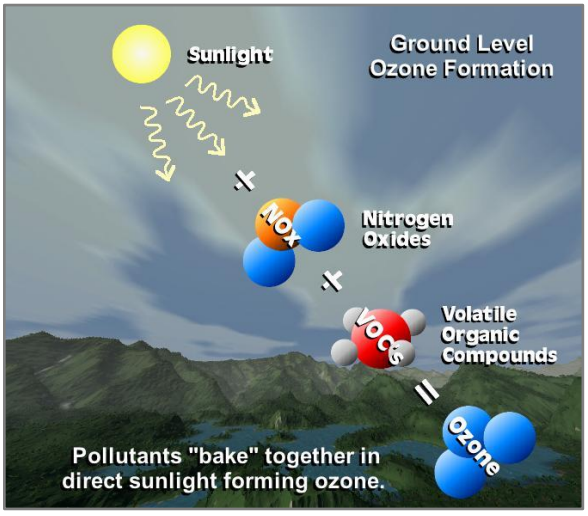
Division of Environmental and Financial Assistance
January 2022

Calculating Emissions from Coating and Painting Operations

This guide explains how to calculate emissions of volatile organic compounds (VOC), hazardous air pollutants (HAP) and select toxic air contaminants (TAC) from common coating and painting operations. This emissions information is needed for air permit applications and for ongoing recordkeeping and reporting requirements for air permits.

This guide includes example calculations that cover the most common scenarios and permit requirements. A brief background on why U.S. EPA regulates emissions from painting operations and the basics of coating formulations is helpful in understanding the concepts of the calculations and the requirements of common air permits.



Source: NASA – Aura

What is a VOC?

A VOC is any compound that contains carbon and reacts with nitrogen oxides in the presence of sunlight to form ground-level ozone, a pollutant regulated by U.S. EPA. This ozone mixes with fine dust particles and other materials to form smog. Although ozone is beneficial to the upper atmosphere, ground-level ozone is an irritant that causes problems for humans, animals, and plants. Because ground-level ozone is not emitted directly, U.S. EPA regulates the emissions of compounds that cause its formation, namely VOCs, nitrogen oxides, and other compounds.

Many compounds, mainly solvents, are VOCs. There is not a complete listing of all VOCs because the definition is so broad. However, some volatile compounds have negligible ozone-forming effects and are known as exempt VOCs. ***Ohio Administrative Code rule 3745-21-01*** defines volatile organic compounds and includes a list of the compounds that are not VOCs. For example, acetone, methylene chloride, and many CFC refrigerants are not VOCs. When used as solvents in coating formulations, these exempt VOCs are commonly referred to as exempt solvents. U.S. EPA determines which chemicals are exempt compounds and thus exempt from the federal definition of VOC. Ohio's definition of VOC in OAC rule 3745-21-01 is consistent with the federal definition.

What is a HAP?

Hazardous air pollutants (HAP), specified in Section 112(b) of the federal Clean Air Act, are those pollutants that cause or may cause cancer or other serious health effects, such as reproductive effects or birth defects, or adverse environmental and ecological effects. Many common solvents, such as xylene, toluene, and methyl isobutyl ketone are HAPs. In addition, pigment solids containing lead, cadmium, chromium, lead, or other heavy metal compounds are also HAPs. A complete listing of all 187 HAPs can be found on ***U.S. EPA's Initial List of Hazardous Air Pollutants with Modifications***.

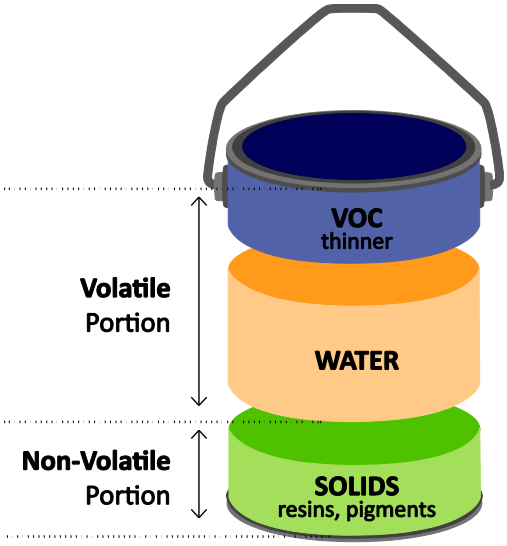
What is a TAC?

Ohio EPA defined 303 compounds that have known toxicological effects when emitted to the atmosphere. Many of the toxic air contaminants on this list are also VOCs or HAPs that are commonly found in paints, coatings, and solvents. Like HAPs, TACs can be found in both the liquid and solid portions of coatings. The complete listing of the toxic air contaminants regulated in Ohio can be found in ***OAC rule 3745-114-01***.

Calculating Emissions from Coating and Painting Operations

How are VOCs, HAPs, and TACs emitted?

In general, coatings and paints are mixtures of liquid (volatile) and solid (non-volatile) materials. Resins and pigments usually make up the solid portion of the coating that forms the film that remains on the part after the coating dries. The solids portion can contain HAPs and/or TACs, which are commonly used in some types of pigments. HAPs and TACs present in coating solids are carried in the overspray that is typically captured by exhaust hoods or spray booths and filtered before being released to the ambient air. A small amount of this overspray escapes the filters and is exhausted to the ambient air as particulate emissions.



The liquid portion of the coating can consist of water, solvents, diluents, reducers, and thinners. These compounds evaporate, or volatilize, during the application and drying processes. Typical hoods or booths capture the fumes and exhaust them to the ambient air. Most solvents, diluents and thinners are, or contain, VOCs, HAPs and TACs. These volatile compounds pass through common types of paint booth exhaust filters.

How to Estimate VOC, HAP, and TAC Emissions

The use of a mass balance approach is the easiest way to calculate VOC, HAP, and TAC emissions from a coating operation. This method uses coating formulation and usage data and assumes that all the VOC, HAP, and TAC contained in the liquid (volatile) portion of the coating is emitted into the air after the coating is applied and dried.

To calculate emissions from the volatile portion of the coating, multiply the amount of VOC/HAP/TAC in a gallon of coating by the total gallons of coating applied during the time frame of interest, for example, hour, day, month, etc.

Pounds of VOC emitted = (pounds of VOC/gallon) x (gallons applied) [for any time frame]

This calculation can be repeated for total HAP, single HAP, and single TAC chemicals by using coating density and the weight percentage of each in the coating formulation. It is very important that you include any diluents, thinners, or reducers mixed with the coating before application. These materials generally increase the VOC/HAP/TAC content of the applied coating and overall emissions.

To estimate HAP/TAC emissions from the solids (non-volatile) portion of the coating, multiply the coating density by the weight percentage of HAP/TAC in the coating, the amount of coating applied, the transfer efficiency*(TE) of the coating equipment, and the exhaust filter efficiency (FE), if filters are present.

Pounds solid HAP emitted = (coating density) x (% wt HAP or TAC) x (gallons applied) x [1-TE] x [1-FE]

**Transfer efficiency (TE) is defined as the ratio of the weight of coatings solids deposited on a substrate to the total weight of coatings solids put through the application equipment. TE is usually expressed as a percentage.*

How do I find the VOC, HAP and TAC content of coatings and solvents?

The amounts of VOC, HAP and TAC in coatings and other materials should be available from the supplier or manufacturer in a data sheet (for example, Environmental Data Sheet (EDS), Technical Data Sheet, Product Specifications or Certified Product Data Sheet) or through independent lab analysis.* Note that the product's Material Safety Data Sheet (MSDS) may or may not include this information in detail. The MSDS is not designed to provide this level of environmental information.

**Lab analysis is rarely required. Contact your coating supplier and ask for the VOC, HAP and TAC content information if it is not listed on the EDS or other data sheets.*

Calculating Emissions from Coating and Painting Operations

What data do I need from the EDS or Technical Data Sheet?

For air emission calculations, the information you need is usually found in the following sections of a typical EDS or similar type of product data sheet.

Hazardous Ingredients/Composition Section

This section typically contains a list of the material's hazardous ingredients, their Chemical Abstract System (CAS) numbers and their percent by weight or by volume. This section will help you identify if there are any HAPs or TACs in the material. Sometimes a data sheet will list a range (for example, Ethylbenzene 1-5% wt.) instead of an exact percentage. In such instances, contact the supplier for the precise value or simply use the highest value of the range listed.

Be aware that a chemical may have several common names, so make special note of the CAS number typically listed on the data sheet beside each chemical. You can positively identify each chemical by the using its unique CAS number.

Product Weight or Material Density: This is how much one gallon of the material weighs – it is not the VOC content.

Specific gravity: Sometimes used in place of material density for liquids, this dimensionless number compares the material's density to the density of water. A specific gravity less than 1.0 means the material is less dense (lighter) than water, greater than 1.0 means the material is more dense (heavier) than water.

Product Weight
9.75 lb/gal

Specific Gravity
1.17

FLASH POINT
103 °F PMCC

Hazard Category (for SARA 311.312)
| Acute | Chronic | Fire |

Volatile Ingredients

Chemical / Compound	SARA 302 EHS	CERCLA	SARA 313 TC	HAPS 112	% by Weight	% by Volume
Mineral Spirits 64742-88-7	N	N	N	N	25	39
Ethylbenzene 100-41-4	N	Y	Y	Y	0.1	< 1

CAS number, unique to each chemical.

This column identifies ingredients that are HAPs, per Section 112 of the Clean Air Act, and shows ethylbenzene is a HAP, while mineral spirits is not.

Calculating Emissions from Coating and Painting Operations

Physical/Chemical Properties Section

This section of the EDS contains some information about the material that is useful for air emission calculations. The key pieces of information are:

Exempt solvents: Listed are any compounds that are excluded from the definition of VOC. Water is not organic and is the only exempt solvent in this formulation.

Total Volatiles: This number, typically expressed as % by weight or % by volume, represents how much of the material evaporates. It typically includes water, all VOCs, and exempt solvents combined.

Volatile Organic Compounds (follows U.S. EPA VOC Data Sheet)

A.	Coating Density			9.75 lb/gal	1168 g/l
B.	Total Volatiles			28.1 % by wt.	42.2 % by vol.
C.	Federally exempt solvents:				
		Water		0.3 % by wt.	0.4 % by vol.
D.	Organic Volatiles			27.8 % by wt.	41.9 % by vol.
E.	Percent Non-Volatile			71.9 % by wt.	57.8 % by vol.
F.	VOC Content	2.71 lb/gal	325 g/l	total	
	1.	2.72 lb/gal	326 g/l	less exempt solvents	
	2.	4.69 lb/gal	562 g/l	of solids	
		0.38 lb/lb	0.38 kg/kg	of solids	

VOC content, total: Typically expressed as pounds of VOC per gallon (lbs VOC/gal) or grams per liter (g/l). This is the number needed for VOC emission calculations.

VOC content, less exempt solvents: This is the value needed to determine if the coating complies with a regulatory formulation limit, e.g., 3.5 lbs VOC/gallon. It is not used for emission calculations.

IMPORTANT: To greatly simplify the emission calculations, it is recommended that you obtain weight percentages (% by weight) for the VOC, HAP and TAC in each product. Percent by weight and percent by volume are not the same thing. If not listed as percent by weight on the EDS or other technical data sheet, contact your supplier and ask for this information.

What does VOC per gallon, excluding water and exempt solvents mean?

Some coatings contain water as a solvent and/or some amounts of exempt solvents. EPA regulations typically limit the amount of VOC per gallon of coating, excluding water and exempt solvents. This is done to regulate the ratio of solids to VOC in the coating formulation since it is the VOC portion that contributes to air pollution. Check the EDS or other technical data to see if the coating contains water and exempt solvents and if the VOC content is expressed as lbs VOC/gal., minus water and exempt solvents, or lbs/gal less exempt solvents. Although this value is useful for determining if the coating meets a regulatory limit for its formulation, it is not typically used for emission calculations.

Why does the EDS list two different VOC contents, and which one do I use for emission calculations?

Sometimes, an EDS will list two or more different "VOC contents" with labels such as t*heoretical, total, actual, as-applied, as-mixed, minus water and exempt solvents, lbs/gal of solids, or less exempt solvents*. These varying VOC contents typically mean different things in terms of regulatory compliance. For emission calculations, use the value labeled *theoretical, total, actual, as-applied, or as-mixed*. This value represents the true mass of VOC in one gallon of coating.

Calculating Emissions from Coating and Painting Operations

What is a compliant coating?

A compliant coating is one that meets a specific regulatory VOC per gallon limitation, for example, 3.5 lbs VOC/gal, 3.0 lbs VOC/gal, etc., *when it is mixed and applied.* Many coating manufacturers include strict thinning or reducing instructions to ensure the as-packaged and as-applied (mixed) VOC content of the coating does not exceed regulatory limits.

What happens to the VOC content if I thin my coatings?

Thinning a water-based coating with water does not change its VOC per gallon minus water value, since the added water is subtracted in the calculation needed to see if it meets a VOC per gallon minus water limit. However, if you thin or reduce a coating with a VOC-containing material, you will typically raise its overall VOC content and risk turning a compliant coating (i.e., one that meets the VOC/gallon limit as packaged) into a non-compliant coating. **See calculation Example 3**.

How do you calculate "VOC per gallon excluding water" to see if your coatings, as mixed and applied, comply with regulatory VOC per gallon, i.e., formulation, limits?

Normally, the value shown on an EDS or Product Data Sheet for the material as "VOC content, less exempt solvents, or "VOC, less water" can be used to demonstrate compliance with regulatory formulation limits. However, if the coating is mixed with a VOC-containing thinner or reducer, you will likely change the VOC content and need to recalculate it to demonstrate compliance with formulation limitations. See ***Ohio EPA's Division of Air Pollution Control Engineering Guides*** 45 and 48 for examples of this calculation.

Which solvents or coating ingredients are considered "exempt solvents"?

Exempt solvents are considered the same as water; that is, they are not VOCs. First, check the coating MSDS or EDS for exempt solvent information. The U.S. EPA researches and determines which solvents and compounds are exempt from the definition of VOC. Ohio EPA adopts these federal determinations and occasionally amends Ohio's definition of VOC in OAC 3745-21-01(B)(16) to add any new exempt compounds. Common exempt solvents found in coatings include acetone, methyl acetate, and t-butyl acetate.

All the coatings I use are water-based. Are there still VOC emissions?

In most cases, yes. Many water-based coatings still contain some VOC, but this amount is usually small compared to solvent-based coatings. Always check the coating EDS or product data sheets for the relevant VOC information.

Where can I find Ohio EPA air pollution regulations?

Air pollution regulations (complete list) - ***epa.ohio.gov/wps/portal/gov/epa/divisions-and-offices/air-pollution-control/regulations***

Regulations for surface coating (OAC 3745-21-01, 09, 10, 15, 18, 19, 20, 24, and 29) - ***epa.ohio.gov/wps/portal/gov/epa/divisions-and-offices/air-pollution-control/regulations/effective-rules***

Engineering Guides - ***epa.ohio.gov/wps/portal/gov/epa/divisions-and-offices/air-pollution-control/guides-and-manuals/engineering-guides-notebook***

Calculating Emissions from Coating and Painting Operations

Example calculations

The following example calculations demonstrate the most common calculations needed for air permit compliance and emissions reporting. It is not an exhaustive list of all possible calculations. Also see the ***Ohio EPA Division of Air Pollution Control Engineering Guides*** 45 and 48 for additional calculation examples.

Useful Conversion Factors

grams/liter = 0.008344 lbs/gal | 1 liter = 0.2642 U.S. gallon | Density of water = 8.34 lbs/gallon

1 pound = 453.6 grams | 1 gallon = 4 quarts = 8 pints = 128 fl. ounces

Example 1: Calculating the hourly VOC emission rate (lbs VOC/hr) for a straight, as-packaged (not reduced) coating

Data needed:
1) coating VOC content = 2.71 lbs VOC/gallon from example EDS
2) application rate = 2.0 gallons/hour

Hourly VOC emission rate:

2.71 lbs VOC/gal x 2.0 gal/hr = 5.42 lbs VOC/hr

Example 2: Calculating annual VOC emissions (tons VOC/yr) from all coating and cleanup operations

Data needed:
1) primer VOC content = 2.80 lbs VOC/gallon from EDS; used 800 gallons/year
2) top coat VOC content = 3.47 lbs VOC/gallon from EDS; used 1,500 gallons/year
3) clean up solvent VOC content = 7.2 lbs VOC/gallon from EDS; used 100 gallons/year

Annual VOC emissions:

$$\frac{[2.80 \text{ lbs VOC/gal} \times 800 \text{ gal/yr}] + [3.47 \text{ lbs VOC/gal} \times 1500 \text{ gal/yr}] + [7.2 \text{ lbs VOC/gal} \times 100 \text{ gal/yr}]}{2{,}000 \text{ lbs/ton}} = 4.08 \text{ tons/yr}$$

Example 3: Calculating the as-applied VOC content and emissions of a reduced (thinned) coating

Data needed:
1) topcoat VOC content = 3.47 lbs/gallon from EDS
2) reducer VOC content = 6.5 lbs/gallon from EDS
3) mix ratio = 4 gallons topcoat to 1 gallon reducer
4) mixed coating application rate = 2.5 gallons/hour

VOC of mixture:

$$\frac{[4 \text{ gal} \times 3.47 \text{ lbs VOC/gal}] + [1 \text{ gal} \times 6.5 \text{ lbs VOC/gal}]}{4 \text{ gal} + 1 \text{ gal}} = 4.08 \text{ lbs VOC/gal, as mixed}$$

Hourly VOC emission rate: 4.08 lbs VOC/gal x 2.5 gal/hr = 10.2 lbs VOC/hr

Example 4: Calculating the single HAP or TAC emission rate (lbs/hr) for a straight, as-packaged (not reduced) coating

Data needed:
1) product density = 8.75 lbs/gallon from EDS
2) HAP/toxic air contaminants in coating: xylene 5% by wt., and toluene 10% by wt. from EDS
3) coating application rate = 2.0 gallons/hour

Xylene emissions: 8.75 lbs/gal x 0.05 x 2.0 gal/hr = 0.88 lb/hr xylene

Toluene emissions: 8.75 lbs/gal x 0.10 x 2.0 gal/hr = 1.75 lbs/hr toluene

Calculating Emissions from Coating and Painting Operations

Example 5: Calculating emissions (lbs/hr) of individual HAPs or TACs from a mixed coating

These calculations require you to first identify any HAPs and TACs contained in the coatings and reducers. For this example, xylene, toluene and MIBK were identified on the EDS as HAPs. In addition, all three of these chemicals are also on the TAC list specified in OAC 3745-114-01.

Data needed:

1) topcoat: product density = 8.5 lbs/gal, 5% wt xylene, 8% wt MIBK from EDS
2) reducer: product density = 7.5 lbs/gal, 10% wt xylene, 20% wt toluene from EDS
3) mix ratio = 4 gallons topcoat to 1 gallon reducer
4) mixed coating application rate = 2.5 gallons/hour

Xylene content of mixed coating:

$$\frac{(8.5 \text{ lbs/gal} \times 0.05 \times 4 \text{ gal}) + (7.5 \text{ lbs/gal} \times 0.10 \times 1 \text{ gal})}{4 \text{ gal} + 1 \text{ gal}} = 0.49 \text{ lb xylene/gal}$$

Toluene content of mixed coating:

$$\frac{(7.5 \text{ lbs/gal} \times 0.20 \times 1 \text{ gal})}{4 \text{ gal} + 1 \text{ gal}} = 0.30 \text{ lb toluene/gal}$$

MIBK content of mixed coating:

$$\frac{(8.5 \text{ lbs/gal} \times 0.08 \times 4 \text{ gal})}{4 \text{ gal} + 1 \text{ gal}} = 0.54 \text{ lb MIBK/gal}$$

Xylene emissions: 0.49 lbs/gal X 2.5 gal/hr = 1.23 lbs/hr xylene

Toluene emissions: 0.30 lbs/gal X 2.5 gal/hr = 0.75 lb/hr toluene

MIBK emissions: 0.54 lbs/gal X 2.5 gal/hr = 1.35 lbs/hr MIBK

Example 6: Calculating annual HAP and TAC emissions (tons/yr) from all coating and cleanup operations

These calculations require you to first identify any HAPs and TACs contained in the coatings, reducers and cleanup solvents. For this example, xylene, toluene and MIBK were identified on the EDS as HAPs. In addition, all three of these chemicals are also on the TAC list specified in OAC 3745-114-01.

Data needed:

1) primer: density = 8.5 lbs/gal, 5% wt xylene, 8% wt MIBK from EDS; used 800 gal/yr
2) top coat: density = 8.2 lbs/gal, 7% wt xylene, 10% wt toluene from EDS; used 1500 gal/yr
3) clean up solvent: density = 7.2 lbs /gal, 50% wt xylene, 50% toluene from EDS; used 100 gal/yr

Xylene emissions:

$$\frac{(8.5 \text{ lbs/gal} \times 0.05 \times 800 \text{ gal/yr}) + (8.2 \text{ lbs/gal} \times 0.07 \times 1{,}500 \text{ gal/yr}) + (7.2 \text{ lbs/gal} \times 0.50 \times 100 \text{ gal/yr})}{2{,}000 \text{ lbs/ton}} = 0.78 \text{ ton/yr xylene}$$

Toluene emissions:

$$\frac{(8.2 \text{ lbs/gal} \times 0.10 \times 1{,}500 \text{ gal/yr}) + (7.2 \text{ lbs/gal} \times 0.50 \times 100 \text{ gal/yr})}{2{,}000 \text{ lbs/ton}} = 0.80 \text{ ton/yr toluene}$$

Calculating Emissions from Coating and Painting Operations

Example 7: Calculating emissions (lbs/hr) for solid HAP/TAC from a coating

This calculation requires you to identify any non-volatile (solid) HAPs and TACs contained in the coating. For this example, lead oxide was identified on the EDS and is a HAP and a TAC (as a lead compound). Check with vendors for transfer efficiency and filter efficiency information.

Data needed:

1) product density = 9.75 lbs/gallon from EDS
2) HAP/toxic air contaminants in coating: lead oxide 2% by wt. from EDS
3) coating application rate = 2.0 gallons/hour
4) transfer efficiency (TE) for HVLP spray equipment = 65%, per HVLP vendor
5) booth filter efficiency (FE) = 95%, per filter manufacturer documentation

Lead oxide emissions:

9.75 lbs/gal x 0.02 x 2.0 gal/hr x [1 – 0.65] x [1 – 0.95] = 0.007 lb/hr lead oxide

Example 8: Calculating product density (lbs/gal) using the specific gravity (S.G.)

Data needed:

1) product specific gravity (S.G.) = 1.17 from example EDS;
2) density of water = 8.34 lbs/gal from standard material density references

Product density: 1.17 x 8.34 lbs/gal = 9.75 lbs/gal