. Mattern, M.Y. and D.A. McLennan. 2000. Phylogeny and Speciation of Felids. Cladistics, 16: 232-253.
7. Modern Puppies. Breed Weight Chart, last accessed August 2018.
8. U.S. Environmental Protection Agency. 1993. AP-42: Compilation of Air Emissions Factors, Fifth Edition, Volume I, Chapter 2.3 - Medical Waste Incineration, Tables 2.3-2 and 2.3-15.
9. U.S. Environmental Protection Agency. 1999. Emission Test Evaluation of a Crematory at Woodlawn Cemetery in the Bronx, NY, Vol. I-III, EPA-454/R-99-049.
10. California Air Resources Board. 1999. Development of Toxic Emissions Factors from Source Test Data Collected Under the Air Toxics Hot Spots Program, Part II, Volume I. Prepared by GE Energy and Environmental Research Corporation.
11. Reindl, J. 2012. Summary of References on Mercury Emissions from Crematoria, last accessed August 2018.
12. Lundquist, J.H. 2012. Mercury Emissions from the Cremation of Human Remains. Bay Area Air Quality Management District.
13. Food and Drug Administration. 2017. About Dental Amalgam Fillings, last accessed August 2018.

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