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AIR QUALITY ASSESSMENT

800 BURLOAK ROAD, BURLINGTON, ONTARIO

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REPORT PREPARED FOR:
EMSHIH DEVELOPMENTS INC

O2E REFERENCE #25-058

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EXECUTIVE SUMMARY AND EMISSION SUMMARY TABLE

At the request of Emshih Developments Inc, O2E Inc. (O2E) completed a revised assessment to characterize the air quality at 800 Burloak Drive (proposed development) due to industrial activities taking place in the vicinity of the proposed development and potential sensitive land uses (e.g., residential, daycare, medical offices, etc.). In addition, the impacts of the Lakeshore West Rail Corridor and passenger vehicle traffic were evaluated using publicly available documents. One sensitive land use scenario been evaluated as part of this revised study. Under the land use scenario, two mid rise residential units (approximately 27 metres or eight storeys in height) and ground level common areas were assessed which included elevated receptors representing operable windows and balconies on each tower face.

The proposed development is expected to be exposed to emissions of suspended particulate matter, metals, volatile organic compounds, as well as the products of natural gas, diesel and gasoline combustion. A complete list of typical sources is included in **Table 1**: Sources and Contaminant Identification Table. Source specifications and details of contaminant emissions are included in **Table 2**: Source Summary Table. Details related to the calculation of contaminant emission rates are provided in **Appendix 1**.

A POI concentration for each significant contaminant emitted from the assessed sources was calculated based on the calculated emission rates and the results of dispersion modelling completed using the procedures outlined in the Ministry publication “Air Dispersion Modelling Guideline for Ontario – Version 3.0”, dated February 2017 (ADMGO) with the results presented in the following Emission Summary Table.

The air quality assessment has been completed using s.20 of O.Reg.419/05: Air Pollution – Local Air Quality, the approved dispersion model (AERMOD v22112) and the standards listed in Schedule 3 of O.Reg.419/05, as well as the applicable limits listed in the Ministry publication, "Air Contaminants Benchmarks (ACB) List: Standards, guidelines and screening levels for assessing point of impingement concentrations of air contaminants – Version 3.0", dated April 2023 (ACB List).

Contaminants impacting the proposed development that are not found on the ACB List or are above the de minimus concentration are considered to be “Contaminants with no Ministry POI Limits”. There are no “Contaminants with no Ministry POI Limits” impacting the proposed development in significant quantities. All of the predicted POI concentrations for the assessed contaminants that are included in the Ministry’s list of POI Limits are below the corresponding limits. The highest maximum POI concentration is 77% of the 24-hour standard for Iron (metallic).

Emission Summary Table – 800 Burloak Drive

Contaminant	CAS	Emission Rate (g/s)	Air Dispersion Model Used	Maximum Concentration (µg/m³)	Averaging Period (Hours)	Ministry POI Limit (µg/m³)	Limiting Effect	Regulation Schedule	Percentage of Limit (%)
2,3,3-trimethylpentane	560-21-4	1.57E-05	AERMOD v22112	2.17E-03	0.1	de minimus	24	de minimus	2%
2-Methylnaphthalene	91-57-6	1.24E-02		3.93E-01	35.5	Health	24	SL-JSL	1%
Acrolein	107-02-8	1.23E-04		1.15E-02	0.4	Health	24	Standard	3%
	107-02-8	1.61E-04		1.46E-02	4.5	Health	1	Standard	0.3%
Arsenic and compounds	7440-38-2	5.13E-05		7.30E-03	0.3	Health	24	Guideline	2.4%
Benzaldehyde	100-52-7	3.04E-03		2.22E-02	2	Health	24	SL-JSL	1%
Benzene	71-43-2	2.88E-03		1.71E-01	0.45	Health	8760	Standard	38%
	71-43-2	8.09E-03		1.76E-01	4.5	AAV	8760	AAV	4%
	71-43-2	8.09E-03		3.10E-01	100	DAV	24	DAV	0.3%
Benzo(a)pyrene	50-32-8	2.28E-08		3.18E-07	0.00001	Health	8760	Standard	3.2%
	50-32-8	7.44E-08		1.03E-06	0.0001	AAV	8760	AAV	1%
	50-32-8	7.44E-08		2.98E-06	0.005	DAV	24	DAV	0.06%
Cadmium	7440-43-9	1.19E-05		1.92E-03	0.025	Health	24	Standard	7.7%
Carbon Monoxide	630-08-0	2.31E+01		4.03E+02	6000	Health	0.5	Standard	7%
Chromium (di, tri and metallic)	7440-47-3	7.77E-04		1.01E-02	0.5	Health	24	Standard	2%
Cobalt	7440-48-4	3.84E-05		5.67E-04	0.1	Health	24	Guideline	0.6%
Crotonaldehyde	4170-30-3	8.02E-04		1.81E-02	1.25	Health	24	SL-JSL	1.4%
Ethylbenzene	100-41-4	5.15E-02		3.77E-01	1000	Health	24	Standard	0.04%
	100-41-4	1.24E-01		2.67E+00	1900	Odour	0.167	Guideline	0.1%
Ethylene	74-85-1	8.09E-03		7.60E-01	40	Vegetation	24	Guideline	2%
Ferric Oxide	1309-37-1	2.06E-01		3.08E+00	25	Health & Soiling	24	Standard	12%
Formaldehyde	50-00-0	2.27E-02		2.27E-01	65	Health	24	Standard	0.3%
Heavy Hydrocarbons (aliphatic hydrocarbon blend)	69430-33-7	4.35E-02		2.87E+00	122.5	Health	24	SL-JSL	2%
Hexavalent Chromium	18540-29-9	2.85E-06		4.59E-06	0.00014	Health	8760	Standard	3%
	18540-29-9	1.04E-05		1.68E-05	0.0014	AAV	8760	AAV	1.2%
	18540-29-9	1.04E-05		7.70E-05	0.07	DAV	24	DAV	0.11%
Hydrogen Chloride	7647-01-0	9.85E-03		2.97E-01	20	Health	24	Standard	1.5%
Iron	7439-89-6	2.07E-01		3.08E+00	4	Health & Soiling	24	Standard	77%
Lead and compounds	7439-92-1	1.66E-04		9.80E-02	0.5	Health	24	Standard	20%
	7439-92-1	1.66E-04		5.10E-02	0.2	Health	720	Standard	26%
Manganese and compounds	7439-96-5	3.34E-03		4.78E-02	0.4	Health	24	Standard	12%
Naphthalene	91-20-3	4.54E-03		1.36E-01	22.5	Health	24	Guideline	1%
	91-20-3	1.98E-02		4.34E+00	50	Odour	0.167	Guideline	9%
Nickel and compounds	7440-02-0	8.46E-04		2.28E-03	0.04	Health	8760	Standard	6%
	7440-02-0	1.90E-03		3.96E-03	0.4	AAV	8760	AAV	1%
	7440-02-0	1.90E-03		1.24E-02	2	DAV	24	DAV	0.6%
Nitrogen Oxides	10102-44-0	1.40E+00		3.05E+01	200	Health	24	Standard	15%
	10102-44-0	2.43E+00		9.64E+01	400	Health	1	Standard	24%
Phosphorus	7723-14-0	7.18E-04		1.56E-02	0.5	Health	24	SL-MD	3%
Quinone	106-51-4	6.25E-03		4.60E-02	15	Health	24	Guideline	0.3%
Silicon	7440-21-3	4.09E-03		2.53E+00	27	Health	24	SL-PA	9.4%
Sulphur Dioxide	7446-09-5	5.00E-02		2.58E-01	10	Health & Vegetation	8760	Standard	2.6%
	7446-09-5	3.47E-01		1.39E+01	100	Health & Vegetation	1	Standard	13.9%
Suspended Particulate Matter	N/A(9)	2.04E+00		6.22E+01	120	Visibility	24	Standard	52%
Suspended Particulate Matter - PM10	NA-M09	9.80E-01		2.38E+01	50	Health	24	AAQC (interim)	48%
Suspended Particulate Matter - PM2.5	NA-M10	4.66E-01		8.92E+00	27	Health	24	CAAQS	33%
	NA-M10	4.66E-01		3.78E+00	8.8	Health	8760	CAAQS	43%
Xylene	1330-20-7	6.51E-02		5.63E-01	730	Health	24	Standard	0.1%
	1330-20-7	1.56E-01		3.35E+00	3000	Odour	0.167	Guideline	0.1%
Zinc	7440-66-6	3.35E-02		4.49E-01	120	Particulate	24	Standard	0.4%

1. INTRODUCTION

At the request of Emshih Developments Inc, O2E Inc. (O2E) completed an assessment to characterize the air quality at 800 Burloak Drive (proposed development) and potential sensitive land uses (e.g., residential, daycare, medical offices, etc.) due to emissions from local industrial land use, rail traffic, and vehicular traffic on Burloak Drive.

1.1 Purpose and Scope of Report

The purpose of this assessment was to develop and assess levels of air contaminants from surrounding industrial operations, rail and vehicular traffic at the proposed development. In particular, the study focuses on potential air contaminant impacts from the following existing industrial facilities: the Bericap Inc. plastic extrusion facility located to the northwest of the proposed development, the Associated Paving and Materials hot mix asphalt plant located to the west-northwest of the proposed development, and the Laurel Steel (Harris Steel) a carbon and carbon free machining steel product manufacturing facility located to the west of the proposed development. The study also focused on potential air contaminant impacts from the following transportation sources: Lakeshore West Rail Corridor (GO Transit) and personal vehicle traffic on Burloak Drive from Harvester Road to Superior Court. The assessment has been completed using publicly available documents.

Two proposed mid rise residential units (up to approximately 27 metres or eight storeys in height) and ground level common areas were assessed which included elevated receptors representing operable windows and balconies on each tower face.

1.2 Limitations of the ESDM Report

Preparation of this report is based on information publicly available for the industrial and transportation sources including:

- The current and previous Environmental Compliance Approvals (Air & Noise) (ECA) held by the facilities.
- Publicly available data reported to the National Pollutant release inventory.
- Publicly available information related to the number and fleet composition of rail traffic in the Lakeshore West Rail Corridor.
- Publicly available information related to the number and fleet composition of vehicular traffic on Burloak Drive.
- Publicly available emission factors published by the Ministry in the ESDM Procedure Document and the U.S. EPA in AP-42.
- Aerial and satellite imagery of the site used to approximate the locations of plant boundaries and sources.

1.3 Industrial Sources

Industrial sources located within 300 metres of the proposed site include the Bericap Inc. (Bericap) facility located at 835 Syscon Court, the Associated Paving & Materials Ltd. (APM) facility located at 850 Syscon Court and the Harris Steel facility located at 5400 Harvester Road. All sites currently hold valid Environmental Compliance Approvals (Air & Noise) issued by the Ontario Ministry of the Environment, Conservation and Parks (Ministry).

1.3.1 Description of Bericap Processes and Emissions

Bericap is a facility manufacturing plastic caps and enclosures for food, automotive and pharmaceutical industries located approximately 150 metres to the northwest and across the existing Lakeshore West Rail Corridor from the proposed development. Operations include raw materials storage and handling, plastic extrusion operations, product assembly, lining, etching, printing, and shipping. The facility operates with a maximum production rate of 24,420,000 kilograms per year of resins consumed. For the purposes of this assessment, it has been assumed that the facility operates 24 hours per day for up to 250 days per year.

The main manufacturing operations include:

- Raw materials storage and handling;
- Plastic extrusion operations;
- Product assembly, lining, etching and printing; and,
- Product handling and shipping.

Natural gas is used for comfort heat.

Sources of emissions from the Bericap facility included in the air quality assessment are the following:

- Seven (7) general exhausts releasing emissions from the extruder areas;
- Two (2) general exhausts servicing three dry offset printers;
- Ten (10) natural gas fired makeup air units and twelve (12) natural gas fired unit heaters; and,
- Four (4) induced draft cooling towers.

1.3.2 Description of APM Processes and Emissions

APM is a facility producing hot mix asphalt located approximately 130 metres to the west-northwest and across the existing Lakeshore West Rail Corridor from the proposed development. The primary operations of the Facility include bulk receiving, on-site storage, material handling, drying, mixing, screening, loading and shipping off-site. The Facility operates between 0700 hours and 2300 hours five (5) days per week with a maximum production rates as follows:

- Hot Mix Asphalt – 400 metric tonnes per hour, 4,000 metric tonnes per day, 400,000 metric tonnes per year
- Liquid Asphalt Receiving – 200 metric tonnes per hour, 2,000 metric tonnes per day, 200,000 metric tonnes per year
- Concrete/Asphalt Crusher – 200 metric tonnes per hour, 2,000 metric tonnes per day

The main manufacturing operations include:

- Raw materials storage and handling;
- Drying operations;
- Mixing operations;
- Screening operations; and,
- Product handling and shipping.

Raw materials used by the Facility include the following: natural gas, liquid asphalt, fine and course aggregates. Finished products include hot mix asphalt. Natural gas is used to heat the asphalt storage tanks and the dryer.

Sources of emissions from the APM facility included in the air quality assessment are the following:

- One (1) baghouse dust collector servicing the dryer/mixer
- One (1) natural gas fired dryer
- One (1) natural gas fired storage tank heater
- Three (3) liquid asphalt storage tanks
- Five (5) hot-mix asphalt storage silos
- One (1) electric/diesel crusher
- Hot-mix asphalt truck loading operations
- Hot-mix asphalt storage tank filling and storage operations
- Asphalt silo filling and storage operations
- Three (3) unpaved haul routes
- Bulk material (sand and aggregate) handling operations (300 metric tonnes per hour).

1.3.3 Description of Harris Steel Processes and Emissions

Harris Steel is a low carbon and carbon free machining steel product manufacturing facility located approximately 285 metres to the west and across the existing Lakeshore West Rail Corridor from the proposed development. Operations include raw materials storage and handling, coil blasting, pickling, mesh fabrication, drawing machines, teurema line, galvanizing line, and shipping. The facility operates with a maximum production rate of 294,000 tonnes of steel bar and wire mesh products per year. For the purposes of this assessment, it has been assumed that the facility operates 24 hours per day for up to 365 days per year.

The main manufacturing operations include:

- Raw materials storage and handling;
- Cold drawing operations;
- Cold rolling operations;
- Coil blasting operations;
- Mesh fabrication operations;
- Pickling and galvanizing operations; and,
- Product handling, and shipping

Natural gas is used for comfort heat and to supply heat to a water boiler.

Sources of emissions from the Harris Steel facility included in the air quality assessment are the following:

- Ten (10) dust collectors discharging back into the building, eight (8) of which are equipped with secondary filtration the emissions from which are released via eleven (11) rooftop and one (1) sidewall general exhausts;
- Five (5) dust collectors equipped with secondary filtration servicing cold drawing machines discharging back into the dust collector room. The emissions from the dust collector room are released to the atmosphere via a general exhaust equipped with high efficiency tertiary filters;
- One (1) dust collector equipped with secondary filtrations servicing Mesh Line #139;
- One (1) wet scrubber servicing the steel coil pickling operations;
- One (1) natural gas fired boiler;
- Thirty-six (36) natural gas fired heaters and twenty-four (24) natural gas fired infrared heaters; and,
- Three (3) induced draft cooling towers.

1.4 Transportation Sources

Transportation sources having the potential to impact the air quality at the proposed development site include the Lakeshore West Rail Corridor, specifically GO Transit rail traffic in this corridor, and personal vehicle traffic on Burloak Drive.

1.4.1 Railway Emissions

Publicly available information regarding the GO Transit train schedules and fleet composition were used to estimate the number and types of locomotives using the Lakeshore West Rail Corridor tracks on an hourly and daily basis. This information, in addition to publicly available emission factors were used to develop emission rates of typical contaminants found in diesel locomotive exhausts. A summary of the assumed information used to estimate locomotive emissions is presented below. Detailed information relating to the emission estimates is provided in **Appendix 1**.

- Total of 84 trains per day pass by the proposed development with a maximum of five trains during a peak hour.
- Locomotive emissions would only be present on the modelled section of track for 2 minutes per train or up to 10 minutes in a given one hour period.
- GO Transit locomotive size is 4,000 bhp-hr.
- Locomotive engines are primarily made up of models encompassing U.S. EPA Tier 4 emission limits. As such, U.S. EPA Tier 4 emission limits were used to complete the emission estimates.
- Emissions of total hydrocarbons were speciated using U.S. EPA SPECIATE Profile #116GROCa for diesel exhaust emissions from Tier 2-3 off-road engines.

1.4.2 Roadway Emissions

Publicly available information regarding personal vehicle traffic was used to determine the average peak hourly traffic counts on Burloak Drive. This information, in addition to publicly available emission factors were used to develop emission rates of typical contaminants found from road traffic including road dust from disturbance of surface materials, brake wear and exhaust emissions. A summary of the assumed information used to estimate roadway emissions is presented below. Detailed information relating to the emission estimates is provided in **Appendix 1**.

- Peak hour traffic data (2,841 vehicles) was obtained from a study completed in 2017 for Metrolinx entitled “Burloak Grade Separation Air Quality Assessment – October 2017” prepared by AECOM for the future “build-out” scenario.

- Average daily traffic count of 31,016 vehicles from the above noted report was used to complete the estimates of roadway emissions over a 24-hour averaging period.
- Roadway suspended particulate matter emissions were determined using equations published by the U.S. EPA in AP-42 Chapter 13.2.1 – Paved Roads.
- Metal species in the suspended particulate matter were determined using U.S. SPECIATE Profile #4113030 which is a composite profile for paved road dust.
- Vehicle exhaust and brake emissions were based on the total distance travelled and emission factors published by the California Air Resources Board in their document entitled "Methods to Find the Cost-Effectiveness of Funding Air Quality Projects - For Evaluating Motor Vehicle Registration Fee Projects and Congestion Mitigation and Air Quality Improvement (CMAQ) Projects - Emission Factor Tables" dated November 2021.
- Emissions of reactive organic compounds in vehicle exhaust were speciated using U.S. EPA SPECIATE Profile #2540 - Vehicle Emissions: Roadway: Busy Intersection.

2. INITIAL IDENTIFICATION OF SOURCES AND CONTAMINANTS

This section provides an initial identification of all the sources and contaminants emitted by sources in the vicinity of the proposed development.

2.1 Sources and Contaminants Identification Table

Table 1 – Sources and Contaminants Identification Table tabulates all the emission sources included in the air quality assessment; for example, the Lakeshore West Rail Corridor was identified as a source.

The expected contaminants from each source are also identified in **Table 1**; for example, the expected contaminants from the rail corridor are the products of diesel combustion. Each of the sources has been assigned a source reference identifier; for example, the rail corridor has been identified as RAIL.

The location of each of the discharges or stacks associated with each source is presented in **Figure 3** – Source Location Plan.

3. ASSESSMENT OF THE SIGNIFICANCE OF CONTAMINANTS AND SOURCES

This section provides an explanation for each source and contaminant identified as negligible in **Table 1** – Sources and Contaminants Identification Table.

In accordance with s.8 of O.Reg. 419/05 emission rate calculations and dispersion modelling does not have to be completed for emissions from negligible sources or for the emissions of negligible contaminants from significant sources.

In keeping with the provisions of the ESDM Procedure Document, there are circumstances where it is appropriate and reasonable to identify the emission of a contaminant, or a source of contaminants, as negligible for the purpose of simplifying the site-wide assessment of emissions.

The Ministry has developed a guidance procedure for assessing the significance of sources and contaminants. This procedure includes:

- screening-out contaminants that are emitted in negligible amounts including:
  - contaminants from the combustion of natural gas and propane with the exception of nitrogen oxides;
  - identifying insignificant contaminants using an emission threshold based on dispersion factors provided in Appendix B, Table B-1 of the ESDM Procedure Document; and/or
  - the consideration of a group of contaminants rather than the sub-speciation;

- screening-out sources that emit contaminants in negligible amounts including:
  - sources on a list provided in Appendix B, Table B-3A and B-3B of the ESDM Procedure Document; and/or
  - in some special cases, sources that in combination represent less than 5% of the total property-wide emissions of a contaminant;

- screening-out sources or contaminants based on Facility specific assessments; and

- screening-out fugitive dust emissions from on-site roadways and storage piles where:
  - fugitive dust from roadways and storage piles is anticipated but generally controlled with the implementation of a best management practices plan (typically for facilities included in Table 7-2 and 7-3 of ESDM Procedure Document; or
  - fugitive dust emissions from on-site roadways and storage piles for facilities that are not included Table 7-2 and 7-3 of ESDM Procedure Document.

3.1 Identification of Negligible Contaminants and Sources

In accordance with the guidance provided in the ESDM Procedure Document, the Sources and Contaminants Identification Table (**Table 1**) presents a summary of the rationale used to screen-out contaminants and/or sources from the overall assessment. Supporting calculations and/or documentation for these negligible or insignificant contaminants and sources are provided in **Appendix 1** of this report, where required.

3.2 Rationale for Assessment

For each source identified in **Table 1** as being negligible, there is an accompanying documented rationale. Additional technical documentation supporting the conclusion of insignificance of a source is presented in **Appendix 1** of this report, where required.

In summary, the following screening was completed for this assessment:

- A total of eighty-three (83) contaminants were screened from the assessment using the methodology described in Section 7.1.2 of the ESDM Procedure Document. Emission thresholds were developed for these contaminants and compared to the calculated aggregate emission rate for each substance.
- Sixteen (16) polyaromatic hydrocarbons (PAHs) were screened from the assessment using Benzo(a)pyrene as the surrogate for all PAHs not having a Ministry Limit.
- Only NOx from natural gas combustion units has been assessed, based on Section 7.1.1 of the ESDM Procedure Document which notes that the significant contaminant from these operations is nitrogen oxides and the other contaminants are "are generally emitted in negligible amounts."

4. OPERATING CONDITIONS, EMISSION ESTIMATING AND DATA QUALITY

This section provides a description of the operating conditions used in the calculation of the emission estimates and an assessment of the data quality of the emission estimates for each significant contaminant affecting the proposed development. In accordance with s.8 of O. Reg. 419/05, emission rate calculations and dispersion modelling does not have to be completed for emissions from negligible sources or for the emissions of negligible contaminants from significant sources.

4.1 Description of Operating Conditions

The air quality assessment has been completed using the hours of operation of the industrial and transportation sources having the potential to impact upon the proposed development. The maximum emissions scenario is based on all sources operating concurrently at their respective maximum capacity over the duration of the averaging period under assessment.

The averaging times for the operating condition are as follows: 10 minute, ½-hour, 1 hour, 24 hour, monthly and annual. The operating condition used for the assessed sources is the scenario where all significant sources are operating simultaneously at their individual maximum rates of emission. The individual maximum rates of emission for each significant source of emissions correspond to the maximum emission rate during any given averaging period. In the case of the monthly and annual scenarios, the maximum 24 hour emission rates were assumed

to be sustained for the duration of the averaging period. The individual maximum rates of production for each significant source of emission are described in detail in **Appendix 1**.

4.2 Explanation of the Methods Used to Calculate Emission Rates

Air emissions sources having the potential to impact the proposed development include a variety of process and non-process sources including dust collectors, storage silos, process exhausts, natural gas combustion sources, rail transportation sources and personal vehicle transportation sources. The proposed development is expected to be exposed to emissions of suspended particulate matter, metals, volatile organic compounds, as well as the products of natural gas, diesel and gasoline combustion. A complete list of sources is included in **Table 1**: Sources and Contaminant Identification Table. Source specifications and details of contaminant emissions are include in **Table 2**: Source Summary Table. Details related to the calculation of contaminant emission rates are provided in **Appendix 1**.

Without specific information regarding the industrial facilities, assumptions were made based on typical operations of the surrounding industrial facilities and transportation sources.

4.3 Assessment of Data Quality

This section provides a description of the assessment of the data quality of the emission estimates for each significant contaminant included in the air quality assessment.

The data quality assessment was completed in accordance with the requirements of O.Reg. 419/05. For example, the emission factor technique used to calculate emissions released from the baghouse servicing the APM mixer is based on the maximum flow rate of the source and concentration factors published by the Ministry in the ESDM Procedure Document. As this estimate is based on an approach recommended through Ministry documentation a data quality rating of “Above Average” applies.

For each contaminant, the emission rate was estimated and the data quality of the estimate is documented in **Table 2** – Source Summary Table. The assessment of data quality for each source listed in **Table 2** is documented in **Appendix 1**.

5. SOURCE SUMMARY TABLE AND SITE PLAN

5.1 Source Summary Table

The emission rate estimates for each source of significant contaminants are documented in **Table 2**: Source Summary Table in accordance with requirements of sub paragraph 8 of s.26(1)

of O. Reg. 419/05. For each source of significant contaminants the following parameters are referenced:

- Contaminant;
- Chemical Abstracts Service (CAS) registry number;
- Source reference number;
- Source description;
- Stack parameters (flow rate, exhaust temperature, diameter, height above grade, height above roof);
- Location referenced to the UTM coordinate system presented on **Figure 3**: Roof Plan);
- Maximum emission rate,
- Averaging period;
- Emission estimating technique;
- Estimation data quality; and
- Percentage of overall emissions.

5.2 Site Plan

The approximate locations of the emission sources listed in **Table 2**: Source Summary Table are presented in **Figure 3**: Source Location Plan; the location of each of the sources is specified with the source reference number. The locations of the proposed development as well as the emission sources are indicated on **Figure 2** clearly referenced to a UTM coordinate system. The location of each source is referenced to the local coordinate system under a column in **Table 2:** Source Summary Table. Emissions source locations have been estimated based on publicly available aerial imagery (i.e., Google Earth).

6. DISPERSION MODELLING

This section provides a description of how the dispersion modelling was conducted for the assessment to calculate the maximum concentration at a POI.

The dispersion modelling was conducted in accordance with the Ministry publication "Air Dispersion Modelling Guideline for Ontario – Version 3.0" PIBS 5165e03 (ADMGO).

The emission rates used in the dispersion model meet the requirements of O. Reg. 419/05 which requires that the emission rates used in the dispersion model are at least as high as the maximum emission rate that the source of the contaminant is reasonably capable of for the relevant contaminant. The emission rates are described in detail in **Appendix 1**.

6.1 AERMOD Modelling

The U.S. Environmental Protection Agency (U.S. EPA) AERMOD modelling system (Version 22112) was used to predict the point of impingement concentrations.

The PRIME plume rise algorithms include vertical wind shear calculations (important for buoyant releases from short stacks (i.e., stacks at release heights within the recirculation zones of buildings). The PRIME algorithm also allows for the wind speed deficit induced by the building to change with respect to the distance from the building. These factors improve the accuracy of predicted concentrations within building wake regions. The AERMOD modelling system is made up of the AERMOD dispersion model, the AERMET meteorological pre-processor and the AERMAP terrain pre-processor.

6.1.1 Meteorology and Land Use Data

The AERMET meteorological pre-processor (Version 22112) pre-processes actual surface and radiosonde meteorological data for the AERMOD dispersion model. Surface meteorological data in the form of hourly observations of wind speed, wind direction, temperature, cloud cover and humidity are typically obtained from the nearest surface/airport station. Radiosonde data used to generate mixing layer depth information is typically obtained from the nearest upper air station. The surface and upper air data are then processed through numerous stages of AERMET, where the final stage utilizes surrounding geophysical data (land use and terrain) from the site to ultimately create a 5-year hourly dataset that is ready to be used by AERMOD. The meteorological data used in this assessment was a pre-processed regional dataset, which was provided by the Ministry for the surrounding land use and terrain (URBAN).

6.1.2 Elimination of Meteorological Anomalies

As noted under Section 6.6 of the ADMGO, modelling applications using regional or local meteorological data sets may have extreme, rare and transient metrological conditions in the data sets that may be considered outliers. In an effort to remove these outliers, the Ministry allows for the elimination of the eight hours having the highest predicted concentrations in each meteorological year in the case of shorter averaging periods (e.g., 10-minute, ½-hour or 1-hour) and the elimination of the highest predicted concentration in each meteorological year when assessing 24-hour concentrations. As a conservatism, elimination of meteorological anomalies was not completed for any substances.

6.1.3 Coordinate System

Universal Transverse Mercator (UTM) coordinate system, as per Section 5.2.2 of the ADMGO was used to specify model object sources, buildings and receptors. All coordinates were defined in the World Geodetic Survey of 1984 (WGS84). All source, building, and property line coordinates are provided in **Figures 2**, and **3**.

6.1.4 Terrain

Relying on the assumption that terrain will affect air quality concentrations at individual receptors, AERMOD captures the essential physics of dispersion in complex terrain through the use of a separate height scale for each receptor. The height scale factor represents the terrain which would dominate flow in the vicinity of that receptor.

The height scale factor that is used by AERMOD is generated by a terrain pre-processor which is called AERMAP. The AERMAP terrain pre-processor (Version 11103) utilizes terrain data, or Canadian Digital Elevation Model (CDEM) data that was obtained from the Ministry (7.5-minute format) in conjunction with a layout of receptors and sources to height scale factors which can be directly used in AERMOD. The following terrain data files were used in completing the modelling assessment:

- cdem_dem_030M.tif

The terrain data used in the current assessment are shown in **Figure 4.**

6.1.5 Source Data

As per Section 4.5 of the ADMGO the significant sources under assessment were classified as point, area or volume sources. The source data required for each source was determined according to the procedures provided in the relevant Section of the guide and summarized in the Dispersion Modelling Source Summary Table (Table 3).

In summary, the significant sources at the sites surrounding the proposed development were modelled as follows:

- Associated Paving Materials
    - Point sources – include the silo baghouse dust collector
    - Volume sources – include the material handling sources, silo filling, truck loading, material storage piles, crusher, and asphalt heater
    - Line volume sources - include heavy vehicle traffic at APM on unpaved roads

- Bericap
    - Volume sources – include all process exhausts and cooling towers
- Harris Steel
    - Point sources – include the pickling scrubber and Mesh Line #139 dust collector
    - Volume sources – include the remaining process sources and general ventilation exhausts
- Transportation Sources
    - Line volume sources – include rail traffic emissions, and roadway traffic on Burloak Drive

6.1.6 Downwash

Building wake effects were considered in this modelling study using the U.S. EPA's Building Profile Input Program for PRIME Version 04274 (BPIPPRM), another pre-processor to AERMOD. The inputs into this pre-processor include the coordinates and heights of the buildings and stacks. The information from BPIPPRM is used in the building wake effect calculation.

The PRIME algorithm also allows for the wind speed deficit induced by the building to change with respect to the distance from the building. These factors improve the accuracy of predicted concentrations within building wake zones that form in the lee of buildings.

6.1.7 Deposition and Depletion

The AERMOD dispersion model has the capability to account for wet and dry deposition and depletion of substances. This would realistically reduce airborne concentrations. These algorithm have not been implemented in the modelling which results in more conservative concentrations being predicted.

6.1.8 Averaging Times

The modelling supporting the air quality assessment was completed based on the actual hours of operation of the various sources surrounding the proposed development. For example, under the maximum operating scenario, the Harris Steel facility was assumed to operate 24 hours daily; therefore the maximum hourly emission rate calculated for those sources was assumed to be sustained over the 24 hour period. In the case of the monthly and annual operating scenario, the modelling has been completed by conservatively assuming that the maximum 24 hour emission rates would be sustained for the entire averaging period.

6.1.9 Receptors

One sensitive land use scenario has been evaluated as part of this study. This scenario included two mid rise residential units (up to 27 metres or eight storeys in height) and ground level common areas were assessed which included elevated receptors representing operable windows and balconies on each tower face.

The resulting maximum POI concentrations and aggregate emission rates are presented in the Emission Summary Table (**Table 4**).

7. EMISSION SUMMARY TABLE AND CONCLUSIONS

This section provides an interpretation of the results of the modelling assessment as required by the ESDM Procedure Document.

7.1 Emission Summary Table

A POI concentration for each significant contaminant emitted from the assessed sources at the proposed development was calculated based on the emission rates listed in **Table 2:** Source Summary Table and the outputs from the approved dispersion models presented in **Appendix 4**. The results are presented in **Table 4:** Emission Summary Table.

The POI concentrations listed in **Table 4** were compared against the limits presented in the Ministry's ACB List.

Of the 34 contaminants listed in **Table 4** that have Ministry Limits, all the predicted POI concentrations are below the corresponding limits. The highest maximum POI concentration is 77% of the 24-hour standard for Iron (metallic).

7.2 Assessment of Contaminants with No Ministry POI Limits

Contaminants impacting the proposed development that are not found on the ACB List or are above the de minimus threshold concentration are considered to be "Contaminants with no Ministry POI Limits". The proposed development is not impacted by any "Contaminants with no Ministry POI Limits" in significant quantities.

7.3 Conclusions

This ESDM report was prepared in accordance with s.26 of O.Reg. 419/05. In addition, guidance from the ESDM Procedure Document was followed as appropriate.

The assessment of compliance has been completed using s.20 of O.Reg.419/05 and using conservative dispersion factors, the approved dispersion model (AERMOD v22112) and the standards listed in Schedule 3 of O.Reg.419/05, as well as the applicable limits presented in the Ministry's ACB List.

The emission rate estimates for each source of significant contaminants are documented in **Table 2** – Source Summary Table. All of the emission rates listed in **Table 2** correspond to the operating scenario where all significant sources are operating simultaneously at their individual maximum rates of production.

A POI concentration for each significant contaminant emitted from the assessed sources was calculated based on the calculated emission rates and the output from the U.S. EPA model AERMOD; the results are presented in **Table 4:** Emission Summary Table.

The POI concentrations listed in **Table 4** were compared against the limits presented in Ministry's ACB List.

Of the 34 contaminants listed in **Table 4** that have Ministry Limits, all of the predicted POI concentrations are below the corresponding limits. The highest maximum POI concentration is 77% of the 24-hour standard for Iron (metallic).

The proposed development is not significantly impacted by any "Contaminants with no Ministry POI Limits"

This report demonstrates that the air quality impacts at the proposed development site resulting from surrounding industrial land use, rail traffic and passenger vehicle traffic are in compliance with the applicable point of impingement limits. As the point of impingement limits have been developed by the Ministry to minimize adverse impacts and risks to the environment and general population, it is expected that the proposed sensitive land uses would be compatible with the existing surrounding land uses.

8. REFERENCES

1. Ministry Document PIBS #3614e04.1, “Procedure for Preparing an Emission Summary and Dispersion Modelling Report, Version 4.1”, dated March 2018.
2. Ministry Document PIBS #5165e03, “Air Dispersion Modelling Guideline for Ontario, Version 3.0”, dated February 2017.
3. Ministry Workbook, "Air Contaminants Benchmarks (ACB) List: Standards, guidelines and screening levels for assessing point of impingement concentrations of air contaminants", Version 3.0, dated April 2023.

TABLES

Table 1A: Sources and Contaminant Identification Table - Associated Paving

Source Information			Expected Contaminants	Included in Modelling?	Rationale
Source ID	Source Description or Title	General Location	Contaminants	Significant	
BH	Dryer/mixer baghouse	Northwest portion of site	Suspended particulate matter	Yes	
			Suspended Particulate Matter - PM10	Yes	
			Suspended Particulate Matter - PM2.5	Yes	
			Sulphur dioxide	Yes	
			Nitrogen oxides	Yes	
			Carbon monoxide	Yes	
			Acetaldehyde	No	ESDM Procedure Document Section 7.1.2
			Benzene	Yes	
			Ethylbenzene	Yes	
			Formaldehyde	Yes	
			Quinone	Yes	
			Toluene	No	ESDM Procedure Document Section 7.1.2
			Xylene	Yes	
			2-Methylnaphthalene	Yes	
			Acenaphthene	No	Assessed using B(a)P as the surrogate
			Acenaphthylene	No	Assessed using B(a)P as the surrogate
			Anthracene	No	Assessed using B(a)P as the surrogate
			Benzo(a)anthracene	No	Assessed using B(a)P as the surrogate
			Benzo(a)pyrene	Yes	
			Benzo(b)fluoranthene	No	Assessed using B(a)P as the surrogate
			Benzo(g,h,i)perylene	No	Assessed using B(a)P as the surrogate
			Benzo(k)fluoranthene	No	Assessed using B(a)P as the surrogate
			Chrysene	No	Assessed using B(a)P as the surrogate
			Dibenz(a,h)anthracene	No	Assessed using B(a)P as the surrogate
			Fluoranthene	No	Assessed using B(a)P as the surrogate
			Fluorene	No	Assessed using B(a)P as the surrogate
			Indeno(1,2,3-cd)pyrene	No	Assessed using B(a)P as the surrogate
			Naphthalene	Yes	
			Phenanthrene	No	Assessed using B(a)P as the surrogate
			Pyrene	No	Assessed using B(a)P as the surrogate
			Benzaldehyde	Yes	
			Butyraldehyde/isobutyraldehyde	No	ESDM Procedure Document Section 7.1.2
			Crotonaldehyde	Yes	
			Hexanal	No	ESDM Procedure Document Section 7.1.2
			Antimony	No	ESDM Procedure Document Section 7.1.2
			Arsenic and compounds	Yes	
			Barium	No	ESDM Procedure Document Section 7.1.2
			Cadmium	Yes	
			Chromium (di, tri and metallic)	Yes	
			Cobalt	Yes	
			Copper	No	ESDM Procedure Document Section 7.1.2
			Hexavalent Chromium	Yes	
			Lead and compounds	Yes	
			Manganese and compounds	Yes	
			Mercury	No	ESDM Procedure Document Section 7.1.2
			Nickel and compounds	Yes	
			Phosphorus	Yes	
			Silver	No	ESDM Procedure Document Section 7.1.2
			Selenium	No	ESDM Procedure Document Section 7.1.2
			Thallium	No	ESDM Procedure Document Section 7.1.2
			Zinc	Yes	

Table 1A: Sources and Contaminant Identification Table - Associated Paving

Source Information			Expected Contaminants	Included in Modelling?	Rationale
Source ID	Source Description or Title	General Location	Contaminants	Significant	
CRUSH	Diesel/electric crusher	Centre of Site	Suspended particulate matter	Yes	
			Suspended Particulate Matter - PM10	Yes	
			Suspended Particulate Matter - PM2.5	Yes	
			Nitrogen oxides	Yes	
			Carbon monoxide	Yes	
			Sulphur dioxide	Yes	
			Benzene	Yes	
			Toluene	No	ESDM Procedure Document Section 7.1.2
			Xylene	Yes	
			Propylene	No	ESDM Procedure Document Section 7.1.2
			1,3-Butadiene	No	ESDM Procedure Document Section 7.1.2
			Formaldehyde	Yes	
			Acetaldehyde	No	ESDM Procedure Document Section 7.1.2
			Acrolein	Yes	
			Benzo(a)pyrene	Yes	
SILO	HMA silo filling and storage	West centre of site	Suspended particulate matter	Yes	
			Suspended particulate matter - PM10	Yes	
			Suspended particulate matter - PM2.5	Yes	
			Acenaphthene	No	Assessed using B(a)P as the surrogate
			Acenaphthylene	No	Assessed using B(a)P as the surrogate
			Anthracene	No	Assessed using B(a)P as the surrogate
			Benzo(a)anthracene	No	Assessed using B(a)P as the surrogate
			Benzo(e)pyrene	No	Assessed using B(a)P as the surrogate
			Chrysene	No	Assessed using B(a)P as the surrogate
			Fluoranthene	No	Assessed using B(a)P as the surrogate
			Fluorene	No	Assessed using B(a)P as the surrogate
			2-Methylnaphthalene	Yes	
			Naphthalene	Yes	
			Perylene	No	Assessed using B(a)P as the surrogate
			Phenanthrene	No	Assessed using B(a)P as the surrogate
			Pyrene	No	Assessed using B(a)P as the surrogate
			Methane	No	ESDM Procedure Document Section 7.1.2
			Acetone	No	ESDM Procedure Document Section 7.1.2
			Ethylene	Yes	
			Benzene	Yes	
			Bromomethane	No	ESDM Procedure Document Section 7.1.2
			2-Butanone	No	ESDM Procedure Document Section 7.1.2
			Carbon Disulfide	No	ESDM Procedure Document Section 7.1.2
			Chloroethane	No	ESDM Procedure Document Section 7.1.2
			Chloromethane	No	ESDM Procedure Document Section 7.1.2
			Ethylbenzene	Yes	
			Formaldehyde	Yes	
			n-Hexane	No	ESDM Procedure Document Section 7.1.2
			Isooctane	No	ESDM Procedure Document Section 7.1.2
			Methylene Chloride	No	ESDM Procedure Document Section 7.1.2
			Styrene	No	ESDM Procedure Document Section 7.1.2
			Toluene	No	ESDM Procedure Document Section 7.1.2
			Xylene	Yes	

Table 1A: Sources and Contaminant Identification Table - Associated Paving

Source Information			Expected Contaminants	Included in Modelling?	Rationale
Source ID	Source Description or Title	General Location	Contaminants	Significant	
YARD	Truck Loading	Centre of Site	Suspended particulate matter	Yes	
			Suspended particulate matter - PM10	Yes	
			Suspended particulate matter - PM2.5	Yes	
			Acenaphthene	No	Assessed using B(a)P as the surrogate
			Acenaphthylene	No	Assessed using B(a)P as the surrogate
			Anthracene	No	Assessed using B(a)P as the surrogate
			Benzo(a)anthracene	No	Assessed using B(a)P as the surrogate
			Benzo(b)fluoranthene	No	Assessed using B(a)P as the surrogate
			Benzo(k)fluoranthene	No	Assessed using B(a)P as the surrogate
			Benzo(g,h,i)perylene	No	Assessed using B(a)P as the surrogate
			Benzo(a)pyrene	Yes	
			Benzo(e)pyrene	No	Assessed using B(a)P as the surrogate
			Chrysene	No	Assessed using B(a)P as the surrogate
			Dibenz(a,h)anthracene	No	Assessed using B(a)P as the surrogate
			Fluoranthene	No	Assessed using B(a)P as the surrogate
			Fluorene	No	Assessed using B(a)P as the surrogate
			Indeno(1,2,3-cd)pyrene	No	Assessed using B(a)P as the surrogate
			2-Methylnaphthalene	Yes	
			Naphthalene	Yes	
			Perylene	No	Assessed using B(a)P as the surrogate
			Phenanthrene	No	Assessed using B(a)P as the surrogate
			Pyrene	No	Assessed using B(a)P as the surrogate
			Phenol	No	ESDM Procedure Document Section 7.1.2
			Methane	No	ESDM Procedure Document Section 7.1.2
			Acetone	No	ESDM Procedure Document Section 7.1.2
			Ethylene	Yes	
			Benzene	Yes	
			Bromomethane	No	ESDM Procedure Document Section 7.1.2
			2-Butanone	No	ESDM Procedure Document Section 7.1.2
			Carbon Disulfide	No	ESDM Procedure Document Section 7.1.2
			Chloroethane	No	ESDM Procedure Document Section 7.1.2
			Chloromethane	No	ESDM Procedure Document Section 7.1.2
			Cumene	No	ESDM Procedure Document Section 7.1.2
			Ethylbenzene	Yes	
			Formaldehyde	Yes	
			n-Hexane	No	ESDM Procedure Document Section 7.1.2
			Isooctane	No	ESDM Procedure Document Section 7.1.2
			Styrene	No	ESDM Procedure Document Section 7.1.2
			Tetrachloroethene	No	ESDM Procedure Document Section 7.1.2
			Toluene	No	ESDM Procedure Document Section 7.1.2
			Trichlorofluoromethane	No	ESDM Procedure Document Section 7.1.2
			Xylene	Yes	

Table 1A: Sources and Contaminant Identification Table - Associated Paving

Source Information			Expected Contaminants	Included in Modelling?	Rationale
Source ID	Source Description or Title	General Location	Contaminants	Significant	
ST	Liquid asphalt storage tanks	West centre of site	Suspended particulate matter	Yes	
			Suspended particulate matter - PM10	Yes	
			Suspended particulate matter - PM2.5	Yes	
			Acenaphthene	No	Assessed using B(a)P as the surrogate
			Acenaphthylene	No	Assessed using B(a)P as the surrogate
			Anthracene	No	Assessed using B(a)P as the surrogate
			Benzo(a)anthracene	No	Assessed using B(a)P as the surrogate
			Benzo(e)pyrene	No	Assessed using B(a)P as the surrogate
			Chrysene	No	Assessed using B(a)P as the surrogate
			Fluoranthene	No	Assessed using B(a)P as the surrogate
			Fluorene	No	Assessed using B(a)P as the surrogate
			2-Methylnaphthalene	Yes	
			Naphthalene	Yes	
			Perylene	No	Assessed using B(a)P as the surrogate
			Phenanthrene	No	Assessed using B(a)P as the surrogate
			Pyrene	No	Assessed using B(a)P as the surrogate
			Methane	No	ESDM Procedure Document Section 7.1.2
			Acetone	No	ESDM Procedure Document Section 7.1.2
			Ethylene	Yes	
			Benzene	Yes	
			Bromomethane	No	ESDM Procedure Document Section 7.1.2
			2-Butanone	No	ESDM Procedure Document Section 7.1.2
			Carbon Disulfide	No	ESDM Procedure Document Section 7.1.2
			Chloroethane	No	ESDM Procedure Document Section 7.1.2
			Chloromethane	No	ESDM Procedure Document Section 7.1.2
			Ethylbenzene	Yes	
			Formaldehyde	Yes	
			n-Hexane	No	ESDM Procedure Document Section 7.1.2
			Isooctane	No	ESDM Procedure Document Section 7.1.2
			Methylene Chloride	No	ESDM Procedure Document Section 7.1.2
			Styrene	No	ESDM Procedure Document Section 7.1.2
			Toluene	No	ESDM Procedure Document Section 7.1.2
			Xylene	Yes	
HR	On-site unpaved haul routes	Various Locations	Suspended particulate matter	Yes	
			Suspended particulate matter - PM10	Yes	
			Suspended particulate matter - PM2.5	Yes	
MH	Material handling operations - hoppers, screens, conveyors, etc.	Various Locations	Suspended particulate matter	Yes	
			Suspended particulate matter - PM10	Yes	
			Suspended particulate matter - PM2.5	Yes	
MS	Material storage piles	Various Locations	Suspended Particulate Matter	No	ESDM Procedure Document Section 7.4.1

Table 1B: Sources and Contaminant Identification Table - Bericap

Source Information			Expected Contaminants	Included in Modelling?	Rationale
Source ID	Source Description or Title	General Location	Contaminants	Significant	
EXT	Extruders	Bericap main roof	2-Butanone	No	ESDM Procedure Document Section 7.1.2
			Acetaldehyde	No	ESDM Procedure Document Section 7.1.2
			Acetic Acid	No	ESDM Procedure Document Section 7.1.2
			Acetone	No	ESDM Procedure Document Section 7.1.2
			Acrolein	Yes	
			Acrylic Acid	No	ESDM Procedure Document Section 7.1.2
			Butyraldehyde	No	ESDM Procedure Document Section 7.1.2
			Ethane	No	ESDM Procedure Document Section 7.1.2
			Ethylene	Yes	
			Formaldehyde	Yes	
			Formic Acid	No	ESDM Procedure Document Section 7.1.2
			Heavy Hydrocarbons (aliphatic hydrocarbon blend)	Yes	
			Propionaldehyde	No	ESDM Procedure Document Section 7.1.2
			Propylene	No	ESDM Procedure Document Section 7.1.2
			Suspended Particulate Matter	Yes	
PRINT	Dry offset printers	Bericap main roof	1,2,3-Trimethylbenzene	No	ESDM Procedure Document Section 7.1.2
			1,3,5-Trimethylbenzene	No	ESDM Procedure Document Section 7.1.2
			Benzene	Yes	
			Diethylbenzene	No	ESDM Procedure Document Section 7.1.2
			Ethylbenzene	Yes	
			Ethyltoluene	No	ESDM Procedure Document Section 7.1.2
			Isobutyl benzene	No	ESDM Procedure Document Section 7.1.2
			Isopropyl Alcohol	No	ESDM Procedure Document Section 7.1.2
			n-Hexane	No	ESDM Procedure Document Section 7.1.2
			n-Propylbenzene	No	ESDM Procedure Document Section 7.1.2
			Toluene	No	ESDM Procedure Document Section 7.1.2
			Xylene	Yes	
NGCH	Natural gas comfort heat	Bericap main roof	Nitrogen oxides	Yes	
CT	Cooling towers	Bericap main roof	Suspended Particulate Matter	Yes	

Table 1C: Sources and Contaminant Identification Table - Harris Steel

Source Information			Expected Contaminants	Included in Modelling?	Rationale
Source ID	Source Description or Title	General Location	Contaminants	Significant	
HSBH	Baghouse dust collectors - discharged by GV	Harris steel - various	Aluminum	No	ESDM Procedure Document Section 7.1.2
			Arsenic and compounds	Yes	
			Calcium	No	ESDM Procedure Document Section 7.1.2
			Carbon	No	ESDM Procedure Document Section 7.1.2
			Chromium (di, tri and metallic)	Yes	
			Cobalt	Yes	
			Copper	No	ESDM Procedure Document Section 7.1.2
			Ferric Oxide	Yes	
			Iron	Yes	
			Lead and compounds	Yes	
			Manganese and compounds	Yes	
			Molybdenum	No	ESDM Procedure Document Section 7.1.2
			Nickel and compounds	Yes	
			Phosphorus	Yes	
			Silicon	Yes	
			Sulphur	No	ESDM Procedure Document Section 7.1.2
			Suspended Particulate Matter	Yes	
			Tin	No	ESDM Procedure Document Section 7.1.2
			Vanadium	No	ESDM Procedure Document Section 7.1.2
			Zinc	Yes	
HSDC	Cartridge dust collectors - discharged by CDM	Harris steel - various	Aluminum	No	ESDM Procedure Document Section 7.1.2
			Arsenic and compounds	Yes	
			Calcium	No	ESDM Procedure Document Section 7.1.2
			Carbon	No	ESDM Procedure Document Section 7.1.2
			Chromium (di, tri and metallic)	Yes	
			Cobalt	Yes	
			Copper	No	ESDM Procedure Document Section 7.1.2
			Ferric Oxide	Yes	
			Iron	Yes	
			Lead and compounds	Yes	
			Manganese and compounds	Yes	
			Molybdenum	No	ESDM Procedure Document Section 7.1.2
			Nickel and compounds	Yes	
			Phosphorus	Yes	
			Silicon	Yes	
			Sulphur	No	ESDM Procedure Document Section 7.1.2
			Suspended Particulate Matter	Yes	
			Tin	No	ESDM Procedure Document Section 7.1.2
			Vanadium	No	ESDM Procedure Document Section 7.1.2

Table 1C: Sources and Contaminant Identification Table - Harris Steel

Source Information			Expected Contaminants	Included in Modelling?	Rationale
Source ID	Source Description or Title	General Location	Contaminants	Significant	
MF2	Mesh Line #139 Cartridge Dust Collector	Harris steel main roof	Aluminum	No	ESDM Procedure Document Section 7.1.2
			Arsenic and compounds	Yes	
			Calcium	No	ESDM Procedure Document Section 7.1.2
			Carbon	No	ESDM Procedure Document Section 7.1.2
			Chromium (di, tri and metallic)	Yes	
			Cobalt	Yes	
			Copper	No	ESDM Procedure Document Section 7.1.2
			Ferric Oxide	Yes	
			Iron	Yes	
			Lead and compounds	Yes	
			Manganese and compounds	Yes	
			Molybdenum	No	ESDM Procedure Document Section 7.1.2
			Nickel and compounds	Yes	
			Phosphorus	Yes	
			Silicon	Yes	
			Sulphur	No	ESDM Procedure Document Section 7.1.2
			Suspended Particulate Matter	Yes	
			Tin	No	ESDM Procedure Document Section 7.1.2
			Vanadium	No	ESDM Procedure Document Section 7.1.2
PS	Steel Coil Pickling Wet Scrubber	Harris steel main roof	Hydrogen Chloride	Yes	
NGC	Natural gas combustion sources	Harris steel main roof	Nitrogen Oxides	Yes	
HSCT	Cooling towers	Harris steel main roof	Suspended Particulate Matter	Yes	

Table 1D: Sources and Contaminant Identification Table - Transportation Sources

Source Information			Expected Contaminants	Included in Modelling?	Rationale
Source ID	Source Description or Title	General Location	Contaminants	Significant	
RAIL	Rail corridor - GO Train Traffic	North of site	1,3-butadiene	No	ESDM Procedure Document Section 7.1.2
			1-hexene	No	ESDM Procedure Document Section 7.1.2
			1-pentene	No	ESDM Procedure Document Section 7.1.2
			2,2-dimethylpentane	No	ESDM Procedure Document Section 7.1.2
			2,3,3-trimethylpentane	Yes	
			2,3,4-trimethylpentane	No	ESDM Procedure Document Section 7.1.2
			2,3-dimethylpentane	No	ESDM Procedure Document Section 7.1.2
			2,4-dimethylpentane	No	ESDM Procedure Document Section 7.1.2
			2,5-Dimethylbenzaldehyde	No	ESDM Procedure Document Section 7.1.2
			2,6-dimethylheptane	No	ESDM Procedure Document Section 7.1.2
			2-Butanone	No	ESDM Procedure Document Section 7.1.2
			2-methyl-1-butene	No	ESDM Procedure Document Section 7.1.2
			2-methyl-1-pentene	No	ESDM Procedure Document Section 7.1.2
			2-methyl-2-butene	No	ESDM Procedure Document Section 7.1.2
			2-methylpentane (isohexane)	No	ESDM Procedure Document Section 7.1.2
			3-methylheptane	No	ESDM Procedure Document Section 7.1.2
			3-methyloctane	No	ESDM Procedure Document Section 7.1.2
			3-methylpentane	No	ESDM Procedure Document Section 7.1.2
			4-methyl-1-pentene	No	ESDM Procedure Document Section 7.1.2
			Acetaldehyde	No	ESDM Procedure Document Section 7.1.2
			Acetylene	No	ESDM Procedure Document Section 7.1.2
			Acrolein	Yes	
			Benzaldehyde	Yes	
			Benzene	Yes	
			Butyraldehyde/isobutyraldehyde	No	ESDM Procedure Document Section 7.1.2
			C9-c12 isoalkanes	No	ESDM Procedure Document Section 7.1.2
			Carbon Monoxide	Yes	
			Crotonaldehyde	Yes	
			Ethylbenzene	Yes	
			Ethylene	Yes	
			Formaldehyde	Yes	
			Isobutane	No	ESDM Procedure Document Section 7.1.2
			Isooctane	No	ESDM Procedure Document Section 7.1.2
			Methane	No	ESDM Procedure Document Section 7.1.2
			Methylbenzaldehyde	No	ESDM Procedure Document Section 7.1.2
			Methylcyclopentane	No	ESDM Procedure Document Section 7.1.2
			N-butane	No	ESDM Procedure Document Section 7.1.2
			Nitrogen Oxides	Yes	
			N-octane	No	ESDM Procedure Document Section 7.1.2
			N-pentane	No	ESDM Procedure Document Section 7.1.2
			N-undecane	No	ESDM Procedure Document Section 7.1.2
			Propane	No	ESDM Procedure Document Section 7.1.2
			Propionaldehyde	No	ESDM Procedure Document Section 7.1.2
			Propylcyclopentane	No	ESDM Procedure Document Section 7.1.2
			Suspended Particulate Matter	Yes	
			Toluene	No	ESDM Procedure Document Section 7.1.2
			Trans-2-pentene	No	ESDM Procedure Document Section 7.1.2
			Valeraldehyde	No	ESDM Procedure Document Section 7.1.2
			Xylene	Yes	

Table 1D: Sources and Contaminant Identification Table - Transportation Sources

Source Information			Expected Contaminants	Included in Modelling?	Rationale
Source ID	Source Description or Title	General Location	Contaminants	Significant	
PAVED	Road Traffic	Burloak Drive from Harvester Rd to Superior Crt	Acetylene	No	ESDM Procedure Document Section 7.1.2
			Aluminum	No	ESDM Procedure Document Section 7.1.2
			Antimony	No	ESDM Procedure Document Section 7.1.2
			Arsenic and compounds	Yes	
			Barium	No	ESDM Procedure Document Section 7.1.2
			Benzene	Yes	
			Cadmium	Yes	
			Calcium	No	ESDM Procedure Document Section 7.1.2
			Carbon Monoxide	Yes	
			Chromium (di, tri and metallic)	Yes	
			Copper	No	ESDM Procedure Document Section 7.1.2
			Ethane	No	ESDM Procedure Document Section 7.1.2
			Ethylbenzene	Yes	
			Ethylene	Yes	
			Indium	No	ESDM Procedure Document Section 7.1.2
			Iron	Yes	
			Isopentane	No	ESDM Procedure Document Section 7.1.2
			Lead and compounds	Yes	
			Manganese and compounds	Yes	
			N-butane	No	ESDM Procedure Document Section 7.1.2
			Nickel and compounds	Yes	
			Nitrogen Oxides	Yes	
			N-pentane	No	ESDM Procedure Document Section 7.1.2
			Phosphorus	Yes	
			Potassium	No	ESDM Procedure Document Section 7.1.2
			Propane	No	ESDM Procedure Document Section 7.1.2
			Propylene	No	ESDM Procedure Document Section 7.1.2
			Silicon	Yes	
			Strontium	No	ESDM Procedure Document Section 7.1.2
			Sulphur	No	ESDM Procedure Document Section 7.1.2
			Suspended Particulate Matter	Yes	
			Tin	No	ESDM Procedure Document Section 7.1.2
			Titanium	No	ESDM Procedure Document Section 7.1.2
			Toluene	No	ESDM Procedure Document Section 7.1.2
			Vanadium	No	ESDM Procedure Document Section 7.1.2
			Xylene	Yes	
			Zinc	Yes	
			Zirconium	No	ESDM Procedure Document Section 7.1.2

Table 2: Source Summary Table

Source Identifier	Source Data									Emission Data						
Model ID	Process Description	Stack ID	Stack Gas Flow Rate (Am^3/s)	Stack Gas Temperature (deg C)	Stack Diameter (m)	Stack Height Above Grade (m)	Stack Height Above Roof (m)	UTM Source Coordinates (Easting, Northing) (m)		Contaminant	Emission Rate (g/s)	Averaging Period(s) (hours)	Data Quality	Estimation Technique	Percentage of Overall Emission (%)	CAS
ASSOCIATED PAVING SOURCES																
BH	Dryer and mixer baghouse dust collector	BH	42.1	130	1.55	20.0	NA	600,969	4,804,756	2-Methylnaphthalene	1.64E-03	24	Marginal	EF	13.3%	91-57-6
										Arsenic and compounds	1.30E-05	24	Marginal	EF	25.3%	7440-38-2
										Benzaldehyde	3.01E-03	24	Marginal	EF	99.0%	100-52-7
										Benzene	1.78E-03	8760	Marginal	EF	61.7%	71-43-2
										Benzo(a)pyrene	1.97E-09	8760	Marginal	EF	8.6%	50-32-8
										Cadmium	9.49E-06	24	Marginal	EF	80.0%	7440-43-9
										Carbon Monoxide	2.22E+01	0.5	Average	EF	96.3%	630-08-0
										Chromium (di, tri and metallic)	1.27E-04	24	Marginal	EF	16.4%	7440-47-3
										Crotonaldehyde	6.71E-04	24	Marginal	EF	83.7%	4170-30-3
										Cobalt	6.02E-07	24	Marginal	EF	1.6%	7440-48-4
										Ethylbenzene	5.09E-02	24	Marginal	EF	98.9%	100-41-4
											1.22E-01	0.167	Marginal	EF	98.9%	100-41-4
										Formaldehyde	1.71E-02	24	Marginal	EF	75.4%	50-00-0
										Hexavalent Chromium	2.85E-06	8760	Marginal	EF	100%	18540-29-9
										Lead and compounds	1.44E-05	24	Marginal	EF	8.7%	7439-92-1
											1.44E-05	720	Marginal	EF	8.7%	7439-92-1
										Manganese and compounds	1.78E-04	24	Marginal	EF	5.3%	7439-96-5
										Naphthalene	8.33E-04	24	Marginal	EF	18.3%	91-20-3
											2.00E-03	0.167	Marginal	EF	10.1%	91-20-3
										Nickel and compounds	4.00E-04	8760	Marginal	EF	47.2%	7440-02-0
										Nitrogen Oxides	5.79E-01	24	Above Average	EF	41.3%	10102-44-0
											1.39E+00	1	Above Average	EF	57.2%	10102-44-0
										Phosphorus	6.48E-04	24	Marginal	EF	90.3%	7723-14-0
										Quinone	6.25E-03	24	Marginal	EF	100.0%	106-51-4
										Sulphur Dioxide	2.92E-02	8760	Marginal	EF	58.4%	7446-09-5
											2.56E-01	1	Marginal	EF	73.7%	7446-09-5
										Suspended Particulate Matter	3.51E-01	24	Above Average	EF	17.2%	N/A(9)
										Suspended Particulate Matter - PM10	1.37E-01	24	Above Average	EF	14.0%	NA-M09
										Suspended Particulate Matter - PM2.5	1.16E-01	24	Above Average	EF	24.9%	NA-M10
										Xylene	6.25E-02	24	Marginal	EF	96.0%	1330-20-7
											1.50E-01	0.167	Marginal	EF	96.1%	1330-20-7
										Zinc	1.41E-03	24	Above Average	EF	4.2%	7440-66-6
CRUSH	Diesel/electric crusher	VOL9	NA	Ambient	NA	NA	NA	601,025	4,804,697	Acrolein	2.98E-05	24	Marginal	EF	24.3%	107-02-8
											4.48E-05	1	Marginal	EF	1.0%	107-02-8
										Benzene	1.03E-04	8760	Marginal	EF	3.6%	71-43-2
										Benzo(a)pyrene	2.08E-08	8760	Marginal	EF	91.3%	50-32-8
										Carbon monoxide	2.56E-01	0.5	Above Average	EF	1.1%	630-08-0
										Formaldehyde	3.81E-04	24	Marginal	EF	1.7%	50-00-0
										Nitrogen oxides	3.12E-01	24	Above Average	EF	22.3%	10102-44-0
											4.68E-01	1	Above Average	EF	19.3%	10102-44-0
										Sulphur dioxide	2.08E-02	8760	Above Average	EF	41.6%	7446-09-5
											9.11E-02	1	Above Average	EF	26.3%	7446-09-5
										Suspended particulate matter	3.96E-01	24	Marginal	EF	19.4%	N/A(9)
										Suspended Particulate Matter - PM10	1.50E-01	24	Marginal	EF	15.3%	NA-M09
										Suspended Particulate Matter - PM2.5	6.77E-02	24	Marginal	EF	14.5%	NA-M10
										Xylene	9.19E-05	24	Marginal	EF	0.1%	1330-20-7
											1.38E-04	0.167	Marginal	EF	0.1%	1330-20-7
YARD	Truck Loading	YARD	NA	Ambient	NA	NA	NA	601,014	4,804,748	2-Methylnaphthalene	6.83E-06	24	Average	EF	0.1%	91-57-6
										Benzene	8.12E-10	8760	Average	EF	0.00003%	71-43-2
										Benzo(a)pyrene	1.98E-11	8760	Average	EF	0.09%	50-32-8
										Ethylbenzene	1.20E-06	24	Average	EF	0.002%	100-41-4
											8.97E-05	0.167	Average	EF	0.1%	100-41-4
										Ethylene	3.03E-06	24	Average	EF	0.04%	74-85-1
										Formaldehyde	3.76E-07	24	Average	EF	0.002%	50-00-0
										Naphthalene	3.59E-06	24	Average	EF	0.079%	91-20-3
											3.28E-04	0.167	Average	EF	1.7%	91-20-3
										Suspended Particulate Matter	1.51E-02	24	Average	EF	0.7%	N/A(9)
										Suspended Particulate Matter - PM10	1.51E-02	24	Average	EF	1.5%	NA-M09
										Suspended Particulate Matter - PM2.5	1.51E-02	24	Average	EF	3.2%	NA-M10
										Xylene	1.75E-06	24	Average	EF	0.0%	1330-20-7
											1.31E-04	0.167	Average	EF	0.1%	1330-20-7

Table 2: Source Summary Table

Source Identifier	Source Data									Emission Data						
Model ID	Process Description	Stack ID	Stack Gas Flow Rate (Am^3/s)	Stack Gas Temperature (deg C)	Stack Diameter (m)	Stack Height Above Grade (m)	Stack Height Above Roof (m)	UTM Source Coordinates (Easting, Northing) (m)		Contaminant	Emission Rate (g/s)	Averaging Period(s) (hours)	Data Quality	Estimation Technique	Percentage of Overall Emission (%)	CAS
SILO	Silo Filling	SILO	Passive	NA	NA	NA	NA	600,997	4,804,753	2-Methylnaphthalene	4.29E-04	24	Average	EF	3%	91-57-6
										Benzene	3.43E-05	8760	Average	EF	1%	71-43-2
										Ethylbenzene	1.49E-04	24	Average	EF	0.3%	100-41-4
											3.57E-04	0.167	Average	EF	0.3%	100-41-4
										Ethylene	4.30E-03	24	Average	EF	53%	74-85-1
										Formaldehyde	2.70E-03	24	Average	EF	12%	50-00-0
										Naphthalene	1.48E-04	24	Average	EF	3%	91-20-3
											3.56E-04	0.167	Average	EF	1.8%	91-20-3
										Suspended Particulate Matter	1.58E-02	24	Average	EF	0.8%	N/A(9)
										Suspended Particulate Matter - PM10	1.58E-02	24	Average	EF	1.6%	NA-M09
										Suspended Particulate Matter - PM2.5	1.58E-02	24	Average	EF	3.4%	NA-M10
										Xylene	7.82E-04	24	Average	EF	1%	1330-20-7
											1.88E-03	0.167	Average	EF	1%	1330-20-7
VOL3	Liquid asphalt storage tanks	VOL3	Passive	NA	NA	NA	NA	600,987	4,804,752	2-Methylnaphthalene	1.03E-02	24	Average	EF	83%	91-57-6
										Benzene	1.71E-05	8760	Average	EF	0.6%	71-43-2
										Ethylbenzene	7.43E-05	24	Average	EF	0.1%	100-41-4
											3.57E-04	0.167	Average	EF	0.3%	100-41-4
										Ethylene	2.15E-03	24	Average	EF	27%	74-85-1
										Formaldehyde	1.35E-03	24	Average	EF	6%	50-00-0
										Naphthalene	3.56E-03	24	Average	EF	78%	91-20-3
											1.71E-02	0.167	Average	EF	86.4%	91-20-3
										Nitrogen Oxides	9.27E-02	24	Above Average	EF	6.6%	10102-44-0
											9.27E-02	1	Average	EF	4%	10102-44-0
										Suspended Particulate Matter	7.91E-03	24	Average	EF	0.4%	N/A(9)
										Suspended Particulate Matter - PM10	7.91E-03	24	Average	EF	1%	NA-M09
										Suspended Particulate Matter - PM2.5	7.91E-03	24	Average	EF	2%	NA-M10
										Xylene	3.91E-04	24	Average	EF	1%	1330-20-7
											1.88E-03	0.167	Average	EF	1.2%	1330-20-7
UPR	Unpaved roads	SLINE1	Passive	NA	NA	NA	NA	601,021	4,804,810	Suspended Particulate Matter	1.52E-01	24	Average	EC	7%	N/A(9)
										Suspended Particulate Matter - PM10	4.18E-02	24	Average	EC	4%	NA-M09
										Suspended Particulate Matter - PM2.5	4.18E-03	24	Average	EC	1%	NA-M10
		SLINE2	Passive	NA	NA	NA	NA	601,014	4,804,741	Suspended Particulate Matter	2.78E-02	24	Average	EC	1%	N/A(9)
										Suspended Particulate Matter - PM10	7.66E-03	24	Average	EC	1%	NA-M09
										Suspended Particulate Matter - PM2.5	7.66E-04	24	Average	EC	0.2%	NA-M10
		SLINE3	Passive	NA	NA	NA	NA	601,029	4,804,784	Suspended Particulate Matter	2.47E-01	24	Average	EC	12%	N/A(9)
										Suspended Particulate Matter - PM10	6.82E-02	24	Average	EC	7%	NA-M09
										Suspended Particulate Matter - PM2.5	6.82E-03	24	Average	EC	1%	NA-M10
MH	Material Handling	VOL1	Passive	NA	NA	NA	NA	600,965	4,804,754	Suspended Particulate Matter	4.50E-02	24	Average	EF	2.2%	N/A(9)
										Suspended Particulate Matter - PM10	2.13E-02	24	Average	EF	2.2%	NA-M09
										Suspended Particulate Matter - PM2.5	3.22E-03	24	Average	EF	0.7%	NA-M10
		VOL2	Passive	NA	NA	NA	NA	600,948	4,804,744	Suspended Particulate Matter	4.50E-02	24	Average	EF	2.2%	N/A(9)
										Suspended Particulate Matter - PM10	2.13E-02	24	Average	EF	2.2%	NA-M09
										Suspended Particulate Matter - PM2.5	3.22E-03	24	Average	EF	0.7%	NA-M10
		VOL8	Passive	NA	NA	NA	NA	601,048	4,804,719	Suspended Particulate Matter	9.00E-02	24	Average	EF	4.4%	N/A(9)
										Suspended Particulate Matter - PM10	4.26E-02	24	Average	EF	4.3%	NA-M09
										Suspended Particulate Matter - PM2.5	6.45E-03	24	Average	EF	1.4%	NA-M10
BERICAP SOURCES																
BC	Extruder area general exhaust	EF1	1.82	20	1.12	8.24	0.58	NA	NA	Acrolein	2.26E-05	24	Marginal	EF	18%	107-02-8
	Extruder area general exhaust	EF2	1.82	20	1.12	8.24	0.58	NA	NA		2.26E-05	1	Marginal	EF	14%	107-02-8
	Extruder area general exhaust	EF3	1.82	20	1.12	8.24	0.58	NA	NA	Ethylene	1.13E-05	24	Marginal	EF	0.1%	74-85-1
	Extruder area general exhaust	EF4	10.04	20	1.27	8.02	0.36	NA	NA	Formaldehyde	6.78E-05	24	Marginal	EF	0.3%	50-00-0
	Extruder area general exhaust	EF5	10.04	20	1.27	8.02	0.36	NA	NA	Heavy Hydrocarbons (aliphatic hydrocarbon blend)	4.35E-02	24	Marginal	EF	100%	69430-33-7
	Extruder area general exhaust	EF6	10.04	20	1.27	8.02	0.36	NA	NA	Suspended Particulate Matter	3.01E-02	24	Marginal	EF	1%	N/A(9)
	Extruder area general exhaust	EF7	10.04	20	1.27	8.02	0.36	NA	NA	Suspended Particulate Matter - PM10	3.01E-02	24	Marginal	EF	3%	NA-M09
										Suspended Particulate Matter - PM2.5	3.01E-02	24	Marginal	EF	6%	NA-M10
	Exhaust system serving a dry offset printing press	EF14	0.86	20	0.23	9.1	1.5	NA	NA	Benzene	3.75E-04	8760	Marginal	EF	13%	71-43-2
	Exhaust system serving two (2) dry offset printing presses	EF15	0.43	20	0.23	9.1	1.5	NA	NA	Ethylbenzene	1.71E-04	24	Marginal	EF	0.3%	100-41-4
											1.71E-04	0.167	Marginal	EF	0.1%	100-41-4
										Xylene	6.09E-04	24	Marginal	EF	1%	1330-20-7
											6.09E-04	0.167	Marginal	EF	0.4%	1330-20-7
	Natural gas comfort heat	MAU1 to MAU10	NA	NA	NA	NA	NA	NA	NA	Nitrogen Oxides	6.77E-02	24	Above Average	EF	5%	10102-44-0
		UH1 to UH12	NA	NA	NA	NA	NA	NA	NA		6.77E-02	1	Above Average	EF	3%	10102-44-0
BCCT	Cooling tower	CT1	NA	NA	NA	NA	NA	NA	NA	Suspended Particulate Matter	1.24E-01	24	Avergage	EF	6%	N/A(9)
	Cooling tower	CT2	NA	NA	NA	NA	NA	NA	NA	Suspended Particulate Matter - PM10	3.45E-02	24	Avergage	EF	4%	NA-M09
	Cooling tower	CT3	NA	NA	NA	NA	NA	NA	NA	Suspended Particulate Matter - PM2.5	2.48E-04	24	Avergage	EF	0.1%	NA-M10
	Cooling tower	CT4	NA	NA	NA	NA	NA	NA	NA							

Table 2: Source Summary Table

Source Identifier	Source Data									Emission Data						
Model ID	Process Description	Stack ID	Stack Gas Flow Rate (Am^3/s)	Stack Gas Temperature (deg C)	Stack Diameter (m)	Stack Height Above Grade (m)	Stack Height Above Roof (m)	UTM Source Coordinates (Easting, Northing) (m)		Contaminant	Emission Rate (g/s)	Averaging Period(s) (hours)	Data Quality	Estimation Technique	Percentage of Overall Emission (%)	CAS
HARRIS STEEL SOURCES																
GV	Draw Bench #106 Baghouse	DB	1.7	20	NA	NA	NA	NA	NA	Arsenic and compounds	2.74E-05	24	Average	EC	54%	7440-38-2
	Coil Blaster Cartridge Dust Collector	CB	4.7	20	NA	NA	NA	NA	NA	Chromium (di, tri and metallic)	6.04E-04	24	Average	EC	78%	7440-47-3
	Inline Drawing Machine Baghouse	ILD1	0.6	20	NA	NA	NA	NA	NA	Cobalt	3.53E-05	24	Average	EC	92%	7440-48-4
	Drawing Machine #68 Portable Baghouse	WD1	0.4	20	NA	NA	NA	NA	NA	Ferric Oxide	1.93E-01	24	Average	EC	93%	1309-37-1
	Drawing Machine #75/81 Cartridge Dust Collector	WD2	2.6	20	NA	NA	NA	NA	NA	Iron	1.93E-01	24	Average	EC	93%	7439-89-6
	Drawing Machine #80 Cartridge Dust Collector	WD3	2.0	20	NA	NA	NA	NA	NA	Lead and compounds	2.82E-05	24	Average	EC	17%	7439-92-1
	Mesh Line #131 Cartridge Dust Collector	MF1	3.8	20	NA	NA	NA	NA	NA		2.82E-05	720	Average	EC	17%	7439-92-1
	Teurema Line Sanding & Descaling Cartridge Dust Collector	TL1	2.4	20	NA	NA	NA	NA	NA	Manganese and compounds	2.94E-03	24	Average	EC	88%	7439-96-5
	Teurema Line Up-ender Tower Cartridge Dust Collector	TL2	6.4	20	NA	NA	NA	NA	NA	Nickel and compounds	4.16E-04	8760	Average	EC	49%	7440-02-0
	Galvanizing Line Sander& Descaler Cartridge Dust Collector	GL1	6.4	20	NA	NA	NA	NA	NA	Phosphorus	4.70E-05	24	Average	EC	7%	7723-14-0
										Silicon	9.02E-04	24	Average	EC	22%	7440-21-3
										Suspended Particulate Matter	3.92E-01	24	Average	EC	19%	N/A(9)
										Suspended Particulate Matter - PM10	3.43E-01	24	Average	EC	35%	NA-M09
										Suspended Particulate Matter - PM2.5	1.68E-01	24	Average	EC	36%	NA-M10
										Zinc	3.20E-02	24	Average	EC	96%	7440-66-6
CDM	Drawing Machine #97 Cartridge Dust Collector	CDM1	2.5	20	NA	NA	NA	NA	NA	Arsenic and compounds	6.37E-07	24	Average	EC	1%	7440-38-2
	Drawing Machine #124 Cartridge Dust Collector	CDM2	2.5	20	NA	NA	NA	NA	NA	Chromium (di, tri and metallic)	1.40E-05	24	Average	EC	2%	7440-47-3
	Drawing Machine #136 Cartridge Dust Collector	CDM3	2.5	20	NA	NA	NA	NA	NA	Cobalt	8.19E-07	24	Average	EC	2%	7440-48-4
	Drawing Machine #123 Cartridge Dust Collector	CDM4	3.2	20	NA	NA	NA	NA	NA	Ferric Oxide	4.47E-03	24	Average	EC	2%	1309-37-1
	Drawing Machine #126 Cartridge Dust Collector	CDM5	3.2	20	NA	NA	NA	NA	NA	Iron	4.47E-03	24	Average	EC	2%	7439-89-6
										Lead and compounds	6.55E-07	24	Average	EC	0.4%	7439-92-1
											6.55E-07	720	Average	EC	0.4%	7439-92-1
										Manganese and compounds	6.83E-05	24	Average	EC	2%	7439-96-5
										Nickel and compounds	9.65E-06	8760	Average	EC	1.1%	7440-02-0
										Phosphorus	1.09E-06	24	Average	EC	0.2%	7723-14-0
										Silicon	2.09E-05	24	Average	EC	0.5%	7440-21-3
										Suspended Particulate Matter	9.10E-03	24	Average	EC	0.4%	N/A(9)
										Suspended Particulate Matter - PM10	7.96E-03	24	Average	EC	0.8%	NA-M09
										Suspended Particulate Matter - PM2.5	3.90E-03	24	Average	EC	0.8%	NA-M10
MF1	Mesh Line #139 Cartridge Dust Collector	MF1	3.8	20	0.6	10	2	600,928	4,804,643	Arsenic and compounds	1.33E-06	24	Average	EC	3%	7440-38-2
										Chromium (di, tri and metallic)	2.93E-05	24	Average	EC	4%	7440-47-3
										Cobalt	1.71E-06	24	Average	EC	4%	7440-48-4
										Ferric Oxide	9.33E-03	24	Average	EC	5%	1309-37-1
										Iron	9.33E-03	24	Average	EC	5%	7439-89-6
										Lead and compounds	1.37E-06	24	Average	EC	1%	7439-92-1
											1.37E-06	720	Average	EC	1%	7439-92-1
										Manganese and compounds	1.43E-04	24	Average	EC	4%	7439-96-5
										Nickel and compounds	2.01E-05	8760	Average	EC	2%	7440-02-0
										Phosphorus	2.28E-06	24	Average	EC	0.3%	7723-14-0
										Silicon	4.37E-05	24	Average	EC	1.1%	7440-21-3
										Suspended Particulate Matter	1.90E-02	24	Average	EC	1%	N/A(9)
										Suspended Particulate Matter - PM10	1.66E-02	24	Average	EC	2%	NA-M09
										Suspended Particulate Matter - PM2.5	8.15E-03	24	Average	EC	2%	NA-M10
PS	Steel Coil Pickling Wet Scrubber	PS	15.1	20	2.1	10.1	2.1	600,917	4,804,655	Hydrogen Chloride	9.85E-03	24	Average	EF	100%	7647-01-0
GV	Natural gas boiler	B	0.59	140	0.5	10	1	NA	NA	Nitrogen Oxides	1.98E-01	24	Above Average	EF	14%	10102-44-0
	Natural gas comfort heating sources	NGCH	NA	NA	NA	NA	NA	NA	NA		1.98E-01	1	Above Average	EF	8%	10102-44-0
GV	Mesh line and hydraulic unit cooling tower	CT1	NA	NA	NA	7.3	NA	NA	NA	Suspended Particulate Matter	1.13E-02	24	Average	EF	0.6%	N/A(9)
	Galvanizing line cooling tower	CT2	NA	NA	NA	10.5	2.5	NA	NA	Suspended Particulate Matter - PM10	3.15E-03	24	Average	EF	0.3%	NA-M09
	Galvanizing line cooling tower	CT3	NA	NA	NA	10.5	2.5	NA	NA	Suspended Particulate Matter - PM2.5	2.27E-05	24	Average	EF	0.005%	NA-M10

Table 2: Source Summary Table

Source Identifier	Source Data									Emission Data						
Model ID	Process Description	Stack ID	Stack Gas Flow Rate (Am^3/s)	Stack Gas Temperature (deg C)	Stack Diameter (m)	Stack Height Above Grade (m)	Stack Height Above Roof (m)	UTM Source Coordinates (Easting, Northing) (m)		Contaminant	Emission Rate (g/s)	Averaging Period(s) (hours)	Data Quality	Estimation Technique	Percentage of Overall Emission (%)	CAS
RAIL CORRIDOR																
RAIL	Rail corridor - GO Train Traffic	RAIL	NA	NA	NA	NA	NA	NA	NA	2,3,3-trimethylpentane	1.57E-05	24	Average	EC	100%	560-21-4
										Acrolein	7.03E-05	24	Average	EC	57%	107-02-8
											9.38E-05	0.167	Average	EC	58%	107-02-8
										Benzaldehyde	2.91E-05	24	Average	EC	1%	100-52-7
										Benzene	2.10E-04	8760	Average	EC	7%	71-43-2
										Carbon Monoxide	2.37E-01	0.5	Average	EC	1.0%	630-08-0
										Crotonaldehyde	1.31E-04	24	Average	EC	16%	4170-30-3
										Ethylbenzene	1.61E-05	24	Average	EC	0.03%	100-41-4
											2.14E-05	0.167	Average	EC	0.0%	100-41-4
										Ethylene	7.64E-04	24	Average	EC	9%	74-85-1
										Formaldehyde	1.10E-03	24	Average	EC	5%	50-00-0
										Nitrogen Oxides	1.39E-01	24	Average	EC	10%	10102-44-0
											1.85E-01	1	Average	EC	8%	10102-44-0
										Sulphur dioxide	2.22E-05	8760	Average	EC	0.04%	7446-09-5
											2.96E-05	1	Average	EC	0.01%	7446-09-5
										Suspended Particulate Matter	2.08E-03	24	Average	EC	0.1%	N/A(9)
										Suspended Particulate Matter - PM10	2.08E-03	24	Average	EC	0.2%	NA-M09
										Suspended Particulate Matter - PM2.5	2.08E-03	24	Average	EC	0.4%	NA-M10
										Xylene	4.43E-05	24	Average	EC	0.1%	1330-20-7
											5.90E-05	0.167	Average	EC	0.0%	1330-20-7
ROAD TRAFFIC																
PAVED	Road Traffic - Burloak Drive from Harvester Rd to Superior Crt	PAVED	NA	NA	NA	NA	NA	NA	NA	Arsenic and compounds	8.89E-06	24	Average	EC	17%	7440-38-2
										Benzene	3.64E-04	8760	Average	EC	13%	71-43-2
										Cadmium	2.37E-06	24	Average	EC	20%	7440-43-9
										Carbon Monoxide	3.61E-01	0.5	Average	EC	2%	630-08-0
										Chromium (di, tri and metallic)	2.96E-06	24	Average	EC	0.4%	7440-47-3
										Ethylbenzene	1.51E-04	24	Average	EC	0.3%	100-41-4
											3.33E-04	0.167	Average	EC	0.3%	100-41-4
										Ethylene	8.65E-04	24	Average	EC	11%	74-85-1
										Iron	6.11E-04	24	Average	EC	0.3%	7439-89-6
										Lead and compounds	1.21E-04	24	Average	EC	73%	7439-92-1
											1.21E-04	720	Average	EC	73%	7439-92-1
										Manganese and compounds	1.42E-05	24	Average	EC	0.4%	7439-96-5
										Nickel and compounds	1.19E-06	8760	Average	EC	0.14%	7440-02-0
										Nitrogen Oxides	1.31E-02	24	Average	EC	1%	10102-44-0
											2.89E-02	1	Average	EC	1.2%	10102-44-0
										Phosphorus	1.90E-05	24	Average	EC	3%	7723-14-0
										Silicon	3.13E-03	24	Average	EC	76%	7440-21-3
										Suspended Particulate Matter	6.24E-02	24	Average	EC	3%	N/A(9)
										Suspended Particulate Matter - PM10	1.45E-02	24	Average	EC	1%	NA-M09
										Suspended Particulate Matter - PM2.5	5.90E-03	24	Average	EC	1%	NA-M10
										Xylene	6.72E-04	24	Average	EC	1%	1330-20-7
											1.48E-03	0.167	Average	EC	0.9%	1330-20-7
										Zinc	7.65E-05	24	Average	EC	0.2%	7440-66-6

Table 3: Dispersion Modelling Input Summary Table

Relevant Section of the Regulation	Section Title	Description of How the Approved Dispersion Model was Used
Section 6	Approved Dispersion Models	AERMOD v22112
Section 8	Negligible Sources	Sources and contaminants were considered negligible in accordance with s.8 of O.Reg. 419. See the Sources and Contaminants Identification Table for more information.
Section 9	Same Structure Contamination	Not Applicable - The proposed development does not have any of the assessed sources.
Section 10	Operating Conditions	All equipment was assumed to be concurrently operating at maximum capacity. See Section 3.1 for additional details.
Section 11	Source of Contaminant Emission Rates	Emission rates were calculated using published emission factors.
Section 12	Combined Effect of Assumptions for Operating Conditions and Emission Rates	The operating conditions were estimated in accordance with s. 10(1)1 and s.11(1)1 and are therefore considered to result in the highest POI concentration that the facility is capable of producing.
Section 13	Meteorological Conditions	Meteorological data from Pearson International Airport for 1996 - 2000 were used.
Section 14	Area of Modelling Coverage	Receptors were placed at the proposed location of the daycare and included outdoor areas and elevated receptors to account for rooftop air intakes.
Section 15	Stack Height for Certain New Sources of Contaminant	Not Applicable - Section 15 of O.Reg. 419 does not apply to the assessed facilites.
Section 16	Terrain Data	Terrain data used to complete the assessment include the following files: cdem_dem_30M.tif
Section 17	Averaging Periods	10 minute, 1/2 hour, 1 hour, 24 hour, monthly, and annual

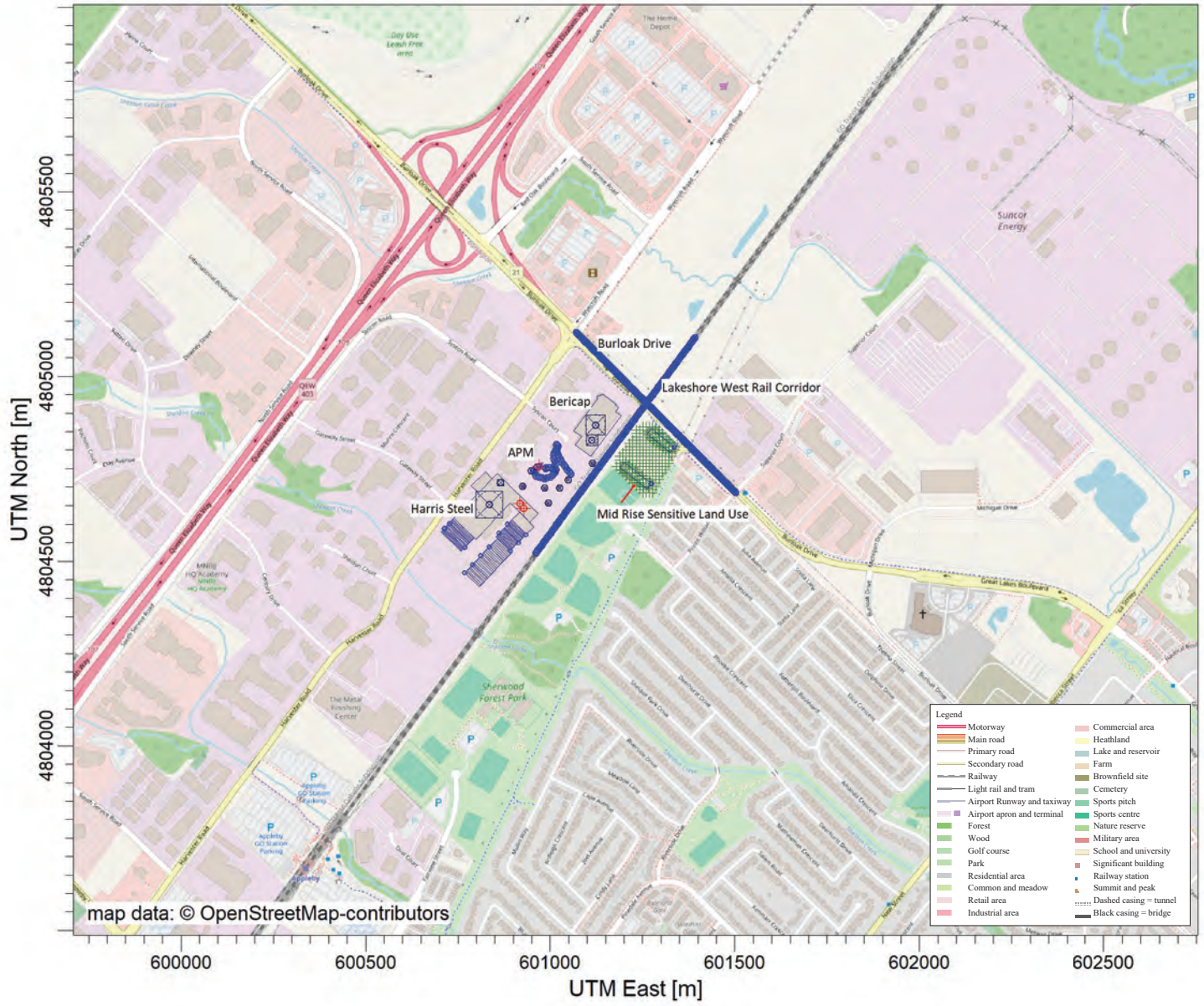
Table 4: Emission Summary Table

Contaminant	CAS	Emission Rate (g/s)	Air Dispersion Model Used	Maximum Predicted Concentration (µg/m³)	POI Limit (µg/m³)	Limiting Effect	Averaging Period (Hours)	Limit Source	Percentage of Limit (%)
2,3,3-trimethylpentane	560-21-4	1.57E-05		2.17E-03	0.1	de minimus	24	de minimus	2%
2-Methylnaphthalene	91-57-6	1.24E-02		3.93E-01	35.5	Health	24	SL-JSL	1%
Acrolein	107-02-8	1.23E-04		1.15E-02	0.4	Health	24	Standard	3%
	107-02-8	1.61E-04		1.46E-02	4.5	Health	1	Standard	0.3%
Arsenic and compounds	7440-38-2	5.13E-05		7.30E-03	0.3	Health	24	Guideline	2.4%
Benzaldehyde	100-52-7	3.04E-03		2.22E-02	2	Health	24	SL-JSL	1%
Benzene	71-43-2	2.88E-03		1.71E-01	0.45	Health	8760	Standard	38%
	71-43-2	8.09E-03		1.76E-01	4.5	AAV	8760	AAV	4%
	71-43-2	8.09E-03		3.10E-01	100	DAV	24	DAV	0.3%
Benzo(a)pyrene	50-32-8	2.28E-08		3.18E-07	0.00001	Health	8760	Standard	3.2%
	50-32-8	7.44E-08		1.03E-06	0.0001	AAV	8760	AAV	1%
	50-32-8	7.44E-08		2.98E-06	0.005	DAV	24	DAV	0.06%
Cadmium	7440-43-9	1.19E-05		1.92E-03	0.025	Health	24	Standard	7.7%
Carbon Monoxide	630-08-0	2.31E+01		4.03E+02	6000	Health	0.5	Standard	7%
Chromium (di, tri and metallic)	7440-47-3	7.77E-04		1.01E-02	0.5	Health	24	Standard	2%
Cobalt	7440-48-4	3.84E-05		5.67E-04	0.1	Health	24	Guideline	0.6%
Crotonaldehyde	4170-30-3	8.02E-04		1.81E-02	1.25	Health	24	SL-JSL	1.4%
Ethylbenzene	100-41-4	5.15E-02		3.77E-01	1000	Health	24	Standard	0.04%
	100-41-4	1.24E-01		2.67E+00	1900	Odour	0.167	Guideline	0.1%
Ethylene	74-85-1	8.09E-03		7.60E-01	40	Vegetation	24	Guideline	2%
Ferric Oxide	1309-37-1	2.06E-01		3.08E+00	25	Health & Soiling	24	Standard	12%
Formaldehyde	50-00-0	2.27E-02		2.27E-01	65	Health	24	Standard	0.3%
Heavy Hydrocarbons (aliphatic hydrocarbon blend)	69430-33-7	4.35E-02		2.87E+00	122.5	Health	24	SL-JSL	2%
Hexavalent Chromium	18540-29-9	2.85E-06		4.59E-06	0.00014	Health	8760	Standard	3%
	18540-29-9	1.04E-05	AERMOD	1.68E-05	0.0014	AAV	8760	AAV	1.2%
	18540-29-9	1.04E-05	v22112	7.70E-05	0.07	DAV	24	DAV	0.11%
Hydrogen Chloride	7647-01-0	9.85E-03		2.97E-01	20	Health	24	Standard	1.5%
Iron	7439-89-6	2.07E-01		3.08E+00	4	Health & Soiling	24	Standard	77%
Lead and compounds	7439-92-1	1.66E-04		9.80E-02	0.5	Health	24	Standard	20%
	7439-92-1	1.66E-04		5.10E-02	0.2	Health	720	Standard	26%
Manganese and compounds	7439-96-5	3.34E-03		4.78E-02	0.4	Health	24	Standard	12%
Naphthalene	91-20-3	4.54E-03		1.36E-01	22.5	Health	24	Guideline	1%
	91-20-3	1.98E-02		4.34E+00	50	Odour	0.167	Guideline	9%
Nickel and compounds	7440-02-0	8.46E-04		2.28E-03	0.04	Health	8760	Standard	6%
	7440-02-0	1.90E-03		3.96E-03	0.4	AAV	8760	AAV	1%
	7440-02-0	1.90E-03		1.24E-02	2	DAV	24	DAV	0.6%
Nitrogen Oxides	10102-44-0	1.40E+00		3.05E+01	200	Health	24	Standard	15%
	10102-44-0	2.43E+00		9.64E+01	400	Health	1	Standard	24%
Phosphorus	7723-14-0	7.18E-04		1.56E-02	0.5	Health	24	SL-MD	3%
Quinone	106-51-4	6.25E-03		4.60E-02	15	Health	24	Guideline	0.3%
Silicon	7440-21-3	4.09E-03		2.53E+00	27	Health	24	SL-PA	9.4%
Sulphur Dioxide	7446-09-5	5.00E-02		2.58E-01	10	Health & Vegetation	8760	Standard	2.6%
	7446-09-5	3.47E-01		1.39E+01	100	Health & Vegetation	1	Standard	13.9%
Suspended Particulate Matter	N/A(9)	2.04E+00		6.22E+01	120	Visibility	24	Standard	52%
Suspended Particulate Matter - PM10	NA-M09	9.80E-01		2.38E+01	50	Health	24	AAQC (interim)	48%
Suspended Particulate Matter - PM2.5	NA-M10	4.66E-01		8.92E+00	27	Health	24	CAAQS	33%
	NA-M10	4.66E-01		3.78E+00	8.8	Health	8760	CAAQS	43%
Xylene	1330-20-7	6.51E-02		5.63E-01	730	Health	24	Standard	0.1%
	1330-20-7	1.56E-01		3.35E+00	3000	Odour	0.167	Guideline	0.1%
Zinc	7440-66-6	3.35E-02		4.49E-01	120	Particulate	24	Standard	0.4%

FIGURES

PROJECT TITLE:

AERMOD Dispersion Modelling Assessment
800 Burloak Drive



COMMENTS:

Figure 1 - Area Location Plan

SOURCES:

23

RECEPTORS:

569

N

COMPANY NAME:

O2E Inc.

MODELER:

TML

DATE:

10/30/2025

SCALE: 1:17,163

0 0.5 km

O2E Inc. ENVIRONMENTAL CONSULTANTS

PROJECT NO.:

25-058

PROJECT TITLE:

AERMOD Dispersion Modelling Assessment
800 Burloak Drive



COMMENTS:

Figure 2- Site Plan

SOURCES:

23

RECEPTORS:

569

N

COMPANY NAME:

O2E Inc.

MODELER:

TML

DATE:

10/30/2025

SCALE: 1:6,473

0 0.2 km

O2E Inc. ENVIRONMENTAL CONSULTANTS

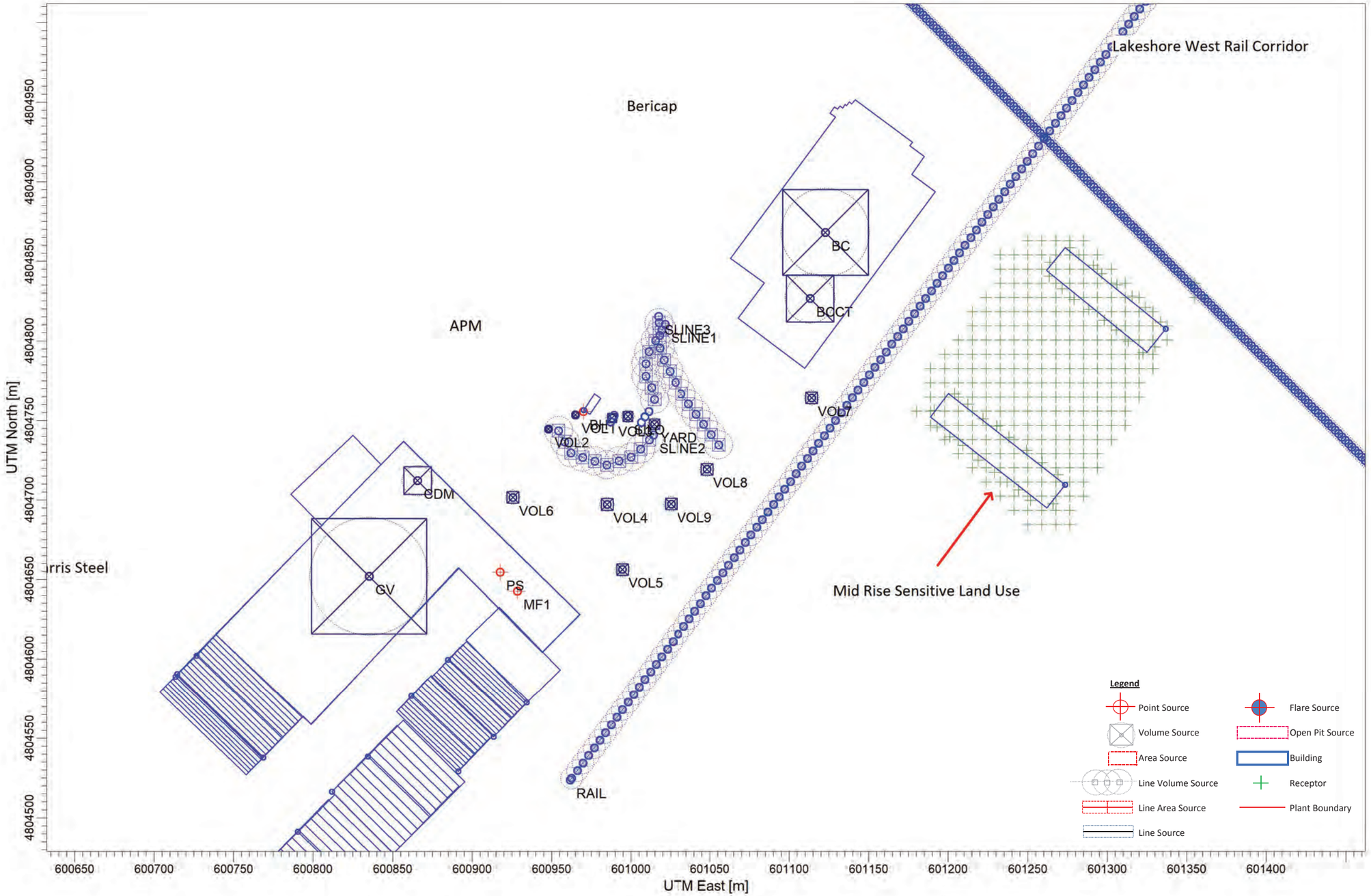
PROJECT NO.:

25-058

AERMOD View - Lakes Environmental Software

PROJECT TITLE:

AERMOD Dispersion Modelling Assessment
800 Burloak Drive



COMMENTS:

Figure 3 - Source Location Plan

SOURCES:

23

RECEPTORS:

569

N

COMPANY NAME:

O2E Inc.

MODELER:

TML

DATE:

10/30/2025

SCALE: 1:2,563

0 0.05 km

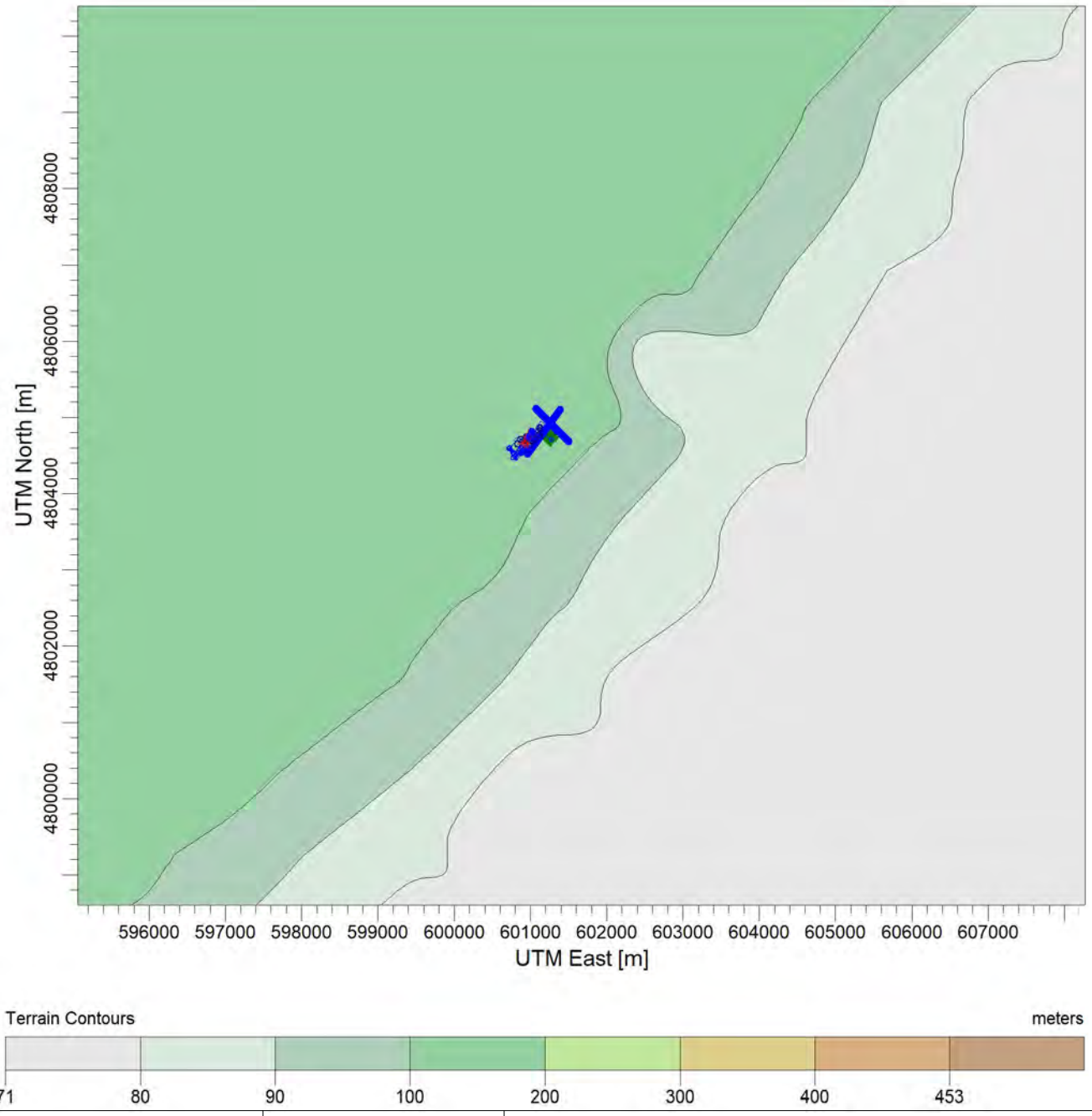
O2E Inc. ENVIRONMENTAL CONSULTANTS

PROJECT NO.:

25-058

PROJECT TITLE:

AERMOD Dispersion Modelling Assessment
800 Burloak Drive



COMMENTS: Figure 4 - Terrain Data	SOURCES: **23**	COMPANY NAME: **O2E Inc.**	
	RECEPTORS: **569**	MODELER: **TML**	
		SCALE: 1:83,079 0 3 km	
		DATE: **10/31/2025**	PROJECT NO.: **25-058**

AERMOD View - Lakes Environmental Software

APPENDIX 1
SUPPORTING CALCULATIONS

Associated Paving
Emission Caculations - based on U.S. EPA AP-42 Chapter 11.1 - Hot Mix Asphalt Plants

Hourly Capacity of site 400 Mg
Daily Capacity of site 4000 Mg
Annual Capacity of Site 400000 Mg
(taken from ECA #A-500-6213472110 issued to the Facility April 2, 2025)

CASRN	Substance	Emission Factor lb/ton	Emission Factor kg/Mg	Hourly Emission Rate g/s	Daily Emission Rate g/s	Annual Emission Rate g/s	Data Quality (U.S. EPA)
N/A(9)	Suspended particulate matter (20 mg/m^3)	NA	NA	8.42E-01	3.51E-01	9.61E-02	NA
NA-M09	Suspended Particulate Matter - PM10 (39% of SPM)	NA	NA	3.28E-01	1.37E-01	3.75E-02	E
NA-M10	Suspended Particulate Matter - PM2.5 (33% of SPM)	NA	NA	2.78E-01	1.16E-01	3.17E-02	E
7446-09-5	Sulphur dioxide	0.0046	0.0023	2.56E-01	1.06E-01	2.92E-02	E
10102-44-0	Nitrogen Oxides	0.025	0.0125	1.39E+00	5.79E-01	1.59E-01	D
630-08-0	Carbon monoxide	0.4	0.2	2.22E+01	9.26E+00	2.54E+00	C
75-07-0	Acetaldehyde	0.00032	0.00016	1.78E-02	7.41E-03	2.03E-03	E
71-43-2	Benzene	0.00028	0.00014	1.56E-02	6.48E-03	1.78E-03	D
100-41-4	Ethylbenzene	0.0022	0.0011	1.22E-01	5.09E-02	1.40E-02	D
50-00-0	Formaldehyde	0.00074	0.00037	4.11E-02	1.71E-02	4.69E-03	D
106-51-4	Quinone	0.00027	0.000135	1.50E-02	6.25E-03	1.71E-03	E
108-88-3	Toluene	0.001	0.0005	5.56E-02	2.31E-02	6.34E-03	D
1330-20-7	Xylene	0.0027	0.00135	1.50E-01	6.25E-02	1.71E-02	D
91-57-6	2-Methylnaphthalene	7.10E-05	0.0000355	3.94E-03	1.64E-03	4.50E-04	D
83-32-9	Acenaphthene	9.00E-07	0.00000045	5.00E-05	2.08E-05	5.71E-06	D
208-96-8	Acenaphthylene	5.80E-07	0.00000029	3.22E-05	1.34E-05	3.68E-06	D
120-12-7	Anthracene	2.10E-07	0.000000105	1.17E-05	4.86E-06	1.33E-06	D
56-55-3	Benzo(a)anthracene	4.60E-09	2.3E-09	2.56E-07	1.06E-07	2.92E-08	E
50-32-8	Benzo(a)pyrene	3.10E-10	1.55E-10	1.72E-08	7.18E-09	1.97E-09	E
205-99-2	Benzo(b)fluoranthene	9.40E-09	4.7E-09	5.22E-07	2.18E-07	5.96E-08	D
191-24-2	Benzo(g,h,i)perylene	5.00E-10	2.5E-10	2.78E-08	1.16E-08	3.17E-09	E
207-08-9	Benzo(k)fluoranthene	1.30E-08	6.5E-09	7.22E-07	3.01E-07	8.24E-08	E
218-01-9	Chrysene	3.80E-09	1.9E-09	2.11E-07	8.80E-08	2.41E-08	E
53-70-3	Dibenz(a,h)anthracene	9.50E-11	4.75E-11	5.28E-09	2.20E-09	6.02E-10	E
206-44-0	Fluoranthene	1.60E-07	0.00000008	8.89E-06	3.70E-06	1.01E-06	D
86-73-7	Fluorene	1.60E-06	0.0000008	8.89E-05	3.70E-05	1.01E-05	D
193-39-5	Indeno(1,2,3-cd)pyrene	3.00E-10	1.5E-10	1.67E-08	6.94E-09	1.90E-09	E
91-20-3	Naphthalene	3.60E-05	0.000018	2.00E-03	8.33E-04	2.28E-04	D
85-01-8	Phenanthrene	2.60E-06	0.0000013	1.44E-04	6.02E-05	1.65E-05	D
129-00-0	Pyrene	6.20E-08	0.000000031	3.44E-06	1.44E-06	3.93E-07	D
100-52-7	Benzaldehyde	0.00013	0.000065	7.22E-03	3.01E-03	8.24E-04	E
78-84-2	Butyraldehyde/isobutyraldehyde	3.00E-05	0.000015	1.67E-03	6.94E-04	1.90E-04	E
4170-30-3	Crotonaldehyde	2.90E-05	0.0000145	1.61E-03	6.71E-04	1.84E-04	E
66-25-1	Hexanal	2.40E-05	0.000012	1.33E-03	5.56E-04	1.52E-04	E
7440-36-0	Antimony	1.80E-07	0.00000009	1.00E-05	4.17E-06	1.14E-06	E
7440-38-2	Arsenic and compounds	5.60E-07	0.00000028	3.11E-05	1.30E-05	3.55E-06	D
7440-39-3	Barium	5.80E-06	0.0000029	3.22E-04	1.34E-04	3.68E-05	E
7440-43-9	Cadmium	4.10E-07	0.000000205	2.28E-05	9.49E-06	2.60E-06	D
7440-47-3	Chromium (di, tri and metallic)	5.50E-06	0.00000275	3.06E-04	1.27E-04	3.49E-05	C
7440-48-4	Cobalt	2.60E-08	0.000000013	1.44E-06	6.02E-07	1.65E-07	E
7440-50-8	Copper	3.10E-06	0.00000155	1.72E-04	7.18E-05	1.97E-05	D
18540-29-9	Hexavalent Chromium	4.50E-07	0.000000225	2.50E-05	1.04E-05	2.85E-06	E
7439-92-1	Lead and compounds	6.20E-07	0.00000031	3.44E-05	1.44E-05	3.93E-06	E
7439-96-5	Manganese and compounds	7.70E-06	0.00000385	4.28E-04	1.78E-04	4.88E-05	D
7439-97-6	Mercury	2.40E-07	0.00000012	1.33E-05	5.56E-06	1.52E-06	E
7440-02-0	Nickel and compounds	6.30E-05	0.0000315	3.50E-03	1.46E-03	4.00E-04	D
7723-14-0	Phosphorus	2.80E-05	0.000014	1.56E-03	6.48E-04	1.78E-04	E
7440-22-4	Silver	4.80E-07	0.00000024	2.67E-05	1.11E-05	3.04E-06	E
7782-49-2	Selenium	3.50E-07	0.000000175	1.94E-05	8.10E-06	2.22E-06	E
7440-28-0	Thallium	4.10E-09	2.05E-09	2.28E-07	9.49E-08	2.60E-08	E
7440-66-6	Zinc	6.10E-05	0.0000305	3.39E-03	1.41E-03	3.87E-04	C

Loadout into trucks (Yard Emissions)

EPA DQ = "C"

Asphalt Volatility -0.5 %

HMA Mix Temperature 338 F

CASRN	Substance	Emission Factor (as noted)	Hourly Emission Rate g/s	Daily Emission Rate g/s	Annual Emission Rate g/s
N/A(9)	Suspended particulate matter	3.27E-04 kg/Mg	3.63E-02	1.51E-02	4.14E-03
NA-M09	Suspended particulate matter - PM10	3.27E-04 kg/Mg	3.63E-02	1.51E-02	4.14E-03
NA-M10	Suspended particulate matter - PM2.5	3.27E-04 kg/Mg	3.63E-02	1.51E-02	4.14E-03
NA	Organic particulate matter	2.36E-04 kg/Mg	2.62E-02	1.09E-02	3.00E-03
NA	Total organic carbon	2.88E-04 kg/Mg	3.20E-02	1.33E-02	3.66E-03
83-32-9	Acenaphthene	0.2600%	6.82E-05	7.46E-07	2.24E-09
208-96-8	Acenaphthylene	0.0280%	7.35E-06	8.04E-08	2.41E-10
120-12-7	Anthracene	0.0700%	1.84E-05	2.01E-07	6.02E-10
56-55-3	Benzo(a)anthracene	0.0190%	4.99E-06	5.45E-08	1.63E-10
205-99-2	Benzo(b)fluoranthene	0.0076%	1.99E-06	2.18E-08	6.54E-11
207-08-9	Benzo(k)fluoranthene	0.0022%	5.77E-07	6.32E-09	1.89E-11
191-24-2	Benzo(g,h,i)perylene	0.0019%	4.99E-07	5.45E-09	1.63E-11
50-32-8	Benzo(a)pyrene	0.0023%	6.04E-07	6.60E-09	1.98E-11
192-97-2	Benzo(e)pyrene	0.0078%	2.05E-06	2.24E-08	6.71E-11
218-01-9	Chrysene	0.1030%	2.70E-05	2.96E-07	8.86E-10
53-70-3	Dibenz(a,h)anthracene	0.0004%	9.71E-08	1.06E-09	3.18E-12
206-44-0	Fluoranthene	0.0500%	1.31E-05	1.44E-07	4.30E-10
86-73-7	Fluorene	0.7700%	2.02E-04	2.21E-06	6.62E-09
193-39-5	Indeno(1,2,3-cd)pyrene	0.0005%	1.23E-07	1.35E-09	4.04E-12
91-57-6	2-Methylnaphthalene	2.3800%	6.25E-04	6.83E-06	2.05E-08
91-20-3	Naphthalene	1.2500%	3.28E-04	3.59E-06	1.08E-08
198-55-0	Perylene	0.0220%	5.77E-06	6.32E-08	1.89E-10
85-01-8	Phenanthrene	0.8100%	2.13E-04	2.33E-06	6.97E-09
129-00-0	Pyrene	0.1500%	3.94E-05	4.31E-07	1.29E-09
108-95-2	Phenol	1.1800%	3.10E-04	3.39E-06	1.02E-08
74-82-8	Methane	6.50%	2.08E-03	2.78E-05	1.01E-07
67-64-1	Acetone	0.05%	1.47E-05	1.97E-07	7.18E-10
74-85-1	Ethylene	0.71%	2.27E-04	3.03E-06	1.11E-08
71-43-2	Benzene	0.052%	1.67E-05	2.22E-07	8.12E-10
74-83-9	Bromomethane	0.01%	3.07E-06	4.10E-08	1.50E-10
78-93-3	2-Butanone	0.05%	1.57E-05	2.09E-07	7.65E-10
75-15-0	Carbon Disulfide	0.01%	4.16E-06	5.55E-08	2.03E-10
75-00-3	Chloroethane	0.00%	6.72E-08	8.97E-10	3.28E-12
74-87-3	Chloromethane	0.02%	4.80E-06	6.41E-08	2.34E-10
92-82-8	Cumene	0.11%	3.52E-05	4.70E-07	1.72E-09
100-41-4	Ethylbenzene	0.28%	8.97E-05	1.20E-06	4.37E-09
50-00-0	Formaldehyde	0.09%	2.82E-05	3.76E-07	1.37E-09
110-54-3	n-Hexane	0.15%	4.80E-05	6.41E-07	2.34E-09
540-84-1	Isooctane	0.00%	5.76E-07	7.69E-09	2.81E-11
100-42-5	Styrene	0.01%	2.34E-06	3.12E-08	1.14E-10
127-18-4	Tetrachloroethene	0.01%	2.47E-06	3.29E-08	1.20E-10
108-88-3	Toluene	0.21%	6.72E-05	8.97E-07	3.28E-09
75-69-4	Trichlorofluoromethane	0.00%	4.16E-07	5.55E-09	2.03E-11
1330-20-7	Xylene	0.41%	1.31E-04	1.75E-06	6.40E-09

HMA Silo Filling
EPA DQ = "C"

Asphalt Volatility -0.5 %
HMA Mix Temperature 338 F

CASRN	Substance	Emission Factor (as noted)	Hourly Emission Rate g/s	Daily Emission Rate g/s	Annual Emission Rate g/s
N/A(9)	Suspended particulate matter	3.42E-04 kg/Mg	3.80E-02	1.58E-02	4.34E-03
NA-M09	Suspended particulate matter - PM10	3.42E-04 kg/Mg	3.80E-02	1.58E-02	4.34E-03
NA-M10	Suspended particulate matter - PM2.5	3.42E-04 kg/Mg	3.80E-02	1.58E-02	4.34E-03
NA	Organic particulate matter	1.76E-04 kg/Mg	1.95E-02	8.14E-03	2.23E-03
NA	Total organic carbon	8.44E-03 kg/Mg	9.38E-01	3.91E-01	1.07E-01
83-32-9	Acenaphthene	0.47%	9.19E-05	3.83E-05	1.05E-05
208-96-8	Acenaphthylene	0.01%	2.74E-06	1.14E-06	3.12E-07
120-12-7	Anthracene	0.13%	2.54E-05	1.06E-05	2.90E-06
56-55-3	Benzo(a)anthracene	0.06%	1.09E-05	4.56E-06	1.25E-06
192-97-2	Benzo(e)pyrene	0.01%	1.86E-06	7.74E-07	2.12E-07
218-01-9	Chrysene	0.21%	4.10E-05	1.71E-05	4.69E-06
206-44-0	Fluoranthene	0.15%	2.93E-05	1.22E-05	3.35E-06
86-73-7	Fluorene	1.01%	1.97E-04	8.23E-05	2.25E-05
91-57-6	2-Methylnaphthalene	5.27%	1.03E-03	4.29E-04	1.18E-04
91-20-3	Naphthalene	1.82%	3.56E-04	1.48E-04	4.06E-05
198-55-0	Perylene	0.03%	5.86E-06	2.44E-06	6.69E-07
85-01-8	Phenanthrene	1.80%	3.52E-04	1.47E-04	4.02E-05
129-00-0	Pyrene	0.44%	8.60E-05	3.58E-05	9.82E-06
74-82-8	Methane	0.26%	2.44E-03	1.02E-03	2.78E-04
67-64-1	Acetone	0.06%	5.16E-04	2.15E-04	5.89E-05
74-85-1	Ethylene	1.10%	1.03E-02	4.30E-03	1.18E-03
71-43-2	Benzene	0.032%	3.00E-04	1.25E-04	3.43E-05
74-83-9	Bromomethane	0.00%	4.60E-05	1.92E-05	5.25E-06
78-93-3	2-Butanone	0.04%	3.66E-04	1.52E-04	4.18E-05
75-15-0	Carbon Disulfide	0.02%	1.50E-04	6.26E-05	1.71E-05
75-00-3	Chloroethane	0.00%	3.75E-05	1.56E-05	4.28E-06
74-87-3	Chloromethane	0.02%	2.16E-04	8.99E-05	2.46E-05
100-41-4	Ethylbenzene	0.04%	3.57E-04	1.49E-04	4.07E-05
50-00-0	Formaldehyde	0.69%	6.47E-03	2.70E-03	7.39E-04
110-54-3	n-Hexane	0.10%	9.38E-04	3.91E-04	1.07E-04
540-84-1	Isooctane	0.00%	2.91E-06	1.21E-06	3.32E-07
75-09-2	Methylene Chloride	0.00%	2.53E-06	1.06E-06	2.89E-07
100-42-5	Styrene	0.01%	5.07E-05	2.11E-05	5.78E-06
108-88-3	Toluene	0.06%	5.82E-04	2.42E-04	6.64E-05
1330-20-7	Xylene	0.20%	1.88E-03	7.82E-04	2.14E-04

Asphalt Storage Tank Filling Limit

200 Mg/hour
2000 Mg/day
200,000 Mg/year

Asphalt Storage Tanks

Asphalt Volatility -0.5 %

EPA DQ = "C"

HMA Mix Temperature 338 F

CASRN	Substance	Emission Factor (as noted)	Hourly Emission Rate g/s	Daily Emission Rate g/s	Annual Emission Rate g/s
N/A(9)	Suspended particulate matter	3.42E-04 kg/Mg	1.90E-02	7.91E-03	2.17E-03
NA-M09	Suspended particulate matter - PM10	3.42E-04 kg/Mg	1.90E-02	7.91E-03	2.17E-03
NA-M10	Suspended particulate matter - PM2.5	3.42E-04 kg/Mg	1.90E-02	7.91E-03	2.17E-03
NA	Organic particulate matter	1.76E-04 kg/Mg	1.95E-02	4.07E-03	1.12E-03
NA	Total organic carbon	8.44E-03 kg/Mg	9.38E-01	1.95E-01	5.36E-02
83-32-9	Acenaphthene	0.47%	4.41E-03	9.19E-04	2.52E-04
208-96-8	Acenaphthylene	0.01%	1.31E-04	2.74E-05	7.50E-06
120-12-7	Anthracene	0.13%	1.22E-03	2.54E-04	6.96E-05
56-55-3	Benzo(a)anthracene	0.06%	5.25E-04	1.09E-04	3.00E-05
192-97-2	Benzo(e)pyrene	0.01%	8.91E-05	1.86E-05	5.09E-06
218-01-9	Chrysene	0.21%	1.97E-03	4.10E-04	1.12E-04
206-44-0	Fluoranthene	0.15%	1.41E-03	2.93E-04	8.03E-05
86-73-7	Fluorene	1.01%	9.48E-03	1.97E-03	5.41E-04
91-57-6	2-Methylnaphthalene	5.27%	4.94E-02	1.03E-02	2.82E-03
91-20-3	Naphthalene	1.82%	1.71E-02	3.56E-03	9.75E-04
198-55-0	Perylene	0.03%	2.81E-04	5.86E-05	1.61E-05
85-01-8	Phenanthrene	1.80%	1.69E-02	3.52E-03	9.64E-04
129-00-0	Pyrene	0.44%	4.13E-03	8.60E-04	2.36E-04
74-82-8	Methane	0.26%	2.44E-03	5.08E-04	1.39E-04
67-64-1	Acetone	0.06%	5.16E-04	1.08E-04	2.95E-05
74-85-1	Ethylene	1.10%	1.03E-02	2.15E-03	5.89E-04
71-43-2	Benzene	0.032%	3.00E-04	6.26E-05	1.71E-05
74-83-9	Bromomethane	0.00%	4.60E-05	9.58E-06	2.62E-06
78-93-3	2-Butanone	0.04%	3.66E-04	7.62E-05	2.09E-05
75-15-0	Carbon Disulfide	0.02%	1.50E-04	3.13E-05	8.57E-06
75-00-3	Chloroethane	0.00%	3.75E-05	7.82E-06	2.14E-06
74-87-3	Chloromethane	0.02%	2.16E-04	4.50E-05	1.23E-05
100-41-4	Ethylbenzene	0.04%	3.57E-04	7.43E-05	2.04E-05
50-00-0	Formaldehyde	0.69%	6.47E-03	1.35E-03	3.70E-04
110-54-3	n-Hexane	0.10%	9.38E-04	1.95E-04	5.36E-05
540-84-1	Isooctane	0.00%	2.91E-06	6.06E-07	1.66E-07
75-09-2	Methylene Chloride	0.00%	2.53E-06	5.28E-07	1.45E-07
100-42-5	Styrene	0.01%	5.07E-05	1.06E-05	2.89E-06
108-88-3	Toluene	0.06%	5.82E-04	1.21E-04	3.32E-05
1330-20-7	Xylene	0.20%	1.88E-03	3.91E-04	1.07E-04

Summary of Estimated Emissions from Associated Paving Operations

CASRN	Substance	Hourly	24 Hour	Annual	Significant?
106-99-0	1,3-Butadiene	1.89E-05	1.26E-05	4.32E-06	No
78-93-3	2-Butanone	7.48E-04	2.29E-04	6.27E-05	No
91-57-6	2-Methylnaphthalene	5.50E-02	1.24E-02	3.39E-03	Yes
83-32-9	Acenaphthene	4.62E-03	9.79E-04	2.68E-04	No
208-96-8	Acenaphthylene	1.74E-04	4.20E-05	1.15E-05	No
75-07-0	Acetaldehyde	1.81E-02	7.65E-03	2.11E-03	No
67-64-1	Acetone	1.05E-03	3.23E-04	8.84E-05	No
107-02-8	Acrolein	4.48E-05	2.98E-05	1.02E-05	Yes
120-12-7	Anthracene	1.28E-03	2.70E-04	7.39E-05	No
7440-36-0	Antimony	1.00E-05	4.17E-06	1.14E-06	No
7440-38-2	Arsenic	3.11E-05	1.30E-05	3.55E-06	Yes
7440-39-3	Barium	3.22E-04	1.34E-04	3.68E-05	No
100-52-7	Benzaldehyde	7.22E-03	3.01E-03	8.24E-04	Yes
71-43-2	Benzene	1.66E-02	6.97E-03	1.93E-03	Yes
56-55-3	Benzo(a)anthracene	5.42E-04	1.14E-04	3.13E-05	No
50-32-8	Benzo(a)pyrene	7.12E-07	7.44E-08	2.28E-08	Yes
205-99-2	Benzo(b)fluoranthene	2.52E-06	2.39E-07	5.97E-08	No
192-97-2	Benzo(e)pyrene	9.30E-05	1.94E-05	5.30E-06	No
191-24-2	Benzo(g,h,i)perylene	5.27E-07	1.70E-08	3.19E-09	No
207-08-9	Benzo(k)fluoranthene	1.30E-06	3.07E-07	8.25E-08	No
74-83-9	Bromomethane	9.50E-05	2.88E-05	7.87E-06	No
78-84-2	Butyraldehyde/isobutyraldehyde	1.67E-03	6.94E-04	1.90E-04	No
7440-43-9	Cadmium	2.28E-05	9.49E-06	2.60E-06	Yes
75-15-0	Carbon Disulfide	3.04E-04	9.39E-05	2.57E-05	No
630-08-0	Carbon Monoxide	2.25E+01	9.43E+00	2.60E+00	Yes
75-00-3	Chloroethane	7.51E-05	2.35E-05	6.43E-06	No
74-87-3	Chloromethane	4.36E-04	1.35E-04	3.70E-05	No
7440-47-3	Chromium	3.06E-04	1.27E-04	3.49E-05	Yes
218-01-9	Chrysene	2.04E-03	4.28E-04	1.17E-04	No
7440-48-4	Cobalt	1.44E-06	6.02E-07	1.65E-07	Yes
7440-50-8	Copper	1.72E-04	7.18E-05	1.97E-05	No
4170-30-3	Crotonaldehyde	1.61E-03	6.71E-04	1.84E-04	Yes
92-82-8	Cumene	3.52E-05	4.70E-07	1.72E-09	No
53-70-3	Dibenz(a,h)anthracene	1.02E-07	3.26E-09	6.06E-10	No
100-41-4	Ethylbenzene	1.23E-01	5.11E-02	1.40E-02	Yes
74-85-1	Ethylene	2.09E-02	6.45E-03	1.77E-03	Yes
206-44-0	Fluoranthene	1.46E-03	3.09E-04	8.47E-05	No
86-73-7	Fluorene	9.96E-03	2.10E-03	5.74E-04	No
50-00-0	Formaldehyde	5.47E-02	2.16E-02	5.93E-03	Yes
66-25-1	Hexanal	1.33E-03	5.56E-04	1.52E-04	No
18540-29-9	Hexavalent Chromium	2.50E-05	1.04E-05	2.85E-06	Yes
193-39-5	Indeno(1,2,3-cd)pyrene	1.40E-07	8.29E-09	1.91E-09	No
540-84-1	Isooctane	6.39E-06	1.83E-06	4.98E-07	No
7439-92-1	Lead	3.44E-05	1.44E-05	3.93E-06	Yes
7439-96-5	Manganese	4.28E-04	1.78E-04	4.88E-05	Yes
7439-97-6	Mercury	1.33E-05	5.56E-06	1.52E-06	No
74-82-8	Methane	6.96E-03	1.55E-03	4.18E-04	No
75-09-2	Methylene Chloride	5.07E-06	1.58E-06	4.34E-07	No
91-20-3	Naphthalene	1.98E-02	4.54E-03	1.24E-03	Yes
110-54-3	n-Hexane	1.92E-03	5.87E-04	1.61E-04	No
7440-02-0	Nickel	3.50E-03	1.46E-03	4.00E-04	Yes
10102-44-0	Nitrogen Oxides	1.95E+00	9.83E-01	6.73E-01	Yes
198-55-0	Perylene	2.93E-04	6.11E-05	1.67E-05	No
85-01-8	Phenanthrene	1.76E-02	3.73E-03	1.02E-03	No
108-95-2	Phenol	3.10E-04	3.39E-06	1.02E-08	No
7723-14-0	Phosphorus	1.56E-03	6.48E-04	1.78E-04	Yes
115-07-1	Propylene	1.25E-04	8.32E-05	2.85E-05	No
129-00-0	Pyrene	4.26E-03	8.98E-04	2.46E-04	No
106-51-4	Quinone	1.50E-02	6.25E-03	1.71E-03	Yes
7782-49-2	Selenium	1.94E-05	8.10E-06	2.22E-06	No
7440-22-4	Silver	2.67E-05	1.11E-05	3.04E-06	No
100-42-5	Styrene	1.04E-04	3.17E-05	8.68E-06	No
7446-09-5	Sulphur dioxide	3.47E-01	1.67E-01	5.00E-02	Yes
N/A(9)	Suspended Particulate Matter	2.57E+00	1.39E+00	7.60E-01	Yes
NA-M09	Suspended Particulate Matter - PM10	1.02E+00	5.28E-01	2.86E-01	Yes
NA-M10	Suspended Particulate Matter - PM2.5	5.56E-01	2.47E-01	1.02E-01	Yes
127-18-4	Tetrachloroethene	2.47E-06	3.29E-08	1.20E-10	No
7440-28-0	Thallium	2.28E-07	9.49E-08	2.60E-08	No
108-88-3	Toluene	5.70E-02	2.36E-02	6.49E-03	No
75-69-4	Trichlorofluoromethane	4.16E-07	5.55E-09	2.03E-11	No
1330-20-7	Xylene	1.54E-01	6.38E-02	1.75E-02	Yes
7440-66-6	Zinc	3.39E-03	1.41E-03	3.87E-04	Yes

Fugitive Emissions from Unpaved Roads - Associated Paving and Materials

Based on AP-42 Chapter 13.2.2

U.S. AP-42 Equation: $E = k * (s/12)^a * (W/3)^b$

U.S EPA AP-42 Unpaved Roads Fugitive Emissions Factors Equation 1: for Industrial sites (Chapter 13.2.2)

Equation Inputs

Factors From Table 13.2.2-2 U.S EPA AP-42

k (lb/VMT) for TSP:	4.9	a (lb/VMT) for TSP:	0.7	b (lb/VMT) for TSP:	0.45
k (lb/VMT) for PM10:	1.5	a (lb/VMT) for PM10:	0.9	b (lb/VMT) for PM10:	0.45
k (lb/VMT) for PM2.5:	0.15	a (lb/VMT) for PM2.5:	0.9	b (lb/VMT) for PM2.5:	0.45

Silt Content (%): 7.1

Average Vehicle Weights (tons)

HMA Trucks	20.00	tons (42 metric tonnes)
Loader/Excavator	15.00	tons
Aggregate/UPM Trucks	46.30	tons

Particle Size Distribution

	TSP	PM10	PM2.5	PM10	PM2.5
HMA Truck Emission Factors (lb/VMT)	7.97	2.20	0.22	28%	2.8%
HMA Truck Emission Factors (kg/VKT)	2.246	0.619	0.062		
Loader/Excavator Emission Factors (lb/VMT)	7.00	1.93	0.19		
Loader/Excavator Emission Factors (kg/VKT)	1.974	0.544	0.054		
Aggregate/UPM Truck Emission Factors (lb/VMT)	11.63	3.20	0.32		
Aggregate/UPM Truck Emission Factors (kg/VKT)	3.278	0.903	0.090		

From Amended ECA

Hot Mix Asphalt (HMA) Trucks	20 per hour
Aggregate Trucks	8 per hour
Unprocessed Material (UPM) Trucks	5 per hour

VKT (Vehicle Kilometer Travelled) Calculations

Abatement factor 84% Apply dust suppressant (WRAP Fugitive Dust Handbook)

Road Segment ID	Source ID	One Way Distance (km)	Percentage Used	Number of Trips Daily	Vehicle Kilometer Travelled (km/day)	Daily Particulate Emissions (kg/day)	Particulate Emissions (g/s)	Abated SPM Emissions (g/s)	Abated PM10 Emissions (g/s)	Abated PM2.5 Emissions (g/s)
HMA Truck Entry/Exit	SLINE1	0.057	43%	320	36	82.0	9.49E-01	1.52E-01	4.18E-02	4.18E-03
Loader/Excavator	SLINE2	0.076	9%	50	8	15.0	1.74E-01	2.78E-02	7.66E-03	7.66E-04
Aggregate/UPM Truck Entry/Exit	SLINE3	0.098	48%	208	41	133.6	1.55E+00	2.47E-01	6.82E-02	6.82E-03
Total			100%	578	85	231	2.67E+00	4.27E-01	1.18E-01	1.18E-02

Material Handling Emissions Coarse Aggregate

EPA Emission Equation - U.S. EPA Data Quality Rating "A"

$$E = k(0.0016) \times \frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}}$$

Where:
E = emission factor in kg particulate per Mg material handled
k = particle size multiplier
U = mean wind speed (m/s)
M = material moisture content

Mean wind speed (Hamilton Station A) 4.7 m/s
Maximum coarse aggregate handling rate 150 Mg/hr
Particle Size Multipliers

Particle Size	**k**
TSP	0.74
PM10	0.35
PM2.5	0.053

Moisture Contents of Various Materials

	%	SPM Factor (kg/Mg)	PM10 Factor (kg/Mg)	PM2.5 Factor (kg/Mg)
Coarse aggr	3	0.0018005	0.0008516	0.000129

Particulate Emissions from Material Handling

	Hourly Emissions	Hourly Emissions (g/s)	Daily Emissions (g/s)	Annual Emissions (g/s)
SPM	2.43E-01 kg/hr	6.75E-02	4.50E-02	3.08E-02
PM10	1.15E-01 kg/hr	3.19E-02	2.13E-02	1.46E-02
PM2.5	1.74E-02 kg/hr	4.84E-03	3.22E-03	2.21E-03

Material Handling Emissions Fine Aggregate

EPA Emission Equation - U.S. EPA Data Quality Rating "A"

$$E = k(0.0016) \times \frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}}$$

Where:
E = emission factor in kg particulate per Mg material handled
k = particle size multiplier
U = mean wind speed (m/s)
M = material moisture content

Mean wind speed (Hamilton Station A) 4.7 m/s
Maximum fine aggregate handling rate 150 Mg/hr
Particle Size Multipliers

Particle Size	**k**
TSP	0.74
PM10	0.35
PM2.5	0.053

Moisture Contents of Various Materials

	%	SPM Factor (kg/Mg)	PM10 Factor (kg/Mg)	PM2.5 Factor (kg/Mg)
Sand	3	0.0018005	0.0008516	0.000129

Particulate Emissions from Material Handling

	Hourly Emissions	Hourly Emissions (g/s)	Daily Emissions (g/s)	Annual Emissions (g/s)
SPM	2.43E-01 kg/hr	6.75E-02	4.50E-02	3.08E-02
PM10	1.15E-01 kg/hr	3.19E-02	2.13E-02	1.46E-02
PM2.5	1.74E-02 kg/hr	4.84E-03	3.22E-03	2.21E-03

Material Handling Emissions Dumping Hopper (DH)

EPA Emission Equation - U.S. EPA Data Quality Rating "A"

$$E = k(0.0016) \times \frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}}$$

Where:
E = emission factor in kg particulate per Mg material handled
k = particle size multiplier
U = mean wind speed (m/s)
M = material moisture content

Mean wind speed (Hamilton Station A) 4.7 m/s
Maximum hopper loading rate 300 Mg/hr
Particle Size Multipliers

Particle Size	k
TSP	0.74
PM10	0.35
PM2.5	0.053

Moisture Contents of Various Materials

	%	SPM Factor (kg/Mg)	PM10 Factor (kg/Mg)	PM2.5 Factor (kg/Mg)
Coarse	3	0.0018005	0.0008516	0.000129
Fine	3	0.0018005	0.0008516	0.000129

Particulate Emissions from Material Handling

	Hourly TSP Emissions (g/s)	Hourly PM10 Emissions (g/s)	Hourly PM2.5 Emissions (g/s)	Daily TSP Emissions (g/s)	Daily PM10 Emissions (g/s)	Daily PM2.5 Emissions (g/s)	Annual TSP Emissions (g/s)	Annual PM10 Emissions (g/s)	Annual PM2.5 Emissions (g/s)
Coarse	6.75E-02	3.19E-02	4.84E-03	4.50E-02	2.13E-02	3.22E-03	3.08E-02	1.46E-02	2.21E-03
Fine	6.75E-02	3.19E-02	4.84E-03	4.50E-02	2.13E-02	3.22E-03	3.08E-02	1.46E-02	2.21E-03
Total	1.35E-01	6.39E-02	9.67E-03	9.00E-02	4.26E-02	6.45E-03	6.17E-02	2.92E-02	4.42E-03

Crusher and Screener Emissions (CRUSH)

U.S. EPA AP-42 Chapter 11.19.2 Crushed Stone Processing and Pulverized Mineral Processing

Maximum processing rates 200 Mg/hour
2000 Mg/day

Crusher

Substance	CASRN	Emission Factor (kg/Mg)	Hourly Emission Rate (g/s)	Daily Emission Rate (g/s)	Annual Emission Rate (g/s)
Suspended particulate matter	N/A(9)	0.0027	1.50E-01	6.25E-02	4.28E-02
PM10	NA-M10	0.0012	6.67E-02	2.78E-02	1.90E-02
PM2.5	NA-M11	0.000405	2.25E-02	9.38E-03	6.42E-03

Screening

Substance	CASRN	Emission Factor (kg/Mg)	Hourly Emission Rate (g/s)	Daily Emission Rate (g/s)	Annual Emission Rate (g/s)
Suspended particulate matter	N/A(9)	0.0125	6.94E-01	2.89E-01	1.98E-01
PM10	NA-M10	0.0043	2.39E-01	9.95E-02	6.82E-02
PM2.5	NA-M11	0.00188	1.04E-01	4.34E-02	2.97E-02

Stacker

Substance	CASRN	Emission Factor (kg/Mg)	Hourly Emission Rate (g/s)	Daily Emission Rate (g/s)	Annual Emission Rate (g/s)
Suspended particulate matter	N/A(9)	0.0015	8.33E-02	3.47E-02	2.38E-02
PM10	NA-M10	0.00055	3.06E-02	1.27E-02	8.72E-03
PM2.5	NA-M11	0.000225	1.25E-02	5.21E-03	3.57E-03

Particle Size Distribution Analysis
Utilizing U.S. EPA AP-42 Appendix B-2: Generalized Particle Size Distributions

Category 3 - Mechanically Generated - Aggregate, Unprocessed Ores

Particle Size,	Cumulative % ≤ Stated Size (Uncontrolled	Minimum Value	Maximum Value	Standard Deviation
1.0[a]	4%			
2.0[a]	11%			
2.5	15%	3	35	7
3.0[a]	18%			
4.0[a]	25%			
5.0[a]	30%			
6	34%	15	65	13
10	51%	23	81	14

[a] Value calculated from data reported at 2.5, 6.0, and 10.0 µm. No statistical parameters are given for the calculated value.

Bericap
Emission Calculations

Current ECA 1852-A4EP8N (LoF)
ECA Facility Production Limit 24,420,000 kilograms of resins used per year.

ECA Facility Description:
A facility manufacturing plastic caps and enclosures for food, automotive and pharmaceuticalindustries, consisting of the following processes and support units:
- plastic extrusion;
- assembly, lining, etching and printing

Extruders

Source ID	Description	Stack Gas Flow Rate (m^3/s)	Stack Gas Temperature (deg C)	Stack Diameter (m)	Stack Height Above Grade (m)	Stack Height Above Roof (m)	Notes
EF1	Extruder area general exhaust	1.82	20	1.12	8.24	0.58	Based on satellite imagery the stack appears to be capped/downblast
EF2	Extruder area general exhaust	1.82	20	1.12	8.24	0.58	Based on satellite imagery the stack appears to be capped/downblast
EF3	Extruder area general exhaust	1.82	20	1.12	8.24	0.58	Based on satellite imagery the stack appears to be capped/downblast
EF4	Extruder area general exhaust	10.04	20	1.27	8.02	0.36	Based on satellite imagery the stack appears to be capped/downblast
EF5	Extruder area general exhaust	10.04	20	1.27	8.02	0.36	Based on satellite imagery the stack appears to be capped/downblast
EF6	Extruder area general exhaust	10.04	20	1.27	8.02	0.36	Based on satellite imagery the stack appears to be capped/downblast
EF7	Extruder area general exhaust	10.04	20	1.27	8.02	0.36	Based on satellite imagery the stack appears to be capped/downblast

Assume use of HDPE - maximum production rate is 24,420,000 kilograms of resins used per year.

HDPE Extrusion at 430 ^{o}F - Source AWMA Journal Article "Development of Emission Factors for Polyethylene Processing 1998)" by Anthony Barlow et. al.

CASRN	Substance	Emission Factor ($lbs/10^6$ lbs)	Emission Factor (kg/Mg)	Annual Emissions (kg)	Hourly Emissions (g/s)	Daily Emissions (g/s)	Annual Emissions (g/s)
N/A(9)	Suspended Particulate Matter	26.6	2.66E-02	649.57	3.01E-02	3.01E-02	2.06E-02
NA-M09	Suspended Particulate Matter - PM10	26.6	2.66E-02	649.57	3.01E-02	3.01E-02	2.06E-02
NA-M10	Suspended Particulate Matter - PM2.5	26.6	2.66E-02	649.57	3.01E-02	3.01E-02	2.06E-02
69430-33-7	Heavy Hydrocarbons (aliphatic hydrocarbon blend)	38.5	3.85E-02	940.17	4.35E-02	4.35E-02	2.98E-02
74-84-0	Ethane	0.02	2.00E-05	0.49	2.26E-05	2.26E-05	1.55E-05
74-85-1	Ethylene	0.01	1.00E-05	0.24	1.13E-05	1.13E-05	7.74E-06
115-07-1	Propylene	0.01	1.00E-05	0.24	1.13E-05	1.13E-05	7.74E-06
50-00-0	Formaldehyde	0.06	6.00E-05	1.47	6.78E-05	6.78E-05	4.65E-05
107-02-8	Acrolein	0.02	2.00E-05	0.49	2.26E-05	2.26E-05	1.55E-05
75-07-0	Acetaldehyde	0.05	5.00E-05	1.22	5.65E-05	5.65E-05	3.87E-05
123-38-6	Propionaldehyde	0.02	2.00E-05	0.49	2.26E-05	2.26E-05	1.55E-05
67-64-1	Acetone	0.03	3.00E-05	0.73	3.39E-05	3.39E-05	2.32E-05
123-72-8	Butyraldehyde	0.02	2.00E-05	0.49	2.26E-05	2.26E-05	1.55E-05
78-93-3	Methyl Ethyl Ketone	0.02	2.00E-05	0.49	2.26E-05	2.26E-05	1.55E-05
64-18-6	Formic Acid	0.17	1.70E-04	4.15	1.92E-04	1.92E-04	1.32E-04
64-19-7	Acetic Acid	0.17	1.70E-04	4.15	1.92E-04	1.92E-04	1.32E-04
79-10-7	Acrylic Acid	0.02	2.00E-05	0.49	2.26E-05	2.26E-05	1.55E-05

Printers

Source ID	Description	Stack Gas Flow Rate (m^3/s)	Stack Gas Temperature (deg C)	Stack Diameter (m)	Stack Height Above Grade (m)	Stack Height Above Roof (m)	Notes
EF14	Exhaust system serving a dry offset printing press	0.86	20	0.23	9.1	1.5	Based on satellite imagery the stack appears to be capped/downblast
EF15	Exhaust system serving two (2) dry offset printing presses	0.43	20	0.23	9.1	1.5	Based on satellite imagery the stack appears to be capped/downblast

Dry Offset Printing Emissions - Source AWMA Journal Article "Determination of VOC Emission Rates and Compositions for Offset Printing (2012)" by R.A. Wadden et.al.

CASRN	Substance	Emission Factor	Hourly Emissions (g/s)	Daily Emissions (g/s)	Annual Emissions (g/s)
NA	Total VOC	0.0759 kg/hr	2.11E-02	2.11E-02	1.44E-02
110-54-3	n-Hexane	1.02%	2.15E-04	2.15E-04	1.47E-04
67-63-0	Isopropyl Alcohol	12.78%	2.69E-03	2.69E-03	1.85E-03
71-43-2	Benzene	2.60%	5.48E-04	5.48E-04	3.75E-04
108-88-3	Toluene	3.55%	7.48E-04	7.48E-04	5.13E-04
100-41-4	Ethylbenzene	0.81%	1.71E-04	1.71E-04	1.17E-04
1330-20-7	Xylene	2.89%	6.09E-04	6.09E-04	4.17E-04
103-65-1	n-Propylbenzene	2.29%	4.83E-04	4.83E-04	3.31E-04
620-14-4	Ethyltoluene	12.67%	2.67E-03	2.67E-03	1.83E-03
538-93-2	Isobutyl benzene	0.52%	1.10E-04	1.10E-04	7.51E-05
108-67-8	1,3,5-Trimethylbenzene	3.10%	6.54E-04	6.54E-04	4.48E-04
25340-17-4	Diethylbenzene	1.39%	2.93E-04	2.93E-04	2.01E-04
526-73-8	1,2,3-Trimethylbenzene	1.16%	2.45E-04	2.45E-04	1.68E-04

Natural Gas Combustion

Assumed heating capacity of natural gas to be 1 020 Btu per scf

AP-42 Emission Factors ($lbs/10^6$ scf)

Capacity (Btu/hr)	Class	Controls	NOx	Data Quality
0	residential	Uncontrolled	94	B
300,000	small boilers	Uncontrolled	100	B
100,000,000	large boilers	Uncontrolled	190	A

Stack ID	Description	Input Capacity (Btu/hr)	Input Capacity (SCF/hr)	AP-42 Category	Controls	Parameter	Emission Factor ($lbs/10^6$ scf)	Emission Rate (lbs/hr)	Emission Rate (g/s)
BC	Makeup Air Units (10) - MAU1 to MAU10	3,674,000	3601.96	small boilers	U	NOx	100	3.60E-01	4.54E-02
	Unit Heaters (12) - UH1 - UH12	1,800,000	1764.71	small boilers	U	NOx	100	1.76E-01	2.23E-02

Cooling Towers - Environment Canada NPRI Cooling Tower Spreadsheet

Suspended Particulate Matter

Equipment ID	Description	Recirc. Rate (L/s)	Recirc. Rate (m^3/hr)	% Liquid Drift	TDS (ppm)	SPM Emissions (g/s)	PM10 Emissions (g/s)	PM2.5 Emissions (g/s)
CT1	Cooling towers	34.1	122.76	0.02%	3000	2.05E-02	5.69E-03	4.09E-05
CT2		34.1	122.76	0.02%	3000	2.05E-02	5.69E-03	4.09E-05
CT3		69.3	249.48	0.02%	3000	4.16E-02	1.16E-02	8.32E-05
CT4		69.3	249.48	0.02%	3000	4.16E-02	1.16E-02	8.32E-05

PM10 Emissions are 27.8% of SPM emissions as per Environment Canada spreadsheet - interpolated Drift Data for Intermediate Mist Elimiators (Table 2)

PM2.5 Emissions are 0.2% of SPM emissions as per Environment Canada spreadsheet - interpolated Drift Data for Intermediate Mist Elimiators (Table 2)

Summary of Estimated Emissions from Bericap Operations

CASRN	Substance	Hourly Emissions (g/s)	Daily Emissions (g/s)	Annual Emissions (g/s)	Significant?
526-73-8	1,2,3-Trimethylbenzene	2.45E-04	2.45E-04	1.68E-04	No
108-67-8	1,3,5-Trimethylbenzene	6.54E-04	6.54E-04	4.48E-04	No
75-07-0	Acetaldehyde	5.65E-05	5.65E-05	3.87E-05	No
64-19-7	Acetic Acid	1.92E-04	1.92E-04	1.32E-04	No
67-64-1	Acetone	3.39E-05	3.39E-05	2.32E-05	No
107-02-8	Acrolein	2.26E-05	2.26E-05	1.55E-05	Yes
79-10-7	Acrylic Acid	2.26E-05	2.26E-05	1.55E-05	No
71-43-2	Benzene	5.48E-04	5.48E-04	3.75E-04	Yes
123-72-8	Butyraldehyde	2.26E-05	2.26E-05	1.55E-05	No
25340-17-4	Diethylbenzene	2.93E-04	2.93E-04	2.01E-04	No
74-84-0	Ethane	2.26E-05	2.26E-05	1.55E-05	No
100-41-4	Ethylbenzene	1.71E-04	1.71E-04	1.17E-04	Yes
74-85-1	Ethylene	1.13E-05	1.13E-05	7.74E-06	Yes
620-14-4	Ethyltoluene	2.67E-03	2.67E-03	1.83E-03	No
50-00-0	Formaldehyde	6.78E-05	6.78E-05	4.65E-05	Yes
64-18-6	Formic Acid	1.92E-04	1.92E-04	1.32E-04	No
69430-33-7	Heavy Hydrocarbons (aliphatic hydrocarbon blend)	4.35E-02	4.35E-02	2.98E-02	Yes
538-93-2	Isobutyl benzene	1.10E-04	1.10E-04	7.51E-05	No
67-63-0	Isopropyl Alcohol	2.69E-03	2.69E-03	1.85E-03	No
78-93-3	Methyl Ethyl Ketone	2.26E-05	2.26E-05	1.55E-05	No
110-54-3	n-Hexane	2.15E-04	2.15E-04	1.47E-04	No
103-65-1	n-Propylbenzene	4.83E-04	4.83E-04	3.31E-04	No
10102-44-0	Nitrogen Oxides	6.77E-02	6.77E-02	4.64E-02	Yes
123-38-6	Propionaldehyde	2.26E-05	2.26E-05	1.55E-05	No
115-07-1	Propylene	1.13E-05	1.13E-05	7.74E-06	No
N/A(9)	Suspended Particulate Matter	1.54E-01	1.54E-01	1.06E-01	Yes
NA-M09	Suspended Particulate Matter - PM10	6.46E-02	6.46E-02	4.42E-02	Yes
NA-M10	Suspended Particulate Matter - PM2.5	3.03E-02	3.03E-02	2.08E-02	Yes
108-88-3	Toluene	7.48E-04	7.48E-04	5.13E-04	No
NA	Total VOC	2.11E-02	2.11E-02	1.44E-02	No
1330-20-7	Xylene	6.09E-04	6.09E-04	4.17E-04	Yes

Laurel Steel (Harris Steel)
Emission Calculations

Current ECA 9602-A5WQQK (LoF)
ECA Facility Production Limit 294,000 tonnes of steel bar and wire mesh products per year

ECA Facility Description:
A low carbon and carbon free machining steel product manufacturing facility, consisting of thefollowing processes and support units:
- coil blasting;
- pickling; - mesh fabrication; - drawing machines; - teurema line; - galvanizing line;

Baghouse Dust Collector Emissions

Source ID	Description	Stack Gas Flow Rate (m^3/s)	Stack Gas Temperature (deg C)	Stack Diameter (m)	Stack Height Above Grade (m)	Stack Height Above Roof (m)	Notes
DB	Draw Bench #106 Baghouse	1.7	20	NA	NA	NA	Equipped with secondary filtration - discharges back into building
CB	Coil Blaster Cartridge Dust Collector	4.7	20	NA	NA	NA	Equipped with secondary filtration - discharges back into building
ILD1	Inline Drawing Machine Baghouse	0.6	20	NA	NA	NA	Discharges back into building
WD1	Drawing Machine #68 Portable Baghouse	0.4	20	NA	NA	NA	Discharges back into building
WD2	Drawing Machine #75/81 Cartridge Dust Collector	2.6	20	NA	NA	NA	Equipped with secondary filtration - discharges back into building
WD3	Drawing Machine #80 Cartridge Dust Collector	2.0	20	NA	NA	NA	Equipped with secondary filtration - discharges back into building
MF1	Mesh Line #131 Cartridge Dust Collector	3.8	20	NA	NA	NA	Equipped with secondary filtration - discharges back into building
TL1	Teurema Line Sanding & Descaling Cartridge Dust Collector	2.4	20	NA	NA	NA	Equipped with secondary filtration - discharges back into building
TL2	Teurema Line Up-ender Tower Cartridge Dust Collector	6.4	20	NA	NA	NA	Equipped with secondary filtration - discharges back into building
GL1	Galvanizing Line Sander& Descaler Cartridge Dust Collector	6.4	20	NA	NA	NA	Equipped with secondary filtration - discharges back into building
GV	General Exhaust System in proximity to dust collectors	78.4	20	NA	NA	NA	Eleven (11) roof exhausts and 1 wall exhaust - combined flow

Assume concentration in plant is less than MOL TWA of 10 mg/m^3 with internally venting dust collectors.

Suspended particulate matter source concentration	5	mg/m^3
Suspended particulate matter emission rate	3.92E-01	g/s - Assume released by all general exhausts in vicinity at combined flow rate
PM10 emission rate	3.43E-01	g/s - Assume 87.5% of SPM - Source: "Characterization of Fine Particles from Machining in Automotive Plants" Dasch, Jean et. al. 2005 - Table II)
PM2.5 emission rate	1.68E-01	g/s - Assume 42.9% of SPM - Source: "Characterization of Fine Particles from Machining in Automotive Plants" Dasch, Jean et. al. 2005 - Table II)
Zinc Oxide Emissions (GL1)	3.20E-02	g/s - Assume 5 mg/m^3 outlet concentration and 100% ZnO

Metal Emissions

CASRN	Substance	% in Steel	Emission Rate (g/s)
7429-90-5	Aluminum	0.002%	7.84E-06
7440-38-2	Arsenic and compounds	0.007%	2.74E-05
1305-78-8	Calcium	0.0009%	3.53E-06
7440-44-0	Carbon	0.202%	7.92E-04
7440-47-3	Chromium (di, tri and metallic)	0.154%	6.04E-04
7440-48-4	Cobalt	0.009%	3.53E-05
7440-50-8	Copper	0.230%	9.02E-04
7439-89-6	Iron	49.1%	1.93E-01
1309-37-1	Ferric Oxide	49.1%	1.93E-01
7439-92-1	Lead and compounds	0.0072%	2.82E-05
7439-96-5	Manganese and compounds	0.75%	2.94E-03
7439-98-7	Molybdenum	0.019%	7.45E-05
7440-02-0	Nickel and compounds	0.106%	4.16E-04
7723-14-0	Phosphorus	0.012%	4.70E-05
7440-21-3	Silicon	0.230%	9.02E-04
7704-34-9	Sulphur	0.025%	9.80E-05
7440-31-5	Tin	0.010%	3.92E-05
7440-62-2	Vanadium	0.002%	7.84E-06

Source ID	Description	Stack Gas Flow Rate (m^3/s)	Stack Gas Temperature (deg C)	Stack Diameter (m)	Stack Height Above Grade (m)	Stack Height Above Roof (m)	Notes
CDM1	Drawing Machine #97 Cartridge Dust Collector	2.5	20	NA	NA	NA	Equipped with secondary filtration - discharges to tertiary filter
CDM2	Drawing Machine #124 Cartridge Dust Collector	2.5	20	NA	NA	NA	Equipped with secondary filtration - discharges to tertiary filter
CDM3	Drawing Machine #136 Cartridge Dust Collector	2.5	20	NA	NA	NA	Equipped with secondary filtration - discharges to tertiary filter
CDM4	Drawing Machine #123 Cartridge Dust Collector	3.2	20	NA	NA	NA	Equipped with secondary filtration - discharges to tertiary filter
CDM5	Drawing Machine #126 Cartridge Dust Collector	3.2	20	NA	NA	NA	Equipped with secondary filtration - discharges to tertiary filter
CDM	Dust Collector Room Ventilation/Exhaust System	9.1	20	0.8	10.0	2.0	Tertiary high efficiency filtration

Assume outlet concentration after tertiary HE filtration is 1 mg/m^3

Suspended particulate matter source concentration	1	mg/m^3
Suspended particulate matter emission rate	0.0091	g/s
PM10 emission rate	7.96E-03	g/s - Assume 87.5% of SPM - Source: "Characterization of Fine Particles from Machining in Automotive Plants" Dasch, Jean et. al. 2005 - Table II)
PM2.5 emission rate	3.90E-03	g/s - Assume 42.9% of SPM - Source: "Characterization of Fine Particles from Machining in Automotive Plants" Dasch, Jean et. al. 2005 - Table II)

Metal Emissions

CASRN	Substance	% in Steel	Emission Rate (g/s)
7429-90-5	Aluminum	0.002%	1.82E-07
7440-38-2	Arsenic and compounds	0.007%	6.37E-07
1305-78-8	Calcium	0.0009%	8.19E-08
7440-44-0	Carbon	0.202%	1.84E-05
7440-47-3	Chromium (di, tri and metallic)	0.154%	1.40E-05
7440-48-4	Cobalt	0.009%	8.19E-07
7440-50-8	Copper	0.230%	2.09E-05
7439-89-6	Iron	49.1%	4.47E-03
1309-37-1	Ferric Oxide	49.1%	4.47E-03
7439-92-1	Lead and compounds	0.0072%	6.55E-07
7439-96-5	Manganese and compounds	0.75%	6.83E-05
7439-98-7	Molybdenum	0.019%	1.73E-06
7440-02-0	Nickel and compounds	0.106%	9.65E-06
7723-14-0	Phosphorus	0.012%	1.09E-06
7440-21-3	Silicon	0.230%	2.09E-05
7704-34-9	Sulphur	0.025%	2.28E-06
7440-31-5	Tin	0.010%	9.10E-07
7440-62-2	Vanadium	0.002%	1.82E-07

Source ID	Description	Stack Gas Flow Rate (m^3/s)	Stack Gas Temperature (deg C)	Stack Diameter (m)	Stack Height Above Grade (m)	Stack Height Above Roof (m)	Notes
MF2	Mesh Line #139 Cartridge Dust Collector	3.8	20	0.6	10.0	2.0	Equipped with secondary filtration

Assume outlet concentration after secondary filtration is 5 mg/m^3

Suspended particulate matter source concentration	5	mg/m^3	
Suspended particulate matter emission rate	0.019	g/s	
PM10 emission rate	1.66E-02	g/s - Assume 87.5% of SPM - Source: "Characterization of Fine Particles from Machining in Automotive Plants" Dasch, Jean et. al. 2005 - Table II)	
PM2.5 emission rate	8.15E-03	g/s - Assume 42.9% of SPM - Source: "Characterization of Fine Particles from Machining in Automotive Plants" Dasch, Jean et. al. 2005 - Table II)	

Metal Emissions

CASRN	Substance	% in Steel	Emission Rate (g/s)
7429-90-5	Aluminum	0.002%	3.80E-07
7440-38-2	Arsenic and compounds	0.007%	1.33E-06
1305-78-8	Calcium	0.0009%	1.71E-07
7440-44-0	Carbon	0.202%	3.84E-05
7440-47-3	Chromium (di, tri and metallic)	0.154%	2.93E-05
7440-48-4	Cobalt	0.009%	1.71E-06
7440-50-8	Copper	0.230%	4.37E-05
7439-89-6	Iron	49.1%	9.33E-03
1309-37-1	Ferric Oxide	49.1%	9.33E-03
7439-92-1	Lead and compounds	0.0072%	1.37E-06
7439-96-5	Manganese and compounds	0.75%	1.43E-04
7439-98-7	Molybdenum	0.019%	3.61E-06
7440-02-0	Nickel and compounds	0.106%	2.01E-05
7723-14-0	Phosphorus	0.012%	2.28E-06
7440-21-3	Silicon	0.230%	4.37E-05
7704-34-9	Sulphur	0.025%	4.75E-06
7440-31-5	Tin	0.010%	1.90E-06
7440-62-2	Vanadium	0.002%	3.80E-07

Galvanizing Line Emissions

Source ID	Description	Stack Gas Flow Rate (m^3/s)	Stack Gas Temperature (deg C)	Stack Diameter (m)	Stack Height Above Grade (m)	Stack Height Above Roof (m)	Notes
PS	Steel Coil Pickling Wet Scrubber	15.1	20	2.1	10.1	2.1	

Hydochloric acid emissions per tank	1553.8	kg per year (uncontrolled) 16% HCl solution, 20^{o}C - Australia Environment Emission Estimation Technique Manual for Galvanizing v2.0 July 2012
	6215.2	kg per year (uncontrolled) all 4 tanks
Scrubber control factor	95%	
Controlled emissions	310.76	kg per year
Scrubber emission rate	9.85E-03	g/s - Assumes scrubber operates continously throughout the year

Natural Gas Combustion

Assumed heating capacity of natural gas to be 1 020 Btu per scf

AP-42 Emission Factors (lbs/10^6 scf)

Capacity (Btu/hr)	Class	Controls	NOx	Data Quality
0	residential	Uncontrolled	94	B
300,000	small boilers	Uncontrolled	100	B
100,000,000	large boilers	Uncontrolled	190	A

Stack ID	Description	Input Capacity (Btu/hr)	Input Capacity (SCF/hr)	AP-42 Category	Controls	Parameter	Emission Factor (lbs/10^6 scf)	Emission Rate (lbs/hr)	Emission Rate (g/s)
B	Natural gas fired boiler	5,900,000	5784.31	small boilers	U	NOx	100	5.78E-01	7.29E-02
NGCH	Natural gas comfort heat (36 heaters, 24 IR heaters)	10,085,000	9887.25	small boilers	U	NOx	100	9.89E-01	1.25E-01

Cooling Towers - Environment Canada NPRI Cooling Tower Spreadsheet

Suspended Particulate Matter

Equipment ID	Description	Recirc. Rate (L/s)	Recirc. Rate (m^3/hr)	% Liquid Drift	TDS (ppm)	SPM Emissions (g/s)	PM10 Emissions (g/s)	PM2.5 Emissions (g/s)
CT1	Mesh line and hydraulic unit cooling tower	6.3	22.68	0.02%	3000	3.78E-03	1.05E-03	7.56E-06
CT2	Galvanizing line cooling tower	6.3	22.68	0.02%	3000	3.78E-03	1.05E-03	7.56E-06
CT3	Galvanizing line cooling tower	6.3	22.68	0.02%	3000	3.78E-03	1.05E-03	7.56E-06

Summary of Estimated Emissions from Harris Steel Operations

CASRN	Substance	Hourly Emissions (g/s)	Daily Emissions (g/s)	Annual Emissions (g/s)	Significant?
7429-90-5	Aluminum	8.40E-06	8.40E-06	8.40E-06	No
7440-38-2	Arsenic and compounds	2.94E-05	2.94E-05	2.94E-05	Yes
1305-78-8	Calcium	3.78E-06	3.78E-06	3.78E-06	No
7440-44-0	Carbon	8.49E-04	8.49E-04	8.49E-04	No
7440-47-3	Chromium (di, tri and metallic)	6.47E-04	6.47E-04	6.47E-04	Yes
7440-48-4	Cobalt	3.78E-05	3.78E-05	3.78E-05	Yes
7440-50-8	Copper	9.66E-04	9.66E-04	9.66E-04	No
7647-01-0	Hydrogen Chloride	9.85E-03	9.85E-03	9.85E-03	Yes
7439-89-6	Iron	2.06E-01	2.06E-01	2.06E-01	Yes
1309-37-1	Ferric Oxide	2.06E-01	2.06E-01	2.06E-01	Yes
7439-92-1	Lead and compounds	3.02E-05	3.02E-05	3.02E-05	Yes
7439-96-5	Manganese and compounds	3.15E-03	3.15E-03	3.15E-03	Yes
7439-98-7	Molybdenum	7.98E-05	7.98E-05	7.98E-05	No
7440-02-0	Nickel and compounds	4.45E-04	4.45E-04	4.45E-04	Yes
10102-44-0	Nitrogen Oxides	1.98E-01	1.98E-01	1.98E-01	Yes
7723-14-0	Phosphorus	5.04E-05	5.04E-05	5.04E-05	Yes
7440-21-3	Silicon	9.66E-04	9.66E-04	9.66E-04	Yes
7704-34-9	Sulphur	1.05E-04	1.05E-04	1.05E-04	No
N/A(9)	Suspended Particulate Matter	4.31E-01	4.31E-01	4.31E-01	Yes
NA-M09	Suspended Particulate Matter - PM10	3.71E-01	3.71E-01	3.71E-01	Yes
NA-M10	Suspended Particulate Matter - PM2.5	1.80E-01	1.80E-01	1.80E-01	Yes
7440-31-5	Tin	4.20E-05	4.20E-05	4.20E-05	No
7440-62-2	Vanadium	8.40E-06	8.40E-06	8.40E-06	No
7440-66-6	Zinc	3.20E-02	3.20E-02	3.20E-02	Yes

Emissions from Rail Traffic

Based on U.S. EPA Document EPA420-F-09-025 titled Technical Highlights - Emission Factors for Locomotives

Assumptions for GO Transit Rail Fleet
Mix of EPA Tier 2, Tier 3 and Tier 4 compliant locomotives

Brake horsepower	4000	Estimated fuel use	32.0 L/hr
Number of trains per day	84	Diesel sulphur concentration	15 ppm
Number of trains per hour	5		
Time trains in vicinity of site	2	minutes per train - total of 10 minutes per hour	

Engine Emission Factors - U.S. EPA Tier 4 Compliance

Substance	CASRN	Emission Factor (g/bhp-hr)	Hourly Emission Rate (g/s)	Daily Emission Rate (g/s)	Annual Emission Rate (g/s)	Significant?
Hydrocarbons	NA	0.04	7.41E-03	5.56E-03	5.56E-03	No
Carbon Monoxide	630-08-0	1.28	2.37E-01	1.78E-01	1.78E-01	Yes
Nitrogen Oxides	10102-44-0	1.00	1.85E-01	1.39E-01	1.39E-01	Yes
Sulphur Dioxide*	7446-09-5	0.02 g/L	2.96E-05	2.22E-05	2.22E-05	Yes
Suspended Particulate Matter	N/A(9)	0.015	2.78E-03	2.08E-03	2.08E-03	Yes
Suspended Particulate Matter - PM10	NA-M09	0.015	2.78E-03	2.08E-03	2.08E-03	Yes
Suspended Particulate Matter - PM2.5	NA-M10	0.015	2.78E-03	2.08E-03	2.08E-03	Yes

* - Factor taken from "Locomotive Emissions Report 2023" published by the Railway Association of Canada.

Speciated Hydrocarbons - EPA SPECIATE Profile 116GROCa - Diesel Exhaust Emissions from Tier 2-3 Off-road Engines

Substance	CASRN	Concentration (%)	Hourly Emission Rate (g/s)	Daily Emission Rate (g/s)	Annual Emission Rate (g/s)	Significant?
Isobutyraldehyde	78-84-2	0.629%	4.66E-05	3.50E-05	3.50E-05	No
Methylbenzaldehyde	104-87-0	0.678%	5.03E-05	3.77E-05	3.77E-05	No
Acetaldehyde	75-07-0	7.100%	5.26E-04	3.94E-04	3.94E-04	No
Acetylene	74-86-2	0.833%	6.17E-05	4.63E-05	4.63E-05	No
Acrolein	107-02-8	1.266%	9.38E-05	7.03E-05	7.03E-05	Yes
Benzaldehyde	100-52-7	0.524%	3.88E-05	2.91E-05	2.91E-05	Yes
Benzene	71-43-2	3.786%	2.80E-04	2.10E-04	2.10E-04	Yes
C9-c12 isoalkanes	64742-82-1	4.535%	3.36E-04	2.52E-04	2.52E-04	No
Crotonaldehyde	4170-30-3	2.356%	1.75E-04	1.31E-04	1.31E-04	Yes
Ethylbenzene	100-41-4	0.289%	2.14E-05	1.61E-05	1.61E-05	Yes
Ethylene	74-85-1	13.749%	1.02E-03	7.64E-04	7.64E-04	Yes
Formaldehyde	50-00-0	19.856%	1.47E-03	1.10E-03	1.10E-03	Yes
Isobutane	75-28-5	0.490%	3.63E-05	2.72E-05	2.72E-05	No
1,3-butadiene	106-99-0	0.139%	1.03E-05	7.72E-06	7.72E-06	No
1-hexene	592-41-6	0.111%	8.19E-06	6.14E-06	6.14E-06	No
1-pentene	109-67-1	0.166%	1.23E-05	9.22E-06	9.22E-06	No
Isooctane	540-84-1	0.543%	4.02E-05	3.01E-05	3.01E-05	No
2,2-dimethylpentane	590-35-2	0.040%	2.98E-06	2.24E-06	2.24E-06	No
2,3,3-trimethylpentane	560-21-4	0.282%	2.09E-05	1.57E-05	1.57E-05	Yes
2,3,4-trimethylpentane	565-75-3	0.340%	2.52E-05	1.89E-05	1.89E-05	No
2,3-dimethylpentane	565-59-3	0.218%	1.62E-05	1.21E-05	1.21E-05	No
2,4-dimethylpentane	108-08-7	0.272%	2.01E-05	1.51E-05	1.51E-05	No
2,6-dimethylheptane	1072-05-5	0.074%	5.49E-06	4.11E-06	4.11E-06	No
2-methyl-1-butene	563-46-2	0.425%	3.15E-05	2.36E-05	2.36E-05	No
2-methyl-1-pentene	763-29-1	0.111%	8.19E-06	6.14E-06	6.14E-06	No
2-methyl-2-butene	513-35-9	0.221%	1.64E-05	1.23E-05	1.23E-05	No
2-methylpentane (isohexane)	107-83-5	0.163%	1.21E-05	9.08E-06	9.08E-06	No
3-methylheptane	589-81-1	0.143%	1.06E-05	7.94E-06	7.94E-06	No
3-methyloctane	2216-33-3	0.148%	1.10E-05	8.23E-06	8.23E-06	No
3-methylpentane	96-14-0	0.028%	2.05E-06	1.54E-06	1.54E-06	No
4-methyl-1-pentene	691-37-2	0.287%	2.12E-05	1.59E-05	1.59E-05	No
Xylene	1330-20-7	0.797%	5.90E-05	4.43E-05	4.43E-05	Yes
Methane	74-82-8	8.280%	6.13E-04	4.60E-04	4.60E-04	No
2-Butanone	78-93-3	0.629%	4.66E-05	3.50E-05	3.50E-05	No
Methylcyclopentane	96-37-7	0.040%	2.98E-06	2.24E-06	2.24E-06	No
N-butane	106-97-8	0.408%	3.03E-05	2.27E-05	2.27E-05	No
N-octane	111-65-9	0.171%	1.27E-05	9.49E-06	9.49E-06	No
N-pentane	109-66-0	1.165%	8.63E-05	6.47E-05	6.47E-05	No
N-undecane	1120-21-4	0.568%	4.21E-05	3.15E-05	3.15E-05	No
Propane	74-98-6	0.111%	8.19E-06	6.14E-06	6.14E-06	No
Propionaldehyde	123-38-6	1.483%	1.10E-04	8.24E-05	8.24E-05	No
Propylcyclopentane	2040-96-2	0.074%	5.49E-06	4.11E-06	4.11E-06	No
Toluene	108-88-3	2.556%	1.89E-04	1.42E-04	1.42E-04	No
Trans-2-pentene	646-04-8	0.397%	2.94E-05	2.21E-05	2.21E-05	No
Valeraldehyde	110-62-3	0.138%	1.02E-05	7.68E-06	7.68E-06	No
2,5-Dimethylbenzaldehyde	5779-94-2	0.390%	2.89E-05	2.17E-05	2.17E-05	No

Fugitive Emissions from Paved Roads - Source SLINE4

Based on AP-42 Chapter 13.2.1

U.S. AP-42 Equation: $E = k * (sL)^{0.91} * (W)^{1.02}$

U.S EPA AP-42 Paved Roads Fugitive Emissions Factors Equation 1 (Chapter 13.2.1)

Equation Inputs

Factors From Table 13.2.2-2 U.S EPA AP-42

k (g/VKT) for PM2.5:	0.15
k (g/VKT) for PM10:	0.62
k (g/VKT) for TSP:	3.23
Silt Content SLINE1 (g/m^2):	0.03

Taken from Table 13.2.1-2 in AP-42 Chapter 13.2.1 for baseline silt loadings on ADT>10,000 roads.

Average Vehicle Weights (tons)

Passenger Vehicles (~97% of all traffic)	2.00	
Burloak Drive from Harvester Rd to Superior Crt	2,841	Maximum Hourly Traffic
	31,016	Maximum Daily Traffic

	PM2.5	PM10	TSP
Vehicle Emission Factors (g/VKT)	0.013	0.052	0.269

VKT (Vehicle Kilometer Travelled) Calculations

Road Segment ID	One Way Distance (km)	Percentage Used	Number of Vehicles per Day	Vehicle Kilometer Travelled (km/day)
SLINE4	0.613	100%	31,016	19012.808
Total		100%	31016	19012.808

Emission Calculations

Source Description	Distance Travelled By all Vehicles (VKT)	Emissions (g/s) TSP	PM10	PM2.5
SLINE4 - Burloak Drive (Hourly Maximum)	2841	2.13E-01	4.08E-02	9.87E-03
SLINE4 - Burloak Drive (Daily)	19012.81	5.93E-02	1.14E-02	2.75E-03

Notes:

VKT - vehicle kilometres travelled

Metals Emissions from Segment A - EPA SPECIATE Profile 4113030

Substance	CAS (#)	Metal Concentration (%)	Hourly Emission Rate (g/s)	Daily Emission Rate (g/s)	Annual Emission Rate (g/s)
Aluminum	7429-90-5	1.649%	3.51E-03	9.78E-04	9.78E-04
Antimony	7440-36-0	0.008%	1.70E-05	4.74E-06	4.74E-06
Arsenic	7440-38-2	0.015%	3.19E-05	8.89E-06	8.89E-06
Barium	7440-39-3	0.028%	5.95E-05	1.66E-05	1.66E-05
Cadmium	7440-43-9	0.004%	8.50E-06	2.37E-06	2.37E-06
Calcium	1305-78-8	0.887%	1.89E-03	5.26E-04	5.26E-04
Chromium	7440-47-3	0.005%	1.06E-05	2.96E-06	2.96E-06
Copper	7440-50-8	0.051%	1.08E-04	3.02E-05	3.02E-05
Indium	7440-74-6	0.002%	4.25E-06	1.19E-06	1.19E-06
Iron	7439-89-6	1.03%	2.19E-03	6.11E-04	6.11E-04
Lead	7439-92-1	0.204%	4.34E-04	1.21E-04	1.21E-04
Manganese	7439-96-5	0.024%	5.10E-05	1.42E-05	1.42E-05
Nickel	7440-02-0	0.002%	4.25E-06	1.19E-06	1.19E-06
Phosphorus	7723-14-0	0.032%	6.80E-05	1.90E-05	1.90E-05
Potassium	7440-09-7	0.268%	5.70E-04	1.59E-04	1.59E-04
Silicon	7440-21-3	5.274%	1.12E-02	3.13E-03	3.13E-03
Strontium	7440-24-6	0.008%	1.70E-05	4.74E-06	4.74E-06
Sulphur	7704-34-9	0.111%	2.36E-04	6.58E-05	6.58E-05
Tin	7440-31-5	0.011%	2.34E-05	6.52E-06	6.52E-06
Titanium	7440-32-6	0.112%	2.38E-04	6.64E-05	6.64E-05
Vanadium	7440-62-2	0.007%	1.49E-05	4.15E-06	4.15E-06
Zinc	7440-66-6	0.129%	2.74E-04	7.65E-05	7.65E-05
Zirconium	7440-67-7	0.001%	2.13E-06	5.93E-07	5.93E-07

Vehicle Exhaust and Brake Emissions

Based on California Air Resources Board (CARB) Methods to Find the Cost-Effectiveness of Funding Air Quality Projects - For Evaluating Motor Vehicle Registration Fee Projects and Congestion Mitigation and Air Quality Improvement (CMAQ) Projects - Emission Factor Tables dated November 2021 (Table 3A - Average Auto Emission Factors)

Substance	CASRN	Emission Factor (g/km)	Hourly Emission Rate (g/s)	Daily Emission Rate (g/s)	Annual Emission Rate (g/s)
Volatile Organic Compounds (ROG)	NA	0.056	2.71E-02	1.23E-02	1.23E-02
Nitrogen Oxides	10102-44-0	0.060	2.89E-02	1.31E-02	1.31E-02
Suspended Particulate Matter (Exhaust)	N/A(9)	0.0019	9.02E-04	4.10E-04	4.10E-04
Suspended Particulate Matter - PM10	NA-M09	0.0019	9.02E-04	4.10E-04	4.10E-04
Suspended Particulate Matter - PM2.5	NA-M10	0.0019	9.02E-04	4.10E-04	4.10E-04
Suspended Particulate Matter (Brake and Tire)	N/A(9)	0.0124	6.01E-03	2.74E-03	2.74E-03
Suspended Particulate Matter - PM10	NA-M09	0.0124	6.01E-03	2.74E-03	2.74E-03
Suspended Particulate Matter - PM2.5	NA-M10	0.0124	6.01E-03	2.74E-03	2.74E-03
Carbon Monoxide	630-08-0	0.746	3.61E-01	1.64E-01	1.64E-01

Speciated ROG - EPA SPECIATE Profile 2540 - Vehicle Emissions: Roadway: Busy Intersection

Substance	CASRN	Concentration (%)	Hourly Emission Rate (g/s)	Daily Emission Rate (g/s)	Annual Emission Rate (g/s)
Acetylene	74-86-2	5.720%	1.55E-03	7.04E-04	7.04E-04
Benzene	71-43-2	2.960%	8.01E-04	3.64E-04	3.64E-04
Ethane	74-84-0	1.770%	4.79E-04	2.18E-04	2.18E-04
Ethylbenzene	100-41-4	1.230%	3.33E-04	1.51E-04	1.51E-04
Ethylene	74-85-1	7.030%	1.90E-03	8.65E-04	8.65E-04
Isopentane	78-78-4	6.040%	1.63E-03	7.43E-04	7.43E-04
Xylene	1330-20-7	5.460%	1.48E-03	6.72E-04	6.72E-04
N-butane	106-97-8	3.140%	8.50E-04	3.86E-04	3.86E-04
N-pentane	109-66-0	2.890%	7.82E-04	3.56E-04	3.56E-04
Propane	74-98-6	0.840%	2.27E-04	1.03E-04	1.03E-04
Propylene	115-07-1	2.510%	6.79E-04	3.09E-04	3.09E-04
Toluene	108-88-3	6.080%	1.65E-03	7.48E-04	7.48E-04

Summary of Roadway Emissions

Substance	CASRN	Hourly Emission Rate (g/s)	Daily Emission Rate (g/s)	Annual Emission Rate (g/s)	Significant?
Acetylene	74-86-2	1.55E-03	7.04E-04	7.04E-04	No
Aluminum	7429-90-5	3.51E-03	9.78E-04	9.78E-04	No
Antimony	7440-36-0	1.70E-05	4.74E-06	4.74E-06	No
Arsenic	7440-38-2	3.19E-05	8.89E-06	8.89E-06	Yes
Barium	7440-39-3	5.95E-05	1.66E-05	1.66E-05	No
Benzene	71-43-2	8.01E-04	3.64E-04	3.64E-04	Yes
Cadmium	7440-43-9	8.50E-06	2.37E-06	2.37E-06	Yes
Calcium	1305-78-8	1.89E-03	5.26E-04	5.26E-04	No
Carbon Monoxide	630-08-0	3.61E-01	1.64E-01	1.64E-01	Yes
Chromium	7440-47-3	1.06E-05	2.96E-06	2.96E-06	Yes
Copper	7440-50-8	1.08E-04	3.02E-05	3.02E-05	No
Ethane	74-84-0	4.79E-04	2.18E-04	2.18E-04	No
Ethylbenzene	100-41-4	3.33E-04	1.51E-04	1.51E-04	Yes
Ethylene	74-85-1	1.90E-03	8.65E-04	8.65E-04	Yes
Indium	7440-74-6	4.25E-06	1.19E-06	1.19E-06	No
Iron	7439-89-6	2.19E-03	6.11E-04	6.11E-04	Yes
Isopentane	78-78-4	1.63E-03	7.43E-04	7.43E-04	No
Lead	7439-92-1	4.34E-04	1.21E-04	1.21E-04	Yes
Manganese	7439-96-5	5.10E-05	1.42E-05	1.42E-05	Yes
N-butane	106-97-8	8.50E-04	3.86E-04	3.86E-04	No
Nickel	7440-02-0	4.25E-06	1.19E-06	1.19E-06	Yes
Nitrogen Oxides	10102-44-0	2.89E-02	1.31E-02	1.31E-02	Yes
N-pentane	109-66-0	7.82E-04	3.56E-04	3.56E-04	No
Phosphorus	7723-14-0	6.80E-05	1.90E-05	1.90E-05	Yes
Potassium	7440-09-7	5.70E-04	1.59E-04	1.59E-04	No
Propane	74-98-6	2.27E-04	1.03E-04	1.03E-04	No
Propylene	115-07-1	6.79E-04	3.09E-04	3.09E-04	No
Silicon	7440-21-3	1.12E-02	3.13E-03	3.13E-03	Yes
Strontium	7440-24-6	1.70E-05	4.74E-06	4.74E-06	No
Sulphur	7704-34-9	2.36E-04	6.58E-05	6.58E-05	No
Suspended Particulate Matter	N/A(9)	2.20E-01	6.24E-02	3.15E-03	Yes
Suspended Particulate Matter - PM10	NA-M09	4.77E-02	1.45E-02	3.15E-03	Yes
Suspended Particulate Matter - PM2.5	NA-M10	1.68E-02	5.90E-03	3.15E-03	Yes
Tin	7440-31-5	2.34E-05	6.52E-06	6.52E-06	No
Titanium	7440-32-6	2.38E-04	6.64E-05	6.64E-05	No
Toluene	108-88-3	1.65E-03	7.48E-04	7.48E-04	No
Vanadium	7440-62-2	1.49E-05	4.15E-06	4.15E-06	No
Xylene	1330-20-7	1.48E-03	6.72E-04	6.72E-04	Yes
Zinc	7440-66-6	2.74E-04	7.65E-05	7.65E-05	Yes
Zirconium	7440-67-7	2.13E-06	5.93E-07	5.93E-07	No

APPENDIX 2
SUPPORTING INFORMATION

ENVIRONMENTAL COMPLIANCE APPROVAL
NUMBER A-500-6213472110
Version: 1.0
Issue Date: April 2, 2025

Pursuant to section 20.3 of the *Environmental Protection Act*, Revised Statutes of Ontario (R.S.O.) 1990, c. E. 19 and subject to all other applicable Acts or regulations this Environmental Compliance Approval is issued to:

ASSOCIATED PAVING & MATERIALS LTD.

5365 MUNRO COURT
BURLINGTON ONTARIO
L7L 5M7

For the following site:

850 SYSCON Court , BURLINGTON, BURLINGTON, ONTARIO, CANADA,
L7L 6C5

Upon issuance of the environmental compliance approval, I hereby revoke Approval No(s) 8840-BCENZE, issued on September 16, 2019.

You have applied under section 20.2 of Part II.1 of the *Environmental Protection Act*, R.S.O. 1990, c. E. 19 (*Environmental Protection Act*) for approval of:

- One (1) permanent drum-type hot mix asphalt (HMA) plant, operating with a maximum production rate of 400 tonnes per hour, 4,000 tonnes HMA per day and 400,000 tonnes of HMA per year; consisting of the following process and support units:
  - one (1) dryer/mixer, equipped with one (1) natural gas fired burner, having a maximum heat input of 142.3 million kilojoules per hour, with particulate emissions controlled by one (1) baghouse dust collector having 1,685 square metres of singed fiber filter bags, and a pulse-jet cleaning mechanism, exhausting into the air at a volumetric flow rate of 42.1 actual cubic metres per second at an approximate temperature of 130 degrees Celsius, through a stack, having an exit diameter of 1.20 metres, extending 16.4 metres above grade;
  - three (3) liquid asphalt cement storage tanks, each having a maximum capacity of 113,550 litres (30,000 US gallons), equipped with one (1) natural gas fired hot-oil heater and air cooled condenser, having a maximum heat input of 2,637,639

kilojoules per hour, discharging into the air through a stack, extending 2.0 metres above grade;

- five (5) hot mix asphalt storage silos, two (2) having a maximum storage capacity of 200 tonnes and three (3) having a maximum storage capacity of 180 tonnes;
- one (1) electric powered (alternatively powered by a 362 kilowatt diesel engine) crusher that is being used to crush broken concrete and broken asphalt, operating with a maximum combined delivery/shipping rate of 200 tonnes per hour and 2,000 tonnes per day;
- fugitive emissions resulting from the delivery, storage, or transfer of raw materials and products associated with hot-mix asphalt production operations;

all in accordance with the Application for Approval (Air & Noise) submitted by Associated Paving & Materials Ltd., dated September 8, 2023 and signed by Kieu Duong - CFO; the supporting information, including the Emission Summary and Dispersion Modelling Report, submitted by ORTECH Consulting Inc., dated September 6, 2023 and signed by Ibrahim Syed; additional information provided by Ibrahim Syed/ORTECH Consulting Inc. dated September 19, 2024 and November 12, 2024; the Acoustic Assessment Report submitted by HGC Engineering, dated July 31, 2024 and signed by Petr Chocensky; and, all other documentation associated with the Application.

DEFINITIONS

For the purpose of this environmental compliance approval, the following definitions apply:

1. "Acoustic Assessment Report" means the report, prepared in accordance with Publication NPC-233 submitted in support of the application, that documents all sources of noise emissions and Noise Control Measures present at the Facility. It also means the Acoustic Assessment Report prepared by Petr Chocensky of HGC Engineering and dated July 31, 2024.
2. "Acoustic Audit" means an investigative procedure consisting of measurements and/or acoustic modelling of all sources of noise emissions due to the operation of the Facility, assessed to determine compliance for the Facility regarding noise emissions, completed in accordance with the procedures set in Publication NPC-103 and reported in accordance with Publication NPC-233.
3. "Acoustic Audit Report" means a report presenting the results of an Acoustic Audit, prepared in accordance with Publication NPC-233.
4. "Acoustical Consultant" means a person currently active in the field of environmental acoustics and noise/vibration control, who is familiar with Ministry noise guidelines and procedures and has a combination of formal university education, training and experience

necessary to assess noise emissions from a facility.

5. "Approval" means this Environmental Compliance Approval, including the application and supporting documentation listed above;
6. "Best Management Practices Plan" means the document titled"Dust Best Management Practices Plan", dated September 6, 2023 and prepared by ORTECH Consulting Inc.;
7. "Company" means Associated Paving & Materials Ltd. that is responsible for the construction or operation of the Facility and includes any successors and assigns in accordance with section 19 of the EPA;
8. "District Manager" means the District Manager of the appropriate local district office of the Ministry, where the Facility is geographically located;
9. "EPA" means the *Environmental Protection Act*, R.S.O. 1990, c.E.19;
10. "Equipment" means the equipment and processes described in the Company`s application, this Approval and in the supporting documentation submitted with the application, to the extent approved by this Approval;
11. "Facility" means the entire operation located on the property where the Equipment is located;
12. "Independent Acoustical Consultant" means an Acoustical Consultant who is not representing the Company and was not involved in preparing the Acoustic Assessment Report or the design/implementation of Noise Control Measures for the Facility and/or Equipment. The Independent Acoustical Consultant shall not be retained by the Acoustical Consultant involved in the noise impact assessment or the design/implementation of Noise Control Measures for the Facility and/or Equipment.
13. "Manual" means a document or a set of documents that provide written instructions to staff of the Company;
14. "Method 22" means the United States Environmental Protection Agency document titled"Method 22 - Visual Determination of Fugitive Emissions from Material Sources and Smoke Emissions from Flares" dated January 14, 2019, as amended;
15. "Ministry" means the ministry of the government of Ontario responsible for the EPA and includes all officials, employees or other persons acting on its behalf;
16. “Noise Abatement Action Plan” means the noise abatement program developed by the Company, submitted to the Director and District Manager and approved by the Director, designed to achieve compliance with the sound level limits set in Publication NPC-300, as applicable. "Noise Abatement Action Plan" also means the noise abatement action plan outlined in Section 8 and Appendix G of the Acoustic Assessment Report.
17. "Noise Control Measures" means measures to reduce the noise emissions from the Facility and/or Equipment including, but not limited to, silencers, acoustic louvres, enclosures,

absorptive treatment, plenums and barriers. It also means the Noise Control Measures identified in the Acoustic Assessment Report and Noise Abatement Action Plan.

18. "Odour Best Management Practices Plan" means the document titled"Odour Best Management Practices Plan", dated November 12, 2024 and prepared by Alliance Technical Group (formerly ORTECH Consulting Inc.);
19. "Professional Engineer" means a Professional Engineer as defined within the *Professional Engineers Act*, R.S.O., c. P.28, as amended;
20. "Publication NPC-103" means the Ministry Publication NPC-103 of the Model Municipal Noise Control By-Law, Final Report, August 1978, published by the Ministry as amended.
21. "Publication NPC-233" means the Ministry Publication NPC-233,"Information to be Submitted for Approval of Stationary Sources of Sound", October 1995.
22. "Publication NPC-300" means the Ministry Publication NPC-300,"Environmental Noise Guideline, Stationary and Transportation Sources - Approval and Planning, Publication NPC-300", August 2013, as amended.

TERMS AND CONDITIONS

You are hereby notified that this environmental compliance approval is issued to you subject to the terms and conditions outlined below:

1. **OPERATION AND MAINTENANCE**
    1. The Company shall ensure that the Equipment is properly operated and maintained at all times. The Company shall:
        a. prepare, not later than three (3) months after the date of this Approval, and update, as necessary, a Manual outlining the operating procedures and a maintenance program for the Equipment, including:
            i. routine operating and maintenance procedures in accordance with good engineering practices and as recommended by the Equipment suppliers;
            ii. emergency procedures, including spill clean-up procedures;
            iii. procedures for any record keeping activities relating to operation and maintenance of the Equipment;
            iv. all appropriate measures to minimize noise and odorous emissions from all potential sources; and
            v. the frequency of inspection and replacement of the filter material in the Equipment;
        b. implement the recommendations of the Manual.

2. The Company shall prepare and implement procedures to determine and keep records of the temperatures of HMA as it leaves the mixing process to ensure the HMA temperature does not exceed 170 degrees Celsius (338°F).

3. The Company shall prepare and implement procedures to monitor and keep records of liquid asphalt cement storage tanks temperature, to ensure that liquid asphalt cement storage tanks do not operate above 170 degrees Celsius (338°F).

4. The Company shall not receive more than 200 tonnes per day and 200,000 tonnes per year of liquid asphalt at the maximum temperature of 170 degrees Celsius (338°F).

2. **VISIBLE FUGITIVE DUST EMISSIONS**

1. The Company shall ensure that visible dust emissions from activities where material is dropped;

    a. will not extend more than 30 metres in any direction from the activities, excluding no more than 6 minutes in any hour; and

    b. will not extend beyond the property boundary at any time.

2. The Company shall determine visible dust emissions, referred to in Condition 2.1, using Method 22, at the closest practical observation location as described in Method 22.

3. **FUGITIVE DUST CONTROL**

1. The Company shall implement the Best Management Practices Plan for the control of fugitive dust emissions resulting from the operation of the Facility. The Company shall update the Best Management Practices Plan as necessary or at the direction of the District Manager.

4. **FUGITIVE ODOUR CONTROL**

1. The Company shall implement the Odour Best Management Practices Plan for the control of fugitive odour emissions resulting from the operation of the Facility. The Company shall update the Odour Best Management Practices Plan as necessary or at the direction of the District Manager.

5. **RECORD RETENTION**

1. The Company shall retain, for a minimum of two (2) years from the date of their creation, all records and information related to or resulting from the recording activities required by this Approval, and make these records available for review by staff of the Ministry upon request. The Company shall retain:

    a. all records on the maintenance, repair and inspection of the Equipment; and

b. all records of any environmental complaints, including:

i. a description, time and date of each incident to which the complaint relates;

ii. wind direction at the time of the incident to which the complaint relates; and

iii. a description of the measures taken to address the cause of the incident to which the complaint relates and to prevent a similar occurrence in the future.

6. **COMPLAINTS/ODOUR-CONTAMINANT EMISSIONS RESPONSE PROCEDURE**

1. A designated representative of the Company shall be available to receive public complaints caused by the operations at the Facility twenty-four (24) hours per day, seven (7) days per week.

2. If at any time, the Company receives any environmental complaints from the public regarding the operation of the Facility, the Company shall record, number, and respond to these complaints according to the following procedures, which shall be kept in a computerized tracking system:

a. The information to be recorded shall include the following:

i. the name, address and the telephone number of the complainant, if the complainant provide this information;

ii. the time and date of the complaint; and

iii. details of the complaint.

b. After the complaint has been received by the Company, the Company shall immediately report, either to the District Manager by phone during office hours or to the Ministry's Spills Action Centre at 1-800-268-6060 off office hours, on the receipt of the complaint. The Company shall immediately initiate investigation of the complaint. The investigation shall include, as a minimum, the following:

i. determination of the activities undertaken in the Facility at the time of the complaint;

ii. meteorological conditions including, but not limited to the ambient temperature, approximate wind speed and its direction;

iii. determination of all the possible cause(s) of the complaint;

iv. determination of the remedial action(s) to address the cause(s) of the complaint, and implementation of the remedial action(s) to eliminate the

cause(s) of the complaint as soon as practicably possible.

c. The Company shall document the response provided to the complainant, if known, and shall make the document(s) available for inspection by staff of the Ministry upon request. The response shall include the results of the investigation of the complaint, the action(s) taken or planned to be taken to address the cause(s) of the complaint, and if follow-up response(s) would be provided.

d. The Company shall, within one (1) week, submit a report to the District Manager on that complaint, and all proposed action(s) to prevent recurrence of the complaint in the future.

7. **NOISE**

1. The Company shall restrict up to a maximum of eight (8) aggregate trucks to enter and exit the site per sixty (60) minute period .

2. The Company shall restrict the operation of the silo loading gates to a maximum of three (3) minutes per sixty (60) minute period.

3. The Company shall restrict up to a maximum of twenty (20) hot mix asphalt trucks to enter and exit the site per sixty (60) minute period.

4. The Company shall restrict the operation of the loading point signal buzzer to a maximum of one minute (1) per sixty (60) minute period.

5. The Company shall restrict up to a maximum of five (5) unprocessed material trucks to enter and exit the site per sixty (60) minute period during the daytime and evening hours of 7:00 am to 11:00 pm.

6. The Company shall restrict up to a maximum of five (5) processed material trucks to enter and exit the site per sixty (60) minute period during the daytime and evening hours of 7:00 am to 11:00 pm.

7. The Company shall prohibit the slamming of tail gates on the site.

8. The Company shall restrict the operation and movement of unprocessed material trucks to the daytime and evening hours of 7:00 am to 11:00 pm

9. The Company shall restrict the operation and movement of processed material trucks to the daytime and evening hours of 7:00 am to 11:00 pm

10. The Company shall restrict the operation of excavator 1 and excavator 2 to the daytime and evening hours of 7:00 am to 11:00 pm

11. The Company shall restrict the operation of the aggregate crusher to the daytime and evening hours of 7:00 am to 11:00 pm

12. The Company shall restrict the operation of the aggregate screener to the daytime and evening hours of 7:00 am to 11:00 pm

13. The Company shall restrict the operation of the crusher generator to the daytime and evening hours of 7:00 am to 11:00 pm

14. The Company shall conduct all on site operations in accordance with Table 1 of the Acoustic Assessment Report

15. The Company shall
    a. implement the Noise Abatement Action Plan as outlined in the Acoustic Assessment Report within twelve (12) months of the date of this Approval;
    b. ensure subsequent to the completion of the Noise Abatement Action Plan that the noise emissions from the Facility comply with the limits in Ministry Publication NPC-300; and
    c. ensure that the Noise Control Measures are properly maintained and continue to provide the acoustical performance outlined in the Acoustic Assessment Report.

8. **PUBLIC ENGAGEMENT**

1. The Company shall develop in consultation with the District Manager and the local community, a Public Engagement Plan for the Facility. This Public Engagement Plan shall:
    a. Outline a process for disseminating, consulting, reviewing and exchanging information relevant to the operation of the Facility with the local community, including environmental monitoring, maintenance and complaint/public

concerns resolution;

b. Describe how the local community was consulted on the development of the Public Engagement Plan, including a list of the local community groups who were consulted; and,

c. Include a list of all comments from the Ministry and the local community, if any, on the development of the Public Engagement Plan, and describe how these comments were addressed in the Public Engagement Plan.

2. The Company shall submit the Public Engagement Plan to the District Manager not later than three (3) months after the date of this Approval, or as otherwise indicated by the District Manager.

3. Upon acceptance of the Public Engagement Plan by the District Manager, the Company shall immediately implement the Public Engagement Plan.

4. The Company shall update the Public Engagement Plan as necessary, or at the direction of the District Manager.

9. **CHANGE OF OWNERSHIP**

1. The Company shall notify the Director in writing, and forward a copy of the notification to the District Manager, within thirty (30) days of the occurrence of any of the following changes to the Facility operations:

a. the ownership of the Facility;

b. the operator of the Facility;

c. the address of the Company;

d. the partners, where the Company is or at any time becomes a partnership and a copy of the most recent declaration filed under the *Business Names Act*, R.S.O. 1990, c. B.17, shall be included in the notification; or

e. the name of the corporation where the Company is or at any time becomes a corporation, other than a municipal corporation, and a copy of the most current information filed under the *Corporations Information Act*, R.S.O. 1990, c. C.39, shall be included in the notification.

2. In the event of any change in ownership of the Facility, the Company shall notify the successor of the existence of this Approval and provide the successor with a copy of this Approval, and the Company shall provide a copy of the notification to the District Manager and the Director.

10. **TECHNOLOGY BENCHMARKING REPORT**

1. The Company shall submit to the Director a Technology Benchmarking Report prepared by a Professional Engineer to identify feasible options to reduce off-property odour impacts, no later than nine (9) months after the date of this Approval.
2. The Technology Benchmarking Report should, at a minimum, include the following:
    a. a comprehensive list of all control methods for odour impact reduction based on the following:
        i. a comparison of methods used by other facilities in the same or similar industrial sector;
        ii. a review of emission control requirements and strategies from other jurisdictions; and
        iii. where applicable, transfer of technologies from other sectors with similar issues, including preventative steps such as material substitutions, process changes and add-on controls or treatment methods;
    b. an evaluation of the technical feasibility of the identified control options individually, and where applicable, control options in combination. This evaluation will include the availability and applicability of the option to the odour source, technical considerations, and any site specific considerations;
    c. a ranking of feasible options, or option combinations with an assessment of predicted impact reductions at sensitive receptors for major sources and hot-mix asphalt facility emissions including percent contribution, maximum and average odour concentrations and frequency assessment at sensitive receptors, and compared to current operations; and
    d. recommendations based on current odour impact assessment, predicted reductions that can be achieved by implementing feasible options, timelines, approval requirements and other applicable considerations.
3. The Company shall update and/or implement the recommendations of the Technology Benchmarking Report as directed by the District Manager.

11. **ACOUSTIC AUDIT**

1. The Company shall carry out Acoustic Audit measurements on the actual noise emissions due to the operation of the Facility. The Company;
    1. shall carry out Acoustic Audit measurements in accordance with the procedures in Ministry Publication NPC-103, ensuring the Acoustic Audit measurements are conducted;
        a. after the completion of the Noise Abatement Action Plan; and

b. during the earlier of the two (2) following date periods dependent on Condition 11.1.1a;

i. June 01 2025 to September 30, 2025;

ii. June 01 2026 to September 30, 2026,

2. shall ensure that the Acoustic Audit measurements are conducted while the Facility is operating under a worse case scenario as outlined in Table 1 of the Acoustic Assessment Report;

3. shall ensure the Acoustic Audit Report addresses each distinct operating period separately, specifically daytime and evening hours (7:00 AM - 11:00 PM) and nighttime hours (11:00 PM - 7:00 AM); and

4. shall submit an Acoustic Audit Report on the results of the Acoustic Audit prepared by an Independent Acoustical Consultant, in accordance with the requirements of Publication NPC-233, to the District Manager and the Director no later than two (2) months after the completion of the Acoustic Audit measurements.

2. The Director;

1. may not accept the results of the Acoustic Audit if the requirements of Ministry Publication NPC-233 were not followed; and

2. may require the Company to repeat the Acoustic Audit if the results of the Acoustic Audit are found unacceptable to the Director.

REASONS

The reasons for the imposition of these terms and conditions are as follows:

1. Condition Nos. 1 to 4 are included to emphasize that the Equipment must be maintained and operated according to a procedure that will result in compliance with the EPA, the Regulations and this Approval.

2. Condition No. 5 is included to require the Company to keep records and to provide information to staff of the Ministry so that compliance with the EPA, the Regulations and this Approval can be verified.

3. Condition No. 6 is included to require the Company to notify staff of the Ministry so as to assist the Ministry with the review of the site's compliance.

4. Condition No. 7 is included to provide the minimum performance requirements considered necessary to prevent an adverse effect resulting from the operation of the

Facility.

5. Condition No. 8 is included to require the Company to properly address environmental issues that may arise from the operation of the Facility and to minimize the impact on the environment.
6. Condition No. 9 is included to require the Company to notify/report to the Ministry so that compliance with the EPA, the regulations and this Approval can be verified.
7. Condition No. 10 is included to require the Company to provide information to the Ministry on the efforts of the Company in minimizing odorous emissions relative to industry best practices.
8. Condition No. 11 is included to require the Company to gather accurate information and submit an Acoustic Audit Report in accordance with procedures set in the Ministry's noise guidelines, so that the environmental impact and subsequent compliance with this Approval can be verified.

APPEAL PROVISIONS

In accordance with Section 139 of the *Environmental Protection Act*, you may by written notice served upon me and the Ontario Land Tribunal, within 15 days after the service of this notice, require a hearing by the Tribunal. You must also provide notice to, the Minister of the Environment, Conservation and Parks in accordance with Section 47 of the *Environmental Bill of Rights*, 1993 who will place notice of your appeal on the Environmental Registry. Section 142 of the *Environmental Protection Act* provides that the notice requiring the hearing ("the Notice") shall state:

1. The portions of the environmental compliance approval or each term or condition in the environmental compliance approval in respect of which the hearing is required, and;
2. The grounds on which you intend to rely at the hearing in relation to each portion appealed.

Pursuant to subsection 139(3) of the *Environmental Protection Act*, a hearing may not be required with respect to any terms and conditions in this environmental compliance approval, if the terms and conditions are substantially the same as those contained in an approval that is amended or revoked by this environmental compliance approval.

The Notice should also include:

1. The name of the appellant;
2. The address of the appellant;
3. The environmental compliance approval number;
4. The date of the environmental compliance approval;
5. The name of the Director, and;
6. The municipality or municipalities within which the project is to be engaged in.

And the Notice should be signed and dated by the appellant.

This Notice must be served upon:

Registrar* Ontario Land Tribunal 655 Bay Street, Suite 1500 Toronto, Ontario M5G 1E5 OLT.Registrar@ontario.ca	and	The Minister of the Environment, Conservation and Parks 777 Bay Street, 5th Floor	and	The Director appointed for the purposes of Part II.1 of the *Environmental Protection Act* Ministry of the Environment, Conservation and Parks 135 St. Clair Avenue West, 1st

	Toronto, Ontario M7A 2J3	Floor Toronto, Ontario M4V 1P5

*** Further information on the Ontario Land Tribunal's requirements for an appeal can be obtained directly from the Tribunal at: Tel: (416) 212-6349 or 1 (866) 448-2248, or Ontario Land Tribunal's**

This instrument is subject to Section 38 of the *Environmental Bill of Rights*, 1993, that allows residents of Ontario to seek leave to appeal the decision on this instrument. Residents of Ontario may seek leave to appeal within 15 days from the date this decision is placed on the Environmental Registry. By accessing the Environmental Registry at Environmental Registry of Ontario, you can determine when the leave to appeal period ends.

The above noted activity is approved under s.20.3 of Part II.1 of the *Environmental Protection Act*.

Dated at Toronto this 2nd day of April, 2025



Nancy Orpana

Director

appointed for the purposes of Part II.1 of the *Environmental Protection Act*

c: Kieu Duong, ASSOCIATED PAVING & MATERIALS LTD.
Ibrahim Syed, ORTECH Consulting Inc.

11.1 Hot Mix Asphalt Plants

11.1.1 General[1-3,23, 392-394]

Hot mix asphalt (HMA) paving materials are a mixture of size-graded, high quality aggregate (which can include reclaimed asphalt pavement [RAP]), and liquid asphalt cement, which is heated and mixed in measured quantities to produce HMA. Aggregate and RAP (if used) constitute over 92 percent by weight of the total mixture. Aside from the amount and grade of asphalt cement used, mix characteristics are determined by the relative amounts and types of aggregate and RAP used. A certain percentage of fine aggregate (less than 74 micrometers [µm] in physical diameter) is required for the production of good quality HMA.

Hot mix asphalt paving materials can be manufactured by: (1) batch mix plants, (2) continuous mix (mix outside dryer drum) plants, (3) parallel flow drum mix plants, and (4) counterflow drum mix plants. This order of listing generally reflects the chronological order of development and use within the HMA industry.

In 1996, approximately 500 million tons of HMA were produced at the 3,600 (estimated) active asphalt plants in the United States. Of these 3,600 plants, approximately 2,300 are batch plants, 1,000 are parallel flow drum mix plants, and 300 are counterflow drum mix plants. The total 1996 HMA production from batch and drum mix plants is estimated at about 240 million tons and 260 million tons, respectively. About 85 percent of plants being manufactured today are of the counterflow drum mix design, while batch plants and parallel flow drum mix plants account for 10 percent and 5 percent respectively. Continuous mix plants represent a very small fraction of the plants in use ($\leq$0.5 percent) and, therefore, are not discussed further.

An HMA plant can be constructed as a permanent plant, a skid-mounted (easily relocated) plant, or a portable plant. All plants can have RAP processing capabilities. Virtually all plants being manufactured today have RAP processing capability. Most plants have the capability to use either gaseous fuels (natural gas) or fuel oil. However, based upon Department of Energy and limited State inventory information, between 70 and 90 percent of the HMA is produced using natural gas as the fuel to dry and heat the aggregate.

11.1.1.1 Batch Mix Plants –

Figure 11.1-1 shows the batch mix HMA production process. Raw aggregate normally is stockpiled near the production unit. The bulk aggregate moisture content typically stabilizes between 3 to 5 percent by weight.

Processing begins as the aggregate is hauled from the storage piles and is placed in the appropriate hoppers of the cold feed unit. The material is metered from the hoppers onto a conveyer belt and is transported into a rotary dryer (typically gas- or oil-fired). Dryers are equipped with flights designed to shower the aggregate inside the drum to promote drying efficiency.

As the hot aggregate leaves the dryer, it drops into a bucket elevator and is transferred to a set of vibrating screens, where it is classified into as many as four different grades (sizes) and is dropped into individual “hot” bins according to size. At newer facilities, RAP also may be transferred to a separate heated storage bin. To control aggregate size distribution in the final batch mix, the operator opens various hot bins over a weigh hopper until the desired mix and weight are obtained. Concurrent with the aggregate being weighed, liquid asphalt cement is pumped from a heated storage tank to an asphalt bucket, where it is weighed to achieve the desired aggregate-to-asphalt cement ratio in the final mix.

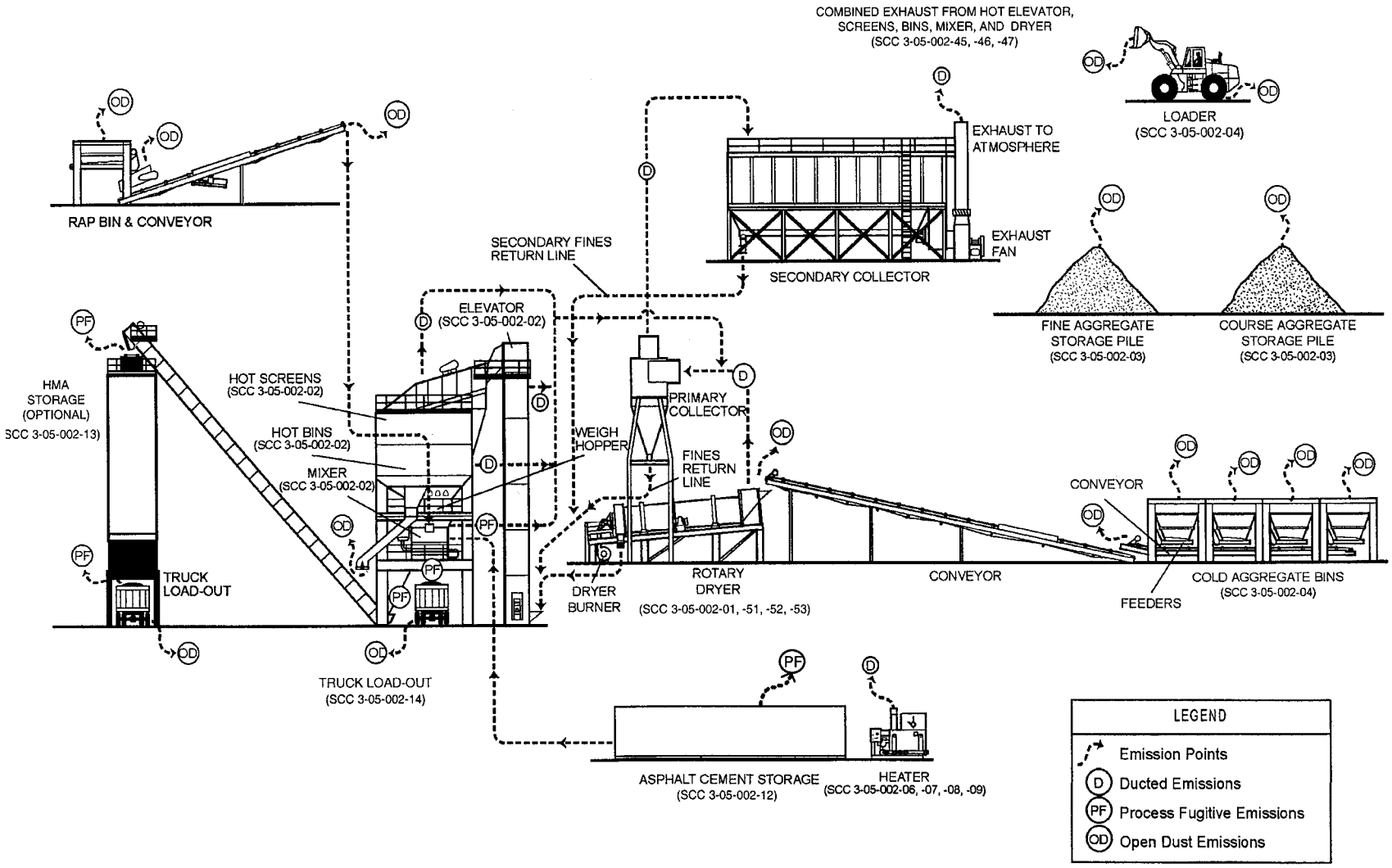


Figure 11.1-1. General process flow diagram for batch mix asphalt plants (source classification codes in parentheses).[3]

The aggregate from the weigh hopper is dropped into the mixer (pug mill) and dry-mixed for 6 to 10 seconds. The liquid asphalt is then dropped into the pug mill where it is mixed for an additional period of time. At older plants, RAP typically is conveyed directly to the pug mill from storage hoppers and combined with the hot aggregate. Total mixing time usually is less than 60 seconds. Then the hot mix is conveyed to a hot storage silo or is dropped directly into a truck and hauled to the job site.

11.1.1.2 Parallel Flow Drum Mix Plants –

Figure 11.1-2 shows the parallel flow drum mix process. This process is a continuous mixing type process, using proportioning cold feed controls for the process materials. The major difference between this process and the batch process is that the dryer is used not only to dry the material but also to mix the heated and dried aggregates with the liquid asphalt cement. Aggregate, which has been proportioned by size gradations, is introduced to the drum at the burner end. As the drum rotates, the aggregates, as well as the combustion products, move toward the other end of the drum in parallel. Liquid asphalt cement flow is controlled by a variable flow pump electronically linked to the new (virgin) aggregate and RAP weigh scales. The asphalt cement is introduced in the mixing zone midway down the drum in a lower temperature zone, along with any RAP and particulate matter (PM) from collectors.

The mixture is discharged at the end of the drum and is conveyed to either a surge bin or HMA storage silos, where it is loaded into transport trucks. The exhaust gases also exit the end of the drum and pass on to the collection system.

Parallel flow drum mixers have an advantage, in that mixing in the discharge end of the drum captures a substantial portion of the aggregate dust, therefore lowering the load on the downstream PM collection equipment. For this reason, most parallel flow drum mixers are followed only by primary collection equipment (usually a baghouse or venturi scrubber). However, because the mixing of aggregate and liquid asphalt cement occurs in the hot combustion product flow, organic emissions (gaseous and liquid aerosol) may be greater than in other asphalt mixing processes. Because data are not available to distinguish significant emissions differences between the two process designs, this effect on emissions cannot be verified.

11.1.1.3 Counterflow Drum Mix Plants –

Figure 11.1-3 shows a counterflow drum mix plant. In this type of plant, the material flow in the drum is opposite or counterflow to the direction of exhaust gases. In addition, the liquid asphalt cement mixing zone is located behind the burner flame zone so as to remove the materials from direct contact with hot exhaust gases.

Liquid asphalt cement flow is controlled by a variable flow pump which is electronically linked to the virgin aggregate and RAP weigh scales. It is injected into the mixing zone along with any RAP and particulate matter from primary and secondary collectors.

Because the liquid asphalt cement, virgin aggregate, and RAP are mixed in a zone removed from the exhaust gas stream, counterflow drum mix plants will likely have organic emissions (gaseous and liquid aerosol) that are lower than parallel flow drum mix plants. However, the available data are insufficient to discern any differences in emissions that result from differences in the two processes. A counterflow drum mix plant can normally process RAP at ratios up to 50 percent with little or no observed effect upon emissions.

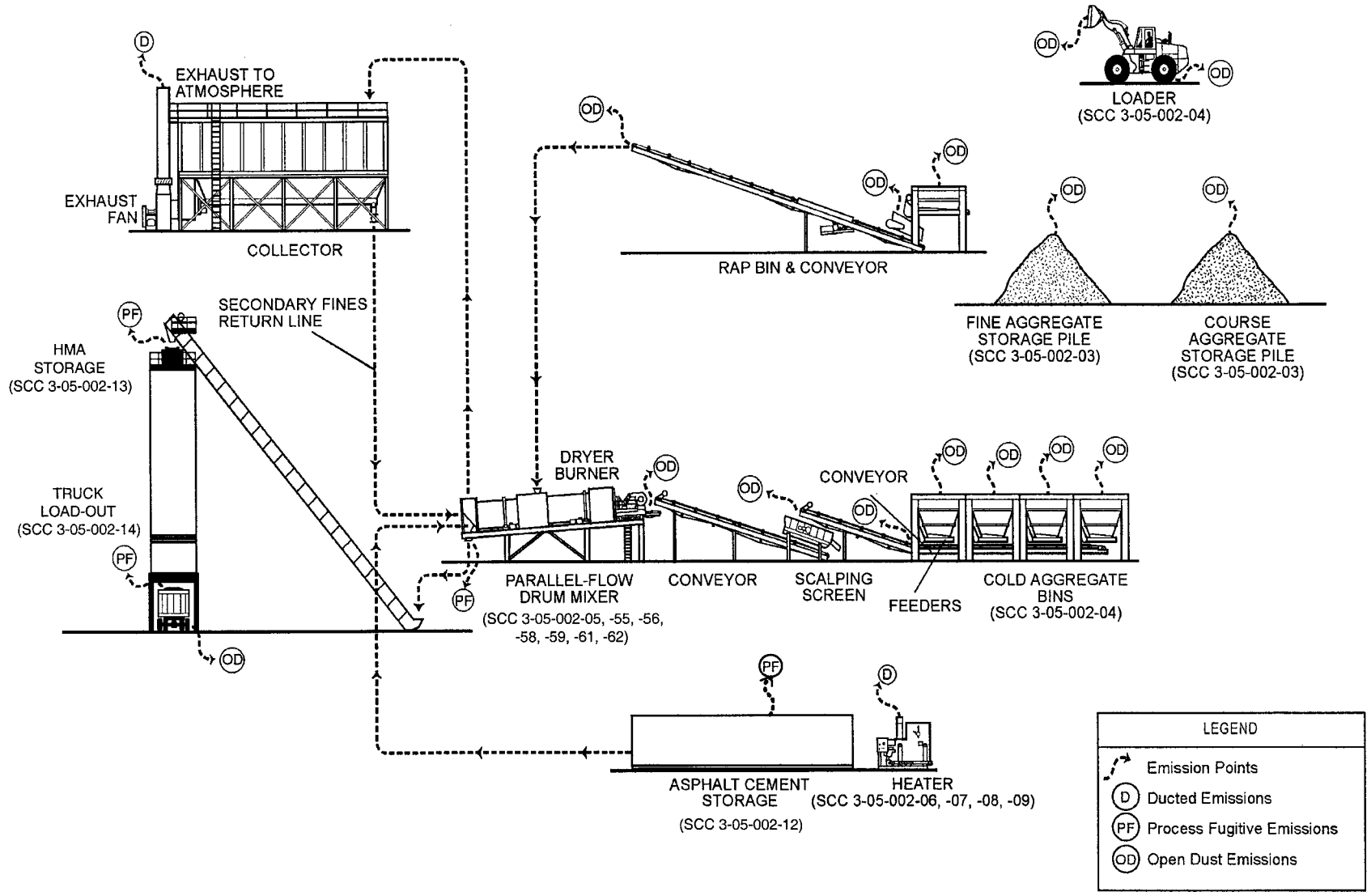


Figure 11.1-2. General process flow diagram for parallel-flow drum mix asphalt plants (source classification codes in parentheses).[3]

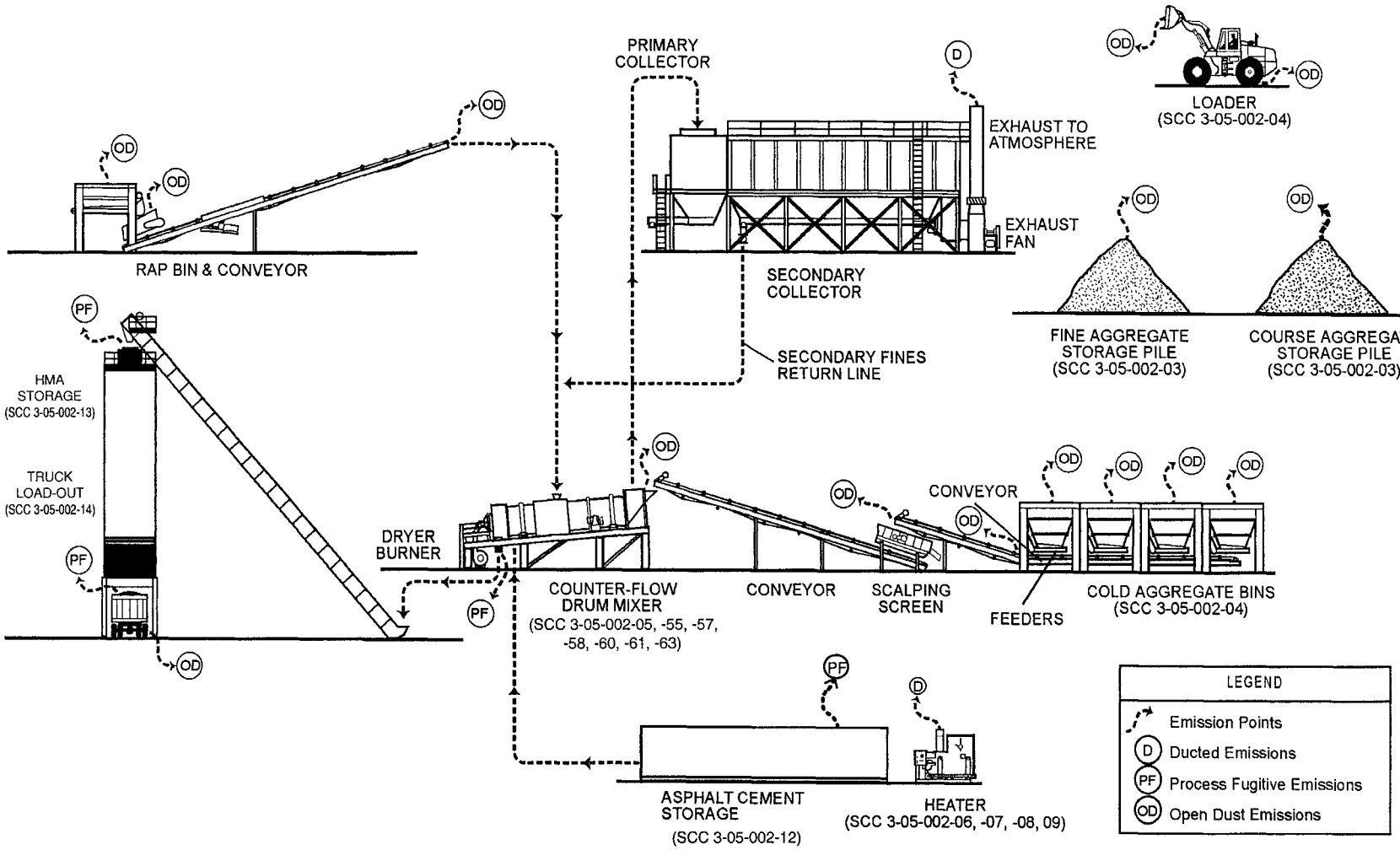


Figure 11.1-3. General process flow diagram for counter-flow drum mix asphalt plants (source classification codes in parentheses).[3]

11.1.1.4 Recycle Processes[393] –

In recent years, the use of RAP has been initiated in the HMA industry. Reclaimed asphalt pavement significantly reduces the amount of virgin rock and asphalt cement needed to produce HMA.

In the reclamation process, old asphalt pavement is removed from the road base. This material is then transported to the plant, and is crushed and screened to the appropriate size for further processing. The paving material is then heated and mixed with new aggregate (if applicable), and the proper amount of new asphalt cement is added to produce HMA that meets the required quality specifications.

11.1.2 Emissions And Controls[2-3,23]

Emissions from HMA plants may be divided into ducted production emissions, pre-production fugitive dust emissions, and other production-related fugitive emissions. Pre-production fugitive dust sources associated with HMA plants include vehicular traffic generating fugitive dust on paved and unpaved roads, aggregate material handling, and other aggregate processing operations. Fugitive dust may range from 0.1 µm to more than 300 µm in aerodynamic diameter. On average, 5 percent of cold aggregate feed is less than 74 µm (minus 200 mesh). Fugitive dust that may escape collection before primary control generally consists of PM with 50 to 70 percent of the total mass less than 74 µm. Uncontrolled PM emission factors for various types of fugitive sources in HMA plants are addressed in Sections 11.19.2, "Crushed Stone Processing", 13.2.1, "Paved Roads", 13.2.2, "Unpaved Roads", 13.2.3, "Heavy Construction Operations", and 13.2.4, "Aggregate Handling and Storage Piles." Production-related fugitive emissions and emissions from ducted production operations are discussed below. Emission points discussed below refer to Figure 11.1-1 for batch mix asphalt plants and to Figures 11.1-2 and 11.1-3 for drum mix plants.

11.1.2.1 Batch Mix Plants –

As with most facilities in the mineral products industry, batch mix HMA plants have two major categories of emissions: ducted sources (those vented to the atmosphere through some type of stack, vent, or pipe), and fugitive sources (those not confined to ducts and vents but emitted directly from the source to the ambient air). Ducted emissions are usually collected and transported by an industrial ventilation system having one or more fans or air movers, eventually to be emitted to the atmosphere through some type of stack. Fugitive emissions result from process and open sources and consist of a combination of gaseous pollutants and PM.

The most significant ducted source of emissions of most pollutants from batch mix HMA plants is the rotary drum dryer. The dryer emissions consist of water (as steam evaporated from the aggregate); PM; products of combustion (carbon dioxide [CO_2], nitrogen oxides [NO_x], and sulfur oxides [SO_x]); carbon monoxide (CO); and small amounts of organic compounds of various species (including volatile organic compounds [VOC], methane [CH_4], and hazardous air pollutants [HAP]). The CO and organic compound emissions result from incomplete combustion of the fuel. It is estimated that between 70 and 90 percent of the energy used at HMA plants is from the combustion of natural gas.

Other potential process sources include the hot-side conveying, classifying, and mixing equipment, which are vented either to the primary dust collector (along with the dryer gas) or to a separate dust collection system. The vents and enclosures that collect emissions from these sources are commonly called "fugitive air" or "scavenger" systems. The scavenger system may or may not have its own separate air mover device, depending on the particular facility. The emissions captured and transported by the scavenger system are mostly aggregate dust, but they may also contain gaseous organic compounds and a fine aerosol of condensed organic particles. This organic aerosol is created by the condensation of vapor into particles during cooling of organic vapors volatilized from the asphalt cement in the mixer (pug mill). The amount of organic aerosol produced depends to a large extent on the temperature of the asphalt cement and aggregate entering the pug mill. Organic vapor and its associated

aerosol also are emitted directly to the atmosphere as process fugitives during truck load-out, from the bed of the truck itself during transport to the job site, and from the asphalt storage tank. Both the low molecular weight organic compounds and the higher weight organic aerosol contain small amounts of HAP. The ducted emissions from the heated asphalt storage tanks include gaseous and aerosol organic compounds and combustion products from the tank heater.

The choice of applicable emission controls for PM emissions from the dryer and vent line includes dry mechanical collectors, scrubbers, and fabric filters. Attempts to apply electrostatic precipitators have met with little success. Practically all plants use primary dust collection equipment such as large diameter cyclones, skimmers, or settling chambers. These chambers often are used as classifiers to return collected material to the hot elevator and to combine it with the drier aggregate. To capture remaining PM, the primary collector effluent is ducted to a secondary collection device. Most plants use either a fabric filter or a venturi scrubber for secondary emissions control. As with any combustion process, the design, operation, and maintenance of the burner provides opportunities to minimize emissions of NO_x, CO, and organic compounds.

11.1.2.2 Parallel Flow Drum Mix Plants –

The most significant ducted source of emissions from parallel-flow drum mix plants is the rotary drum dryer. Emissions from the drum consist of water (as steam evaporated from the aggregate); PM; products of combustion; CO; and small amounts of organic compounds of various species (including VOC, CH_4, and HAP). The organic compound and CO emissions result from incomplete combustion of the fuel and from heating and mixing of the liquid asphalt cement inside the drum. Although it has been suggested that the processing of RAP materials at these type plants may increase organic compound emissions because of an increase in mixing zone temperature during processing, the data supporting this hypothesis are very weak. Specifically, although the data show a relationship only between RAP content and condensible organic particulate emissions, 89 percent of the variations in the data were the result of other unknown process variables.

Once the organic compounds cool after discharge from the process stack, some condense to form a fine organic aerosol or “blue smoke” plume. A number of process modifications or restrictions have been introduced to reduce blue smoke, including installation of flame shields, rearrangement of flights inside the drum, adjustments of the asphalt injection point, and other design changes.

11.1.2.3 Counterflow Drum Mix Plants –

The most significant ducted source of emissions from counterflow drum mix plants is the rotary drum dryer. Emissions from the drum consist of water (as steam evaporated from the aggregate); PM; products of combustion; CO; and small amounts of organic compounds of various species (including VOC, CH_4, and HAP). The CO and organic compound emissions result primarily from incomplete combustion of the fuel, and can also be released from the heated asphalt. Liquid asphalt cement, aggregate, and sometimes RAP, are mixed in a zone not in contact with the hot exhaust gas stream. As a result, kiln stack emissions of organic compounds from counterflow drum mix plants may be lower than parallel flow drum mix plants. However, variations in the emissions due to other unknown process variables are more significant. As a result, the emission factors for parallel flow and counterflow drum mix plants are the same.

11.1.2.4 Parallel and Counterflow Drum Mix Plants –

Process fugitive emissions associated with batch plant hot screens, elevators, and the mixer (pug mill) are not present in the drum mix processes. However, there are fugitive PM and VOC emissions from transport and handling of the HMA from the drum mixer to the storage silo and also from the load-out operations to the delivery trucks. Since the drum process is continuous, these plants have surge

bins or storage silos. The fugitive dust sources associated with drum mix plants are similar to those of batch mix plants with regard to truck traffic and to aggregate material feed and handling operations.

Table 11.1-1 presents emission factors for filterable PM and PM-10, condensable PM, and total PM for batch mix HMA plants. Particle size data for batch mix HMA plants, based on the control technology used, are shown in Table 11.1-2. Table 11.1-3 presents filterable PM and PM-10, condensable PM, and total PM emission factors for drum mix HMA plants. Particle size data for drum mix HMA plants, based on the control technology used, are shown in Table 11.1-4. Tables 11.1-5 and -6 present emission factors for CO, CO_2, NO_x, sulfur dioxide (SO_2), total organic compounds (TOC), formaldehyde, CH_4, and VOC from batch mix plants. Tables 11.1-7 and -8 present emission factors for CO, CO_2, NO_x, SO_2, TOC, CH_4, VOC, and hydrochloric acid (HCl) from drum mix plants. The emission factors for CO, NO_x, and organic compounds represent normal plant operations without scrutiny of the burner design, operation, and maintenance. Information provided in Reference 390 indicates that attention to burner design, periodic evaluation of burner operation, and appropriate maintenance can reduce these emissions. Table 11.1-9 presents organic pollutant emission factors for batch mix plants. Table 11.1-10 presents organic pollutant emission factors for drum mix plants. Tables 11.1-11 and -12 present metals emission factors for batch and drum mix plants, respectively. Table 11.1-13 presents organic pollutant emission factors for hot (asphalt) oil systems.

11.1.2.5 Fugitive Emissions from Production Operations –

Emission factors for HMA load-out and silo filling operations can be estimated using the data in Tables 11.1-14, -15, and -16. Table 11.1-14 presents predictive emission factor equations for HMA load-out and silo filling operations. Separate equations are presented for total PM, extractable organic PM (as measured by EPA Method 315), TOC, and CO. For example, to estimate total PM emissions from drum mix or batch mix plant load-out operations using an asphalt loss-on-heating of 0.41 percent and temperature of 290°F, the following calculation is made:

$$
\begin{aligned}
EF &= 0.000181 + 0.00141(-V)e^{((0.0251)(290 + 460) - 20.43)} \\
&= 0.000181 + 0.00141(-(-0.41))e^{((0.0251)(290 + 460) - 20.43)} \\
&= 0.000181 + 0.00141(0.41)e^{(-1.605)} \\
&= 0.000181 + 0.00141(0.41)(0.2009) \\
&= 0.000181 + 0.000116 \\
&= 0.00030 \text{ lb total PM/ton of asphalt loaded}
\end{aligned}
$$

Tables 11.1-15 and -16 present speciation profiles for organic particulate-based and volatile particulate-based compounds, respectively. The speciation profile shown in Table 11.1-15 can be applied to the extractable organic PM emission factors estimated by the equations in Table 11.1-14 to estimate emission factors for specific organic PM compounds. The speciation profile presented in Table 11.1-16 can be applied to the TOC emission factors estimated by the equations in Table 11.1-14 to estimate emission factors for specific volatile organic compounds. The derivations of the predictive emission factor equations and the speciation profiles can be found in Reference 1.

For example, to estimate TOC emissions from drum mix plant load-out operations using an asphalt loss-on-heating of 0.41 percent and temperature of 290°F, the following calculation is made:

$$
\begin{aligned}
EF &= 0.0172(-V)e^{((0.0251)(290 + 460) - 20.43)} \\
&= 0.0172(-(-0.41))e^{((0.0251)(290 + 460) - 20.43)} \\
&= 0.0172(0.41)e^{(-1.605)} \\
&= 0.0172(0.41)(0.2009) \\
&= 0.0014 \text{ lb TOC/ton of asphalt loaded}
\end{aligned}
$$

To estimate the benzene emissions from the same operation, use the TOC emission factor calculated above and apply the benzene fraction for load-out emissions from Table 11.1-16:

EF = 0.0014 (0.00052)
= 7.3×10^{-7} lb benzene/ton of asphalt loaded

Emissions from asphalt storage tanks can be estimated using the procedures described in AP-42 Section 7.1, Organic Liquid Storage Tanks, and the TANKS software. Site-specific data should be used for storage tank specifications and operating parameters, such as temperature. If site-specific data for Antoine's constants for an average asphalt binder used by the facility are unavailable, the following values for an average liquid asphalt binder can be used:

A = 75,350.06
B = 9.00346

These values should be inserted into the Antoine's equation in the following form:

$$\log_{10} P = \frac{-0.05223A}{T} + B$$

where:

P = vapor pressure, mm Hg
T = absolute temperature, Kelvin

The assumed average liquid molecular weight associated with these Antoine's constants is 1,000 atomic mass units and the average vapor molecular weight is 105. Emission factors estimated using these default values should be assigned a rating of E. Carbon monoxide emissions can be estimated by multiplying the THC emissions calculated by the TANKS program by 0.097 (the ratio of silo filling CO emissions to silo filling TOC emissions).

Vapors from the HMA loaded into transport trucks continue following load-out operations. The TOC emissions for the 8-minute period immediately following load-out (yard emissions) can be estimated using an emission factor of 0.00055 kg/Mg (0.0011 lb/ton) of asphalt loaded. This factor is assigned a rating of E. The derivation of this emission factor is described in Reference 1. Carbon monoxide emissions can be estimated by multiplying the TOC emissions by 0.32 (the ratio of truck load-out CO emissions to truck load-out THC emissions).

11.2.3 Updates Since the Fifth Edition

The Fifth Edition was released in January 1995. Revisions to this section since that date are summarized below. For further detail, consult the background report for this section. This and other documents can be found on the CHIEF Web Site at http://www.epa.gov/ttn/chief/, or by calling the Info CHIEF Help Desk at (919)541-1000.

December 2000

- All emission factors were revised and new factors were added. For selected pollutant emissions, separate factors were developed for distilate oil, No. 6 oil and waste oil fired dryers. Dioxin and Furan emission factors were developed for oil fired drum mix plants. Particulate, VOC and CO factors were developed for silo filling, truck load out and post truck load out operations at batch plants and drum mix plants. Organic species profiles were developed for silo filling, truck load out and post truck load out operations.

March 2004

- The emission factor for formaldehyde for oil fired hot oil heaters was revised. An emission factor for formaldehyde for gas fired hot oil heaters and emission factors for CO and CO_2 for gas and oil fired hot oil heaters were developed. (Table 11.1-13)

Table 11.1-1. PARTICULATE MATTER EMISSION FACTORS FOR BATCH MIX HOT MIX ASPHALT PLANTS[a]

	Filterable PM				Condensable PM[b]				Total PM			
Process	PM[c]	EMISSION FACTOR RATING	PM-10[d]	EMISSION FACTOR RATING	Inorganic	EMISSION FACTOR RATING	Organic	EMISSION FACTOR RATING	PM[e]	EMISSION FACTOR RATING	PM-10[f]	EMISSION FACTOR RATING
Dryer, hot screens, mixer[g] (SCC 3-05-002-45, -46, -47)												
Uncontrolled	32[h]	E	4.5	E	0.013[j]	E	0.0041[j]	E	32	E	4.5	E
Venturi or wet scrubber	0.12[k]	C	ND	NA	0.013[m]	B	0.0041[n]	B	0.14	C	ND	NA
Fabric filter	0.025[p]	A	0.0098	C	0.013[m]	A	0.0041[n]	A	0.042	B	0.027	C

[a] Factors are lb/ton of product. SCC = Source Classification Code. ND = no data. NA = not applicable. To convert from lb/ton to kg/Mg, multiply by 0.5.

[b] Condensable PM is that PM collected using an EPA Method 202, Method 5 (analysis of "back-half" or impingers), or equivalent sampling train.

[c] Filterable PM is that PM collected on or before the filter of an EPA Method 5 (or equivalent) sampling train.

[d] Particle size data from Reference 23 were used in conjunction with the filterable PM emission factors shown.

[e] Total PM is the sum of filterable PM, condensable inorganic PM, and condensable organic PM.

[f] Total PM-10 is the sum of filterable PM-10, condensable inorganic PM, and condensable organic PM.

[g] Batch mix dryer fired with natural gas, propane, fuel oil, waste oil, and coal. The data indicate that fuel type does not significantly effect PM emissions.

[h] Reference 5.

[j] Although no data are available for uncontrolled condensable PM, values are assumed to be equal to the controlled value measured.

[k] Reference 1, Table 4-19. Average of data from 16 facilities. Range: 0.047 to 0.40 lb/ton. Median: 0.049 lb/ton. Standard deviation: 0.11 lb/ton.

[m] Reference 1, Table 4-19. Average of data from 35 facilities. Range: 0.00073 to 0.12 lb/ton. Median: 0.0042 lb/ton. Standard deviation: 0.024 lb/ton.

[n] Reference 1, Table 4-19. Average of data from 24 facilities. Range: 0.000012 to 0.018 lb/ton. Median: 0.0026 lb/ton. Standard deviation: 0.0042 lb/ton.

[p] Reference 1, Table 4-19. Average of data from 89 facilities. Range: 0.0023 to 0.18 lb/ton. Median: 0.012 lb/ton. Standard deviation: 0.033 lb/ton.

Table 11.1-2. SUMMARY OF PARTICLE SIZE DISTRIBUTION FOR BATCH MIX DRYERS, HOT SCREENS, AND MIXERS[a]

EMISSION FACTOR RATING: E

Particle Size, μm[b]	Cumulative Mass Less Than or Equal to Stated Size (%)[c]		Emission Factors, lb/ton	
	Uncontrolled[d]	Fabric Filter	Uncontrolled[d]	Fabric Filter
1.0	ND	30[e]	ND	0.0075[e]
2.5	0.83	33[e]	0.27	0.0083[e]
5.0	3.5	36[e]	1.1	0.0090[e]
10.0	14	39[f]	4.5	0.0098[f]
15.0	23	47[e]	7.4	0.012[e]

[a] Emission factor units are lb/ton of HMA provided. Rounded to two significant figures. SCC 3-05-002-45, -46, -47. ND = no data available. To convert from lb/ton to kg/Mg, multiply by 0.5.

[b] Aerodynamic diameter.

[c] Applies only to the mass of filterable PM.

[d] References 23, Table 3-36. The emission factors are calculated using the particle size data from this reference in conjunction with the filterable PM emission factor shown in Table 11.1-1.

[e] References 23, Page J-61. The emission factors are calculated using the particle size data from this reference in conjunction with the filterable PM emission factor shown in Table 11.1-1.

[f] References 23-24. The emission factors are calculated using the particle size data from these references in conjunction with the filterable PM emission factor shown in Table 11.1-1.

Table 11.1-3. PARTICULATE MATTER EMISSION FACTORS FOR DRUM MIX HOT MIX ASPHALT PLANTS[a]

Process	Filterable PM				Condensable PM[b]				Total PM			
	PM[c]	EMISSION FACTOR RATING	PM-10[d]	EMISSION FACTOR RATING	Inorganic	EMISSION FACTOR RATING	Organic	EMISSION FACTOR RATING	PM[e]	EMISSION FACTOR RATING	PM-10[f]	EMISSION FACTOR RATING
Dryer[g] (SCC 3-05-002-05,-55 to -63)												
Uncontrolled	28[h]	D	6.4	D	0.0074[j]	E	0.058[k]	E	28	D	6.5	D
Venturi or wet scrubber	0.026[m]	A	ND	NA	0.0074[n]	A	0.012[p]	A	0.045	A	ND	NA
Fabric filter	0.014[q]	A	0.0039	C	0.0074[n]	A	0.012[p]	A	0.033	A	0.023	C

[a] Factors are lb/ton of product. SCC = Source Classification Code. ND = no data. NA = not applicable. To convert from lb/ton to kg/Mg, multiply by 0.5.

[b] Condensable PM is that PM collected using an EPA Method 202, Method 5 (analysis of "back-half" or impingers), or equivalent sampling train.

[c] Filterable PM is that PM collected on or before the filter of an EPA Method 5 (or equivalent) sampling train.

[d] Particle size data from Reference 23 were used in conjunction with the filterable PM emission factors shown.

[e] Total PM is the sum of filterable PM, condensable inorganic PM, and condensable organic PM.

[f] Total PM-10 is the sum of filterable PM-10, condensable inorganic PM, and condensable organic PM.

[g] Drum mix dryer fired with natural gas, propane, fuel oil, and waste oil. The data indicate that fuel type does not significantly effect PM emissions.

[h] References 31, 36-38, 340.

[j] Because no data are available for uncontrolled condensable inorganic PM, the emission factor is assumed to be equal to the maximum controlled condensable inorganic PM emission factor.

[k] References 36-37.

[m] Reference 1, Table 4-14. Average of data from 36 facilities. Range: 0.0036 to 0.097 lb/ton. Median: 0.020 lb/ton. Standard deviation: 0.022 lb/ton.

[n] Reference 1, Table 4-14. Average of data from 30 facilities. Range: 0.0012 to 0.027 lb/ton. Median: 0.0051 lb/ton. Standard deviation: 0.0063 lb/ton.

[p] Reference 1, Table 4-14. Average of data from 41 facilities. Range: 0.00035 to 0.074 lb/ton. Median: 0.0046 lb/ton. Standard deviation: 0.016 lb/ton.

[q] Reference 1, Table 4-14. Average of data from 155 facilities. Range: 0.00089 to 0.14 lb/ton. Median: 0.010 lb/ton. Standard deviation: 0.017 lb/ton.

Table 11.1-4. SUMMARY OF PARTICLE SIZE DISTRIBUTION FOR DRUM MIX DRYERS[a]

EMISSION FACTOR RATING: E

Particle Size, μm[b]	Cumulative Mass Less Than or Equal to Stated Size (%)[c]		Emission Factors, lb/ton	
	Uncontrolled[d]	Fabric Filter	Uncontrolled[d]	Fabric Filter
1.0	ND	15[e]	ND	0.0021[e]
2.5	5.5	21[f]	1.5	0.0029[f]
10.0	23	30[g]	6.4	0.0042[g]
15.0	27	35[d]	7.6	0.0049[d]

[a] Emission factor units are lb/ton of HMA produced. Rounded to two significant figures. SCC 3-05-002-05, and 3-05-002-55 to -63. ND = no data available. To convert from lb/ton to kg/Mg, multiply by 0.5.

[b] Aerodynamic diameter.

[c] Applies only to the mass of filterable PM.

[d] Reference 23, Table 3-35. The emission factors are calculated using the particle size data from this reference in conjunction with the filterable PM emission factor shown in Table 11.1-3.

[e] References 214, 229. The emission factors are calculated using the particle size data from these references in conjunction with the filterable PM emission factor shown in Table 11.1-3.

[f] References 23, 214, 229. The emission factors are calculated using the particle size data from these references in conjunction with the filterable PM emission factor shown in Table 11.1-3.

[g] Reference 23, 25, 229. The emission factors are calculated using the particle size data from these references in conjunction with the filterable PM emission factor shown in Table 11.1-3. EMISSION FACTOR RATING: D.

Table 11.1-5. EMISSION FACTORS FOR CO, CO_2, NO_x, AND SO_2 FROM BATCH MIX HOT MIX ASPHALT PLANTS[a]

Process	CO[b]	EMISSION FACTOR RATING	CO_2[c]	EMISSION FACTOR RATING	NO_x	EMISSION FACTOR RATING	SO_2[c]	EMISSION FACTOR RATING
Natural gas-fired dryer, hot screens, and mixer (SCC 3-05-002-45)	0.40	C	37[d]	A	0.025[e]	D	0.0046[f]	E
No. 2 fuel oil-fired dryer, hot screens, and mixer (SCC 3-05-002-46)	0.40	C	37[d]	A	0.12[g]	E	0.088[h]	E
Waste oil-fired dryer, hot screens, and mixer (SCC 3-05-002-47)	0.40	C	37[d]	A	0.12[g]	E	0.088[h]	E
Coal-fired dryer, hot screens, and mixer[j] (SCC 3-05-002-98)	ND	NA	37[d]	A	ND	NA	0.043[k]	E

[a] Emission factor units are lb per ton of HMA produced. SCC = Source Classification Code. ND = no data available. NA = not applicable. To convert from lb/ton to kg/Mg, multiply by 0.5.

[b] References 24, 34, 46-47, 49, 161, 204, 215-217, 282, 370, 378, 381. The CO emission factors represent normal plant operations without scrutiny of the burner design, operation, and maintenance. Information is available that indicates that attention to burner design, periodic evaluation of burner operation, and appropriate maintenance can reduce CO emissions. Data for dryers firing natural gas, No. 2 fuel oil, and No. 6 fuel oil were combined to develop a single emission factor because the magnitude of emissions was similar for dryers fired with these fuels.

[c] Emissions of CO_2 and SO_2 can also be estimated based on fuel usage and the fuel combustion emission factors (for the appropriate fuel) presented in AP-42 Chapter 1. The CO_2 emission factors are an average of all available data, regardless of the dryer fuel (emissions were similar from dryers firing any of the various fuels). Based on data for drum mix facilities, 50 percent of the fuel-bound sulfur, up to a maximum (as SO_2) of 0.1 lb/ton of product, is expected to be retained in the product, with the remainder emitted as SO_2.

[d] Reference 1, Table 4-20. Average of data from 115 facilities. Range: 6.9 to 160 lb/ton. Median: 32 lb/ton. Standard deviation: 22 lb/ton.

[e] References 24, 34, 46-47.

[f] References 46-47.

[g] References 49, 226.

[h] References 49, 226, 228, 385.

[j] Dryer fired with coal and supplemental natural gas or fuel oil.

[k] Reference 126.

Table 11.1-6. EMISSION FACTORS FOR TOC, METHANE, AND VOC FROM BATCH MIX HOT MIX ASPHALT PLANTS[a]

Process	TOC[b]	EMISSION FACTOR RATING	CH_4[c]	EMISSION FACTOR RATING	VOC[d]	EMISSION FACTOR RATING
Natural gas-fired dryer, hot screens, and mixer (SCC 3-05-002-45)	0.015[e]	D	0.0074	D	0.0082	D
No. 2 fuel oil-fired dryer, hot screens, and mixer (SCC 3-05-002-46)	0.015[e]	D	0.0074	D	0.0082	D
No. 6 fuel oil-fired dryer, hot screens, and mixer (SCC 3-05-002-47)	0.043[f]	E	0.0074	D	0.036	E

[a] Emission factor units are lb per ton of HMA produced. SCC = Source Classification Code. ND = no data available. NA = not applicable. To convert from lb/ton to kg/Mg, multiply by 0.5.

[b] TOC equals total hydrocarbons as propane, as measured with an EPA Method 25A or equivalent sampling train plus formaldehyde.

[c] References 24, 46-47, 49. Factor includes data from natural gas- and No. 6 fuel oil-fired dryers. Methane measured with an EPA Method 18 or equivalent sampling train.

[d] The VOC emission factors are equal to the TOC factors minus the methane emission factors; differences in values reported are due to rounding.

[e] References 24, 46-47, 155.

[f] Reference 49.

Table 11.1-7. EMISSION FACTORS FOR CO, CO_2, NO_x, AND SO_2 FROM DRUM MIX HOT MIX ASPHALT PLANTS[a]

Process	CO[b]	EMISSION FACTOR RATING	CO_2[c]	EMISSION FACTOR RATING	NO_x	EMISSION FACTOR RATING	SO_2[c]	EMISSION FACTOR RATING
Natural gas-fired dryer (SCC 3-05-002-55,-56,-57)	0.13	B	33[d]	A	0.026[e]	D	0.0034[f]	D
No. 2 fuel oil-fired dryer (SCC 3-05-002-58,-59,-60)	0.13	B	33[d]	A	0.055[g]	C	0.011[h]	E
Waste oil-fired dryer (SCC 3-05-002-61,-62,-63)	0.13	B	33[d]	A	0.055[g]	C	0.058[j]	B
Coal-fired dryer[k] (SCC 3-05-002-98)	ND	NA	33[d]	A	ND	NA	0.19[m]	E

[a] Emission factor units are lb per ton of HMA produced. SCC = Source Classification Code. ND = no data available. NA = not applicable. To convert from lb/ton to kg/Mg, multiply by 0.5.

[b] References 25, 44, 48, 50, 149, 154, 197, 214, 229, 254, 339-342, 344, 346, 347, 390. The CO emission factors represent normal plant operations without scrutiny of the burner design, operation, and maintenance. Information is available that indicates that attention to burner design, periodic evaluation of burner operation, and appropriate maintenance can reduce CO emissions. Data for dryers firing natural gas, No. 2 fuel oil, and No. 6 fuel oil were combined to develop a single emission factor because the magnitude of emissions was similar for dryers fired with these fuels.

[c] Emissions of CO_2 and SO_2 can also be estimated based on fuel usage and the fuel combustion emission factors (for the appropriate fuel) presented in AP-42 Chapter 1. The CO_2 emission factors are an average of all available data, regardless of the dryer fuel (emissions were similar from dryers firing any of the various fuels). Fifty percent of the fuel-bound sulfur, up to a maximum (as SO_2) of 0.1 lb/ton of product, is expected to be retained in the product, with the remainder emitted as SO_2.

[d] Reference 1, Table 4-15. Average of data from 180 facilities. Range: 2.6 to 96 lb/ton. Median: 31 lb/ton. Standard deviation: 13 lb/ton.

[e] References 44-45, 48, 209, 341, 342.

[f] References 44-45, 48.

[g] References 25, 50, 153, 214, 229, 344, 346, 347, 352-354.

[h] References 50, 119, 255, 340

[j] References 25, 299, 300, 339, 345, 351, 371-377, 379, 380, 386-388.

[k] Dryer fired with coal and supplemental natural gas or fuel oil.

[m] References 88, 108, 189-190.

Table 11.1-8. EMISSION FACTORS FOR TOC, METHANE, VOC, AND HCl FROM DRUM MIX HOT MIX ASPHALT PLANTS[a]

Process	TOC[b]	EMISSION FACTOR RATING	CH_4[c]	EMISSION FACTOR RATING	VOC[d]	EMISSION FACTOR RATING	HCl[e]	EMISSION FACTOR RATING
Natural gas-fired dryer (SCC 3-05-002-55, -56,-57)	0.044[f]	B	0.012	C	0.032	C	ND	NA
No. 2 fuel oil-fired dryer (SCC 3-05-002-58, -59,-60)	0.044[f]	B	0.012	C	0.032	C	ND	NA
Waste oil-fired dryer (SCC 3-05-002-61, -62,-63)	0.044[f]	E	0.012	C	0.032	E	0.00021	D

[a] Emission factor units are lb per ton of HMA produced. SCC = Source Classification Code. ND = no data available. NA = not applicable. To convert from lb/ton to kg/Mg, multiply by 0.5.

[b] TOC equals total hydrocarbons as propane as measured with an EPA Method 25A or equivalent sampling train plus formaldehyde.

[c] References 25, 44-45, 48, 50, 339-340, 355. Factor includes data from natural gas-, No. 2 fuel oil, and waste oil-fired dryers. Methane measured with an EPA Method 18 or equivalent sampling train.

[d] The VOC emission factors are equal to the TOC factors minus the sum of the methane emission factors and the emission factors for compounds with negligible photochemical reactivity shown in Table 11.1-10; differences in values reported are due to rounding.

[e] References 348, 374, 376, 379, 380.

[f] References 25, 44-45, 48, 50, 149, 153-154, 209-212, 214, 241, 242, 339-340, 355.

Table 11.1-9. EMISSION FACTORS FOR ORGANIC POLLUTANT EMISSIONS FROM BATCH MIX HOT MIX ASPHALT PLANTS[a]

Process	Pollutant		Emission Factor, lb/ton	Emission Factor Rating	Ref. Nos.
	CASRN	Name			
Natural gas- or No. 2 fuel oil-fired dryer, hot screens, and mixer with fabric filter (SCC 3-05-002-45,-46)	Non-PAH Hazardous Air Pollutants[b]				
	75-07-0	Acetaldehyde	0.00032	E	24,34
	71-43-2	Benzene	0.00028	D	24,34,46, 382
	100-41-4	Ethylbenzene	0.0022	D	24,46,47,49
	50-00-0	Formaldehyde	0.00074	D	24,34,46,47,49,226,382
	106-51-4	Quinone	0.00027	E	24
	108-88-3	Toluene	0.0010	D	24,34,46,47
	1330-20-7	Xylene	0.0027	D	24,46,47,49
		Total non-PAH HAPs	0.0075		
	PAH HAPs				
	91-57-6	2-Methylnaphthalene[c]	7.1×10^{-5}	D	24,47,49
	83-32-9	Acenaphthene[c]	9.0×10^{-7}	D	34,46,226
	208-96-8	Acenaphthylene[c]	5.8×10^{-7}	D	34,46,226
	120-12-7	Anthracene[c]	2.1×10^{-7}	D	34,46,226
	56-55-3	Benzo(a)anthracene[c]	4.6×10^{-9}	E	46,226
	50-32-8	Benzo(a)pyrene[c]	3.1×10^{-10}	E	226
	205-99-2	Benzo(b)fluoranthene[c]	9.4×10^{-9}	D	34,46,226
	191-24-2	Benzo(g,h,i)perylene[c]	5.0×10^{-10}	E	226
	207-08-9	Benzo(k)fluoranthene[c]	1.3×10^{-8}	E	34,226
	218-01-9	Chrysene[c]	3.8×10^{-9}	E	46,226
	53-70-3	Dibenz(a,h)anthracene[c]	9.5×10^{-11}	E	226
	206-44-0	Fluoranthene[c]	1.6×10^{-7}	D	34,46,47,226
	86-73-7	Fluorene[c]	1.6×10^{-6}	D	34,46,47,226
	193-39-5	Indeno(1,2,3-cd)pyrene[c]	3.0×10^{-10}	E	226
	91-20-3	Naphthalene	3.6×10^{-5}	D	34,46,47,49,226
	85-01-8	Phenanthrene[c]	2.6×10^{-6}	D	34,46,47,226
	129-00-0	Pyrene[c]	6.2×10^{-8}	D	34,46,226
		Total PAH HAPs	0.00011		
	Total HAPs		0.0076		
	Non-HAP organic compounds				
	100-52-7	Benzaldehyde	0.00013	E	24
	78-84-2	Butyraldehyde/ isobutyraldehyde	3.0×10^{-5}	E	24
	4170-30-3	Crotonaldehyde	2.9×10^{-5}	E	24
	66-25-1	Hexanal	2.4×10^{-5}	E	24
		Total non-HAPs	0.00019		

Table 11.1-9 (cont.)

Process	Pollutant		Emission Factor, lb/ton	Emission Factor Rating	Ref. Nos.
	CASRN	Name			
Waste oil-, drain oil-, or No. 6 fuel oil-fired dryer, hot screens, and mixer with fabric filter (SCC 3-05-002-47)	Non-PAH Hazardous Air Pollutants[b]				
	75-07-0	Acetaldehyde	0.00032	E	24,34
	71-43-2	Benzene	0.00028	D	24,34,46, 382
	100-41-4	Ethylbenzene	0.0022	D	24,46,47,49
	50-00-0	Formaldehyde	0.00074	D	24,34,46,47,49,226, 382
	106-51-4	Quinone	0.00027	E	24
	108-88-3	Toluene	0.0010	D	24,34,46,47
	1330-20-7	Xylene	0.0027	D	24,46,47,49
		Total non-PAH HAPs	0.0075		
	PAH HAPs[b]				
	91-57-6	2-Methylnaphthalene[c]	7.1×10^{-5}	D	24,47,49
	83-32-9	Acenaphthene[c]	9.0×10^{-7}	D	34,46,226
	208-96-8	Acenaphthylene[c]	5.8×10^{-7}	D	34,46,226
	120-12-7	Anthracene[c]	2.1×10^{-7}	D	34,46,226
	56-55-3	Benzo(a)anthracene[c]	4.6×10^{-9}	E	46,226
	50-32-8	Benzo(a)pyrene[c]	3.1×10^{-10}	E	226
	205-99-2	Benzo(b)fluoranthene[c]	9.4×10^{-9}	D	34,46,226
	191-24-2	Benzo(g,h,i)perylene[c]	5.0×10^{-10}	E	226
	207-08-9	Benzo(k)fluoranthene[c]	1.3×10^{-8}	E	34,226
	218-01-9	Chrysene[c]	3.8×10^{-9}	E	46,226
	53-70-3	Dibenz(a,h)anthracene[c]	9.5×10^{-11}	E	226
	206-44-0	Fluoranthene[c]	2.4×10^{-5}	E	49
	86-73-7	Fluorene[c]	1.6×10^{-6}	D	34,46,47,226
	193-39-5	Indeno(1,2,3-cd)pyrene[c]	3.0×10^{-10}	E	226
	91-20-3	Naphthalene	3.6×10^{-5}	D	34,46,47,49, 226
	85-01-8	Phenanthrene[c]	3.7×10^{-5}	E	49
	129-00-0	Pyrene[c]	5.5×10^{-5}	E	49
		Total PAH HAPs	0.00023		
	Total HAPs		0.0077		
	Non-HAP organic compounds				
	100-52-7	Benzaldehyde	0.00013	E	24
	78-84-2	Butyraldehyde/ isobutyraldehyde	3.0×10^{-5}	E	24
	4170-30-3	Crotonaldehyde	2.9×10^{-5}	E	24
	66-25-1	Hexanal	2.4×10^{-5}	E	24
		Total non-HAPs	0.00019		

[a] Emission factor units are lb/ton of hot mix asphalt produced. Factors represent uncontrolled emissions, unless noted. CASRN = Chemical Abstracts Service Registry Number. SCC = Source Classification Code. To convert from lb/ton to kg/Mg, multiply by 0.5.

[b] Hazardous air pollutants (HAP) as defined in the 1990 Clean Air Act Amendments (CAAA).

[c] Compound is classified as polycyclic organic matter, as defined in the 1990 CAAA.

Table 11.1-10. EMISSION FACTORS FOR ORGANIC POLLUTANT EMISSIONS FROM DRUM MIX HOT MIX ASPHALT PLANTS[a]

Process	Pollutant		Emission Factor, lb/ton	Emission Factor Rating	Ref. No.
	CASRN	Name			
Natural gas-fired dryer with fabric filter[b] (SCC 3-05-002-55, -56,-57)	Non-PAH hazardous air pollutants[c]				
	71-43-2	Benzene[d]	0.00039	A	25,44,45,50, 341, 342, 344-351, 373, 376, 377, 383, 384
	100-41-4	Ethylbenzene	0.00024	D	25,44,45
	50-00-0	Formaldehyde[e]	0.0031	A	25,35,44,45,50, 339-344, 347-349, 371-373, 384, 388
	110-54-3	Hexane	0.00092	E	339-340
	540-84-1	Isooctane (2,2,4-trimethylpentane)	4.0×10^{-5}	E	339-340
	71-55-6	Methyl chloroform[f]	4.8×10^{-5}	E	35
	108-88-3	Toluene	0.00015	D	35,44,45
	1330-20-7	Xylene	0.00020	D	25,44,45
		Total non-PAH HAPs	0.0051		
	PAH HAPs				
	91-57-6	2-Methylnaphthalene[g]	7.4×10^{-5}	D	44,45,48
	83-32-9	Acenaphthene[g]	1.4×10^{-6}	E	48
	208-96-8	Acenaphthylene[g]	8.6×10^{-6}	D	35,45,48
	120-12-7	Anthracene[g]	2.2×10^{-7}	E	35,48
	56-55-3	Benzo(a)anthracene[g]	2.1×10^{-7}	E	48
	50-32-8	Benzo(a)pyrene[g]	9.8×10^{-9}	E	48
	205-99-2	Benzo(b)fluoranthene[g]	1.0×10^{-7}	E	35,48
	192-97-2	Benzo(e)pyrene[g]	1.1×10^{-7}	E	48
	191-24-2	Benzo(g,h,i)perylene[g]	4.0×10^{-8}	E	48
	207-08-9	Benzo(k)fluoranthene[g]	4.1×10^{-8}	E	35,48
	218-01-9	Chrysene[g]	1.8×10^{-7}	E	35,48
	206-44-0	Fluoranthene[g]	6.1×10^{-7}	D	35,45,48
	86-73-7	Fluorene[g]	3.8×10^{-6}	D	35,45,48,163
	193-39-5	Indeno(1,2,3-cd)pyrene[g]	7.0×10^{-9}	E	48
	91-20-3	Naphthalene[g]	9.0×10^{-5}	D	35,44,45,48,163
	198-55-0	Perylene[g]	8.8×10^{-9}	E	48
	85-01-8	Phenanthrene[g]	7.6×10^{-6}	D	35,44,45,48,163
	129-00-0	Pyrene[g]	5.4×10^{-7}	D	45,48
		Total PAH HAPs	0.00019		

Table 11.1-10 (cont.)

Process	Pollutant		Emission Factor, lb/ton	Emission Factor Rating	Ref. No.
	CASRN	Name			
Natural gas-fired dryer with fabric filter[b] (SCC 3-05-002-55, -56,-57) (cont.)	Total HAPs		0.0053		
	Non-HAP organic compounds				
	106-97-8	Butane	0.00067	E	339
	74-85-1	Ethylene	0.0070	E	339-340
	142-82-5	Heptane	0.0094	E	339-340
	763-29-1	2-Methyl-1-pentene	0.0040	E	339,340
	513-35-9	2-Methyl-2-butene	0.00058	E	339,340
	96-14-0	3-Methylpentane	0.00019	D	339,340
	109-67-1	1-Pentene	0.0022	E	339-340
	109-66-0	n-Pentane	0.00021	E	339-340
		Total non-HAP organics	0.024		
No. 2 fuel oil-fired dryer with fabric filter (SCC 3-05-002-58, -59,-60)	Non-PAH HAPs[c]				
	71-43-2	Benzene[d]	0.00039	A	25,44,45,50, 341, 342, 344-351, 373, 376, 377, 383, 384
	100-41-4	Ethylbenzene	0.00024	D	25,44,45
	50-00-0	Formaldehyde[e]	0.0031	A	25,35,44,45,50, 339-344, 347-349, 371-373, 384, 388
	110-54-3	Hexane	0.00092	E	339-340
	540-84-1	Isooctane (2,2,4-trimethylpentane)	4.0×10^{-5}	E	339-340
	71-55-6	Methyl chloroform[f]	4.8×10^{-5}	E	35
	108-88-3	Toluene	0.0029	E	25, 50, 339-340
	1330-20-7	Xylene	0.00020	D	25,44,45
		Total non-PAH HAPs	0.0078		
	PAH HAPs				
	91-57-6	2-Methylnaphthalene[g]	0.00017	E	50
	83-32-9	Acenaphthene[g]	1.4×10^{-6}	E	48
	208-96-8	Acenaphthylene[g]	2.2×10^{-5}	E	50
	120-12-7	Anthracene[g]	3.1×10^{-6}	E	50,162
	56-55-3	Benzo(a)anthracene[g]	2.1×10^{-7}	E	48
	50-32-8	Benzo(a)pyrene[g]	9.8×10^{-9}	E	48
	205-99-2	Benzo(b)fluoranthene[g]	1.0×10^{-7}	E	35,48
	192-97-2	Benzo(e)pyrene[g]	1.1×10^{-7}	E	48

Table 11.1-10 (cont.)

Process	Pollutant		Emission Factor, lb/ton	Emission Factor Rating	Ref. No.
	CASRN	Name			
No. 2 fuel oil-fired dryer with fabric filter (SCC 3-05-002-58, -59,-60) (cont.)	191-24-2	Benzo(g,h,i)perylene[g]	4.0×10^{-8}	E	48
	207-08-9	Benzo(k)fluoranthene[g]	4.1×10^{-8}	E	35,48
	218-01-9	Chrysene[g]	1.8×10^{-7}	E	35,48
	206-44-0	Fluoranthene[g]	6.1×10^{-7}	D	35,45,48
	86-73-7	Fluorene[g]	1.1×10^{-5}	E	50,164
	193-39-5	Indeno(1,2,3-cd)pyrene[g]	7.0×10^{-9}	E	48
	91-20-3	Naphthalene[g]	0.00065	D	25,50,162,164
	198-55-0	Perylene[g]	8.8×10^{-9}	E	48
	85-01-8	Phenanthrene[g]	2.3×10^{-5}	D	50,162,164
	129-00-0	Pyrene[g]	3.0×10^{-6}	E	50
		Total PAH HAPs	0.00088		
		Total HAPs	0.0087		
	Non-HAP organic compounds				
	106-97-8	Butane	0.00067	E	339
	74-85-1	Ethylene	0.0070	E	339-340
	142-82-5	Heptane	0.0094	E	339-340
	763-29-1	2-Methyl-1-pentene	0.0040	E	339,340
	513-35-9	2-Methyl-2-butene	0.00058	E	339,340
	96-14-0	3-Methylpentane	0.00019	D	339,340
	109-67-1	1-Pentene	0.0022	E	339-340
	109-66-0	n-Pentane	0.00021	E	339-340
		Total non-HAP organics	0.024		

Table 11.1-10 (cont.)

Process	Pollutant		Emission Factor, lb/ton	Emission Factor Rating	Ref. No.
	CASRN	Name			
Fuel oil- or waste oil-fired dryer with fabric filter (SCC 3-05-002-58, -59,-60,-61,-62, -63)	Dioxins				
	1746-01-6	2,3,7,8-TCDD[g]	$2.1x10^{-13}$	E	339
		Total TCDD[g]	$9.3x10^{-13}$	E	339
	40321-76-4	1,2,3,7,8-PeCDD[g]	$3.1x10^{-13}$	E	339
		Total PeCDD[g]	$2.2x10^{-11}$	E	339-340
	39227-28-6	1,2,3,4,7,8-HxCDD[g]	$4.2x10^{-13}$	E	339
	57653-85-7	1,2,3,6,7,8-HxCDD[g]	$1.3x10^{-12}$	E	339
	19408-24-3	1,2,3,7,8,9-HxCDD[g]	$9.8x10^{-13}$	E	339
		Total HxCDD[g]	$1.2x10^{-11}$	E	339-340
	35822-46-9	1,2,3,4,6,7,8-HpCDD[g]	$4.8x10^{-12}$	E	339
		Total HpCDD[g]	$1.9x10^{-11}$	E	339-340
	3268-87-9	Octa CDD[g]	$2.5x10^{-11}$	E	339
		Total PCDD[g]	$7.9x10^{-11}$	E	339-340
	Furans				
	51207-31-9	2,3,7,8-TCDF[g]	$9.7x10^{-13}$	E	339
		Total TCDF[g]	$3.7x10^{-12}$	E	339-340
		1,2,3,7,8-PeCDF[g]	$4.3x10^{-12}$	E	339-340
		2,3,4,7,8-PeCDF[g]	$8.4x10^{-13}$	E	339
		Total PeCDF[g]	$8.4x10^{-11}$	E	339-340
		1,2,3,4,7,8-HxCDF[g]	$4.0x10^{-12}$	E	339
		1,2,3,6,7,8-HxCDF[g]	$1.2x10^{-12}$	E	339
		2,3,4,6,7,8-HxCDF[g]	$1.9x10^{-12}$	E	339
		1,2,3,7,8,9-HxCDF[g]	$8.4x10^{-12}$	E	340
		Total HxCDF[g]	$1.3x10^{-11}$	E	339-340
		1,2,3,4,6,7,8-HpCDF[g]	$6.5x10^{-12}$	E	339
		1,2,3,4,7,8,9-HpCDF[g]	$2.7x10^{-12}$	E	339
		Total HpCDF[g]	$1.0x10^{-11}$	E	339-340
	39001-02-0	Octa CDF[g]	$4.8x10^{-12}$	E	339
		Total PCDF[g]	$4.0x10^{-11}$	E	339-340
		Total PCDD/PCDF[g]	$1.2x10^{-10}$	E	339-340

Table 11.1-10 (cont.)

Process	Pollutant		Emission Factor, lb/ton	Emission Factor Rating	Ref. No.
	CASRN	Name			
Fuel oil- or waste oil-fired dryer (uncontrolled) (SCC 3-05-002-58, -59,-60,-61,-62, -63)	Hazardous air pollutants[c]				
	Dioxins				
		Total HxCDD[g]	$5.4x10^{-12}$	E	340
	35822-46-9	1,2,3,4,6,7,8-HpCDD[g]	$3.4x10^{-11}$	E	340
		Total HpCDD[g]	$7.1x10^{-11}$	E	340
	3268-87-9	Octa CDD[g]	$2.7x10^{-9}$	E	340
		Total PCDD[g]	$2.8x10^{-9}$	E	340
	Furans				
		Total TCDF[g]	$3.3x10^{-11}$	E	340
		Total PeCDF[g]	$7.4x10^{-11}$	E	340
		1,2,3,4,7,8-HxCDF[g]	$5.4x10^{-12}$	E	340
		2,3,4,6,7,8-HxCDF[g]	$1.6x10^{-12}$	E	340
		Total HxCDF[g]	$8.1x10^{-12}$	E	340
Fuel oil- or waste oil-fired dryer (uncontrolled) (SCC 3-05-002-58, -59,-60,-61,-62, -63) (cont.)		1,2,3,4,6,7,8-HpCDF[g]	$1.1x10^{-11}$	E	340
		Total HpCDF[g]	$3.8x10^{-11}$	E	340
		Total PCDF[g]	$1.5x10^{-10}$	E	340
		Total PCDD/PCDF[g]	$3.0x10^{-9}$	E	340

Table 11.1-10 (cont.)

Process	Pollutant		Emission Factor, lb/ton	Emission Factor Rating	Ref. No.
	CASRN	Name			
Waste oil-fired dryer with fabric filter (SCC 3-05-002-61, -62,-63)	Non-PAH HAPs[c]				
	75-07-0	Acetaldehyde	0.0013	E	25
	107-02-8	Acrolein	2.6×10^{-5}	E	25
	71-43-2	Benzene[d]	0.00039	A	25,44,45,50,341,342, 344-351, 373, 376, 377, 383, 384
	100-41-4	Ethylbenzene	0.00024	D	25,44,45
	50-00-0	Formaldehyde[e]	0.0031	A	25,35,44,45,50,339-344,347-349,371-373, 384, 388
	110-54-3	Hexane	0.00092	E	339-340
	540-84-1	Isooctane (2,2,4-trimethylpentane)	4.0×10^{-5}	E	339-340
	78-93-3	Methyl Ethyl Ketone	2.0×10^{-5}	E	25
	123-38-6	Propionaldehyde	0.00013	E	25
	106-51-4	Quinone	0.00016	E	25
	71-55-6	Methyl chloroform[f]	4.8×10^{-5}	E	35
	108-88-3	Toluene	0.0029	E	25, 50, 339-340
	1330-20-7	Xylene	0.00020	D	25,44,45
		Total non-PAH HAPs	0.0095		
	PAH HAPs				
	91-57-6	2-Methylnaphthalene[g]	0.00017	E	50
	83-32-9	Acenaphthene[g]	1.4×10^{-6}	E	48
	208-96-8	Acenaphthylene[g]	2.2×10^{-5}	E	50
	120-12-7	Anthracene[g]	3.1×10^{-6}	E	50,162
	56-55-3	Benzo(a)anthracene[g]	2.1×10^{-7}	E	48
	50-32-8	Benzo(a)pyrene[g]	9.8×10^{-9}	E	48
	205-99-2	Benzo(b)fluoranthene[g]	1.0×10^{-7}	E	35,48
	192-97-2	Benzo(e)pyrene[g]	1.1×10^{-7}	E	48
	191-24-2	Benzo(g,h,i)perylene[g]	4.0×10^{-8}	E	48

Table 11.1-10 (cont.)

Process	Pollutant		Emission Factor, lb/ton	Emission Factor Rating	Ref. No.
	CASRN	Name			
Waste oil-fired dryer with fabric filter (SCC 3-05-002-61, -62,-63) (cont.)	207-08-9	Benzo(k)fluoranthene[g]	$4.1x10^{-8}$	E	35,48
	218-01-9	Chrysene[g]	$1.8x10^{-7}$	E	35,48
	206-44-0	Fluoranthene[g]	$6.1x10^{-7}$	D	35,45,48
	86-73-7	Fluorene[g]	$1.1x10^{-5}$	E	50,164
	193-39-5	Indeno(1,2,3-cd)pyrene[g]	$7.0x10^{-9}$	E	48
	91-20-3	Naphthalene[g]	0.00065	D	25,50,162,164
	198-55-0	Perylene[g]	$8.8x10^{-9}$	E	48
	85-01-8	Phenanthrene[g]	$2.3x10^{-5}$	D	50,162,164
	129-00-0	Pyrene[g]	$3.0x10^{-6}$	E	50
		Total PAH HAPs	0.00088		
		Total HAPs	0.010		
	Non-HAP organic compounds				
	67-64-1	Acetone[f]	0.00083	E	25
	100-52-7	Benzaldehyde	0.00011	E	25
	106-97-8	Butane	0.00067	E	339
	78-84-2	Butyraldehyde	0.00016	E	25
	4170-30-3	Crotonaldehyde	$8.6x10^{-5}$	E	25
	74-85-1	Ethylene	0.0070	E	339, 340
	142-82-5	Heptane	0.0094	E	339, 340
	66-25-1	Hexanal	0.00011	E	25
	590-86-3	Isovaleraldehyde	$3.2x10^{-5}$	E	25
	763-29-1	2-Methyl-1-pentene	0.0040	E	339, 340
	513-35-9	2-Methyl-2-butene	0.00058	E	339, 340
	96-14-0	3-Methylpentane	0.00019	D	339, 340
	109-67-1	1-Pentene	0.0022	E	339, 340
	109-66-0	n-Pentane	0.00021	E	339, 340
	110-62-3	Valeraldehyde	$6.7x10^{-5}$	E	25
		Total non-HAP organics	0.026		

[a] Emission factor units are lb/ton of hot mix asphalt produced. Table includes data from both parallel flow and counterflow drum mix dryers. Organic compound emissions from counterflow systems are expected to be less than from parallel flow systems, but the available data are insufficient to quantify

accurately the difference in these emissions. CASRN = Chemical Abstracts Service Registry Number. SCC = Source Classification Code. To convert from lb/ton to kg/Mg, multiply by 0.5.

[b] Tests included dryers that were processing reclaimed asphalt pavement. Because of limited data, the effect of RAP processing on emissions could not be determined.

[c] Hazardous air pollutants (HAP) as defined in the 1990 Clean Air Act Amendments (CAAA).

[d] Based on data from 19 tests. Range: 0.000063 to 0.0012 lb/ton; median: 0.00030; Standard deviation: 0.00031.

[e] Based on data from 21 tests. Range: 0.0030 to 0.014 lb/ton; median: 0.0020; Standard deviation: 0.0036.

[f] Compound has negligible photochemical reactivity.

[g] Compound is classified as polycyclic organic matter, as defined in the 1990 CAAA. Total PCDD is the sum of the total tetra through octa dioxins; total PCDF is sum of the total tetra through octa furans; and total PCDD/PCDF is the sum of total PCDD and total PCDF.

Table 11.1-11. EMISSION FACTORS FOR METAL EMISSIONS FROM BATCH MIX HOT MIX ASPHALT PLANTS[a]

Process	Pollutant	Emission Factor, lb/ton	Emission Factor Rating	Reference Numbers
Dryer, hot screens, and mixer[b] (SCC 3-05-002-45,-46,-47)	Arsenic[c]	4.6×10^{-7}	D	34, 40, 226
	Barium	1.5×10^{-6}	E	24
	Beryllium[c]	1.5×10^{-7}	E	34, 226
	Cadmium[c]	6.1×10^{-7}	D	24, 34, 226
	Chromium[c]	5.7×10^{-7}	D	24, 34, 226
	Hexavalent chromium[c]	4.8×10^{-8}	E	34, 226
	Copper	2.8×10^{-6}	D	24, 34, 226
	Lead[c]	8.9×10^{-7}	D	24, 34, 226
	Manganese[c]	6.9×10^{-6}	D	24, 34, 226
	Mercury[c]	4.1×10^{-7}	E	34, 226
	Nickel[c]	3.0×10^{-6}	D	24, 34, 226
	Selenium[c]	4.9×10^{-7}	E	34, 226
	Zinc	6.8×10^{-6}	D	24, 34, 226

[a] Emission factor units are lb/ton of HMA produced. Emissions controlled by a fabric filter. SCC = Source Classification Code. To convert from lb/ton to kg/Mg, multiply by 0.5.

[b] Natural gas-, propane-, No. 2 fuel oil-, or waste oil-/drain oil-/No. 6 fuel oil-fired dryer. For waste oil-/drain oil-/No. 6 fuel oil-fired dryer, use a lead emission factor of 1.0×10^{-5} lb/ton (References 177 and 321, Emission factor rating: E) in lieu of the emission factor shown.

[c] Arsenic, beryllium, cadmium, chromium, hexavalent chromium, lead, manganese, mercury, nickel, and selenium are HAPs as defined in the 1990 CAAA.

Table 11.1-12. EMISSION FACTORS FOR METAL EMISSIONS FROM DRUM MIX HOT MIX ASPHALT PLANTS[a]

Process	Pollutant	Emission Factor, lb/ton	Emission Factor Rating	Reference Numbers
Fuel oil-fired dryer, uncontrolled (SCC 3-05-002-58, -59,-60)	Arsenic[b]	1.3×10^{-6}	E	340
	Barium	0.00025	E	340
	Beryllium[b]	0.0	E	340
	Cadmium[b]	4.2×10^{-6}	E	340
	Chromium[b]	2.4×10^{-5}	E	340
	Cobalt[b]	1.5×10^{-5}	E	340
	Copper	0.00017	E	340
	Lead[b]	0.00054	E	340
	Manganese[b]	0.00065	E	340
	Nickel[b]	0.0013	E	340
	Phosphorus[b]	0.0012	E	340
	Selenium[b]	2.4×10^{-6}	E	340
	Thallium	2.2×10^{-6}	E	340
	Zinc	0.00018	E	340
Natural gas- or propane-fired dryer, with fabric filter (SCC 3-05-002-55, -56,-57))	Antimony	1.8×10^{-7}	E	339
	Arsenic[b]	5.6×10^{-7}	D	25, 35, 339-340
	Barium	5.8×10^{-6}	E	25, 339-340
	Beryllium[b]	0.0	E	339-340
	Cadmium[b]	4.1×10^{-7}	D	25, 35, 162, 301, 339-340
	Chromium[b]	5.5×10^{-6}	C	25, 162-164, 301, 339-340
	Cobalt[b]	2.6×10^{-8}	E	339-340
	Copper	3.1×10^{-6}	D	25, 162-164, 339-340
	Hexavalent chromium[b]	4.5×10^{-7}	E	163
	Lead[b]	6.2×10^{-7}	E	35
	Manganese[b]	7.7×10^{-6}	D	25, 162-164, 339-340
	Mercury[b]	2.4×10^{-7}	E	35, 163
	Nickel[b]	6.3×10^{-5}	D	25, 163-164, 339-340
	Phosphorus[b]	2.8×10^{-5}	E	25, 339-340
	Silver	4.8×10^{-7}	E	25, 339-340
	Selenium[b]	3.5×10^{-7}	E	339-340
	Thallium	4.1×10^{-9}	E	339-340
	Zinc	6.1×10^{-5}	C	25, 35, 162-164, 339-340

Table 11.1-12 (cont.)

Process	Pollutant	Emission Factor, lb/ton	Emission Factor Rating	Reference Numbers
No. 2 fuel oil-fired dryer or waste oil/drain oil/No. 6 fuel oil-fired dryer, with fabric filter (SCC 3-05-002-58, -59,-60,-61,-62,-63)	Antimony	1.8×10^{-7}	E	339
	Arsenic[b]	5.6×10^{-7}	D	25, 35, 339-340
	Barium	5.8×10^{-6}	E	25, 339-340
	Beryllium[b]	0.0	E	339-340
	Cadmium[b]	4.1×10^{-7}	D	25, 35, 162, 301, 339-340
	Chromium[b]	5.5×10^{-6}	C	25, 162-164, 301, 339-340
	Cobalt[b]	2.6×10^{-8}	E	339-340
	Copper	3.1×10^{-6}	D	25, 162-164, 339-340
	Hexavalent chromium[b]	4.5×10^{-7}	E	163
	Lead[b]	1.5×10^{-5}	C	25, 162, 164, 178-179, 183, 301, 315, 339-340
	Manganese[b]	7.7×10^{-6}	D	25, 162-164, 339-340
	Mercury[b]	2.6×10^{-6}	D	162, 164, 339-340
	Nickel[b]	6.3×10^{-5}	D	25, 163-164, 339-340
	Phosphorus[b]	2.8×10^{-5}	E	25, 339-340
	Silver	4.8×10^{-7}	E	25, 339-340
	Selenium[b]	3.5×10^{-7}	E	339-340
	Thallium	4.1×10^{-9}	E	339-340
	Zinc	6.1×10^{-5}	C	25, 35, 162-164, 339-340

[a] Emission factor units are lb/ton of HMA produced. SCC = Source Classification Code. To convert from lb/ton to kg/Mg, multiply by 0.5. Emission factors apply to facilities processing virgin aggregate or a combination of virgin aggregate and RAP.

[b] Arsenic, beryllium, cadmium, chromium, hexavalent chromium, cobalt, lead, manganese, mercury, nickel, and selenium compounds are HAPs as defined in the 1990 CAAA. Elemental phosphorus also is a listed HAP, but the phosphorus measured by Method 29 is not elemental phosphorus.

Table 11.1-13. EMISSION FACTORS FOR HOT MIX ASPHALT HOT OIL SYSTEMS[a]

Process	Pollutant		Emission factor	Emission factor units	EMISSION FACTOR RATING	Reference
	CASRN	Name				
Hot oil system fired with natural gas (SCC 3-05-002-06)	630-08-0	Carbon monoxide	8.9×10^{-6}	lb/ft^3	C	395
	124-38-9	Carbon dioxide	0.20	lb/ft^3	C	395
	50-00-0	Formaldehyde	2.6×10^{-8}	lb/ft^3	C	395
Hot oil system fired with No. 2 fuel oil (SCC 3-05-002-08)	630-08-0	Carbon monoxide	0.0012	lb/gal	C	395
	124-38-9	Carbon dioxide	28	lb/gal	C	395
	50-00-0	Formaldehyde	3.5×10^{-6}	lb/gal	C	395
	83-32-9	Acenaphthene[b]	5.3×10^{-7}	lb/gal	E	35
	208-96-8	Acenaphthylene[b]	2.0×10^{-7}	lb/gal	E	35
	120-12-7	Anthracene[b]	1.8×10^{-7}	lb/gal	E	35
	205-99-2	Benzo(b)fluoranthene[b]	1.0×10^{-7}	lb/gal	E	35
	206-44-0	Fluoranthene[b]	4.4×10^{-8}	lb/gal	E	35
	86-73-7	Fluorene[b]	3.2×10^{-8}	lb/gal	E	35
	91-20-3	Naphthalene[b]	1.7×10^{-5}	lb/gal	E	35
	85-01-8	Phenanthrene[b]	4.9×10^{-6}	lb/gal	E	35
	129-00-0	Pyrene[b]	3.2×10^{-8}	lb/gal	E	35
	Dioxins					
	19408-74-3	1,2,3,7,8,9-HxCDD[b]	7.6×10^{-13}	lb/gal	E	35
	39227-28-6	1,2,3,4,7,8-HxCDD[b]	6.9×10^{-13}	lb/gal	E	35
		HxCDD[b]	6.2×10^{-12}	lb/gal	E	35
	35822-46-9	1,2,3,4,6,7,8-HpCDD[b]	1.5×10^{-11}	lb/gal	E	35
		HpCDD[b]	2.0×10^{-11}	lb/gal	E	35
	3268-87-9	OCDD[b]	1.6×10^{-10}	lb/gal	E	35
		Total PCDD	2.0×10^{-10}	lb/gal	E	35
	Furans					
		TCDF[b]	3.3×10^{-12}	lb/gal	E	35
		PeCDF[b]	4.8×10^{-13}	lb/gal	E	35
		HxCDF[b]	2.0×10^{-12}	lb/gal	E	35
		HpCDF[b]	9.7×10^{-12}	lb/gal	E	35
	67562-39-4	1,2,3,4,6,7,8-HpCDF[b]	3.5×10^{-12}	lb/gal	E	35
	39001-02-0	OCDF[b]	1.2×10^{-11}	lb/gal	E	35
		Total PCDF	3.1×10^{-11}	lb/gal	E	35
		Total PCDD/PCDF	2.3×10^{-10}	lb/gal	E	35

[a] Emission factor units are lb/gal of fuel consumed. To convert from pounds per standard cubic foot (lb/ft^3) to kilograms per standard cubic meter (kg/m^3), multiply by 16. To convert from lb/gal to kilograms per liter (kg/l), multiply by 0.12. CASRN = Chemical Abstracts Service Registry Number. SCC = Source Classification Code.

[b] Compound is classified as polycyclic organic matter, as defined in the 1990 Clean Air Act Amendments (CAAA). Total PCDD is the sum of the total tetra through octa dioxins; total PCDF is sum of the total tetra through octa furans; and total PCDD/PCDF is the sum of total PCDD and total PCDF.

Table 11.1-14. PREDICTIVE EMISSION FACTOR EQUATIONS FOR LOAD-OUT AND SILO FILLING OPERATIONS[a]

EMISSION FACTOR RATING: C

Source	Pollutant	Equation
Drum mix or batch mix plant load-out (SCC 3-05-002-14)	Total PM[b]	$EF = 0.000181 + 0.00141(-V)e^{((0.0251)(T + 460) - 20.43)}$
	Organic PM[c]	$EF = 0.00141(-V)e^{((0.0251)(T + 460) - 20.43)}$
	TOC[d]	$EF = 0.0172(-V)e^{((0.0251)(T + 460) - 20.43)}$
	CO	$EF = 0.00558(-V)e^{((0.0251)(T + 460) - 20.43)}$
Silo filling (SCC 3-05-002-13)	Total PM[b]	$EF = 0.000332 + 0.00105(-V)e^{((0.0251)(T + 460) - 20.43)}$
	Organic PM[c]	$EF = 0.00105(-V)e^{((0.0251)(T + 460) - 20.43)}$
	TOC[d]	$EF = 0.0504(-V)e^{((0.0251)(T + 460) - 20.43)}$
	CO	$EF = 0.00488(-V)e^{((0.0251)(T + 460) - 20.43)}$

[a] Emission factor units are lb/ton of HMA produced. SCC = Source Classification Code. To convert from lb/ton to kg/Mg, multiply by 0.5. EF = emission factor; V = asphalt volatility, as determined by ASTM Method D2872-88 "Effects of Heat and Air on a Moving Film of Asphalt (Rolling Thin Film Oven Test - RTFOT)," where a 0.5 percent loss-on-heating is expressed as "-0.5." Regional- or site-specific data for asphalt volatility should be used, whenever possible; otherwise, a default value of -0.5 should be used for V in these equations. T = HMA mix temperature in °F. Site-specific temperature data should be used, whenever possible; otherwise a default temperature of 325°F can be used. Reference 1, Tables 4-27 through 4-31, 4-34 through 4-36, and 4-38 through 4-41.

[b] Total PM, as measured by EPA Method 315 (EPA Method 5 plus the extractable organic particulate from the impingers). Total PM is assumed to be predominantly PM-2.5 since emissions consist of condensed vapors.

[c] Extractable organic PM, as measured by EPA Method 315 (methylene chloride extract of EPA Method 5 particulate plus methylene chloride extract of impinger particulate).

[d] TOC as propane, as measured with an EPA Method 25A sampling train or equivalent sampling train.

Table 11.1-15. SPECIATION PROFILES FOR LOAD-OUT, SILO FILLING, AND ASPHALT STORAGE EMISSIONS–ORGANIC PARTICULATE-BASED COMPOUNDS

EMISSION FACTOR RATING: C

Pollutant	CASRN[a]	Speciation Profile for Load-out and Yard Emissions[b] Compound/Organic PM[c]	Speciation Profile for Silo Filling and Asphalt Storage Tank Emissions Compound/Organic PM[c]
PAH HAPs			
Acenaphthene	83-32-9	0.26%	0.47%
Acenaphthylene	208-96-8	0.028%	0.014%
Anthracene	120-1207	0.070%	0.13%
Benzo(a)anthracene	56-55-3	0.019%	0.056%
Benzo(b)fluoranthene	205-99-2	0.0076%	ND[d]
Benzo(k)fluoranthene	207-08-9	0.0022%	ND[d]
Benzo(g,h,i)perylene	191-24-2	0.0019%	ND[d]
Benzo(a)pyrene	50-32-8	0.0023%	ND[d]
Benzo(e)pyrene	192-97-2	0.0078%	0.0095%
Chrysene	218-01-9	0.103%	0.21%
Dibenz(a,h)anthracene	53-70-3	0.00037%	ND[d]
Fluoranthene	206-44-0	0.050%	0.15%
Fluorene	86-73-7	0.77%	1.01%
Indeno(1,2,3-cd)pyrene	193-39-5	0.00047%	ND[d]
2-Methylnaphthalene	91-57-6	2.38%	5.27%
Naphthalene	91-20-3	1.25%	1.82%
Perylene	198-55-0	0.022%	0.030%
Phenanthrene	85-01-8	0.81%	1.80%
Pyrene	129-00-0	0.15%	0.44%
Total PAH HAPs		5.93%	11.40%
Other semi-volatile HAPs			
Phenol		1.18%	ND[d]

[a] Chemical Abstract Service Registry Number.
[b] Emissions from loaded trucks during the period between load-out and the time the truck departs the plant.
[c] Emission factor for compound is determined by multiplying the percentage presented for the compound by the emission factor for extractable organic particulate (organic PM) as determined from Table 11.1-14.
[d] ND = Measured data below detection limits.

Table 11.1-16. SPECIATION PROFILES FOR LOAD-OUT, SILO FILLING, AND ASPHALT STORAGE EMISSIONS–ORGANIC VOLATILE-BASED COMPOUNDS

EMISSION FACTOR RATING: C

Pollutant	CASRN	Speciation Profile for Load-Out and Yard Emissions Compound/TOC[a]	Speciation Profile for Silo Filling and Asphalt Storage Tank Emissions Compound/TOC (%)[a]
VOC[b]		94%[b]	100%
Non-VOC/non-HAPs			
Methane	74-82-8	6.5%	0.26%
Acetone	67-64-1	0.046%	0.055%
Ethylene	74-85-1	0.71%	1.1%
Total non-VOC/non-HAPS		7.3%	1.4%
Volatile organic HAPS			
Benzene	71-43-2	0.052%	0.032%
Bromomethane	74-83-9	0.0096%	0.0049%
2-Butanone	78-93-3	0.049%	0.039%
Carbon Disulfide	75-15-0	0.013%	0.016%
Chloroethane	75-00-3	0.00021%	0.0040%
Chloromethane	74-87-3	0.015%	0.023%
Cumene	92-82-8	0.11%	ND[c]
Ethylbenzene	100-41-4	0.28%	0.038%
Formaldehyde	50-00-0	0.088%	0.69%
n-Hexane	100-54-3	0.15%	0.10%
Isooctane	540-84-1	0.0018%	0.00031%
Methylene Chloride	75-09-2	0.0%[d]	0.00027%
MTBE	596899	0.0%[d]	ND[c]
Styrene	100-42-5	0.0073%	0.0054%
Tetrachloroethene	127-18-4	0.0077%	ND[c]
Toluene	100-88-3	0.21%	0.062%
1,1,1-Trichloroethane	71-55-6	0.0%[d]	ND[c]
Trichloroethene	79-01-6	0.0%[d]	ND[c]
Trichlorofluoromethane	75-69-4	0.0013%	ND[c]
m-/p-Xylene	1330-20-7	0.41%	0.2%
o-Xylene	95-47-6	0.08%	0.057%
Total volatile organic HAPs		1.5%	1.3%

Table 11.1-16 (cont.)

[a] Emission factor for compound is determined by multiplying the percentage presented for the compound by the emission factor for total organic compounds (TOC) as determined from Table 11.1-14.

[b] The VOC percentages are equal to 100 percent of TOC minus the methane, acetone, methylene chloride, and 1,1,1-trichloroethane percentages.

[c] ND = Measured data below detection limits. Additional compounds that were not detected are: acrylonitrile, allyl chloride, bromodichloromethane, bromoform, 1,3-butadiene, carbon tetrachloride, chlorobenzene, chloroform, dibromochloromethane, 1,2-dibromoethane, 1,1-dichloroethane, 1,2-dichloroethane, 1,1-dichloroethene, cis-1,2-dichloroethene, trans-1,2-dichloroethene, 1,2-dichloropropane, cis-1,3-dichloropropene, trans-1,3-dichloropropene, 1,2-epoxybutane, ethyl acrylate, 2-hexanone, iodomethane, methyl methacrylate, 1,1,2,2-tetrachloroethane, 1,1,2-trichloroethane, vinyl acetate, vinyl bromide, and vinyl chloride

[d] Values presented as 0.0% had background concentrations higher than the capture efficiency-corrected measured concentration.

13.2.4 Aggregate Handling And Storage Piles

13.2.4.1 General

Inherent in operations that use minerals in aggregate form is the maintenance of outdoor storage piles. Storage piles are usually left uncovered, partially because of the need for frequent material transfer into or out of storage.

Dust emissions occur at several points in the storage cycle, such as material loading onto the pile, disturbances by strong wind currents, and loadout from the pile. The movement of trucks and loading equipment in the storage pile area is also a substantial source of dust.

13.2.4.2 Emissions And Correction Parameters

The quantity of dust emissions from aggregate storage operations varies with the volume of aggregate passing through the storage cycle. Emissions also depend on 3 parameters of the condition of a particular storage pile: age of the pile, moisture content, and proportion of aggregate fines.

When freshly processed aggregate is loaded onto a storage pile, the potential for dust emissions is at a maximum. Fines are easily disaggregated and released to the atmosphere upon exposure to air currents, either from aggregate transfer itself or from high winds. As the aggregate pile weathers, however, potential for dust emissions is greatly reduced. Moisture causes aggregation and cementation of fines to the surfaces of larger particles. Any significant rainfall soaks the interior of the pile, and then the drying process is very slow.

Silt (particles equal to or less than 75 micrometers [μm] in diameter) content is determined by measuring the portion of dry aggregate material that passes through a 200-mesh screen, using ASTM-C-136 method.[1] Table 13.2.4-1 summarizes measured silt and moisture values for industrial aggregate materials.

Table 13.2.4-1. TYPICAL SILT AND MOISTURE CONTENTS OF MATERIALS AT VARIOUS INDUSTRIES[a]

Industry	No. Of Facilities	Material	Silt Content (%)			Moisture Content (%)		
			No. Of Samples	Range	Mean	No. Of Samples	Range	Mean
Iron and steel production	9	Pellet ore	13	1.3 - 13	4.3	11	0.64 - 4.0	2.2
		Lump ore	9	2.8 - 19	9.5	6	1.6 - 8.0	5.4
		Coal	12	2.0 - 7.7	4.6	11	2.8 - 11	4.8
		Slag	3	3.0 - 7.3	5.3	3	0.25 - 2.0	0.92
		Flue dust	3	2.7 - 23	13	1	—	7
		Coke breeze	2	4.4 - 5.4	4.9	2	6.4 - 9.2	7.8
		Blended ore	1	—	15	1	—	6.6
		Sinter	1	—	0.7	0	—	—
		Limestone	3	0.4 - 2.3	1.0	2	ND	0.2
Stone quarrying and processing	2	Crushed limestone	2	1.3 - 1.9	1.6	2	0.3 - 1.1	0.7
		Various limestone products	8	0.8 - 14	3.9	8	0.46 - 5.0	2.1
Taconite mining and processing	1	Pellets	9	2.2 - 5.4	3.4	7	0.05 - 2.0	0.9
		Tailings	2	ND	11	1	—	0.4
Western surface coal mining	4	Coal	15	3.4 - 16	6.2	7	2.8 - 20	6.9
		Overburden	15	3.8 - 15	7.5	0	—	—
		Exposed ground	3	5.1 - 21	15	3	0.8 - 6.4	3.4
Coal-fired power plant	1	Coal (as received)	60	0.6 - 4.8	2.2	59	2.7 - 7.4	4.5
Municipal solid waste landfills	4	Sand	1	—	2.6	1	—	7.4
		Slag	2	3.0 - 4.7	3.8	2	2.3 - 4.9	3.6
		Cover	5	5.0 - 16	9.0	5	8.9 - 16	12
		Clay/dirt mix	1	—	9.2	1	—	14
		Clay	2	4.5 - 7.4	6.0	2	8.9 - 11	10
		Fly ash	4	78 - 81	80	4	26 - 29	27
		Misc. fill materials	1	—	12	1	—	11

[a] References 1-10. ND = no data.

13.2.4.3 Predictive Emission Factor Equations

Total dust emissions from aggregate storage piles result from several distinct source activities within the storage cycle:

1. Loading of aggregate onto storage piles (batch or continuous drop operations).
2. Equipment traffic in storage area.
3. Wind erosion of pile surfaces and ground areas around piles.
4. Loadout of aggregate for shipment or for return to the process stream (batch or continuous drop operations).

Either adding aggregate material to a storage pile or removing it usually involves dropping the material onto a receiving surface. Truck dumping on the pile or loading out from the pile to a truck with a front-end loader are examples of batch drop operations. Adding material to the pile by a conveyor stacker is an example of a continuous drop operation.

The quantity of particulate emissions generated by either type of drop operation, per kilogram (kg) (ton) of material transferred, may be estimated, with a rating of A, using the following empirical expression:[11]

$$E = k(0.0016) \frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}} \text{ (kg/megagram [Mg])} \quad (1)$$

$$E = k(0.0032) \frac{\left(\frac{U}{5}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}} \text{ (pound [lb]/ton)}$$

where:

E = emission factor
k = particle size multiplier (dimensionless)
U = mean wind speed, meters per second (m/s) (miles per hour [mph])
M = material moisture content (%)

The particle size multiplier in the equation, k, varies with aerodynamic particle size range, as follows:

Aerodynamic Particle Size Multiplier (k) For Equation 1				
< 30 µm	< 15 µm	< 10 µm	< 5 µm	< 2.5 µm
0.74	0.48	0.35	0.20	0.053[a]

[a] Multiplier for < 2.5 µm taken from Reference 14.

The equation retains the assigned quality rating if applied within the ranges of source conditions that were tested in developing the equation, as follows. Note that silt content is included, even though silt content does not appear as a correction parameter in the equation. While it is reasonable to expect that silt content and emission factors are interrelated, no significant correlation between the 2 was found during the derivation of the equation, probably because most tests with high silt contents were conducted under lower winds, and vice versa. It is recommended that estimates from the equation be reduced 1 quality rating level if the silt content used in a particular application falls outside the range given:

Ranges Of Source Conditions For Equation 1			
Silt Content (%)	Moisture Content (%)	Wind Speed	
		m/s	mph
0.44 - 19	0.25 - 4.8	0.6 - 6.7	1.3 - 15

To retain the quality rating of the equation when it is applied to a specific facility, reliable correction parameters must be determined for specific sources of interest. The field and laboratory procedures for aggregate sampling are given in Reference 3. In the event that site-specific values for

correction parameters cannot be obtained, the appropriate mean from Table 13.2.4-1 may be used, but the quality rating of the equation is reduced by 1 letter.

For emissions from equipment traffic (trucks, front-end loaders, dozers, etc.) traveling between or on piles, it is recommended that the equations for vehicle traffic on unpaved surfaces be used (see Section 13.2.2). For vehicle travel between storage piles, the silt value(s) for the areas among the piles (which may differ from the silt values for the stored materials) should be used.

Worst-case emissions from storage pile areas occur under dry, windy conditions. Worst-case emissions from materials-handling operations may be calculated by substituting into the equation appropriate values for aggregate material moisture content and for anticipated wind speeds during the worst case averaging period, usually 24 hours. The treatment of dry conditions for Section 13.2.2, vehicle traffic, "Unpaved Roads", follows the methodology described in that section centering on parameter p. A separate set of nonclimatic correction parameters and source extent values corresponding to higher than normal storage pile activity also may be justified for the worst-case averaging period.

13.2.4.4 Controls[12-13]

Watering and the use of chemical wetting agents are the principal means for control of aggregate storage pile emissions. Enclosure or covering of inactive piles to reduce wind erosion can also reduce emissions. Watering is useful mainly to reduce emissions from vehicle traffic in the storage pile area. Watering of the storage piles themselves typically has only a very temporary slight effect on total emissions. A much more effective technique is to apply chemical agents (such as surfactants) that permit more extensive wetting. Continuous chemical treating of material loaded onto piles, coupled with watering or treatment of roadways, can reduce total particulate emissions from aggregate storage operations by up to 90 percent.[12]

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9. *PM-10 Emission Inventory Of Landfills In the Lake Calumet Area*, EPA Contract No. 68-02-3891, Midwest Research Institute, Kansas City, MO, September 1987.

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14. C. Cowherd, *Background Document for Revisions to Fine Fraction Ratios &sed for AP-42 Fugitive Dust Emission Factors*. Prepared by Midwest Research Institute for Western Governors Association, Western Regional Air Partnership, Denver, CO, February 1, 2006.

11.19.2 Crushed Stone Processing and Pulverized Mineral Processing

11.19.2.1 Process Description [24, 25]

Crushed Stone Processing

Major rock types processed by the crushed stone industry include limestone, granite, dolomite, traprock, sandstone, quartz, and quartzite. Minor types include calcareous marl, marble, shell, and slate. Major mineral types processed by the pulverized minerals industry, a subset of the crushed stone processing industry, include calcium carbonate, talc, and barite. Industry classifications vary considerably and, in many cases, do not reflect actual geological definitions.

Rock and crushed stone products generally are loosened by drilling and blasting and then are loaded by power shovel or front-end loader into large haul trucks that transport the material to the processing operations. Techniques used for extraction vary with the nature and location of the deposit. Processing operations may include crushing, screening, size classification, material handling and storage operations. All of these processes can be significant sources of PM and PM-10 emissions if uncontrolled.

Quarried stone normally is delivered to the processing plant by truck and is dumped into a bin. A feeder is used as illustrated in Figure 11.19.2-1. The feeder or screens separate large boulders from finer rocks that do not require primary crushing, thus reducing the load to the primary crusher. Jaw, impactor, or gyratory crushers are usually used for initial reduction. The crusher product, normally 7.5 to 30 centimeters (3 to 12 inches) in diameter, and the grizzly throughs (undersize material) are discharged onto a belt conveyor and usually are conveyed to a surge pile for temporary storage or are sold as coarse aggregates.

The stone from the surge pile is conveyed to a vibrating inclined screen called the scalping screen. This unit separates oversized rock from the smaller stone. The undersized material from the scalping screen is considered to be a product stream and is transported to a storage pile and sold as base material. The stone that is too large to pass through the top deck of the scalping screen is processed in the secondary crusher. Cone crushers are commonly used for secondary crushing (although impact crushers are sometimes used), which typically reduces material to about 2.5 to 10 centimeters (1 to 4 inches). The material (throughs) from the second level of the screen bypasses the secondary crusher because it is sufficiently small for the last crushing step. The output from the secondary crusher and the throughs from the secondary screen are transported by conveyor to the tertiary circuit, which includes a sizing screen and a tertiary crusher.

Tertiary crushing is usually performed using cone crushers or other types of impactor crushers. Oversize material from the top deck of the sizing screen is fed to the tertiary crusher. The tertiary crusher output, which is typically about 0.50 to 2.5 centimeters (3/16th to 1 inch), is returned to the sizing screen. Various product streams with different size gradations are separated in the screening operation. The products are conveyed or trucked directly to finished product bins, to open area stock piles, or to other processing systems such as washing, air separators, and screens and classifiers (for the production of manufactured sand).

Some stone crushing plants produce manufactured sand. This is a small-sized rock product with a maximum size of 0.50 centimeters (3/16 th inch). Crushed stone from the tertiary sizing screen is sized in a vibrating inclined screen (fines screen) with relatively small mesh sizes.

Oversized material is processed in a cone crusher or a hammermill (fines crusher) adjusted to produce small diameter material. The output is returned to the fines screen for resizing.

In certain cases, stone washing is required to meet particulate end product specifications or demands.

Pulverized Mineral Processing

Pulverized minerals are produced at specialized processing plants. These plants supply mineral products ranging from sizes of approximately 1 micrometer to more than 75 micrometers aerodynamic diameter. Pharmaceutical, paint, plastics, pigment, rubber, and chemical industries use these products. Due to the specialized characteristics of the mineral products and the markets for these products, pulverized mineral processing plants have production rates that are less than 5% of the production capacities of conventional crushed stone plants. Two alternative processing systems for pulverized minerals are summarized in Figure 11-19.2-2.

In dry processing systems, the mineral aggregate material from conventional crushing and screening operations is subject to coarse and fine grinding primarily in roller mills and/or ball mills to reduce the material to the necessary product size range. A classifier is used to size the ground material and return oversized material that can be pulverized using either wet or dry processes. The classifier can either be associated with the grinding operation, or it can be a stand-alone process unit. Fabric filters control particulate matter emissions from the grinding operation and the classifier. The products are stored in silos and are shipped by truck or in bags.

In wet processing systems, the mineral aggregate material is processed in wet mode coarse and fine grinding operations. Beneficiation processes use flotation to separate mineral impurities. Finely ground material is concentrated and flash dried. Fabric filters are used to control particulate matter emissions from the flash dryer. The product is then stored in silos, bagged, and shipped.

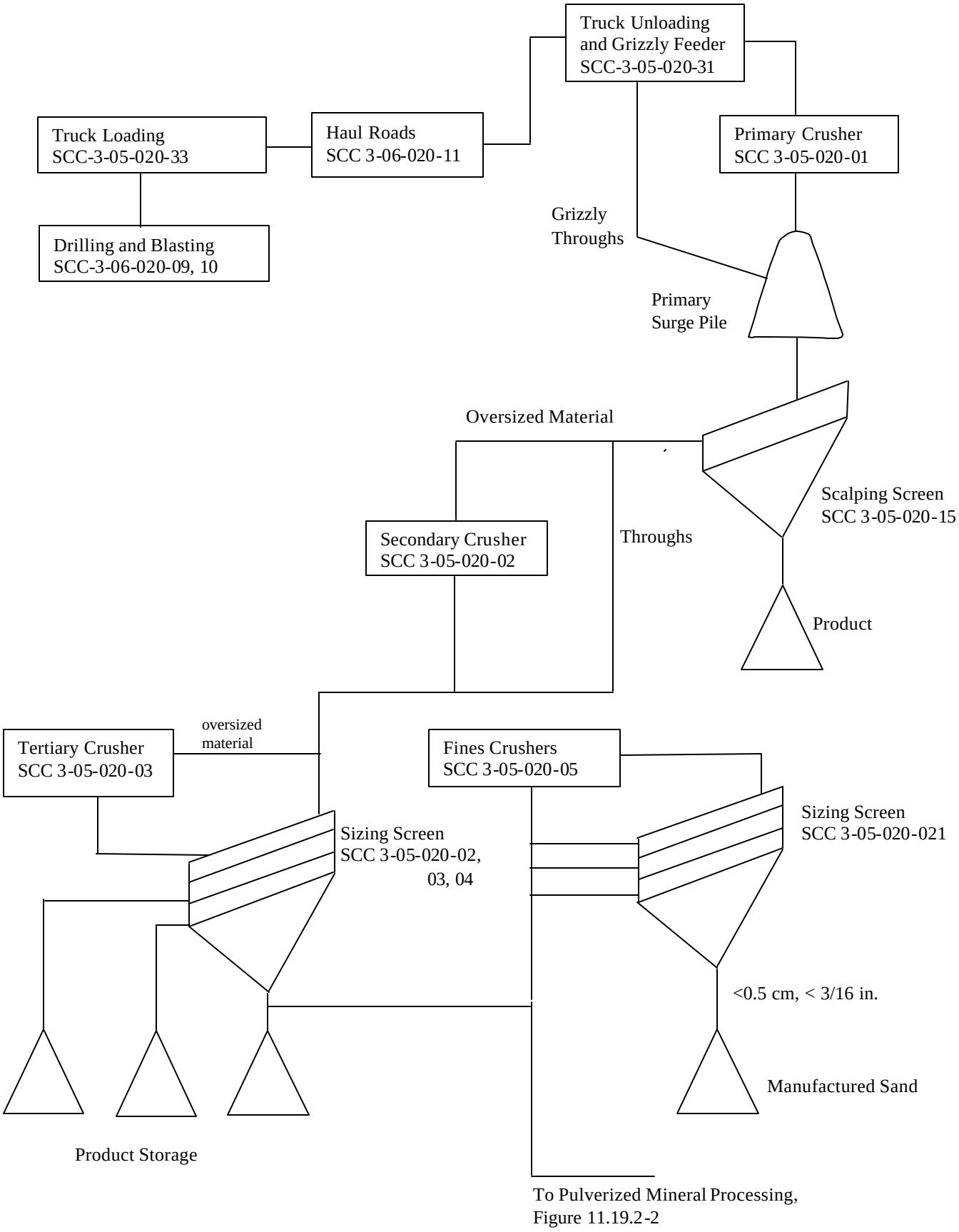


Figure 11.19.2-1. Typical stone processing plant

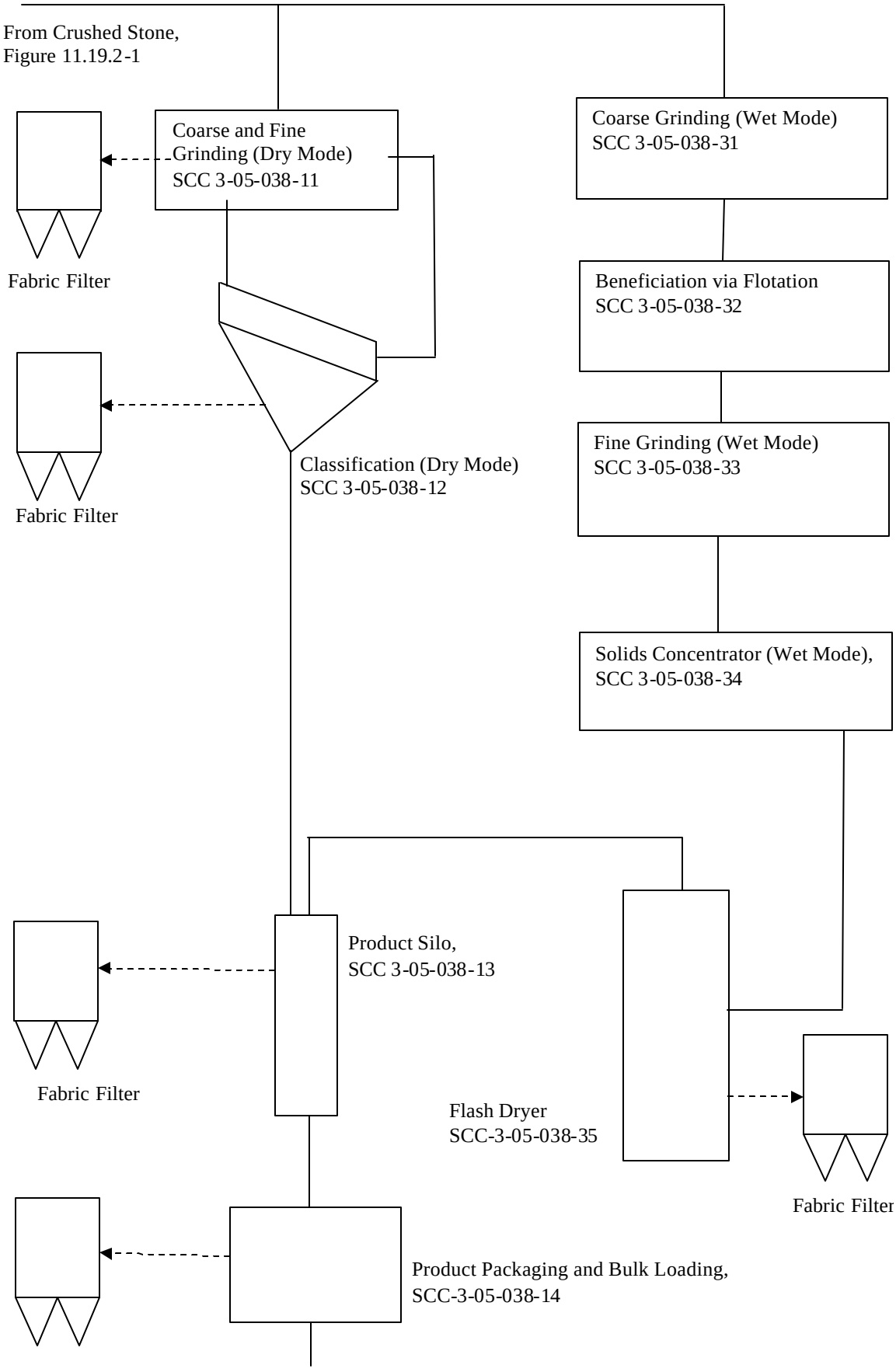


Figure 11.19.2-2 Flowchart for Pulverized Mineral Processing

11.19.2.2 Emissions and Controls [10, 11, 12, 13, 14, and 26]

Crushed Stone Processing

Emissions of PM, PM-10, and PM-2.5 occur from a number of operations in stone quarrying and processing. A substantial portion of these emissions consists of heavy particles that may settle out within the plant. As in other operations, crushed stone emission sources may be categorized as either process sources or fugitive dust sources. Process sources include those for which emissions are amenable to capture and subsequent control. Fugitive dust sources generally involve the reentrainment of settled dust by wind or machine movement. Emissions from process sources should be considered fugitive unless the sources are vented to a baghouse or are contained in an enclosure with a forced-air vent or stack. Factors affecting emissions from either source category include the stone size distribution and the surface moisture content of the stone processed, the process throughput rate, the type of equipment and operating practices used, and topographical and climatic factors.

Of graphical and seasonal factors, the primary variables affecting uncontrolled PM emissions are wind and material moisture content. Wind parameters vary with geographical location, season, and weather. It can be expected that the level of emissions from unenclosed sources (principally fugitive dust sources) will be greater during periods of high winds. The material moisture content also varies with geographical location, season, and weather. Therefore, the levels of uncontrolled emissions from both process emission sources and fugitive dust sources generally will be greater in arid regions of the country than in temperate ones and greater during the summer months because of a higher evaporation rate.

The moisture content of the material processed can have a substantial effect on emissions. This effect is evident throughout the processing operations. Surface wetness causes fine particles to agglomerate on or to adhere to the faces of larger stones, with a resulting dust suppression effect. However, as new fine particles are created by crushing and attrition and as the moisture content is reduced by evaporation, this suppressive effect diminishes and may disappear. Plants that use wet suppression systems (spray nozzles) to maintain relatively high material moisture contents can effectively control PM emissions throughout the process. Depending on the geographical and climatic conditions, the moisture content of mined rock can range from nearly zero to several percent. Because moisture content is usually expressed on a basis of overall weight percent, the actual moisture amount per unit area will vary with the size of the rock being handled. On a constant mass-fraction basis, the per-unit area moisture content varies inversely with the diameter of the rock. The suppressive effect of the moisture depends on both the absolute mass water content and the size of the rock product. Typically, wet material contains >1.5 percent water.

A variety of material, equipment, and operating factors can influence emissions from crushing. These factors include (1) stone type, (2) feed size and distribution, (3) moisture content, (4) throughput rate, (5) crusher type, (6) size reduction ratio, and (7) fines content. Insufficient data are available to present a matrix of rock crushing emission factors detailing the above classifications and variables. Available data indicate that PM-10 and PM-2.5 emissions from limestone and granite processing operations are similar. Therefore, the emission factors developed from the emissions data gathered at limestone and granite processing facilities are considered to be representative of typical crushed stone processing operations. Emission factors for filterable PM, PM-10, and PM-2.5 emissions from crushed stone processing operations are presented in Tables 11.19.2-1 (Metric units) and 11.19.2-2 (English units.)

Table 11.19.2-1 (Metric Units). EMISSION FACTORS FOR CRUSHED STONE PROCESSING OPERATIONS (kg/Mg)[a]

Source [b]	Total Particulate Matter [r,s]	EMISSION FACTOR RATING	Total PM-10	EMISSION FACTOR RATING	Total PM-2.5	EMISSION FACTOR RATING
Primary Crushing (SCC 3-05-020-01)	ND		ND[n]		ND[n]	
Primary Crushing (controlled) (SCC 3-05-020-01)	ND		ND[n]		ND[n]	
Secondary Crushing (SCC 3-05-020-02)	ND		ND[n]		ND[n]	
Secondary Crushing (controlled) (SCC 3-05-020-02)	ND		ND[n]		ND[n]	
Tertiary Crushing (SCC 3-050030-03)	0.0027[d]	E	0.0012[o]	C	ND[n]	
Tertiary Crushing (controlled) (SCC 3-05-020-03)	0.0006[d]	E	0.00027[p]	C	0.00005[q]	E
Fines Crushing (SCC 3-05-020-05)	0.0195[e]	E	0.0075[e]	E	ND	
Fines Crushing (controlled) (SCC 3-05-020-05)	0.0015[f]	E	0.0006[f]	E	0.000035[q]	E
Screening (SCC 3-05-020-02, 03)	0.0125[c]	E	0.0043[l]	C	ND	
Screening (controlled) (SCC 3-05-020-02, 03)	0.0011[d]	E	0.00037[m]	C	0.000025[q]	E
Fines Screening (SCC 3-05-020-21	0.15[g]	E	0.036[g]	E	ND	
Fines Screening (controlled) (SCC 3-05-020-21)	0.0018[g]	E	0.0011[g]	E	ND	
Conveyor Transfer Point (SCC 3-05-020-06)	0.0015[h]	E	0.00055[h]	D	ND	
Conveyor Transfer Point (controlled) (SCC 3-05-020-06)	0.00007[i]	E	2.3×10^{-5}[i]	D	6.5×10^{-6}[q]	E
Wet Drilling - Unfragmented Stone (SCC 3-05-020-10)	ND		4.0×10^{-5}[j]	E	ND	
Truck Unloading - Fragmented Stone (SCC 3-05-020-31)	ND		8.0×10^{-6}[j]	E	ND	
Truck Loading - Conveyor, crushed stone (SCC 3-05-020-32)	ND		5.0×10^{-5}[k]	E	ND	

a. Emission factors represent uncontrolled emissions unless noted. Emission factors in kg/Mg of material throughput. SCC = Source Classification Code. ND = No data.

b. Controlled sources (with wet suppression) are those that are part of the processing plant that employs current wet suppression technology similar to the study group. The moisture content of the study group without wet suppression systems operating (uncontrolled) ranged from 0.21 to 1.3 percent, and the same facilities operating wet suppression systems (controlled) ranged from 0.55 to 2.88 percent. Due to carry over of the small amount of moisture required, it has been shown that each source, with the exception of crushers, does not need to employ direct water sprays. Although the moisture content was the only variable measured, other process features may have as much influence on emissions from a given source. Visual observations from each source under normal operating conditions are probably the best indicator of which emission factor is most appropriate. Plants that employ substandard control measures as indicated by visual observations should use the uncontrolled factor with appropriate control efficiency that best reflects the effectiveness of the controls employed.

c. References 1, 3, 7, and 8

d. References 3, 7, and 8

e. Reference 4

f. References 4 and 15

g. Reference 4

h. References 5 and 6

i. References 5, 6, and 15

j. Reference 11

k. Reference 12

l. References 1, 3, 7, and 8

m. References 1, 3, 7, 8, and 15

n. No data available, but emission factors for PM-10 for tertiary crushers can be used as an upper limit for primary or secondary crushing

o. References 2, 3, 7, 8

p. References 2, 3, 7, 8, and 15

q. Reference 15

r. PM emission factors are presented based on PM-100 data in the Background Support Document for Section 11.19.2

s. Emission factors for PM-30 and PM-50 are available in Figures 11.19.2-3 through 11.19.2-6.

Note: Truck Unloading - Conveyor, crushed stone (SCC 3-05-020-32) was corrected to Truck Loading - Conveyor, crushed stone (SCC 3-05-020-32). October 1, 2010.

Table 11.19.2-2 (English Units). EMISSION FACTORS FOR CRUSHED STONE PROCESSING OPERATIONS (lb/Ton)[a]

Source [b]	Total Particulate Matter [r,s]	EMISSION FACTOR RATING	Total PM-10	EMISSION FACTOR RATING	Total PM-2.5	EMISSION FACTOR RATING
Primary Crushing (SCC 3-05-020-01)	ND		ND[n]		ND[n]	
Primary Crushing (controlled) (SCC 3-05-020-01)	ND		ND[n]		ND[n]	
Secondary Crushing (SCC 3-05-020-02)	ND		ND[n]		ND[n]	
Secondary Crushing (controlled) (SCC 3-05-020-02)	ND		ND[n]		ND[n]	
Tertiary Crushing (SCC 3-050030-03)	0.0054[d]	E	0.0024[o]	C	ND[n]	
Tertiary Crushing (controlled) (SCC 3-05-020-03)	0.0012[d]	E	0.00054[p]	C	0.00010[q]	E
Fines Crushing (SCC 3-05-020-05)	0.0390[e]	E	0.0150[e]	E	ND	
Fines Crushing (controlled) (SCC 3-05-020-05)	0.0030[f]	E	0.0012[f]	E	0.000070[q]	E
Screening (SCC 3-05-020-02, 03)	0.025[c]	E	0.0087[l]	C	ND	
Screening (controlled) (SCC 3-05-020-02, 03)	0.0022[d]	E	0.00074[m]	C	0.000050[q]	E
Fines Screening (SCC 3-05-020-21)	0.30[g]	E	0.072[g]	E	ND	
Fines Screening (controlled) (SCC 3-05-020-21)	0.0036[g]	E	0.0022[g]	E	ND	
Conveyor Transfer Point (SCC 3-05-020-06)	0.0030[h]	E	0.00110[h]	D	ND	
Conveyor Transfer Point (controlled) (SCC 3-05-020-06)	0.00014[i]	E	4.6×10^{-5}[i]	D	1.3×10^{-5}[q]	E
Wet Drilling - Unfragmented Stone (SCC 3-05-020-10)	ND		8.0×10^{-5}[j]	E	ND	
Truck Unloading -Fragmented Stone (SCC 3-05-020-31)	ND		1.6×10^{-5}[j]	E	ND	
Truck Loading - Conveyor, crushed stone (SCC 3-05-020-32)	ND		0.00010[k]	E	ND	

a. Emission factors represent uncontrolled emissions unless noted. Emission factors in lb/Ton of material of throughput. SCC = Source Classification Code. ND = No data.

b. Controlled sources (with wet suppression) are those that are part of the processing plant that employs current wet suppression technology similar to the study group. The moisture content of the study group without wet suppression systems operating (uncontrolled) ranged from 0.21 to 1.3 percent, and the same facilities operating wet suppression systems (controlled) ranged from 0.55 to 2.88 percent. Due to carry over of the small amount of moisture required, it has been shown that each source, with the exception of crushers, does not need to employ direct water sprays. Although the moisture content was the only variable measured, other process features may have as much influence on emissions from a given source. Visual observations from each source under normal operating conditions are probably the best indicator of which emission factor is most appropriate. Plants that employ substandard control measures as indicated by visual observations should use the uncontrolled factor with an appropriate control efficiency that best reflects the effectiveness of the controls employed.

c. References 1, 3, 7, and 8

d. References 3, 7, and 8

e. Reference 4

f. References 4 and 15

g. Reference 4

h. References 5 and 6

i. References 5, 6, and 15

j. Reference 11

k. Reference 12

l. References 1, 3, 7, and 8

m. References 1, 3, 7, 8, and 15

n. No data available, but emission factors for PM-10 for tertiary crushers can be used as an upper limit for primary or secondary crushing

o. References 2, 3, 7, 8

p. References 2, 3, 7, 8, and 15

q. Reference 15

r. PM emission factors are presented based on PM-100 data in the Background Support Document for Section 11.19.2

s. Emission factors for PM-30 and PM-50 are available in Figures 11.19.2-3 through 11.19.2-6.

Note: Truck Unloading - Conveyor, crushed stone (SCC 3-05-020-32) was corrected to Truck Loading - Conveyor, crushed stone (SCC 3-05-020-32). October 1, 2010.

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Emission factor estimates for stone quarry blasting operations are not presented because of the sparsity and unreliability of available tests. While a procedure for estimating blasting emissions is presented in Section 11.9, Western Surface Coal Mining, that procedure should not be applied to stone quarries because of dissimilarities in blasting techniques, material blasted, and size of blast areas. Emission factors for fugitive dust sources, including paved and unpaved roads, materials handling and transfer, and wind erosion of storage piles, can be determined using the predictive emission factor equations presented in AP-42 Section 13.2.

The data used in the preparation of the controlled PM calculations was derived from the individual A-rated tests for PM-2.5 and PM-10 summarized in the Background Support Document. For conveyor transfer points, the controlled PM value was derived from A-rated PM-2.5, PM-10, and PM data summarized in the Background Support Document.

The extrapolation line was drawn through the PM-2.5 value and the mean of the PM-10 values. PM emission factors were calculated for PM-30, PM-50, and PM-100. Each of these particle size limits is used by one or more regulatory agencies as the definition of total particulate matter. The graphical extrapolations used in calculating the emission factors are presented in Figures 11.19.2-3, -4, -5, and -6.

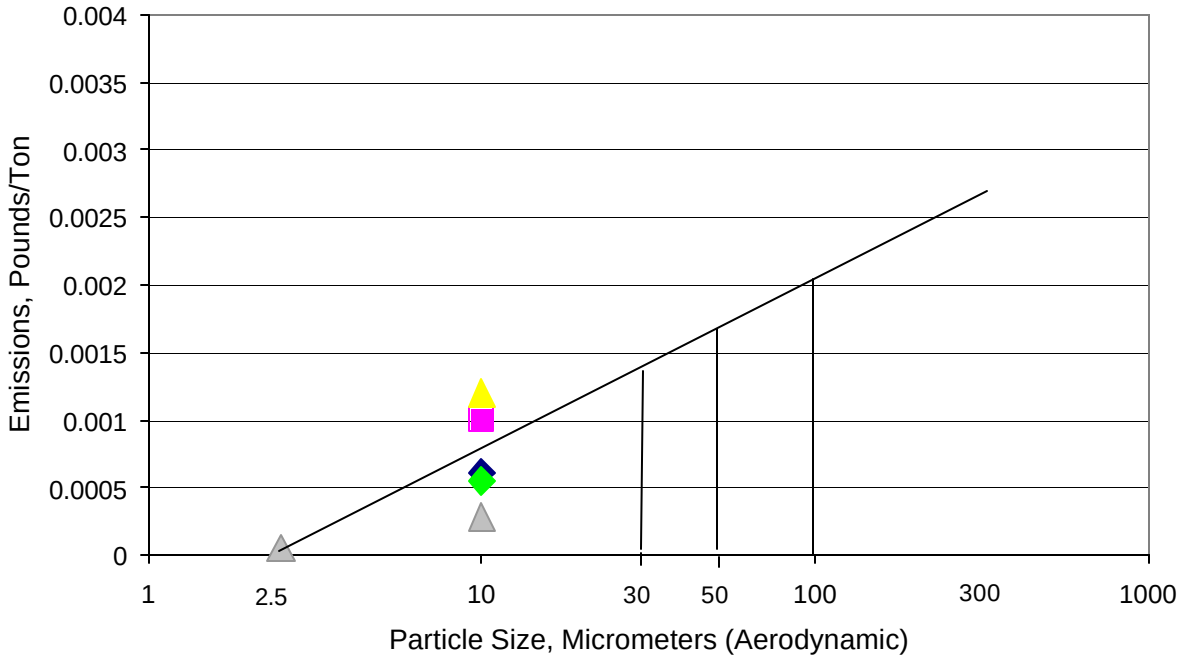


Figure 11-19-3. PM Emission Factor Calculation, Screening (Controlled)

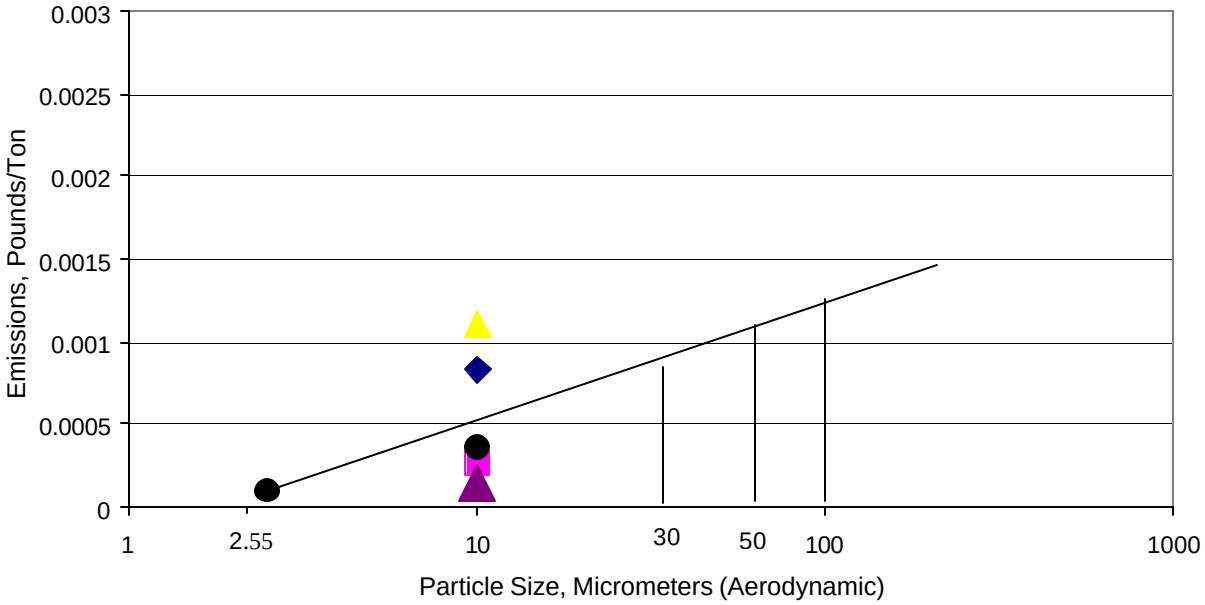


Figure 11.19-4. PM Emission Factor Calculation, Tertiary Crushing (Controlled)

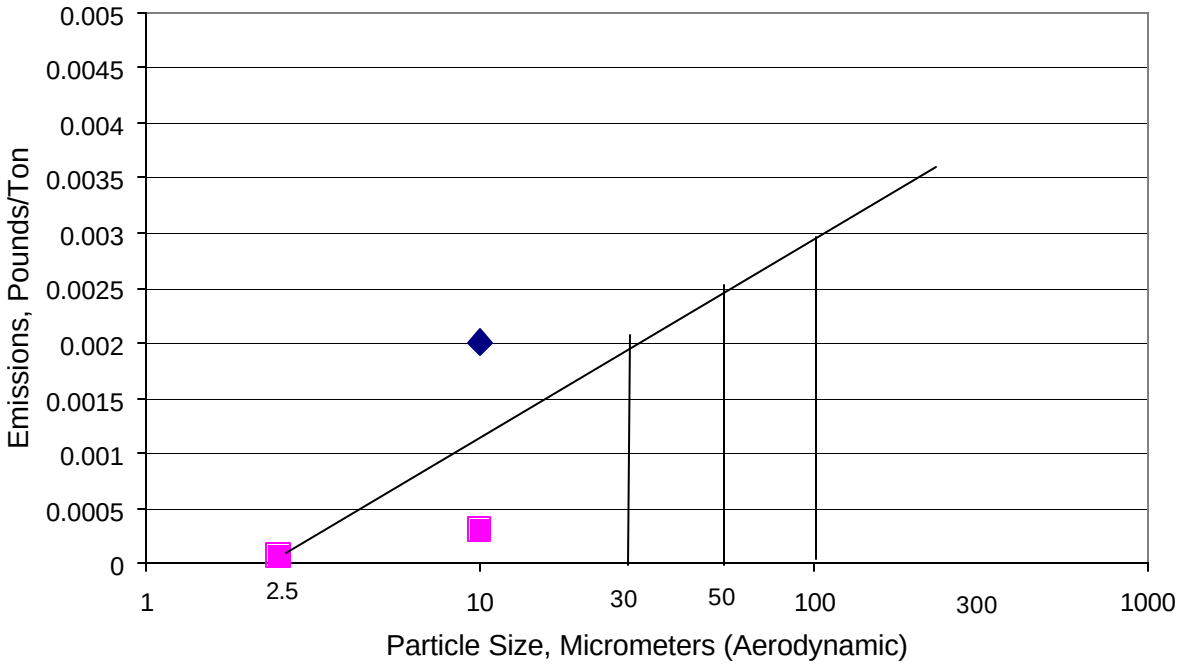


Figure 11-19.5. PM Emission Factor Calculation, Fines Crushing (Controlled)

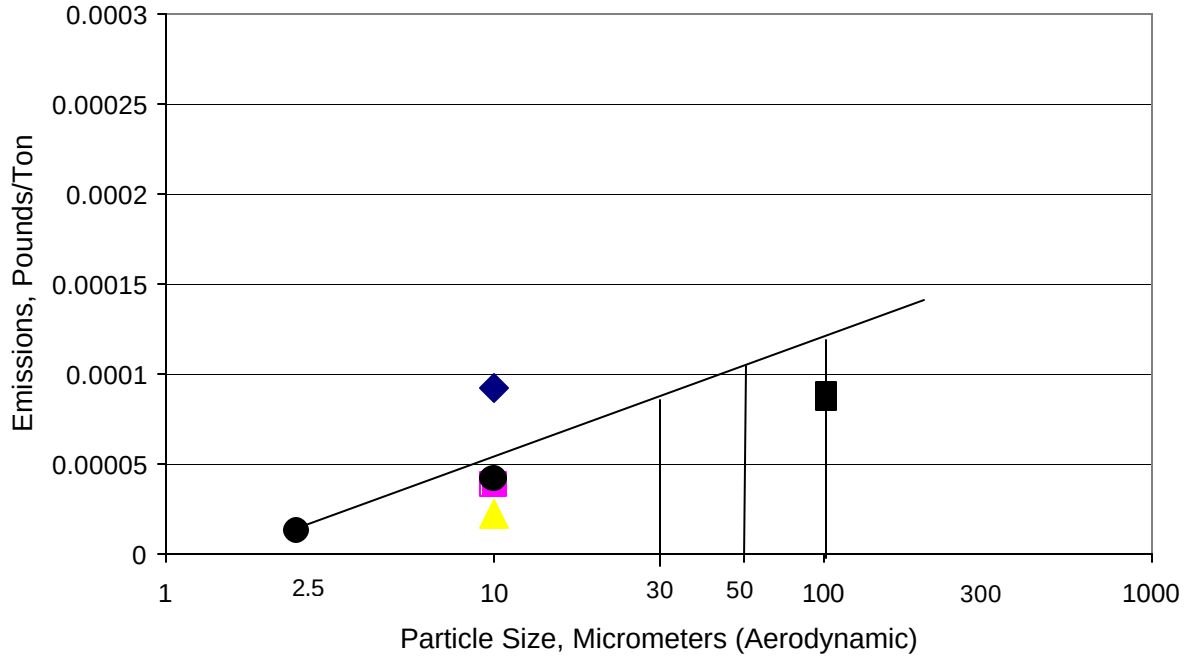


Figure 11.19-6. PM Emission Factor Calculation, Conveyor Transfer Points (Controlled)

The uncontrolled PM emission factors have been calculated from the controlled PM emission factors calculated in accordance with Figures 11.19.2-3 through 11.19.2-6. The PM-10 control efficiencies have been applied to the PM controlled emission factor data to calculate the uncontrolled PM emission rates.

Screening PM-10

Controlled = 0.00073 Lbs./Ton.

Uncontrolled = 0.00865 Lbs./Ton.

Efficiency = 91.6%

Tertiary Crushing PM-10

Controlled = 0.00054

Uncontrolled = 0.00243

Efficiency = 77.7%

Fines Crushing PM-10:

Controlled = 0.0012

Uncontrolled = 0.015

Efficiency = 92.0%

Conveyor Transfer Points PM-10

Controlled = 0.000045

Uncontrolled = 0.0011

Efficiency = 95.9%

The uncontrolled total particulate matter emission factor was calculated from the controlled total particulate matter using Equation 1:

$$\text{Uncontrolled emission factor} = \frac{\text{Controlled total particulate emission factor}}{(100\% - \text{PM-10 Efficiency \%})/100\%}$$

Equation 1

The Total PM emission factors calculated using Figures 11.19.2-3 through 11.19.2-6 were developed because (1) there are more A-rated test data supporting the calculated values and (2) the extrapolated values provide the flexibility for agencies and source operators to select the most appropriate definition for Total PM. All of the Total PM emission factors have been rated as E due to the limited test data and the need to estimate emission factors using extrapolations of the PM-2.5 and PM-10 data.

Pulverized Mineral Processing

Emissions of particulate matter from dry mode pulverized mineral processing operations are controlled by pulse jet and envelope type fabric filter systems. Due to the low-to-moderate gas temperatures generated by the processing equipment, conventional felted filter media are used. Collection efficiencies for fabric filter-controlled dry process equipment exceed 99.5%. Emission factors for pulverized mineral processing operations are presented in Tables 11.19.2-3 and 11.19.2-4.

Table 11.19.2-3 (Metric Units). EMISSION FACTORS FOR PULVERIZED MINERAL PROCESSING OPERATIONS [a]

Source [b]	Total Particulate Matter	EMISSION FACTOR RATING	Total PM-10	EMISSION FACTOR RATING	Total PM-2.5	EMISSION FACTOR RATING
Grinding (Dry) with Fabric Filter Control (SCC 3-05-038-11)	0.0202	D	0.0169	B	0.0060	B
Classifiers (Dry) with Fabric Filter Control (SCC 3-05-038-12)	0.0112	E	0.0052	E	0.0020	E
Flash Drying with Fabric Filter Control (SCC 3-05-038-35)	0.0134	C	0.0073	C	0.0042	C
Product Storage with Fabric Filter Control (SCC 3-05-38-13)	0.0055	E	0.0008	E	0.0003	E

a. Emission factors represent controlled emissions unless noted. Emission factors are in kg/Mg of material throughput.

b. Date from references 16 through 23

Table 11.19.2-4 (English Units). EMISSION FACTORS FOR PULVERIZED MINERAL PROCESSING OPERATIONS [a]

Source [b]	Total Particulate Matter	EMISSION FACTOR RATING	Total PM-10	EMISSION FACTOR RATING	Total PM-2.5	EMISSION FACTOR RATING
Grinding (Dry) with Fabric Filter Control (SCC 3-05-038-11)	0.0404	D	0.0339	B	0.0121	B
Classifiers (Dry) with Fabric Filter Control (SCC 3-05-038-12)	0.0225	E	0.0104	E	0.0041	E
Flash Drying with Fabric Filter Control (SCC 3-05-038-35)	0.0268	C	0.0146	C	0.0083	C
Product Storage with Fabric Filter Control (SCC 3-05-038-13)	0.0099	E	0.0016	E	0.0006	E

a. Emission factors represent controlled emissions unless noted. Emission factors are in lb/Ton of material throughput.

b. Data from references 16 through 23

13.2.2 Unpaved Roads

13.2.2.1 General

When a vehicle travels an unpaved road, the force of the wheels on the road surface causes pulverization of surface material. Particles are lifted and dropped from the rolling wheels, and the road surface is exposed to strong air currents in turbulent shear with the surface. The turbulent wake behind the vehicle continues to act on the road surface after the vehicle has passed.

The particulate emission factors presented in the previous draft version of this section of AP-42, dated October 2001, implicitly included the emissions from vehicles in the form of exhaust, brake wear, and tire wear as well as resuspended road surface material[25]. EPA included these sources in the emission factor equation for unpaved public roads (equation 1b in this section) since the field testing data used to develop the equation included both the direct emissions from vehicles and emissions from resuspension of road dust.

This version of the unpaved public road emission factor equation only estimates particulate emissions from resuspended road surface material [23, 26]. The particulate emissions from vehicle exhaust, brake wear, and tire wear are now estimated separately using EPA's MOBILE6.2 [24]. This approach eliminates the possibility of double counting emissions. Double counting results when employing the previous version of the emission factor equation in this section and MOBILE6.2 to estimate particulate emissions from vehicle traffic on unpaved public roads. It also incorporates the decrease in exhaust emissions that has occurred since the unpaved public road emission factor equation was developed. The previous version of the unpaved public road emission factor equation includes estimates of emissions from exhaust, brake wear, and tire wear based on emission rates for vehicles in the 1980 calendar year fleet. The amount of PM released from vehicle exhaust has decreased since 1980 due to lower new vehicle emission standards and changes in fuel characteristics.

13.2.2.2 Emissions Calculation And Correction Parameters[1-6]

The quantity of dust emissions from a given segment of unpaved road varies linearly with the volume of traffic. Field investigations also have shown that emissions depend on source parameters that characterize the condition of a particular road and the associated vehicle traffic. Characterization of these source parameters allow for "correction" of emission estimates to specific road and traffic conditions present on public and industrial roadways.

Dust emissions from unpaved roads have been found to vary directly with the fraction of silt (particles smaller than 75 micrometers [μm] in diameter) in the road surface materials.[1] The silt fraction is determined by measuring the proportion of loose dry surface dust that passes a 200-mesh screen, using the ASTM-C-136 method. A summary of this method is contained in Appendix C of AP-42. Table 13.2.2-1 summarizes measured silt values for industrial unpaved roads. Table 13.2.2-2 summarizes measured silt values for public unpaved roads. It should be noted that the ranges of silt content vary over two orders of magnitude. Therefore, the use of data from this table can potentially introduce considerable error. Use of this data is strongly discouraged when it is feasible to obtain locally gathered data.

Since the silt content of a rural dirt road will vary with geographic location, it should be measured for use in projecting emissions. As a conservative approximation, the silt content of the parent soil in the area can be used. Tests, however, show that road silt content is normally lower than in the surrounding parent soil, because the fines are continually removed by the vehicle traffic, leaving a higher percentage of coarse particles.

Other variables are important in addition to the silt content of the road surface material. For example, at industrial sites, where haul trucks and other heavy equipment are common, emissions are highly correlated with vehicle weight. On the other hand, there is far less variability in the weights of cars and pickup trucks that commonly travel publicly accessible unpaved roads throughout the United States. For those roads, the moisture content of the road surface material may be more dominant in determining differences in emission levels between, for example a hot, desert environment and a cool, moist location.

The PM-10 and TSP emission factors presented below are the outcomes from stepwise linear regressions of field emission test results of vehicles traveling over unpaved surfaces. Due to a limited amount of information available for PM-2.5, the expression for that particle size range has been scaled against the result for PM-10. Consequently, the quality rating for the PM-2.5 factor is lower than that for the PM-10 expression.

Table 13.2.2-1. TYPICAL SILT CONTENT VALUES OF SURFACE MATERIAL ON INDUSTRIAL UNPAVED ROADS[a]

Industry	Road Use Or Surface Material	Plant Sites	No. Of Samples	Silt Content (%)	
				Range	Mean
Copper smelting	Plant road	1	3	16 - 19	17
Iron and steel production	Plant road	19	135	0.2 - 19	6.0
Sand and gravel processing	Plant road	1	3	4.1 - 6.0	4.8
	Material storage area	1	1	-	7.1
Stone quarrying and processing	Plant road	2	10	2.4 - 16	10
	Haul road to/from pit	4	20	5.0-15	8.3
Taconite mining and processing	Service road	1	8	2.4 - 7.1	4.3
	Haul road to/from pit	1	12	3.9 - 9.7	5.8
Western surface coal mining	Haul road to/from pit	3	21	2.8 - 18	8.4
	Plant road	2	2	4.9 - 5.3	5.1
	Scraper route	3	10	7.2 - 25	17
	Haul road (freshly graded)	2	5	18 - 29	24
Construction sites	Scraper routes	7	20	0.56-23	8.5
Lumber sawmills	Log yards	2	2	4.8-12	8.4
Municipal solid waste landfills	Disposal routes	4	20	2.2 - 21	6.4

[a]References 1,5-15.

The following empirical expressions may be used to estimate the quantity in pounds (lb) of size-specific particulate emissions from an unpaved road, per vehicle mile traveled (VMT):

For vehicles traveling on unpaved surfaces at industrial sites, emissions are estimated from the following equation:

$$E = k\,(s/12)^a (W/3)^b \quad (1a)$$

and, for vehicles traveling on publicly accessible roads, dominated by light duty vehicles, emissions may be estimated from the following:

$$E = \frac{k\,(s/12)^a (S/30)^d}{(M/0.5)^c} - C \quad (1b)$$

where k, a, b, c and d are empirical constants (Reference 6) given below and

E = size-specific emission factor (lb/VMT)
s = surface material silt content (%)
W = mean vehicle weight (tons)
M = surface material moisture content (%)
S = mean vehicle speed (mph)
C = emission factor for 1980's vehicle fleet exhaust, brake wear and tire wear.

The source characteristics s, W and M are referred to as correction parameters for adjusting the emission estimates to local conditions. The metric conversion from lb/VMT to grams (g) per vehicle kilometer traveled (VKT) is as follows:

1 lb/VMT = 281.9 g/VKT

The constants for Equations 1a and 1b based on the stated aerodynamic particle sizes are shown in Tables 13.2.2-2 and 13.2.2-4. The PM-2.5 particle size multipliers (k-factors) are taken from Reference 27.

Table 13.2.2-2. CONSTANTS FOR EQUATIONS 1a AND 1b

Constant	Industrial Roads (Equation 1a)			Public Roads (Equation 1b)		
	PM-2.5	PM-10	PM-30*	PM-2.5	PM-10	PM-30*
k (lb/VMT)	0.15	1.5	4.9	0.18	1.8	6.0
a	0.9	0.9	0.7	1	1	1
b	0.45	0.45	0.45	-	-	-
c	-	-	-	0.2	0.2	0.3
d	-	-	-	0.5	0.5	0.3
Quality Rating	B	B	B	B	B	B

*Assumed equivalent to total suspended particulate matter (TSP)
"-" = not used in the emission factor equation

Table 13.2.2-2 also contains the quality ratings for the various size-specific versions of Equation 1a and 1b. The equation retains the assigned quality rating, if applied within the ranges of source conditions, shown in Table 13.2.2-3, that were tested in developing the equation:

Table 13.2.2-3. RANGE OF SOURCE CONDITIONS USED IN DEVELOPING EQUATION 1a AND 1b

Emission Factor	Surface Silt Content, %	Mean Vehicle Weight		Mean Vehicle Speed		Mean No. of Wheels	Surface Moisture Content, %
		Mg	ton	km/hr	mph		
Industrial Roads (Equation 1a)	1.8-25.2	1.8-260	2-290	8-69	5-43	4-17[a]	0.03-13
Public Roads (Equation 1b)	1.8-35	1.4-2.7	1.5-3	16-88	10-55	4-4.8	0.03-13

[a] See discussion in text.

As noted earlier, the models presented as Equations 1a and 1b were developed from tests of traffic on unpaved surfaces. Unpaved roads have a hard, generally nonporous surface that usually dries quickly after a rainfall or watering, because of traffic-enhanced natural evaporation. (Factors influencing how fast a road dries are discussed in Section 13.2.2.3, below.) The quality ratings given above pertain to the mid-range of the measured source conditions for the equation. A higher mean vehicle weight and a higher than normal traffic rate may be justified when performing a worst-case analysis of emissions from unpaved roads.

The emission factors for the exhaust, brake wear and tire wear of a 1980's vehicle fleet (*C*) was obtained from EPA's MOBILE6.2 model [23]. The emission factor also varies with aerodynamic size range

as shown in Table 13.2.2-4

Table 13.2.2-4. EMISSION FACTOR FOR 1980'S VEHICLE FLEET EXHAUST, BRAKE WEAR AND TIRE WEAR

Particle Size Range[a]	*C*, Emission Factor for Exhaust, Brake Wear and Tire Wear[b] lb/VMT
$PM_{2.5}$	0.00036
PM_{10}	0.00047
PM_{30}[c]	0.00047

[a] Refers to airborne particulate matter (PM-x) with an aerodynamic diameter equal to or less than x micrometers.
[b] Units shown are pounds per vehicle mile traveled (lb/VMT).
[c] PM-30 is sometimes termed "suspendable particulate" (SP) and is often used as a surrogate for TSP.

It is important to note that the vehicle-related source conditions refer to the average weight, speed, and number of wheels for all vehicles traveling the road. For example, if 98 percent of traffic on the road are 2-ton cars and trucks while the remaining 2 percent consists of 20-ton trucks, then the mean weight is 2.4 tons. More specifically, Equations 1a and 1b are *not* intended to be used to calculate a separate emission factor for each vehicle class within a mix of traffic on a given unpaved road. That is, in the example, one should *not* determine one factor for the 2-ton vehicles and a second factor for the 20-ton trucks. Instead, only one emission factor should be calculated that represents the "fleet" average of 2.4 tons for all vehicles traveling the road.

Moreover, to retain the quality ratings when addressing a group of unpaved roads, it is necessary that reliable correction parameter values be determined for the road in question. The field and laboratory procedures for determining road surface silt and moisture contents are given in AP-42 Appendices C.1 and C.2. Vehicle-related parameters should be developed by recording visual observations of traffic. In some cases, vehicle parameters for industrial unpaved roads can be determined by reviewing maintenance records or other information sources at the facility.

In the event that site-specific values for correction parameters cannot be obtained, then default values may be used.In the absence of site-specific silt content information, an appropriate mean value from Table 13.2.2-1 may be used as a default value, but the quality rating of the equation is reduced by two letters. Because of significant differences found between different types of road surfaces and between different areas of the country, use of the default moisture content value of 0.5 percent in Equation 1b is discouraged. The quality rating should be downgraded two letters when the default moisture content value is used. (It is assumed that readers addressing industrial roads have access to the information needed to develop average vehicle information in Equation 1a for their facility.)

The effect of routine watering to control emissions from unpaved roads is discussed below in Section 13.2.2.3, “Controls”. However, all roads are subject to some natural mitigation because of rainfall and other precipitation. The Equation 1a and 1b emission factors can be extrapolated to annual

average uncontrolled conditions (but including natural mitigation) under the simplifying assumption that annual average emissions are inversely proportional to the number of days with measurable (more than 0.254 mm [0.01 inch]) precipitation:

$$E_{ext} = E\ [(365 - P)/365] \quad (2)$$

where:

E_{ext} = annual size-specific emission factor extrapolated for natural mitigation, lb/VMT

E = emission factor from Equation 1a or 1b

P = number of days in a year with at least 0.254 mm (0.01 in) of precipitation (see below)

Figure 13.2.2-1 gives the geographical distribution for the mean annual number of "wet" days for the United States.

Equation 2 provides an estimate that accounts for precipitation on an annual average basis for the purpose of inventorying emissions. It should be noted that Equation 2 does not account for differences in the temporal distributions of the rain events, the quantity of rain during any event, or the potential for the rain to evaporate from the road surface. In the event that a finer temporal and spatial resolution is desired for inventories of public unpaved roads, estimates can be based on a more complex set of assumptions. These assumptions include:

1. The moisture content of the road surface material is increased in proportion to the quantity of water added;
2. The moisture content of the road surface material is reduced in proportion to the Class A pan evaporation rate;
3. The moisture content of the road surface material is reduced in proportion to the traffic volume; and
4. The moisture content of the road surface material varies between the extremes observed in the area. The CHIEF Web site (http://www.epa.gov/ttn/chief/ap42/ch13/related/c13s02-2.html) has a file which contains a spreadsheet program for calculating emission factors which are temporally and spatially resolved. Information required for use of the spreadsheet program includes monthly Class A pan evaporation values, hourly meteorological data for precipitation, humidity and snow cover, vehicle traffic information, and road surface material information.

It is emphasized that the simple assumption underlying Equation 2 and the more complex set of assumptions underlying the use of the procedure which produces a finer temporal and spatial resolution have not been verified in any rigorous manner. For this reason, the quality ratings for either approach should be downgraded one letter from the rating that would be applied to Equation 1.

13.2.2.3 Controls[18-22]

A wide variety of options exist to control emissions from unpaved roads. Options fall into the following three groupings:

1. Vehicle restrictions that limit the speed, weight or number of vehicles on the road;

2. Surface improvement, by measures such as (a) paving or (b) adding gravel or slag to a dirt road; and
3. Surface treatment, such as watering or treatment with chemical dust suppressants.

Available control options span broad ranges in terms of cost, efficiency, and applicability. For example, traffic controls provide moderate emission reductions (often at little cost) but are difficult to enforce. Although paving is highly effective, its high initial cost is often prohibitive. Furthermore, paving is not feasible for industrial roads subject to very heavy vehicles and/or spillage of material in transport. Watering and chemical suppressants, on the other hand, are potentially applicable to most industrial roads at moderate to low costs. However, these require frequent reapplication to maintain an acceptable level of control. Chemical suppressants are generally more cost-effective than water but not in cases of temporary roads (which are common at mines, landfills, and construction sites). In summary, then, one needs to consider not only the type and volume of traffic on the road but also how long the road will be in service when developing control plans.

Vehicle restrictions. These measures seek to limit the amount and type of traffic present on the road or to lower the mean vehicle speed. For example, many industrial plants have restricted employees from driving on plant property and have instead instituted bussing programs. This eliminates emissions due to employees traveling to/from their worksites. Although the heavier average vehicle weight of the busses increases the base emission factor, the decrease in vehicle-miles-traveled results in a lower overall emission rate.

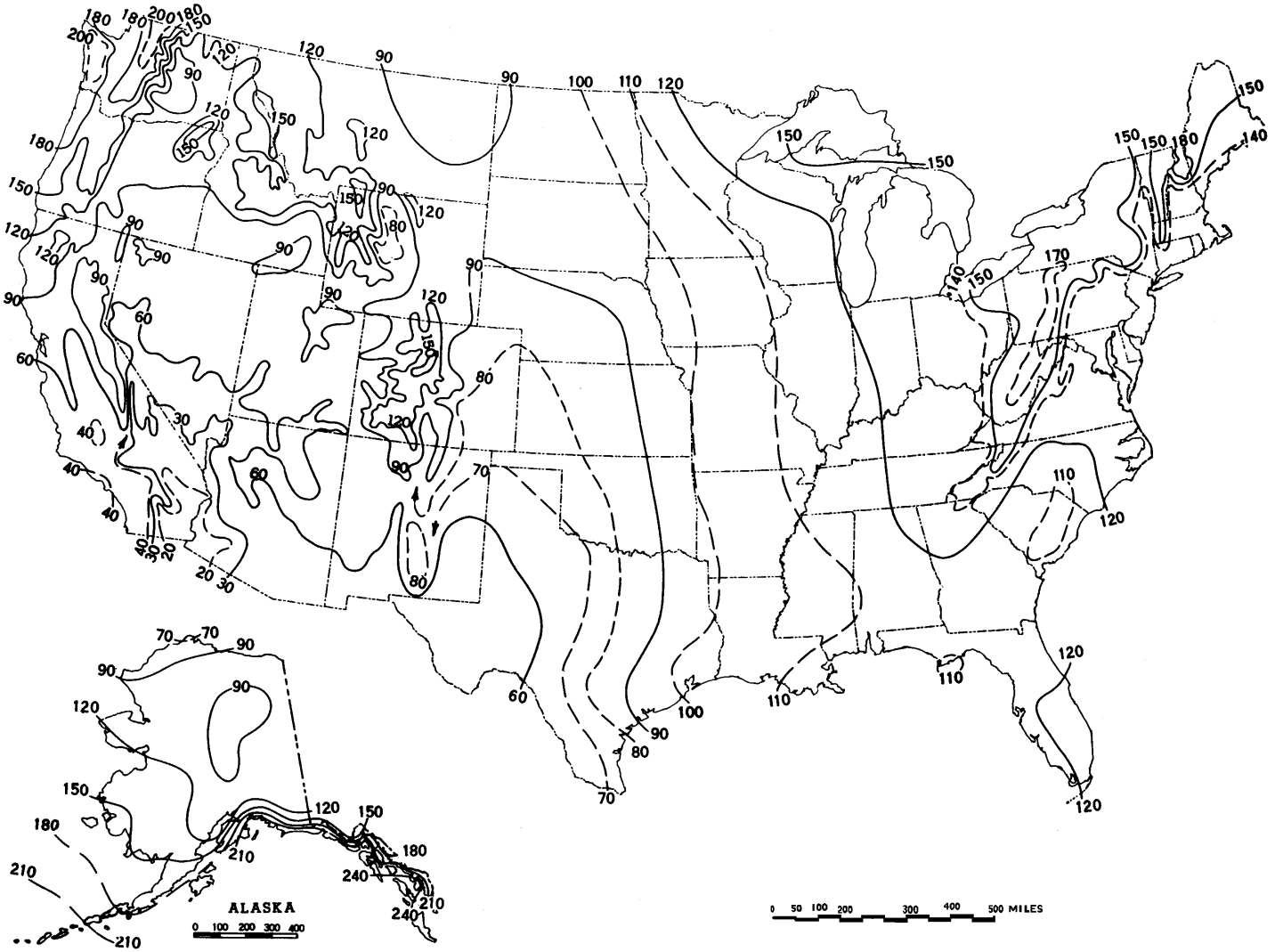


Figure 13.2.2-1. Mean number of days with 0.01 inch or more of precipitation in United States.

Surface improvements. Control options in this category alter the road surface. As opposed to the "surface treatments" discussed below, improvements are relatively "permanent" and do not require periodic retreatment.

The most obvious surface improvement is paving an unpaved road. This option is quite expensive and is probably most applicable to relatively short stretches of unpaved road with at least several hundred vehicle passes per day. Furthermore, if the newly paved road is located near unpaved areas or is used to transport material, it is essential that the control plan address routine cleaning of the newly paved road surface.

The control efficiencies achievable by paving can be estimated by comparing emission factors for unpaved and paved road conditions. The predictive emission factor equation for paved roads, given in Section 13.2.1, requires estimation of the silt loading on the traveled portion of the paved surface, which in turn depends on whether the pavement is periodically cleaned. Unless curbing is to be installed, the effects of vehicle excursion onto unpaved shoulders (berms) also must be taken into account in estimating the control efficiency of paving.

Other improvement methods cover the road surface with another material that has a lower silt content. Examples include placing gravel or slag on a dirt road. Control efficiency can be estimated by comparing the emission factors obtained using the silt contents before and after improvement. The silt content of the road surface should be determined after 3 to 6 months rather than immediately following placement. Control plans should address regular maintenance practices, such as grading, to retain larger aggregate on the traveled portion of the road.

Surface treatments refer to control options which require periodic reapplication. Treatments fall into the two main categories of (a) "wet suppression" (i. e., watering, possibly with surfactants or other additives), which keeps the road surface wet to control emissions and (b) "chemical stabilization/ treatment", which attempts to change the physical characteristics of the surface. The necessary reapplication frequency varies from several minutes for plain water under summertime conditions to several weeks or months for chemical dust suppressants.

Watering increases the moisture content, which conglomerates particles and reduces their likelihood to become suspended when vehicles pass over the surface. The control efficiency depends on how fast the road dries after water is added. This in turn depends on (a) the amount (per unit road surface area) of water added during each application; (b) the period of time between applications; (c) the weight, speed and number of vehicles traveling over the watered road during the period between applications; and (d) meteorological conditions (temperature, wind speed, cloud cover, etc.) that affect evaporation during the period.

Figure 13.2.2-2 presents a simple bilinear relationship between the instantaneous control efficiency due to watering and the resulting increase in surface moisture. The moisture ratio "M" (i.e., the x-axis in Figure 13.2.2-2) is found by dividing the surface moisture content of the watered road by the surface moisture content of the uncontrolled road. As the watered road surface dries, both the ratio M and the predicted instantaneous control efficiency (i.e., the y-axis in the figure) decrease. The figure shows that between the uncontrolled moisture content and a value twice as large, a small increase in moisture content results in a large increase in control efficiency. Beyond that, control efficiency grows slowly with increased moisture content.

Given the complicated nature of how the road dries, characterization of emissions from watered roadways is best done by collecting road surface material samples at various times between water truck passes. (Appendices C.1 and C.2 present the sampling and analysis procedures.) The moisture content measured can then be associated with a control efficiency by use of Figure 13.2.2-2. Samples that reflect average conditions during the watering cycle can take the form of either a series of samples between water applications or a single sample at the midpoint. It is essential that samples be collected during periods with active traffic on the road. Finally, because of different evaporation rates, it is recommended that samples be collected at various times during the year. If only one set of samples is to be collected, these must be collected during hot, summertime conditions.

When developing watering control plans for roads that do not yet exist, it is strongly recommended that the moisture cycle be established by sampling similar roads in the same geographic area. If the moisture cycle cannot be established by similar roads using established watering control plans, the more complex methodology used to estimate the mitigation of rainfall and other precipitation can be used to estimate the control provided by routine watering. An estimate of the maximum daytime Class A pan evaporation (based upon daily evaporation data published in the monthly Climatological Data for the state by the National Climatic Data Center) should be used to insure that adequate watering capability is available during periods of highest evaporation. The hourly precipitation values in the spreadsheet should be replaced with the equivalent inches of precipitation (where the equivalent of 1 inch of precipitation is provided by an application of 5.6 gallons of water per square yard of road). Information on the long term average annual evaporation and on the percentage that occurs between May and October was published in the Climatic Atlas (Reference 16). Figure 13.2.2-3 presents the geographical distribution for "Class A pan evaporation" throughout the United States. Figure 13.2.2-4 presents the geographical distribution of the percentage of this evaporation that occurs between May and October. The U. S. Weather Bureau Class A evaporation pan is a cylindrical metal container with a depth of 10 inches and a diameter of 48 inches. Periodic measurements are made of the changes of the water level.

The above methodology should be used only for prospective analyses and for designing watering programs for existing roadways. The quality rating of an emission factor for a watered road that is based on this methodology should be downgraded two letters. Periodic road surface samples should be collected and analyzed to verify the efficiency of the watering program.

As opposed to watering, chemical dust suppressants have much less frequent reapplication requirements. These materials suppress emissions by changing the physical characteristics of the existing road surface material. Many chemical unpaved road dust suppressants form a hardened surface that binds particles together. After several applications, a treated road often resembles a paved road except that the surface is not uniformly flat. Because the improved surface results in more grinding of small particles, the silt content of loose material on a highly controlled surface may be substantially higher than when the surface was uncontrolled. For this reason, the models presented as Equations 1a and 1b cannot be used to estimate emissions from chemically stabilized roads. Should the road be allowed to return to an

uncontrolled state with no visible signs of large-scale cementing of material, the Equation 1a and 1b emission factors could then be used to obtain conservatively high emission estimates.

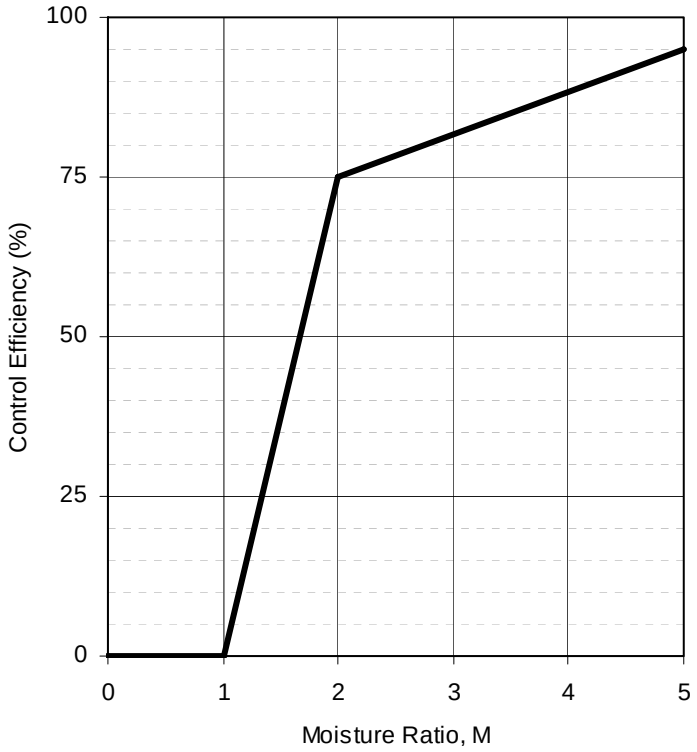


Figure 13.2.2-2. Watering control effectiveness for unpaved travel surfaces

The control effectiveness of chemical dust suppressants appears to depend on (a) the dilution rate used in the mixture; (b) the application rate (volume of solution per unit road surface area); (c) the time between applications; (d) the size, speed and amount of traffic during the period between applications; and (e) meteorological conditions (rainfall, freeze/thaw cycles, etc.) during the period. Other factors that affect the performance of dust suppressants include other traffic characteristics (e. g., cornering, track-on from unpaved areas) and road characteristics (e. g., bearing strength, grade). The variabilities in the above factors and differences between individual dust control products make the control efficiencies of chemical dust suppressants difficult to estimate. Past field testing of emissions from controlled unpaved roads has shown that chemical dust suppressants provide a PM-10 control efficiency of about 80 percent when applied at regular intervals of 2 weeks to 1 month.

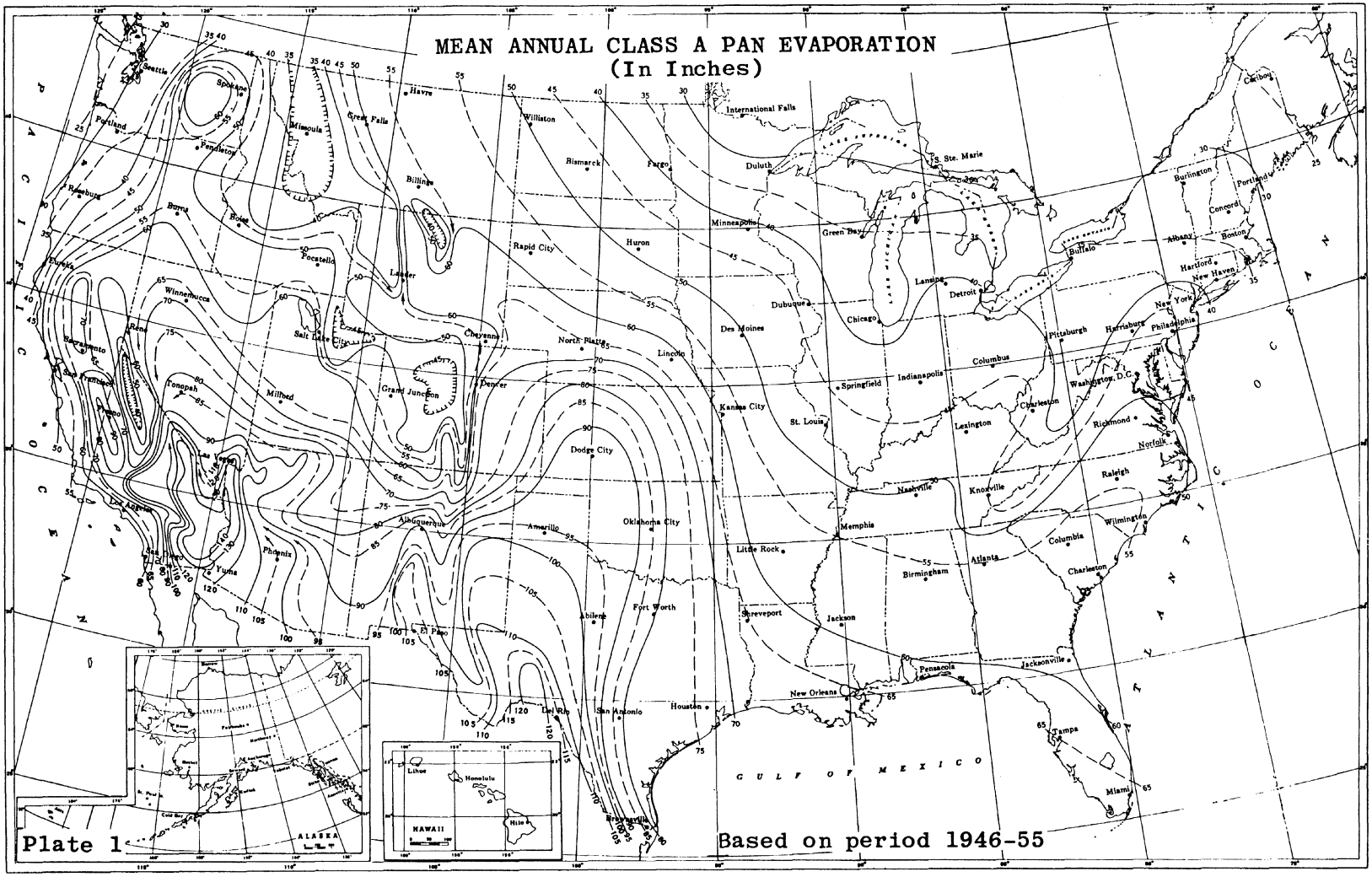


Figure 13.2.2-3. Annual evaporation data.

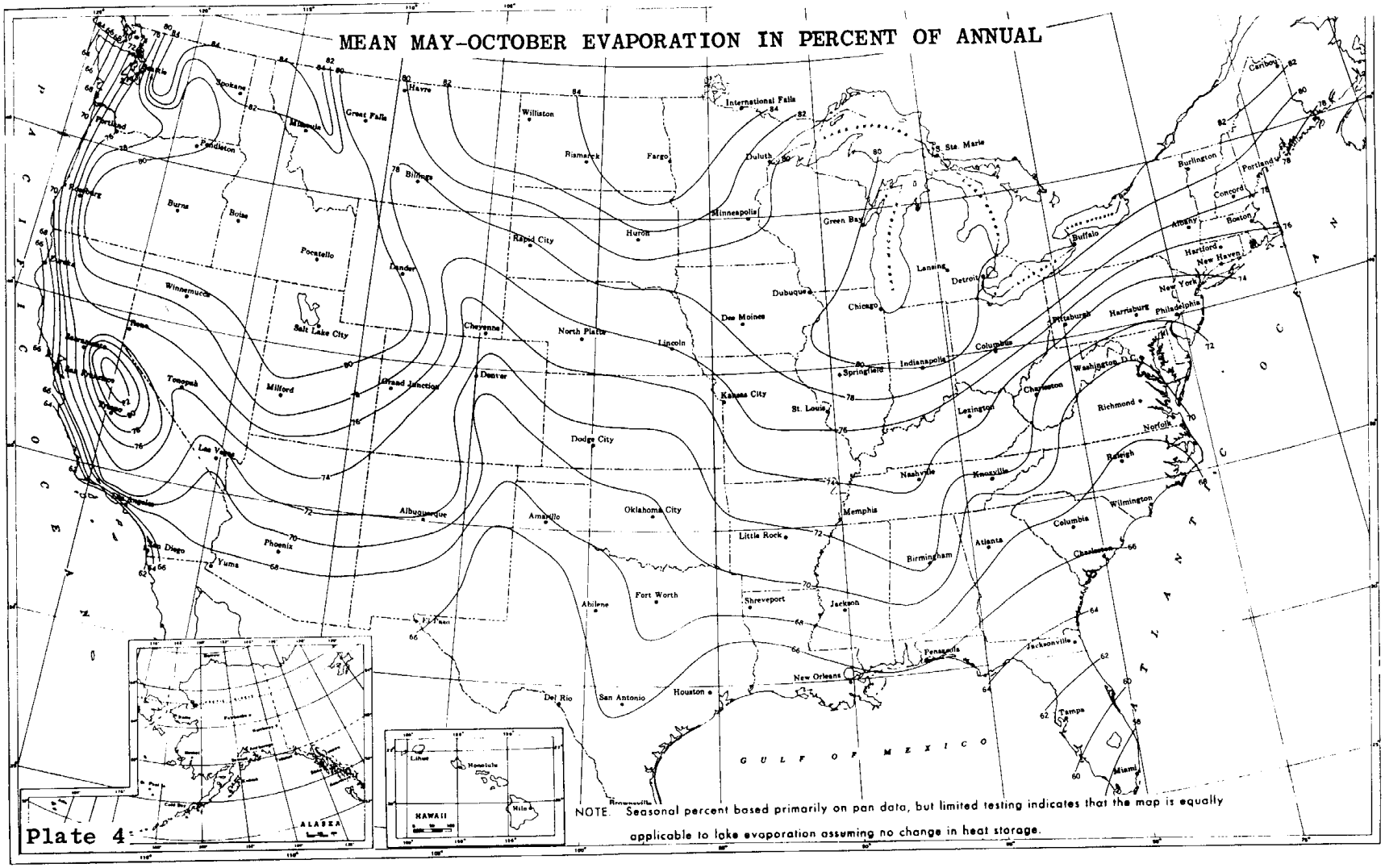


Figure 13.2.2-4. Geographical distribution of the percentage of evaporation occurring between May and October.

Petroleum resin products historically have been the dust suppressants (besides water) most widely used on industrial unpaved roads. Figure 13.2.2-5 presents a method to estimate average control efficiencies associated with petroleum resins applied to unpaved roads.[20] Several items should be noted:

1. The term "ground inventory" represents the total volume (per unit area) of petroleum resin concentrate (*not solution*) applied since the start of the dust control season.

2. Because petroleum resin products must be periodically reapplied to unpaved roads, the use of a time-averaged control efficiency value is appropriate. Figure 13.2.2-5 presents control efficiency values averaged over two common application intervals, 2 weeks and 1 month. Other application intervals will require interpolation.

3. Note that zero efficiency is assigned until the ground inventory reaches 0.05 gallon per square yard (gal/yd^2). Requiring a minimum ground inventory ensures that one must apply a reasonable amount of chemical dust suppressant to a road before claiming credit for emission control. Recall that the ground inventory refers to the amount of petroleum resin concentrate rather than the total solution.

As an example of the application of Figure 13.2.2-5, suppose that Equation 1a was used to estimate an emission factor of 7.1 lb/VMT for PM-10 from a particular road. Also, suppose that, starting on May 1, the road is treated with 0.221 gal/yd^2 of a solution (1 part petroleum resin to 5 parts water) on the first of each month through September. Then, the average controlled emission factors, shown in Table 13.2.2-5, are found.

Table 13.2-2-5. EXAMPLE OF AVERAGE CONTROLLED EMISSION FACTORS FOR SPECIFIC CONDITIONS

Period	Ground Inventory, gal/yd^2	Average Control Efficiency, %[a]	Average Controlled Emission Factor, lb/VMT
May	0.037	0	7.1
June	0.073	62	2.7
July	0.11	68	2.3
August	0.15	74	1.8
September	0.18	80	1.4

[a] From Figure 13.2.2-5, ≤10 µm. Zero efficiency assigned if ground inventory is less than 0.05 gal/yd^2. 1 lb/VMT = 281.9 g/VKT. 1 gal/yd^2 = 4.531 L/m^2.

Besides petroleum resins, other newer dust suppressants have also been successful in controlling emissions from unpaved roads. Specific test results for those chemicals, as well as for petroleum resins and watering, are provided in References 18 through 21.

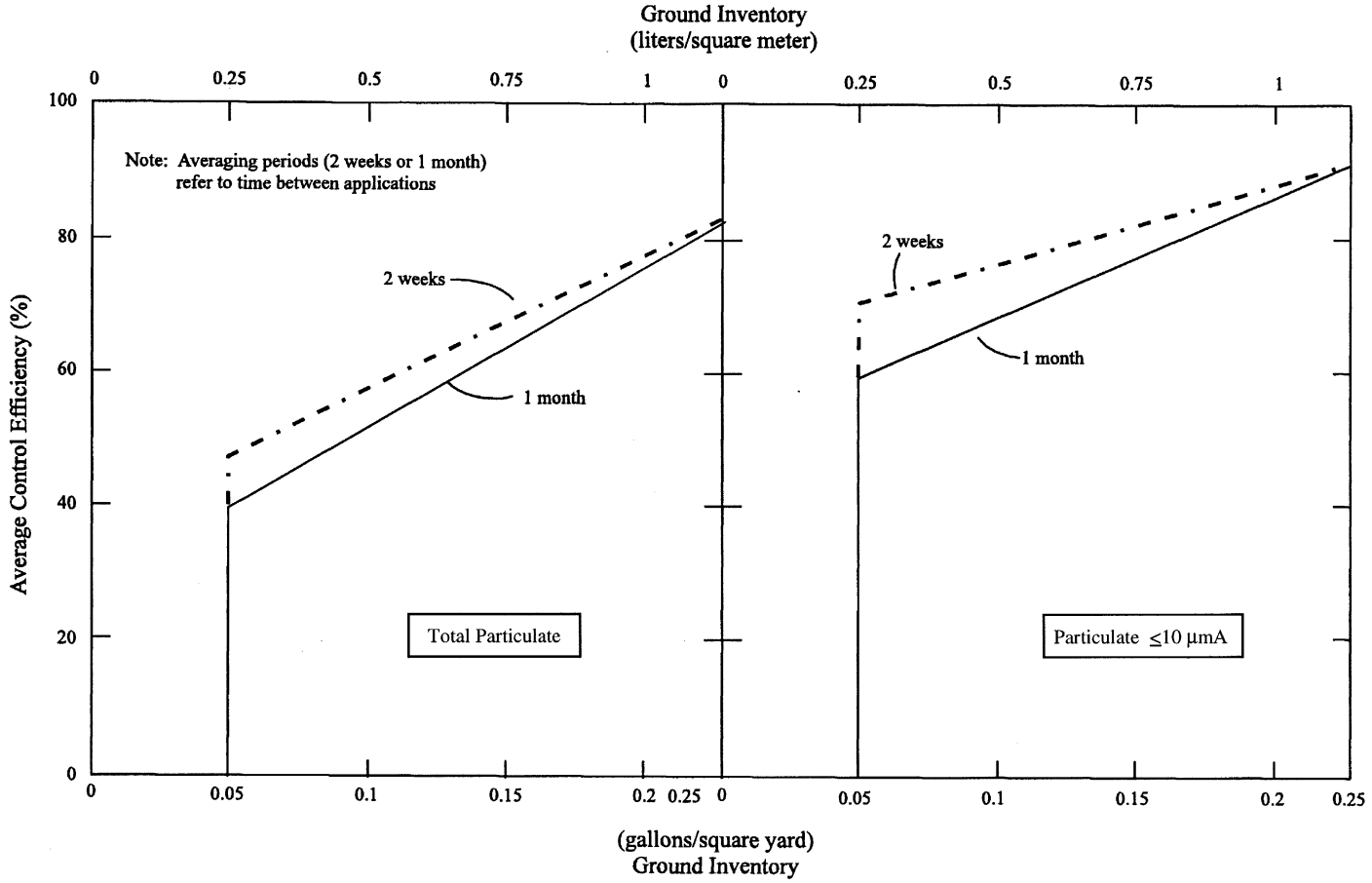


Figure 13.2.2-5. Average control efficiencies over common application intervals.

13.2.2.4 Updates Since The Fifth Edition

The Fifth Edition was released in January 1995. Revisions to this section since that date are summarized below. For further detail, consult the background report for this section (Reference 6).

October 1998 (Supplement E)– This was a major revision of this section. Significant changes to the text and the emission factor equations were made.

October 2001 – Separate emission factors for unpaved surfaces at industrial sites and publicly accessible roads were introduced. Figure 13.2.2-2 was included to provide control effectiveness estimates for watered roads.

December 2003 – The public road emission factor equation (equation 1b) was adjusted to remove the component of particulate emissions from exhaust, brake wear, and tire wear. The parameter C in the new equation varies with aerodynamic size range of the particulate matter. Table 13.2.2-4 was added to present the new coefficients.

January 2006 – The PM-2.5 particle size multipliers (i.e., factors) in Table 13.2.2-2 were modified and the quality ratings were upgraded from C to B based on the wind tunnel studies of a variety of dust emitting surface materials.

References For Section 13.2.2

1. C. Cowherd, Jr., *et al., Development Of Emission Factors For Fugitive Dust Sources,* EPA-450/3-74-037, U. S. Environmental Protection Agency, Research Triangle Park, NC, June 1974.

2. R. J. Dyck and J. J. Stukel, "Fugitive Dust Emissions From Trucks On Unpaved Roads", *Environmental Science And Technology, 10*(10):1046-1048, October 1976.

3. R. O. McCaldin and K. J. Heidel, "Particulate Emissions From Vehicle Travel Over Unpaved Roads", Presented at the 71st Annual Meeting of the Air Pollution Control Association, Houston, TX, June 1978.

4. C. Cowherd, Jr, *et al., Iron And Steel Plant Open Dust Source Fugitive Emission Evaluation*, EPA-600/2-79-013, U. S. Environmental Protection Agency, Cincinnati, OH, May 1979.

5. G. Muleski, *Unpaved Road Emission Impact*, Arizona Department of Environmental Quality, Phoenix, AZ, March 1991.

6. *Emission Factor Documentation For AP-42, Section 13.2.2, Unpaved Roads, Final Report*, Midwest Research Institute, Kansas City, MO, September 1998.

7. T. Cuscino, Jr., *et al., Taconite Mining Fugitive Emissions Study*, Minnesota Pollution Control Agency, Roseville, MN, June 1979.

8. *Improved Emission Factors For Fugitive Dust From Western Surface Coal Mining Sources*, 2 Volumes, EPA Contract No. 68-03-2924, Office of Air Quality Planning and Standards, U. S. Environmental Protection Agency, Research Triangle Park, NC.

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Ontario

Ministry of the Environment and Climate Change
Ministère de l'Environnement et de l'Action en matière de changement climatique

AMENDED ENVIRONMENTAL COMPLIANCE APPROVAL
NUMBER 1852-A4EP8N
Issue Date: April 3, 2017

Bericap Inc.
835 Syscon Court
Burlington, Ontario
L7L 6C5

Site Location: 835 Syscon Court
Burlington, Ontario

You have applied under section 20.2 of Part II.1 of the Environmental Protection Act, R.S.O. 1990, c. E. 19 (Environmental Protection Act) for approval of:

Description Section

A facility manufacturing plastic caps and enclosures for food, automotive and pharmaceutical industries, consisting of the following processes and support units:

- plastic extrusion;

- assembly, lining, etching and printing;

including the *Equipment* and any other ancillary and support processes and activities, operating at a *Facility Production Limit* of up to 24,420,000 kilograms per year of resins consumed, discharging to the air as described in the *Original ESDM Report.*

For the purpose of this environmental compliance approval, the following definitions apply:

1. " *ACB list"* means the document entitled "Air Contaminants Benchmarks (ACB) List: Standards, guidelines and screening levels for assessing point of impingement concentrations of air contaminants", as amended from time to time and published by the *Ministry* and available on a Government website.

2. "*Acceptable Point of Impingement Concentration"* means a concentration accepted by the *Ministry* as not likely to cause an adverse effect for a *Compound of Concern* that,

(a) is not identified in the *ACB list,* or

(b) is identified in the *ACB list* as belonging to the category "Benchmark 2" and has a concentration at a *Point of Impingement* that exceeds the concentration set out for the contaminant in that document.

With respect to the *Original ESDM Report,* the *Acceptable Point of Impingement Concentration* for a *Compound of Concern* mentioned above is the concentration set out in the *Original ESDM Report.*

3. "*Acoustic Assessment Report"* means the report, prepared in accordance with *Publication NPC-233* and Appendix A of the *Basic Comprehensive User Guide,* by Aidan Maher, P.Eng. / Pinchin

Environmental Ltd. and dated December 20, 2013 submitted in support of the application, that documents all sources of noise emissions and *Noise Control Measures* present at the *Facility,* as updated in accordance with Condition 5 of this *Approval.*

4. "*Acoustic Assessment Summary Table"* means a table prepared in accordance with the *Basic Comprehensive User Guide* summarising the results of the *Acoustic Assessment Report,* as updated in accordance with Condition 5 of this *Approval.*

5. "*Acoustic Audit*" means an investigative procedure consisting of measurements and/or acoustic modelling of all sources of noise emissions due to the operation of the *Facility*, assessed to determine compliance with the Performance Limits for the *Facility* regarding noise emissions, completed in accordance with the procedures set in *Publication NPC-103* and reported in accordance with *Publication NPC-233.*

6. "*Acoustic Audit Report*" means a report presenting the results of an *Acoustic Audit,* prepared in accordance with *Publication NPC-233.*

7. "*Acoustical Consultant*" means a person currently active in the field of environmental acoustics and noise/vibration control, who is familiar with *Ministry* noise guidelines and procedures and has a combination of formal university education, training and experience necessary to assess noise emissions from a *Facility.*

8. "*Approval"* means this entire Environmental Compliance Approval and any *Schedules* to it.

9. "*Basic Comprehensive User Guide"* means the *Ministry* document titled "Basic Comprehensive Certificates of Approval (Air) User Guide" dated March 2011, as amended.

10. "*Company"* means Bericap Inc. that is responsible for the construction or operation of the *Facility* and includes any successors and assigns in accordance with section 19 of the *EPA.*

11. "*Compound of Concern"* means a contaminant described in paragraph 4 subsection 26 (1) of *O. Reg. 419/05,* namely, a contaminant that is discharged from the *Facility* in an amount that is not negligible.

12. "*Description Section"* means the section on page one of this *Approval* describing the *Company's* operations and the *Equipment* located at the *Facility* and specifying the *Facility Production Limit* for the *Facility.*

13. "*Director"* means a person appointed for the purpose of section 20.3 of the *EPA* by the *Minister* pursuant to section 5 of the *EPA.*

14. "*District Manager"* means the District Manager of the appropriate local district office of the *Ministry,* where the *Facility* is geographically located.

15. "*Emission Summary Table"* means a table described in paragraph 14 of subsection 26 (1) of *O. Reg. 419/05.*

16. "*Environmental Assessment Act"* means the Environmental Assessment Act, R.S.O. 1990, c.E.18, as amended.

17. "*EPA"* means the Environmental Protection Act, R.S.O. 1990, c.E.19, as amended.

18. "*Equipment"* means equipment or processes described in the *ESDM Report,* this *Approval* and in the *Schedules* referred to herein and any other equipment or processes.

19. "*Equipment with Specific Operational Limits"* means any *Equipment* related to the thermal oxidation of waste or waste derived fuels, fume incinerators or any other *Equipment* that is specifically referenced in any published *Ministry* document that outlines specific operational guidance that must be considered by the *Director* in issuing an *Approval.*

20. "*ESDM Report"* means the most current Emission Summary and Dispersion Modelling Report that describes the *Facility.* The *ESDM Report* is based on the *Original ESDM Report* and is updated after the issuance of this *Approval* in accordance with section 26 of *O. Reg. 419/05* and the *Procedure Document.*

21. "*Facility"* means the entire operation located on the property where the *Equipment* is located.

22. "*Facility Production Limit"* means the production limit placed by the *Director* on the main product(s) or raw materials used by the *Facility.*

23. "*Independent Acoustical Consultant*" means an *Acoustical Consultant* who is not representing the *Company* and was not involved in preparing the *Acoustic Assessment Report* or the design/implementation of *Noise Control Measures* for the *Facility* and/or *Equipment*. The *Independent Acoustical Consultant* shall not be retained by the *Acoustical Consultant* involved in the noise impact assessment or the design/implementation of *Noise Control Measures* for the *Facility* and/or *Equipment.*

24. "*Log"* means a document that contains a record of each change that is required to be made to the *ESDM Report* and *Acoustic Assessment Report,* including the date on which the change occurred. For example, a record would have to be made of a more accurate emission rate for a source of contaminant, more accurate meteorological data, a more accurate value of a parameter that is related to a source of contaminant, a change to a *Point of Impingement* and all changes to information associated with a *Modification* to the *Facility* that satisfies Condition 2**.**

25. "*Minister"* means the Minister of the Environment and Climate Change or such other member of the Executive Council as may be assigned the administration of the *EPA* under the Executive Council Act.

26. "*Ministry"* means the ministry of the *Minister.*

27. "*Modification"* means any construction, alteration, extension or replacement of any plant, structure, equipment, apparatus, mechanism or thing, or alteration of a process or rate of production at the *Facility* that may discharge or alter the rate or manner of discharge of a *Compound of Concern* to the air or discharge or alter noise or vibration emissions from the *Facility.*

28. *"Noise Control Measures"* means measures to reduce the noise emission from the *Facility* and/or Equipment including, but not limited to silencers, acoustic louvers, enclosures, absorptive treatment, plenums and barriers. It also means the noise control measures outlined in the *Acoustic Assessment Report.*

29. "*O. Reg. 419/05"* means Ontario Regulation 419/05, Air Pollution – Local Air Quality, as amended.

30. "*Original ESDM Report"* means the Emission Summary and Dispersion Modelling Report which was prepared in accordance with section 26 of *O. Reg. 419/05* and the *Procedure Document* by Pinchin Environmental Ltd. and dated January 10, 2014, submitted in support of the application, and includes any changes to the report made up to the date of issuance of this *Approval.*

31. "*Point of Impingement"* has the same meaning as in section 2 of *O. Reg. 419/05.*

32. "*Point of Reception"* means Point of Reception as defined by *Publication NPC-300.*

33. "*Procedure Document"* means *Ministry* guidance document titled "Procedure for Preparing an Emission Summary and Dispersion Modelling Report" dated February 2017, as amended.

34. "*Processes with Significant Environmental Aspects"* means the *Equipment* which, during regular operation, would discharge one or more contaminants into the air in an amount which is not considered as negligible in accordance with section 26 (1) 4 of *O. Reg. 419/05* and the *Procedure Document.*

35. "*Publication NPC-103*" means the *Ministry* Publication NPC-103 of the Model Municipal Noise Control By-Law, Final Report, August 1978, published by the *Ministry* as amended.

36. "*Publication NPC-207"* means the *Ministry* draft technical publication "Impulse Vibration in Residential Buildings", November 1983, supplementing the Model Municipal Noise Control By-Law, Final Report, published by the *Ministry,* August 1978, as amended.

37. "*Publication NPC-233"* means the *Ministry* Publication NPC-233, "Information to be Submitted for Approval of Stationary Sources of Sound", October, 1995, as amended.

38. "*Publication NPC-300"* means the *Ministry* Publication NPC-300, "Environmental Noise Guideline, Stationary and Transportation Sources – Approval and Planning, Publication NPC-300", August 2013, as amended.

39. "*Schedules"* means the following schedules attached to this *Approval* and forming part of this *Approval* namely:

Schedule A - Supporting Documentation.

40. "*Toxicologist"* means a qualified professional currently active in the field of risk assessment and toxicology that has a combination of formal university education, training and experience necessary to assess contaminants.

41. "*Written Summary Form"* means the electronic questionnaire form, available on the *Ministry* website, and supporting documentation, that documents the activities undertaken at the *Facility* in the previous calendar year.

You are hereby notified that this environmental compliance approval is issued to you subject to the terms and conditions outlined below:

TERMS AND CONDITIONS

1. GENERAL

1.1 Except as otherwise provided by this *Approval,* the *Facility* shall be designed, developed, built, operated and maintained in accordance with the terms and conditions of this *Approval* and in accordance with the following *Schedules* attached hereto:

Schedule A - Supporting Documentation.

2. LIMITED OPERATIONAL FLEXIBILITY

2.1 Pursuant to section 20.6 (1) of the *EPA* and subject to Conditions 2.2 and 2.3 of this *Approval,* future construction, alterations, extensions or replacements are approved in this *Approval* if the future construction, alterations, extensions or replacements are *Modifications* to the *Facility* that:

(a) are within the scope of the operations of the *Facility* as described in the *Description Section* of this *Approval;*

(b) do not result in an increase of the *Facility Production Limit* above the level specified in the *Description Section* of this *Approval;* and

(c) result in compliance with the performance limits as specified in Condition 4.

2.2 Condition 2.1 does not apply to,

(a) the addition of any new *Equipment with Specific Operational Limits* or to the *Modification* of any existing *Equipment with Specific Operational Limits* at the *Facility;* or

(b) *Modifications* to the *Facility* that would be subject to the *Environmental Assessment Act.*

2.3 Condition 2.1 of this *Approval* shall expire on February 1, 2020*,* unless this *Approval* is revoked prior to the expiry date.

3. REQUIREMENT TO REQUEST AN *ACCEPTABLE POINT OF IMPINGEMENT CONCENTRATION*

3.1 Prior to making a *Modification* to the *Facility* that satisfies Condition 2.1 (a) and (b), the *Company* shall prepare a proposed update to the *ESDM Report* to reflect the proposed *Modification.*

3.2 The *Company* shall request approval of an *Acceptable Point of Impingement Concentration* for a *Compound of Concern* if the *Compound of Concern* is not identified in the *ACB list* as belonging to the category "Benchmark 1" and a proposed update to an *ESDM Report* indicates that one of the following changes with respect to the concentration of the *Compound of Concern* may occur:

(a) The *Compound of Concern* was not a *Compound of Concern* in the previous version of the *ESDM Report* and

(i) the concentration of the *Compound of Concern* exceeds the concentration set out for the contaminant in the *ACB list;* or

(ii) the *Compound of Concern* is not identified in the *ACB list;* or

(b) The concentration of the *Compound of Concern* in the updated *ESDM Report* exceeds the higher of,

(i) the most recent *Acceptable Point of Impingement Concentration,* and

(ii) the concentration set out for the contaminant in the *ACB list,* if the contaminant is identified in that document.

3.3 The request required by Condition 3.2 shall propose a concentration for the *Compound of Concern* and shall contain an assessment, performed by a *Toxicologist,* of the likelihood of the proposed concentration causing an adverse effect at *Points of Impingement.*

3.4 If the request required by Condition 3.2 is a result of a proposed *Modification* described in Condition 3.1, the *Company* shall submit the request, in writing, to the *Director* at least 30 days prior to commencing to make the *Modification.* The *Director* shall provide written confirmation of receipt of this request to the *Company.*

3.5 If a request is required to be made under Condition 3.2 in respect of a proposed *Modification* described in Condition 3.1, the *Company* shall not make the *Modification* mentioned in Condition 3.1 unless the request is approved in writing by the *Director.*

3.6 If the *Director* notifies the *Company* in writing that the *Director* does not approve the request, the *Company* shall,

(a) revise and resubmit the request; or

(b) notify the *Director* that it will not be making the *Modification.*

3.7 The re-submission mentioned in Condition 3.6 shall be deemed a new submission under Condition 3.2.

3.8 If the *Director* approves the request, the *Company* shall update the *ESDM Report* to reflect the *Modification.*

3.9 Condition 3 does not apply if Condition 2.1 has expired.

4. PERFORMANCE LIMITS

4.1. Subject to Condition 4.2, the *Company* shall not discharge or cause or permit the discharge of a *Compound of Concern* into the air if,

(a) the *Compound of Concern* is identified in the *ACB list* as belonging to the category "Benchmark 1" and the discharge results in the concentration at a *Point of Impingement* exceeding the Benchmark 1 concentration; or

(b) the *Compound of Concern* is not identified in the *ACB list* as belonging to the category "Benchmark 1" and the discharge results in the concentration at a *Point of Impingement* exceeding the higher of,

(i) if an *Acceptable Point of Impingement Concentration* exists, the most recent *Acceptable Point of Impingement Concentration,* and

(ii) the concentration set out for the contaminant in the *ACB list,* if the contaminant is identified in that document.

4.2 Condition 4.1 does not apply if the benchmark set out in the *ACB list* has a 10-minute averaging period and no ambient monitor indicates an exceedance at a *Point of Impingement* where human activities regularly occur at a time when those activities regularly occur.

4.3 The *Company* shall:

(a) implement by not later than twelve (12) months after the date of this *Approval*, the *Noise Control Measures* outlined in the *Acoustic Assessment Report;*

(b) ensure, subsequent to the implementation of the *Noise Control Measures* that the noise emissions from the *Facility* comply with the limits set in *Ministry Publication NPC-300;* and

(c) ensure that the *Noise Control Measures* are properly maintained and continue to provide the acoustical performance outlined in the *Acoustic Assessment Report.*

4.4 The *Company* shall, at all times, ensure that the vibration emissions from the *Facility* comply with the limits set out in *Ministry Publication NPC-207.*

4.5 The *Company* shall operate any *Equipment with Specific Operational Limits* approved by this *Approval* in accordance with the *Original ESDM Report.*

5. **DOCUMENTATION REQUIREMENTS**

5.1. The *Company* shall maintain an up-to-date *Log.*

5.2. No later than June 30 in each year, the *Company* shall update the *Acoustic Assessment Report* and shall update the *ESDM Report* in accordance with section 26 of *O. Reg. 419/05* so that the information in the reports is accurate as of December 31 in the previous year.

5.3. The *Company* shall make the *Emission Summary Table* (see section 27 of *O. Reg. 419/05)* and *Acoustic Assessment Summary Table* available for examination by any person, without charge, by posting it on the Internet or by making it available during regular business hours at the *Facility.*

5.4 The *Company* shall, within three (3) months after the expiry of Condition 2.1 of this

Approval, update the *ESDM Report* and the *Acoustic Assessment Report* such that the information in the reports is accurate as of the date that Condition 2.1 of this *Approval* expired.

5.5. Conditions 5.1 and 5.2 do not apply if Condition 2.1 has expired.

6. REPORTING REQUIREMENTS

6.1 Subject to Condition 6.2, the *Company* shall provide the *Director* no later than August 31 of each year, a *Written Summary Form* to be submitted through the *Ministry's* website that shall include the following:

(a) a declaration of whether the *Facility* was in compliance with section 9 of the *EPA, O. Reg. 419/05* and the conditions of this *Approval;*

(b) a summary of each *Modification* satisfying Condition 2.1 (a) and (b) that took place in the previous calendar year that resulted in a change in the previously calculated concentration at a *Point of Impingement* for any *Compound of Concern* or resulted in a change in the sound levels reported in the *Acoustic Assessment Summary Table* at any *Point of Reception.*

6.2 Condition 6.1 does not apply if Condition 2.1 has expired.

7. OPERATION AND MAINTENANCE

7.1 The *Company* shall prepare and implement, not later than three (3) months from the date of this *Approval,* operating procedures and maintenance programs for all *Processes with Significant Environmental Aspects,* which shall specify as a minimum:

(a) frequency of inspections and scheduled preventative maintenance;

(b) procedures to prevent upset conditions;

(c) procedures to minimize all fugitive emissions;

(d) procedures to prevent and/or minimize odorous emissions;

(e) procedures to prevent and/or minimize noise emissions; and

(f) procedures for record keeping activities relating to the operation and maintenance programs.

7.2 The *Company* shall ensure that all *Processes with Significant Environmental Aspects* are operated and maintained in accordance with this *Approval,* the operating procedures and maintenance programs.

8. COMPLAINTS RECORDING AND REPORTING

8.1 If at any time, the *Company* receives an environmental complaint from the public regarding the operation of the *Equipment* approved by this *Approval,* the *Company* shall take the following steps:

(a) Record and number each complaint, either electronically or in a log book. The record shall include the following information: the time and date of the complaint and incident to which the complaint relates, the nature of the complaint, wind direction at the time and date of the incident to which the complaint relates and, if known, the address of the complainant.

(b) Notify the *District Manager* of the complaint within two (2) business days after the complaint is received, or in a manner acceptable to the *District Manager.*

(c) Initiate appropriate steps to determine all possible causes of the complaint, and take the necessary actions to appropriately deal with the cause of the subject matter of the complaint.

(d) Complete and retain on-site a report written within one (1) week of the complaint date. The report shall list the actions taken to appropriately deal with the cause of the complaint and set out steps to be taken to avoid the recurrence of similar incidents.

9. RECORD KEEPING REQUIREMENTS

9.1 Any information requested by any employee in or agent of the *Ministry* concerning the *Facility* and its operation under this *Approval,* including, but not limited to, any records required to be kept by this *Approval,* shall be provided to the employee in or agent of the *Ministry,* upon request**,** in a timely manner.

9.2 Unless otherwise specified in this *Approval,* the *Company* shall retain, for a minimum of five (5) years from the date of their creation all reports, records and information described in this *Approval,* including,

(a) a copy of the *Original ESDM Report* and each updated version*;*

(b) a copy of each version of the *Acoustic Assessment Report;*

(c) supporting information used in the emission rate calculations performed in the *ESDM Reports* and *Acoustic Assessment Reports;*

(d) the records in the *Log;*

(e) copies of each *Written Summary Form* provided to the *Ministry* under Condition 6.1 of this *Approval;*

(f) records of maintenance, repair and inspection of *Equipment* related to all *Processes with Significant Environmental Aspects;* and

(g) all records related to environmental complaints made by the public as required by Condition 8 of this *Approval.*

10. REVOCATION OF PREVIOUS APPROVALS

This *Approval* replaces and revokes all Certificates of Approval (Air) issued under section 9 *EPA* and Environmental Compliance Approvals issued under Part II.1 *EPA* to the *Facility* in regards to the activities mentioned in subsection 9(1) of the *EPA* and dated prior to the date of this *Approval.*

11. *ACOUSTIC AUDIT*

11.1 The *Company* shall carry out *Acoustic Audit* measurements on the actual noise emissions due to the operation of the *Facility.* The *Company:*

(a) shall carry out *Acoustic Audit* measurements in accordance with the procedures in *Publication NPC-103;*

(b) shall submit an *Acoustic Audit Report* on the results of the *Acoustic Audit* , prepared by an *Independent Acoustical Consultant* , in accordance with the requirements of *Publication NPC-233* , to the *District Manager* and the *Director* , not later than six (6) months after the full implementation of the *Noise Control Measures.*

11.2 The *Director:*

(a) may not accept the results of the *Acoustic Audit* if the requirements of *Publication NPC-233* were

not followed;

(b) may require the *Company* to repeat the *Acoustic Audit* if the results of the *Acoustic Audit* are found unacceptable to the *Director.*

SCHEDULE A

Supporting Documentation

(a) Environmental Compliance Approval Application, dated January 9, 2014, signed by Harry LeClaire and submitted by the *Company;*

(b) Emission Summary and Dispersion Modelling Report, prepared by Pinchin Environmental Ltd. and dated January 10, 2014;

(c) *Acoustic Assessment Report,* prepared by Aidan Maher, P.Eng. / Pinchin Environmental Ltd. and dated December 20, 2013;

(d) Additional information provided by by Aidan Maher, P.Eng. / Pinchin Environmental Ltd. by email on March 20, 2017.

The reasons for the imposition of these terms and conditions are as follows:

GENERAL

1. Condition No. 1 is included to require the *Approval* holder to build, operate and maintain the *Facility* in accordance with the Supporting Documentation in Schedule A considered by the *Director* in issuing this *Approval.*

LIMITED OPERATIONAL FLEXIBILITY, REQUIREMENT TO REQUEST AN *ACCEPTABLE POINT OF IMPINGEMENT CONCENTRATION* AND PERFORMANCE LIMITS

2. Conditions No. 2, 3 and 4 are included to limit and define the *Modifications* permitted by this *Approval,* and to set out the circumstances in which the *Company* shall request approval of an *Acceptable Point of Impingement Concentration* prior to making *Modifications.* The holder of the *Approval* is approved for operational flexibility for the *Facility* that is consistent with the description of the operations included with the application up to the *Facility Production Limit.* In return for the operational flexibility, the *Approval* places performance based limits that cannot be exceeded under the terms of this *Approval. Approval* holders will still have to obtain other relevant approvals required to operate the *Facility,* including requirements under other environmental legislation such as the *Environmental Assessment Act.*

DOCUMENTATION REQUIREMENTS

3. Condition No. 5 is included to require the *Company* to maintain ongoing documentation that demonstrates compliance with the performance limits as specified in Condition 4 of this *Approval* and allows the *Ministry* to monitor on-going compliance with these performance limits. The *Company* is required to have an up to date *ESDM Report* and *Acoustic Assessment Report* that describe the *Facility* at all times and make the *Emission Summary Table* and *Acoustic Assessment Summary Table* from these reports available to the public on an ongoing basis in order to maintain public communication with regard to the emissions from the *Facility.*

REPORTING REQUIREMENTS

4. Condition No. 6 is included to require the *Company* to provide a yearly *Written Summary Form* to the *Ministry,* to assist the *Ministry* with the review of the site's compliance with the *EPA,* the regulations and this *Approval.*

OPERATION AND MAINTENANCE

5. Condition No. 7 is included to require the *Company* to properly operate and maintain the *Processes with Significant Environmental Aspects* to minimize the impact to the environment from these processes.

COMPLAINTS RECORDING AND REPORTING PROCEDURE

6. Condition No. 8 is included to require the *Company* to respond to any environmental complaints regarding the operation of the *Equipment,* according to a procedure that includes methods for preventing recurrence of similar incidents and a requirement to prepare and retain a written report.

RECORD KEEPING REQUIREMENTS

7. Condition No. 9 is included to require the *Company* to retain all documentation related to this *Approval* and provide access to employees in or agents of the *Ministry,* upon request, so that the *Ministry* can determine if a more detailed review of compliance with the performance limits as specified in Condition 4 of this *Approval* is necessary.

REVOCATION OF PREVIOUS APPROVALS

8. Condition No. 10 is included to identify that this *Approval* replaces all Section 9 Certificate(s) of Approval and Part II.1 Approvals in regards to the activities mentioned in subsection 9(1) of the *EPA* and dated prior to the date of this *Approval.*

ACOUSTIC AUDIT

9. Condition No. 11 is included to require the *Company* to gather accurate information and submit an *Acoustic Audit Report* in accordance with procedures set in the *Ministry*'s noise guidelines, so that the environmental impact and subsequent compliance with this *Approval* can be verified.

Upon issuance of the environmental compliance approval, I hereby revoke Approval No(s). 1136-5ZCNBU issued on April 24, 2005.

In accordance with Section 139 of the Environmental Protection Act, you may by written Notice served upon me, the Environmental Review Tribunal and in accordance with Section 47 of the Environmental Bill of Rights, 1993 , S.O. 1993, c. 28 (Environmental Bill of Rights), the Environmental Commissioner, within 15 days after receipt of this Notice, require a hearing by the Tribunal. The Environmental Commissioner will place notice of your appeal on the Environmental Registry. Section 142 of the Environmental Protection Act provides that the Notice requiring the hearing shall state:

1. The portions of the environmental compliance approval or each term or condition in the environmental compliance approval in respect of which the hearing is required, and;
2. The grounds on which you intend to rely at the hearing in relation to each portion appealed.

Pursuant to subsection 139(3) of the Environmental Protection Act, a hearing may not be required with respect to any terms and conditions in this environmental compliance approval, if the terms and conditions are substantially the same as those contained in an approval that is amended or revoked by this environmental compliance approval.

The Notice should also include:

3. The name of the appellant;

4. The address of the appellant;
5. The environmental compliance approval number;
6. The date of the environmental compliance approval;
7. The name of the Director, and;
8. The municipality or municipalities within which the project is to be engaged in.

And the Notice should be signed and dated by the appellant.

This Notice must be served upon:

The Secretary* Environmental Review Tribunal 655 Bay Street, Suite 1500 Toronto, Ontario M5G 1E5	AND	The Environmental Commissioner 1075 Bay Street, Suite 605 Toronto, Ontario M5S 2B1	AND The Director appointed for the purposes of Part II.1 of the Environmental Protection Act Ministry of the Environment and Climate Change 135 St. Clair Avenue West, 1st Floor Toronto, Ontario M4V 1P5

*** Further information on the Environmental Review Tribunal's requirements for an appeal can be obtained directly from the Tribunal at: Tel: (416) 212-6349, Fax: (416) 326-5370 or www.ert.gov.on.ca**

This instrument is subject to Section 38 of the Environmental Bill of Rights, 1993, that allows residents of Ontario to seek leave to appeal the decision on this instrument. Residents of Ontario may seek leave to appeal within 15 days from the date this decision is placed on the Environmental Registry. By accessing the Environmental Registry at www.ebr.gov.on.ca , you can determine when the leave to appeal period ends.

The above noted activity is approved under s.20.3 of Part II.1 of the Environmental Protection Act.

DATED AT TORONTO this 3rd day of April, 2017

Rudolf Wan, P.Eng.
Director
appointed for the purposes of Part II.1 of
the *Environmental Protection Act*

QN/
c: District Manager, MOECC Halton-Peel
Spencer Ludwig, Pinchin Ltd.

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Ontario

Ministry of the Environment **Ministère de l'Environnement**

AMENDED CERTIFICATE OF APPROVAL
AIR
NUMBER 1136-5ZCNBU

Bericap Inc.
835 Syscon Court
Burlington, Ontario
L7L 6C5

Site Location: Burlington Facility, 835 Syscon Court, Burlington, Ontario.

You have applied in accordance with Section 9 of the Environmental Protection Act for approval of:

- three (3) production area general exhausts serving the extruder area, each discharging into the atmosphere at a volumetric flow rate of 1.82 cubic metres per second, through separte stacks (EF-1 to EF-3), having an exit diameter of 1.12 metres, extending 0.58 metre above the roof and 8.24 metres above grade;

- four (4) production area general exhausts serving the extruder area, each discharging into the atmosphere at a volumetric flow rate of 10.04 cubic metres per second, through separte stacks (EF-4 to EF-7), having an exit diameter of 1.27 metres, extending 0.36 metre above the roof and 8.02 metres above grade;

- one (1) exhaust system serving a dry offset printing press, discharging into the atmosphere at a volumetric flow rate of 0.86 cubic metre per second, through a stack (EF-14), having an exit diameter of 0.23 metre, extending 1.5 metres above the roof and 9.1 metres above grade;

- one (1) exhaust system serving two (2) dry offset printing presses, exhausting into the atmosphere at a volumetric flow rate of 0.43 cubic metre per second, through a stack (EF-15), having an exit diameter of 0.23 metre, extending 1.5 metres above the roof and 9.1 metres above grade;

- one (1) exhaust system serving a dip tank, exhausting into the atmosphere at a volumetric flow rate of 2.2 cubic metre per second, through a stack (EF-23), having an exit diameter of 0.3 metre, extending 1.5 metres above the roof and 9.2 metres above grade;

- seven (7) vacuum pump exhausts (EF 16 to EF-22);

- two (2) cooling towers (CT-1 and CT-2), each having a water flow rate of 34.1 litres per second;

- two (2) cooling towers (CT-3 and CT-4), each having a water flow rate of 69.3 litres per second;

- seven (7) raw material storage silos, containing plastic resins;

- ten (10) natural gas fired make up air units (MAU-1 to MAU-10), having a total heat input of 3,876,276 kilojoules per hour;

- twelve (12) natural gas fired unit heaters (UH-1 to UH-12), having a total heat input of 1,897,200 kilojoules per hour;

all in accordance with the application for a Certificate of Approval (Air) and all supporting information dated October 23, 2003, signed by G. Shelley.

For the purpose of this Certificate of Approval and the terms and conditions specified below, the following definitions apply:

1. "Act" means the *Environmental Protection Act*;

2. "Certificate" means this Certificate of Approval, issued in accordance with Section 9 of the Act;

CONTENT COPY OF ORIGINAL

3. "Company" means Bericap Inc.;

4. "District Manager" means the District Manager, Halton Peel District Office, Central Region of the Ministry;

5. "Equipment" means the equipment described in this Certificate and in the supporting documentation referred to herein, to the extent approved by this Certificate;

6. "Facility" means the entire operation located on the property where the Equipment is located;

7. "Manual" means a document or a set of documents that provide written instructions to staff of the Company;

8. "Ministry" means the Ontario Ministry of Environment; and

9. "Publication NPC-205" means Publication NPC-205, Sound Level Limits for Stationary Sources in Class 1 & 2 Areas (Urban), October, 1995.

You are hereby notified that this approval is issued to you subject to the terms and conditions outlined below:

TERMS AND CONDITIONS

OPERATION AND MAINTENANCE

1. The Company shall ensure that the Facility is properly operated and maintained at all times. The Company shall:

Complaint Response Procedure

(1) prepare, no later than three (3) months from the date of this Certificate, and implement and maintain on ongoing basis a Complaint Response Procedure for receiving and logging environmental complaints from the neighbouring public and the actions taken in response. This procedure shall include, but not be limited to the following:

(a) a description, date and time of the incident;
(b) operating conditions (such as operating parameters and production or processing rates), as well as any upset conditions, or unusual events at the time of the incident;
(c) wind direction, wind speed and atmospheric condition at the time of the incident; and
(d) a description of any measures taken to address the cause of the complaint and to prevent a similar occurrence in the future;
(e) notify the District Manager, in writing within two (2) business days of the receipt of a complaint.

Operating and Maintenance Manual

(2) prepare, not later than three (3) months after the date of this Certificate, and update as necessary an Operating and Maintenance Manual outlining the maintenance and operating procedures for the Facility. This Manual shall contain, but not be limited to:

(a) routine operating and maintenance procedures in accordance with good engineering practices and as recommended by the Equipment suppliers;
(b) all measures to minimize noise, odour and dust emissions from all potential sources at the Facility;
(c) emergency procedures;
(d) procedures for any record keeping activities relating to operation and maintenance of the Facility/Equipment;
(e) procedures for recording and responding to environmental complaints relating to operation of the Facility;
(f) list of trained personnel responsible for the operation and maintenance of the Facility;

(3) implement the Complaint Response Procedure and the requirements of the Operating and Maintenance Manual;

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(4) retain for a minimum of two (2) years from the date of their creation, all records and information related to or resulting from the Operation and Maintenance Manual and Complaint Response Procedure required by this Certificate, and make these records available for review by staff of the Ministry upon request.

2. The Company shall ensure that the noise emissions from the Equipment comply with the limits set in Publication NPC-205.

The reasons for the imposition of these terms and conditions are as follows:

1. Condition No. 1 is included to emphasize that the Facility must be maintained and operated according to a procedure that will result in compliance with the Act, the regulations and this Certificate.

2. Condition No. 2 is included to provide the minimum performance requirement considered necessary to prevent an adverse effect resulting from the operation of the Equipment.

This Certificate of Approval revokes and replaces Certificate(s) of Approval No. 8-3341-91-926 issued on May 4, 1992.

In accordance with Section 139 of the Environmental Protection Act, R.S.O. 1990, Chapter E-19, as amended, you may by written Notice served upon me, the Environmental Review Tribunal and in accordance with Section 47 of the Environmental Bill of Rights, S.O. 1993, Chapter 28, the Environmental Commissioner, within 15 days after receipt of this Notice, require a hearing by the Tribunal. The Environmental Commissioner will place notice of your appeal on the Environmental Registry. Section 142 of the Environmental Protection Act, provides that the Notice requiring the hearing shall state:

1. The portions of the approval or each term or condition in the approval in respect of which the hearing is required, and;
2. The grounds on which you intend to rely at the hearing in relation to each portion appealed.

The Notice should also include:

3. The name of the appellant;
4. The address of the appellant;
5. The Certificate of Approval number;
6. The date of the Certificate of Approval;
7. The name of the Director;
8. The municipality within which the works are located;

And the Notice should be signed and dated by the appellant.

This Notice must be served upon:

The Secretary*
Environmental Review Tribunal
2300 Yonge St., 12th Floor
P.O. Box 2382
Toronto, Ontario
M4P 1E4

AND

The Environmental Commissioner
1075 Bay Street, 6th Floor
Suite 605
Toronto, Ontario
M5S 2B1

AND

The Director
Section 9, *Environmental Protection Act*
Ministry of Environment and Energy
2 St. Clair Avenue West, Floor 12A
Toronto, Ontario
M4V 1L5

*** Further information on the Environmental Review Tribunal's requirements for an appeal can be obtained directly from the Tribunal at: Tel: (416) 314-4600, Fax: (416) 314-4506 or www.ert.gov.on.ca**

This instrument is subject to Section 38 of the Environmental Bill of Rights, that allows residents of Ontario to seek leave to appeal the decision on this instrument. Residents of Ontario may seek leave to appeal within 15 days from the date this decision is placed on the Environmental Registry. By accessing the Environmental Registry at www.ene.gov.on.ca, you can determine when the leave to appeal period ends.

The above noted works are approved under Section 9 of the Environmental Protection Act.

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DATED AT TORONTO this 24th day of April, 2005

Victor Low, P.Eng.
Director
Section 9, *Environmental Protection Act*

QN/
c: District Manager, MOE Halton-Peel
Malcolm Bingley, Pinchin Environmental Ltd.



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TECHNICAL PAPER

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Determination of VOC Emission Rates and Compositions for Offset Printing

R.A. Wadden, P.A. Scheff, J.E. Franke, and L.M. Conroy
Environmental and Occupational Health Sciences, School of Public Health, University of Illinois, Chicago, Illinois

C.B. Keil
College of Health and Human Services, Bowling Green State University, Bowling Green, Ohio

ABSTRACT

The release rates of volatile organic compounds (VOC) as fugitive emissions from offset printing are difficult to quantify, and the compositions are usually not known. Tests were conducted at three offset printing shops that varied in size and by process. In each case, the building shell served as the test "enclosure," and air flow and concentration measurements were made at each air entry and exit point. Emission rates and VOC composition were determined during production for (1) a small shop containing three sheetfed presses and two spirit duplicators (36,700 sheets, 47,240 envelopes and letterheads), (2) a medium-size industrial in-house shop with two webfed and three sheetfed presses, and one spirit duplicator (315,130 total sheets), and (3) one print room of a large commercial concern containing three webfed, heatset operations (1.16×10^6 ft) served by catalytic air pollution control devices. Each test consisted of 12 one-hour periods over two days. Air samples were collected simultaneously during each period at 7–14 specified locations within each space. The samples were analyzed by gas chromatography (GC) for total VOC and for 13–19 individual organics. Samples of solvents used at each shop were also analyzed by GC. Average VOC emission rates were 4.7–6.1 kg/day for the small sheetfed printing shop, 0.4–0.9 kg/day for the industrial shop, and 79–82 kg/day for the commercial print room. Emission compositions were similar and included benzene, toluene, xylenes, ethylbenzene, and hexane. Comparison of the emission rates with mass balance estimates based on solvent usage and composition were quite consistent. The average compositions of emissions from these tests were much more detailed than has been previously available, but they agreed well with previous chemical fingerprint values for toluene and o-xylene, which have been successfully applied to source-receptor modeling for graphic arts.

IMPLICATIONS

Offset printing is characterized by significant uncontrolled, and frequently unquantified, fugitive emissions of volatile organic compounds (VOC). This study demonstrates a methodology, applied to three plants of different capacities and processes, by which fugitive emissions can be quantified in printing and other surface coating operations without recourse to a Temporary Total Enclosure (TTE). The average compositions of emissions from each plant, despite process and solvent differences, were similar. These concentration data are much more detailed than have been available up until this time, but they agreed well with previous chemical fingerprint values for toluene and o-xylene, which have been successfully applied to source-receptor modeling for graphic arts.

INTRODUCTION

Offset printing has the potential to release volatile organic compounds (VOC) as fugitive emissions. In addition, under the Clean Air Act Amendments of 1990, many individual components of VOC have been identified as hazardous air pollutants (HAPs) and thus require control. Because printing operations are often not served by local exhaust ventilation control systems, the release rates are difficult to quantify and the compositions are usually not known.[1-4]

Offset printing consists of an inking system which produces and delivers a thin, uniform ink film to a printing plate. An aqueous fountain solution, which contains small amounts of phosphoric acid and *i*-propyl alcohol or glycol ethers, wets nonprinting areas of the plate. The printing plate, positioned on a cylinder, delivers only the inked images to an elastomeric, rubber-covered, multitiered lithographic blanket on the blanket cylinder. The blanket, in turn, passes images onto substrate (paper or paperboard), while the impression cylinder controls the force imposed on the substrate to insure proper transfer of inked images. Blankets and ink rollers must be cleaned before, during, and after jobs, usually with volatile solvents. Webfed presses print on a continuous sheet that is fed from an unwinding paper roll. Sheetfed printing is a slower process in which individual sheets from a stack are run through a press. Sheetfed printing and some webfed presses use nonheatset inks which are formulated to set within minutes of application and generally contain drying oil (linseed or soy), resins and pigments, and petroleum distillates. The ink is nearly dry as the sheet or web leaves the press.[1] Other webfed processes use heatset

inks, typically containing about 40% by weight VOC. Most of this VOC (80–90%) is evaporated in a dryer after the ink has been applied to the web. Ordinarily, a control device, such as a catalytic incinerator, will be used to destroy the evaporated VOC.

This paper summarizes the results from tests conducted at three offset printing shops that varied in size and by process. In each case, the building shell served as the test "enclosure," and air flow and concentration measurements were made at each air entry and exit point. Emission rates and VOC composition were determined during production for (1) a small shop containing four sheetfed presses and three spirit duplicators, (2) a medium-size industrial in-house shop with two webfed and three sheetfed presses and two spirit duplicators, and (3) one print room of a large commercial concern containing three webfed, heatset operations served by catalytic air pollution control devices.

METHODS

Each test consisted of 12 one-hour periods over two days. Air samples were collected simultaneously on charcoal tubes at calibrated flow rates of 300 ml/min during each period at 7–14 specified locations within each space. Each sample flow rate was checked at the beginning of the hour, on the half-hour, and at the end of the hour. The tubes were extracted with carbon disulfide and were analyzed by gas chromatography (GC) for VOC and for speciation of 13–19 organic compounds. The same sampling and extraction methodology was used for hexane equivalent VOC and the 19 speciated organics. A 30 m x 0.53 mm Supelcowax 10 column was used in a Hewlett-Packard 5890 gas chromatograph with flame ionization detection (FID), basically following the procedures of NIOSH Method 1501.[5] VOC was defined as the total area under the chromatogram trace, interpreted with the hexane response factor, after the CS_2 peak. We used the designation VOC (volatile organic compounds) in the generic sense rather than the regulatory sense. The regulatory interpretation of VOC excludes certain specific halogenated compounds. Some of these, if present, may contribute to the total area under the GC response curve. However, these compounds were not likely to have constituted major contributions to our measurement of VOC. Samples of solvents used at each shop were also analyzed by GC.

Each sample consisted of two tubes in series. Each tube was extracted and analyzed separately. However, breakthrough never occurred for either VOC or for the identified compounds because the mass collected in the backup tubes was always less than the detection limit (<0.25 μg C/m³). Duplicate samples were collected for about 20% of the test samples. These were sent to a commercial laboratory for VOC analysis. (We did not have the resources to compare the speciated compounds.) The procedures were generally similar between the two laboratories. However, the evaluations differed somewhat because of the limitations imposed on

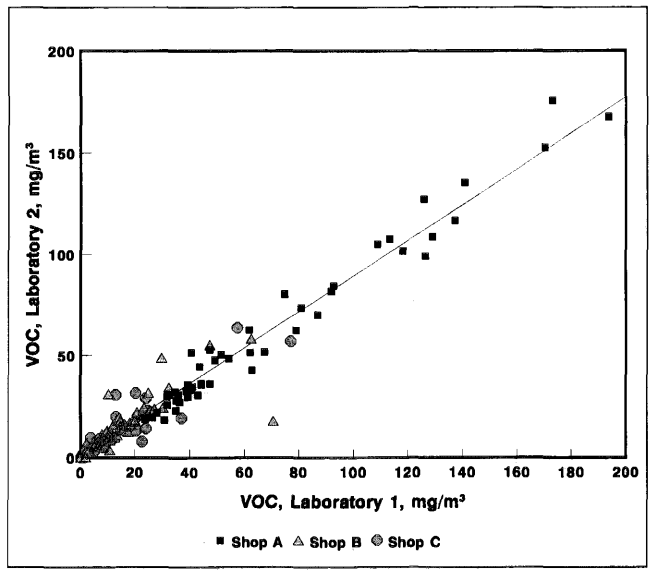


Figure 1. Hexane equivalent VOC analysis quality control comparison for two laboratories. (N = 150; r^2 = 0.96; [Laboratory 2 VOC] = 0.88 [Laboratory 1 VOC] + 0.81.)

the in-house analyses by the Supelcowax 10 column, which was the only one available. (The commercial laboratory used a different column and slightly different temperature profiles). Figure 1 shows a comparison of the VOC analyses for the paired samples. Overall, the agreement was quite good, with $r^2 = 0.99$ and the slope of the comparison equal to 0.88 (perhaps suggesting a small consistent offset because of the difference in methods).

Air flow was measured at each entry and exit point from each of the spaces. Air supply from diffusers was measured using an Alnor Balometer. Air return and make-up air flow rates were measured using a thermoanemometer. Cross drafts and air flow in and out of doors were determined with smoke tubes and a thermoanemometer. Air flow surveys were performed at least once each day of a test, and usually twice. (All air flows are reported at standard conditions of 25 °C and 1 atm). The mixing characteristics of the spaces were determined by SF_6 tracer concentration decay tests[6] or by decay of a residual material, such as CO from lift truck exhaust after the source had been turned off.

Plan views of the three print shops are shown in Figures 2 through 4. The sampling locations are also shown. Plant A is a small shop containing four sheetfed presses and three spirit duplicators. Three of the presses and two of the spirit duplicators in the press room were operated during the test, printing 36,700 sheets and 47,240 envelopes and letterheads. A six-color press was also operated in an adjacent room, and we measured these emissions as well. Dilution ventilation was used for control because no local exhaust ventilation control existed for either press room. The ventilation system shown in Figure 2 served all the spaces shown except the six-color press room, which was served by a separate system. Make-up outdoor air enters each system, is mixed with the air return flow, and is returned to each space through the air

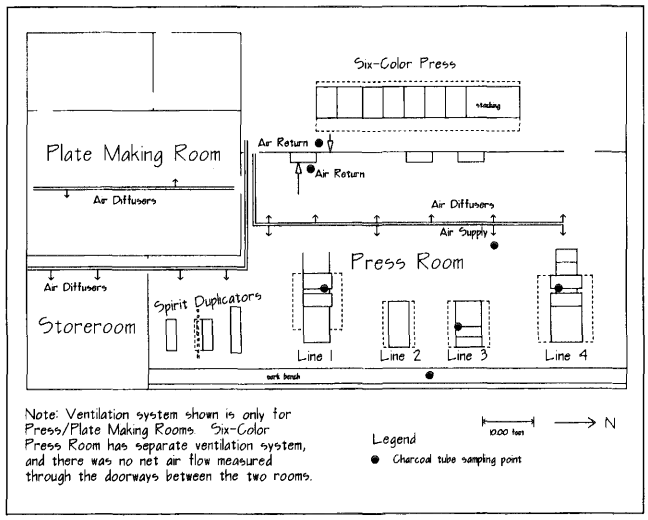


Figure 2. Plan view of Plant A (sheetfed presses). Dotted lines are raised walkways.

supply diffusers. The make-up air rate was 8391 m^3/hr for the print/plate making area and 7064 m^3/hr for the six-color press room. The air change rate based on make-up air entering the print/plate making area was 5.1 hr^{-1}.

Plant B (Figure 3) is a medium-size industrial in-house shop with two webfed presses, three sheetfed presses, and two spirit duplicators (one operating) (315,130 total sheets during test; 181,108 web sheets, 95,504 sheetfed, and 38,581 duplicator sheets). There was no local exhaust control. Air entered through diffusers and exhausted to a space above the false ceiling through the air return ducts. Most of the air entering from the diffusers appeared to have been recycled from this space. Net flow from the press room was down a stairwell to a factory area. Make-up air infiltrated from outdoors at a rate of 7211 m^3/hr. The air change rate based on make-up air was 0.93 hr^{-1}.

Plant C (Figure 4) is one print room of a large commercial concern containing three webfed, heatset operations (1,115,200 ft of 38-in. web during the test, or 554,496 sheets). Each web line is served by a catalytic air pollution control device. Three-shift operation is typical. The Line 1, 2, and 3 Exhausts shown in Figure 3 collect VOC vapors released from the ink dryers. These vapors are then passed to the control devices. The print room was also served by its own air intake system on the roof, which is well removed from two large roof exhaust ports. There were also several entry and exit points at doors from other parts of the plant but no recycle flow. The ventilation rate was 182,000 m^3/hr, and the air change rate was 10.9 hr^{-1}.

Emission rates were determined based on the measured concentrations C (mass/volume) and flow rates Q (volume/time) at entry and exit points.[7] The emission rate S (mass/time) is then

$$S_{mass\ balance} = \sum_{1}^{total\ exit\ points} Q_{exit} \cdot C_{exit} - \sum_{1}^{total\ entry\ points} Q_{entry} \cdot C_{entry} \quad (1)$$

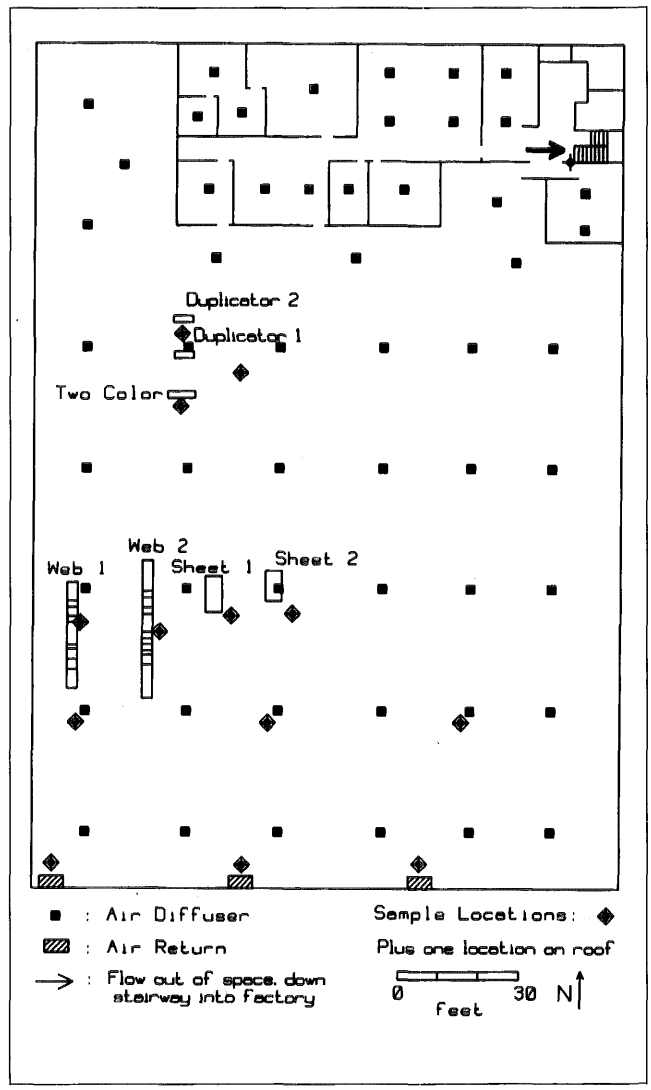


Figure 3. Plant B plan view (webfed and sheetfed presses).

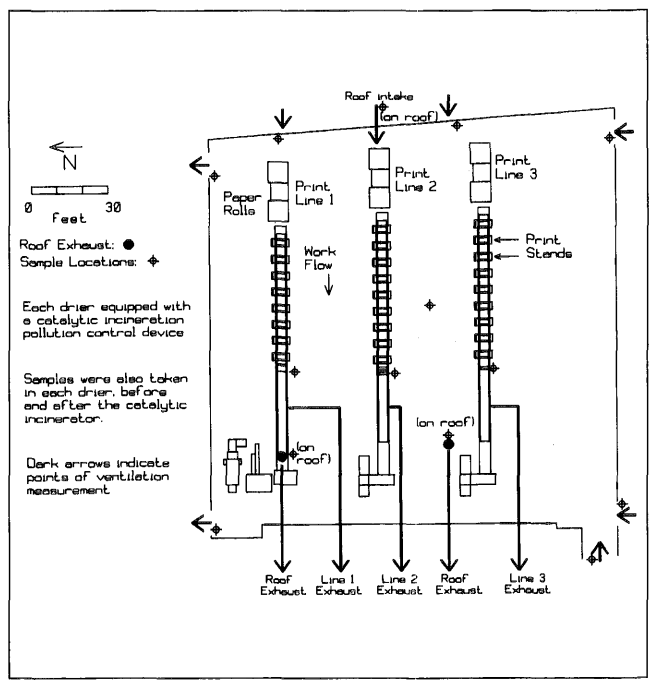


Figure 4. Plan view of Plant C (heatset webfed presses).

Table 1. Plant C average concentrations and ventilation flow rates for each sampling location.

	Flow In						*Flow Out*							
Location	SE door	S screen	N screen	Receiving door	SW door	Spot cooler intake	N ceiling exhaust	S ceiling exhaust	NE door	NW door	Line 1 dryer inlet	Line 2 dryer inlet	Line 3 dryer inlet	Leakage into dryers
Flowrate (m^3/min)[a]	604.8	467.3	392.0	626.4	361.3	285.3	846.6	845.8	389.5	284.9	133.0	113.3	112.9	300.0
Component	*Concentration, mg/m^3*													
n-Hexane	0.70	0.02	.005	.003	0.16	< dl	0.18	0.23	0.12	0.10	0.18	0.18	0.15	0.17
Isopropanol	0.77	0.13	0.09	< dl	0.19	< dl	2.52	0.89	1.00	0.22	4.94	0.72	0.46	2.20
Benzene	1.02	0.14	0.10	0.03	0.32	< dl	2.03	1.65	1.02	0.55	2.82	1.43	0.70	1.72
Toluene	2.90	0.11	0.04	0.06	0.67	0.02	2.16	2.42	0.91	0.56	3.71	2.33	1.01	2.43
Ethylbenzene	0.46	0.01	< dl	< dl	0.10	< dl	0.32	0.19	0.10	0.02	0.78	0.15	0.03	0.34
p-Xylene	0.23	0.01	< dl	< dl	0.03	< dl	0.09	0.05	0.05	0.01	0.39	0.06	0.01	0.17
m-Xylene	0.47	0.02	.002	0.01	0.10	< dl	0.13	0.09	0.07	0.02	0.12	0.10	0.04	0.09
Isopropylbenzene	0.50	0.02	.005	0.01	0.14	< dl	0.21	0.16	0.09	0.02	0.28	0.16	0.10	0.19
o-Xylene	0.67	0.04	0.01	0.01	0.17	< dl	0.52	0.37	0.25	0.07	0.97	0.39	0.26	0.56
n-Propylbenzene	1.12	0.07	0.02	0.02	0.32	< dl	0.42	0.32	0.22	0.07	0.56	0.34	0.23	0.39
m&p-Ethyltoluene	4.99	0.33	0.09	0.12	1.49	< dl	1.95	1.50	1.09	0.43	2.64	1.67	1.15	1.87
Isobutylbenzene	< dl[b]	< dl	< dl	< dl	< dl	< dl	0.11	0.06	0.07	< dl	0.22	0.08	0.083	0.13
1,3,5-Trimethylbenzene	1.89	0.11	0.02	0.04	0.55	< dl	0.62	0.50	0.35	0.12	0.79	0.52	0.38	0.58
o-Ethyltoluene	1.46	0.08	0.02	0.03	0.39	< dl	0.56	0.44	0.35	0.12	0.79	0.49	0.40	0.57
1,2,4-Trimethylbenzene	2.89	0.15	0.09	0.09	0.88	.002	1.73	0.96	0.79	0.31	3.56	1.31	0.96	2.03
m-Diethylbenzene	0.28	0.07	0.01	< dl	0.07	< dl	0.23	0.16	0.07	0.02	0.57	0.18	0.10	0.30
p-Diethylbenzene	0.18	0.01	0.00	< dl	0.02	< dl	0.20	0.06	0.07	< dl	0.36	0.17	0.10	0.22
o-Diethylbenzene	0.13	.001	.002	< dl	0.01	< dl	0.17	0.04	0.02	0.02	1.48	0.05	0.01	0.57
1,2,3-Trimethylbenzene	0.41	0.02	.022	0.02	0.14	< dl	0.82	0.57	0.53	0.11	1.03	0.72	0.41	0.74
Identified compounds, % hexane equivalent VOC	65.6	18.0	12.7	33.3	58.7	7.6	40.4	38.4	46.6	29.4	44.5	42.7	48.9	44.6
Total VOC	32.14	7.47	4.14	1.33	9.79	0.29	37.02	27.76	15.40	9.41	58.91	25.90	13.46	34.21

[a] All flow rates were measured entering or exiting the space except for leakage into the dryers, which was based on measured flow and energy balances around the dryer on Line 1.
[b] less than detection limit = 0.25µg c/m^3.

RESULTS

As an example of the emission rate calculation, Table 1 shows the volumetric flow rates and average compositions over the 12 hours of the test for each entry and exit point at Plant C. The air balance was good, with total measured flow rates in and out being within 0.5%. In addition to the stream compositions and flow rates summarized in Table 1, we also made temperature and flow measurements around the dryer for Line 1. These indicated that additional room air leaked into the dryer. For Line 1, this amounted to 3924 cfm. We estimated similar leakage volumes for Line 2 (3343 cfm) and Line 3 (3332 cfm). The composition given for leakage into the dryers in Table 1 is a composite of the dryer inlet compositions for Lines 1 through 3 weighted by the respective leakage volumes. Table 2 shows the mass balance for VOC. The net release into the room was 57 g/min, and the amount released to the atmosphere was 55 g/min.

Emission rates were similarly calculated for each hour of measurement for each plant. A range of emission rates is reported for Plants A and B because there were several ways to characterize the concentration of air leakage from the spaces. We were able to identify obvious exit and entrance points such as doors, windows, and forced-air ventilation

Table 2. Summary of mass flow rates for Plant C.

Location	*VOC flow rate, mg/min*
FLOW IN	
SE door	19,452
S screen	3,495
N screen	1,626
Receiving door	835
SW door	3,539
Spot cooler intake	82
Air leakage from outdoors[a]	87
TOTAL VOC FLOW IN	29,116
FLOW OUT	
N ceiling exhaust	31,361
S ceiling exhaust	23,497
NE door	5,998
NW door	2,683
Press Line 1 dryer inlet	7,834
Press Line 2 dryer inlet	2,934
Press Line 3 dryer inlet	1,520
Room air leakage into dryers	10,261
TOTAL VOC FLOW OUT	86,088
VOC EMISSION RATE INTO ROOM	56,972
VOC EMISSION RATE TO ATMOSPHERE *(ceiling exhaust fans)*	*54,858*

[a] 10,599 cfm; same composition as spot cooler intake.

Table 3. Composition of emissions.

	Average Weight % of VOC [1]						
	Plant A			Plant B		Plant C	
	Press/plate making rooms		Six-color press				
	Air return	Avg. of six sites[2]	air return	Avg. of all rooms	Stairwell air	Roof fans	Room composition
	(N = 12)	(N = 72)	(N = 12)	(N = 68)	(N = 12)	(N = 24)	(N = 48)
n-Hexane	3.18	2.63	0.22	1.02	0.89	1.12	1.28
i-Propyl alcohol				12.78	11.11	4.67	4.43
Benzene				2.60	1.46	5.70	5.19
Toluene	31.56	29.57	31.18	3.55	3.76	7.80	7.90
Ethylbenzene	0.38	0.45	0.46	0.96	0.81	0.63	0.60
p-Xylene	0.26	0.27	0.24	0.56	0.47	0.18	0.24
m-Xylene	0.61	0.61	0.44	1.42	1.31	0.30	0.42
i-Propylbenzene				1.02	0.92	0.50	0.52
o-Xylene	0.87	0.93	0.76	1.37	1.31	1.39	1.53
n-Propylbenzene	2.30	2.43	2.51	2.29	1.95	1.03	1.07
m&p-Ethyltoluene	9.74	10.26	10.69	10.31	8.86	4.85	5.63
i-Butylbenzene				0.52	<.001	0.32	0.29
1,3,5-Trimethylbenzene	3.39	3.60	3.72	3.10	2.94	1.55	1.63
o-Ethyltoluene	2.25	2.40	2.52	2.36	1.93	1.50	2.11
1,2,4-Trimethylbenzene	4.70	5.01	5.22			3.97	4.30
m-Diethylbenzene	0.53	0.58	0.52	0.71	0.56	0.58	0.65
p-Diethylbenzene				0.24	0.12	0.46	0.53
o-Diethylbenzene				0.44	0.46	0.28	0.56
1,2,3-Trimethylbenzene	0.46	0.51	0.55	1.16	1.03	2.45	2.39

[1] If a value is not shown it means that either we could not determine a concentration because of interfering peaks, or the GC was not calibrated for a particular component.
[2] Average of compositions measured at all six sites in press room (Figure 2).

ducts, and we made flow and concentration measurements at these locations. However, room air also was likely to leak from the space through cracks and other small openings in walls and ductwork. These openings were not easy to identify. Consequently, although we had a good estimate of the total air leaving the space (equal to the measured make-up air), we were less sure of the exact composition. This was less of a problem for Plant C because the space was served by a once-through ventilation system with no recycle. Average VOC emission rates for Plant A from the press/plate making rooms ranged from 0.467 kg/hr (based only on the return air composition) to 0.608 kg/hr (based on the average concentration from all six sample sites in the space), and 0.462 kg/hr from the six-color press (based on the air return). The VOC emissions from Plant B, the industrial shop, ranged from 0.052 kg/hr (based only on the stairwell concentration) to 0.107 kg/hr based on the average of all concentration measurements in the space. The workspace release for Plant C, the commercial print room, was 3.42 kg/hr, with 3.29 kg/hr released to the atmosphere.

Emission compositions from each plant were similar and included benzene, toluene, xylenes, ethylbenzene, and hexane. Table 3 compares compositions for several streams from each plant in terms of weight percent. For the Plant A analyses, it was not possible to separate *i*-propyl-alcohol and benzene with the particular chromatography column used for analysis, although analyses of the solvents by a commercial laboratory with a GC/MS system and a different column indicated that both were present.[8]

DISCUSSION

In general, except for toluene, the emission compositions shown in Table 3 are quite similar despite the differences among plants in printing processes, production rate, and control. Toluene concentrations among the plants varied by a factor of about 10. The 31% toluene composition for Plant A is reflected in both the press room samples and in those from the six-color press. In addition, significant toluene concentrations were found in the solvents from this plant. At this stage, although admittedly we only have three tests on which to base judgment, we believe that the range of toluene compositions shown for the three plants is representative.

If it is assumed that all solvents used in the process are completely evaporated to workroom air, it is also possible to estimate an emission rate from measurements of solvent usage and analyses of the composition of each solvent. (It is perhaps of interest to note that the Material Data Sheets on

Table 4. Solvent compositions and usage for Plants B and C.

	Plant B Solvent Composition					*Plant C Solvent composition*						
	Weight % of hexane equivalent VOC[a]											
	V-120	Pronto	Rycoline	Stay-open	i-Propyl Alcohol	Profit Plus Kleer Gum	Dupont Kleer Gum	Flash Oil Spray	Automatic Blanket Wash	Blanket Rejuve-nator	Manual Blanket Wash	Type Wash
n-Hexane						3.1	7.6	38.4	6.2	7.8	7.1	
Isopropanol	94.0		21.2		100		1.2					62.0
Benzene				1.4		2.8	4.2		4.2		3.1	5.9
Toluene			0.2			12.7	8.2		2.8		5.5	
Ethylbenzene			15.4			0.7						0.1
p-Xylene			10.1	0.1			3.1		0.7		1.5	
m-Xylene			23.0			3.1			0.3		0.7	
Isopropylbenzene		0.04				2.2	0.4				0.1	
o-Xylene		0.04	4.1				1.1		1.2		1.9	
n-Propylbenzene		0.01				3.8					0.6	
m&p-Ethyltoluene		0.6				1.8	0.3		1.7	76.6	2.3	
Isobutylbenzene		0.02					0.3					
1,3,5-Trimethylbenzene						0.3	0.8		9.0		12.3	
o-Ethyltoluene		0.10				0.6	1.1		3.5		4.8	
1,2,4-Trimethylbenzene		0.5					0.5		2.3		3.2	0.2
m-Diethylbenzene		0.03				0.1	0.9		0.2		0.3	
p-Diethylbenzene						0.1	2.2		5.1		7.0	0.3
o-Diethylbenzene		0.01				0.1	0.4		0.6		0.6	0.3
1,2,3-Trimethylbenzene		0.06				0.6	0.4		1.2		1.2	0.4
Total VOC, g/ml	0.835	0.725	0.545	0.409	0.785	1.434	0.590	0.171	1.042	0.773	0.785	0.820
						Line 1, lbs/12 hrs			75		15	1
gallons/month	11.25	0.42	0.73	0.01	6.67	Line 2, lbs/12 hrs			0		19	0
						Line 3, lbs/12 hrs			10		14	0

[a] detection limit for all organics corresponds to < 0.0001 g C/ml

these solvents did not specify the hydrocarbon composition). Solvent compositions for Plants B and C are shown in Table 4. The composition of Plant A solvents has been reported elsewhere.[8]

One difficulty in implementing such a comparison is determining an appropriate value for solvent usage. Even if inventory values exist, these are usually for longer periods of time (a month or year) than two specific days. For Plants A and B, it was not possible to quantitatively measure actual solvent usage during the tests because of the way that the printers mixed and applied cleaning solvents and because of the relatively small amounts. Consequently, we had to determine alternative ways to estimate solvent use.

At Plant A in the press room, each line was usually operated by the same person; therefore, we asked the individual printers to estimate weekly solvent usage. We then applied the solvent compositions to the estimates of each solvent to determine VOC and component usage rates.[8] We used typical work periods of 10 hrs/day (which we observed) and 5 days/week to put the usage data on the same basis as the emission rates determined using Equation 1. For Plant B, only 12-month usage from the solvent storage cabinet was available (Table 4). The daily inventory value was estimated using 12 months and 22 working days/month. Our overall emission rate from the test data was based on an 8-hour day, which was what we observed.

Solvent application rates were much greater for Plant C than for the other two plants (Table 4). Consequently, we developed an estimate of usage from actual observation during the test period. Considerable imprecision remains because we were trying to measure a usage rate of about 5 kg/hr (11 lbs/hr) on three large press lines. In addition, a complicating factor was that some of the workroom emissions from solvent cleaning could be trapped in the dryers on the three lines and subsequently destroyed in the catalytic incinerators. Consequently, although the atmospheric emission rates shown in Tables 1 and 2 for Plant C are accurate, they are not exactly comparable to the inventory values because of the effect of the control devices. If we assume that 100% of the ink solvents that vaporize are driven off and destroyed in the dryer/catalytic converter, the data suggest that, at a minimum, 60% by weight of the solvents applied to the presses escaped to the workspace.

Table 5. Comparison of emission rate with estimated solvent usage.

	VOC		BTEX[1]	
	Mass balance[2]	Inventory	Mass balance[2]	Inventory
Plant A (print room), kg/day	4.7-6.1[3]	7.4[4]	1.4-2.0[3]	1.5[4]
Plant B, kg/day	0.4-0.9[5]	2.6[6]	0.04-0.08[5]	0.04[6]
Plant C, kg/12 hours	39.5-41.0[7]	62.2[8]	6.1-6.5[7]	6.4[8]

1 BTEX = sum of benzene, toluene, ethylbenzene, and the xylenes.
2 Emissions based on 12-hr average air exhaust concentrations and air flow rates from each exit point to the atmosphere.
3 Based on 10-hr/day operation.
4 Emissions based on operator estimates of weekly usage and measured solvent composition for each line adjusted on the basis of 5 working days/week.
5 Based on 8-hr/day operation.
6 Inventory based on 12-month usage of solvents from solvent storage cabinet and measured solvent compositions adjusted on the basis of 22 working days/month.
7 Mass balance measurements do not include cleaning solvents drawn into the dryers with the web which are subsequently destroyed by catalytic oxidation.
8 Inventory based on estimated and measured usage during 12 hours of testing and measured solvent compositions.

Table 6. VOC balance around heatset dryer on Line 1, Plant C.

	Six-hour average concentrations, mg/m³		VOC vaporized in dryer[a]	Ink VOC vaporized[b]
	Inlet air	Exit air	kg	kg
Day 1	73.13	871.10	67.3	79.9
Day 2	44.69	617.53	48.3	43.8
12-Hour Totals			115.6	123.7
	Vaporized VOC/Ink VOC			0.93

a Air flow rate = 234.25 m3/min.
b Based on laboratory measurements, it was assumed that 14% of the ink VOC was retained in the ink after it had heatset on the paper. VOC fractions by ink color were: black - 0.402; blue - 0.413; red - 0.409; yellow - 0.456. Usages (in lbs/6 hours): Day 1 - black, 82; blue, 131, red, 151; yellow, 123; Day 2 - black, 41; blue, 77; red, 76; yellow, 72.

Mass balance and inventory comparisons of VOC and BTEX (the sum of benzene, toluene, ethylbenzene, and xylenes) emissions for each plant are shown in Table 5. Most of the comparisons are reasonable considering the uncertainty in approximating the usage value. We suspect that the difference for Plant B BTEX arises from the inventory estimate and possibly a lack of precision in determination of toluene in the solvent compositions from this plant. (During the test on Plant B, we observed other solvent materials being used, in addition to those recorded in the solvent storage cabinet. Subsequent visits to the plant have indicated that these materials are now accounted for, possibly in response to the Clean Air Act Amendments of 1990, but they were not systematically inventoried at the time of the test.)

For Plant C, we also had specific flow and composition measurements around the dryer for Line 1, as well as daily measurements of ink usage. These data provided us with an independent check of our analytical methods for VOC. Table 6 shows the comparison between VOC based on the entry and exit concentrations, and the estimated VOC release from ink usage. We assumed that 14% of the ink VOC remains on the paper (based on a previous study by the company) and that the VOC fractions of the applied ink were typically 40–45% (also based on previous analyses by the company). The agreement was very good, as over the 12 hours of the test, the composition measurements were able to explain 93% of the vaporized ink VOC.

Emissions from the dryers are sent to the catalytic oxidation units. These devices were quite effective; the average destruction efficiency was above 99% for each unit. However, the average exit concentrations (Line 1, 6.66 mg/m³; Line 2, 2.78 mg/m³; and Line 3, 2.45 mg/m³) were well above the ambient VOC level (0.10 mg/m³), and the control devices did not regulate VOC escaping through the roof fans.

Another method of determining emission rate consistency was to compare the hourly emission rates with source activities during the same periods. Source activities were recorded at approximately five-minute intervals simultaneously with air sampling. The activity observations included number of sheets printed, number of setup and cleaning periods, number and duration of idle periods, job number, and number and duration of ink addition intervals. A typical relationship is shown for Plant A in Figure 5. VOC emission rates calculated from Equation 1 using measured flow rates, and the average concentration from the six measurement sites for leakage air, are plotted versus frequency of solvent cleaning. The emission rate and cleaning frequency are associated ($r^2 = 0.57$). Other comparisons with different data supported this relationship.[8] In addition, the slope of the least squares fit line (shown in the figure) provides an estimate of an emission factor, 70 g VOC released/press cleaning.

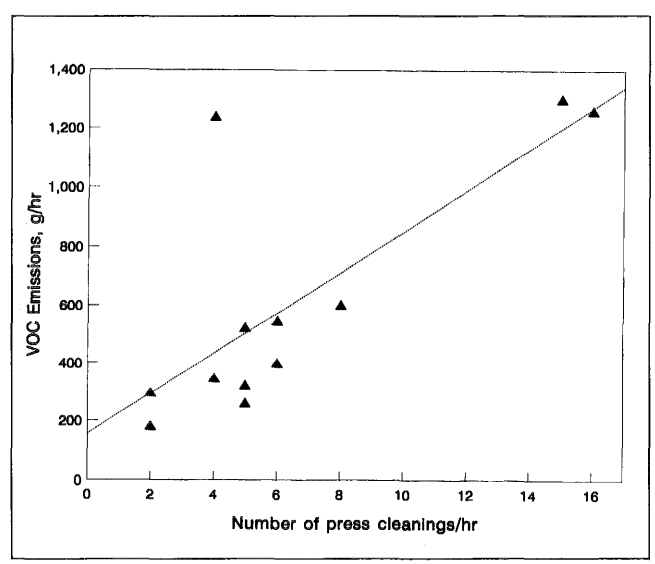


Figure 5. Plant A (sheetfed offset printing): Emission rate based on Equation 1 vs. solvent cleaning frequency. Line is least squares fit of data and slope represents an emission factor of 69.7 g VOC/press cleaning.

With reference to Figure 5, the high emission point at four press cleanings/hour occurred while another activity besides press cleaning was taking place. Small bottles were being filled with solvent from gallon jugs. Using the association between emissions and cleaning of Figure 5, we estimated that this transfer activity caused an additional emission of about 800 g/hr of VOC. Such comparisons of emission rates with source activities also give us confidence in the quality of our concentration measurements; i.e., the measurements reflect what is actually occurring in the workplace.

The relationship between emissions and press cleaning is also interesting because another study of an offset printing shop reported an association between plate changes and personal exposure of printers to VOC.[2] In addition, a recent study in a printing/bookbinding shop, which compared personal and area samples and solvent composition, identified blanket wash as a part of the printers' exposure,[9] although no attempt was made to identify specific activities. Solvent cleaning always occurs during plate changing, although as noted earlier, other periods of intensive press cleaning will also occur. The exposure relationship determined in Reference 2 includes considerable variability, which might have been caused by exposures during cleaning intervals other than plate changing.

Comparison of the emission rates with mass balance estimates based on solvent usage and composition was reasonably consistent, particularly given the variability of the inventory values. The average composition of emissions from these tests was much more detailed than has been available up until this time but agreed well with previous chemical fingerprint values for toluene and o-xylene, which have been successfully applied to source-receptor modeling for graphic arts.[10-13] For example, the graphic arts (printing) contribution to the concentration of organics in Chicago air in 1988 was determined from receptor modeling to be 6.6% of total VOC. This was in reasonable agreement with the emission inventory estimate of 9.8% of total VOC.[12]

We recognize that tests were only conducted for two days at each plant. However, these measurements were made during typical printing activity for each shop. Although the results may not precisely mirror all-year emissions, it is interesting to estimate annual VOC release on the basis of the data that we have. If we use the total emission rate from Plant A (print/plate making room and six-color press) of 929-1170 g VOC/hr, 10 hours/workday (observed during the test), and 250 days/year, the annual emissions become

$$\frac{kg_{voc}}{year} = 1.0\frac{kg_{voc}}{hr} \times \frac{10\ hr}{day} \times \frac{250\ days}{year} = 2500\frac{kg}{year}\left\{2.8\frac{T_{voc}}{year}\right\} \quad (2)$$

Similarly, the annual emissions rate (based on the 8 hour/day observed) would be about 200 kg/yr (0.2 T) for Plant B and about 19,700 kg/yr (21.7 T) for Plant C based on 250 days and three-shift operation. The emissions from Plant A are large considering the volume of printing being done. It is useful to recognize that most printing installations are this size. About half of all printing in the United States is done on offset presses. Eighty-five percent of offset shops employ fewer than 20 persons.[14] Both Plants A and B fall into this category. Our experience indicates that small plants are much less likely to have local exhaust capability, which exacerbates workplace exposures to benzene and other toxic materials. (As a qualitative example of such a condition, frequent complaints about poor ventilation in Plant B were made by people using the offices near the stairwell [Figure 3]). In addition, the emissions of 2 T/year or more of VOC from each such shop constitute a significant contribution to ozone precursors and also to HAPs such as toluene and xylene. In the case of Plant C, the catalytic incinerators destroy some of the cleaning solvents that are evaporated into the room, but a significant amount evidently is released into the atmosphere.

CONCLUSIONS

The application of this method may have general implications for the printing industry and for other surface coating operations. Presently these types of processes, characterized by significant uncontrolled and frequently unquantified fugitive emissions, must be surrounded by a Temporary Total Enclosure (TTE) for the purpose of determining VOC emissions.[15,16] We were able to determine the emission rate without recourse to a TTE, and without interfering with worker activities, increasing worker exposure to air pollutants and noise, or increasing safety and explosion hazards.[17,18]

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Development of Emission Factors for Polyethylene Processing

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TECHNICAL PAPER

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Development of Emission Factors for Polyethylene Processing

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ABSTRACT

Emission factors for selected volatile organic and particulate emissions were developed over a range of temperatures during extrusion of polyethylene resins. A pilot scale extruder was used. Polymer melt temperatures ranged from 500 °F to 600 °F for low density polyethylene (LDPE), 355 °F to 500 °F for linear low density polyethylene (LLDPE), and 380 °F to 430 °F for high density polyethylene (HDPE). An emission factor was calculated for each substance measured and reported as pounds released to the atmosphere per million pounds of polymer processed (ppm[wt/wt]). Based on production volumes, these emission factors can be used by processors to estimate emissions from polyethylene extrusion operations that are similar to the conditions used in this study.

INTRODUCTION

The Clean Air Act Amendments of 1990 (CAAA) mandated the reduction of various pollutants released to the atmosphere, such as volatile organic compounds (VOCs) and the U.S. Environmental Protection Agency's (EPA) list of 189 hazardous air pollutants (HAPs). Title V of the amended Clean Air Act establishes a permit program for emission sources to ensure a reduction in emissions. This program will radically impact tens of thousands of companies that will have to apply for state operating permits. In response to the needs of the industry, the Society of the Plastics Industry, Inc. (SPI) organized a study to measure emissions produced during polyethylene processing to assist processors in complying with the CAAA. Sponsored by nine major resin producers, the work was performed at Battelle, a not-for-profit research organization in Columbus, Ohio.

Prior to this study, a review of the literature revealed earlier polyethylene thermal emissions work that provided a wealth of qualitative data as well as some quantitative data on emissions. However, because of the concerns about the emission generation techniques used, the quantitative information is not deemed adequate for addressing the regulatory issues currently at hand.

The primary concern about previous emissions data is that they were generated using static, small-scale,[1] or otherwise unspecified procedures.[2,3] These techniques may not adequately simulate the temperature and oxygen exposure condition typically encountered in the extrusion process. That is, in most extruders, the polymer melt continuously flows through the system, limiting the residence time in the heated zones. This contrasts with static procedures where the polymer may be exposed to the equivalent temperature but for an effectively longer period of time, thus resulting in an exaggerated thermal exposure. In a similar way, the concern over oxygen in the industrial extrusion process is minimized as the extruder screw design forces entrapped air back along the barrel during the initial compression and melting process. The air exits the system via the hopper; consequently, hot polymer is only briefly in contact with oxygen

IMPLICATIONS

This study provides quantitative emissions data collected during extrusion of polyethylene under specific operating conditions. The emission factors developed in this study are two orders of magnitude lower than those reported in an earlier EPA document. These data can be used by processors as a point of reference to estimate emissions from similar polyethylene extrusion equipment based on production volumes.

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when it is extruded through the die. Again, this is in contrast to static testing where hot polymer may be exposed to air for extended periods of time. In view of these concerns, it is apparent that the accuracy of data obtained from these techniques may be limited when used to predict emissions generated by polyethylene processors.

As an alternative to small-scale static technology, a better approach would be to measure emissions directly from the extrusion process. Since the type and quantity of emissions are often influenced by operational parameters, the ideal situation would be to study each process under the specific operating conditions of concern. Parameters that can alter the nature of the emissions include: extruder size and type, extrusion temperature and rate, the air-exposed surface to volume ratio of the extrudate, the cooling rate of the extrudate, and the shear effect from the extruder screw. Other variables related to the material(s) being extruded can also influence emissions. These include: resin type, age of the resin, additive package, and any additional materials added to the resin prior to extrusion. If a processor uses recycled materials, the thermal history is also an important factor.

In view of these variables, it is clear that it would be a considerable task to devise and conduct emission measurement studies for all major extrusion applications. Therefore, SPI's objective in this work was to develop baseline emission factors for polyethylene processing under conditions that would provide reasonable reference data for processors involved in similar extrusion operations.

A pilot-scale extruder equipped with a 1.5 inch screw and fitted with an eight-strand die was chosen to process resins associated with three major applications: extrusion coating, blown film, and blow molding. The resin types were respectively: low density polyethylene (LDPE), linear low density polyethylene (LLDPE), and high density polyethylene (HDPE).

The emissions were measured over a 30-minute period and were related to the weight of resin extruded. The emission factor for each substance measured was reported as pounds evolved to the atmosphere per million pounds of polymer processed (ppm[wt/wt]). Processors using similar equipment can use these emission factors as relative reference points to assist in estimating emissions from their specific polyethylene application.

EXPERIMENTAL

Test Resins

Resins were selected for this study to cover the main processing applications for each major type of polyethylene, i.e., LDPE, LLDPE, and HDPE. Where applicable, project sponsors submitted a fresh sample of their most common resin grade using their standard additive package for each application. Equal portions of the sponsor samples were mixed by Battelle to provide an aggregate test sample for each resin type. The additives in the final LLDPE blend were slip (900 ppm), antioxidants/stabilizers (1775 ppm), process aids (580 ppm), and antiblock (4750 ppm). The additives in the final HDPE blend were antioxidants/stabilizers (350 ppm), and process aids (200 ppm). None of the LDPE resins contained additives in their formulation. All resins were eight months old or less at the start of testing.

Experimental Process Conditions

A HPM Corporation 15 horsepower unvented extruder was used to process the polyethylene composite test samples at Battelle. The extruder was equipped with a 1.5 inch single screw (L/D ratio of 30) and fitted with an eight strand die.[4] Extruded resin strands were allowed to flow into a stainless steel drum located directly under the die head (see Figure 1). Process conditions were selected to be representative of several commercial processing applications. These are provided in Tables 1 and 2.

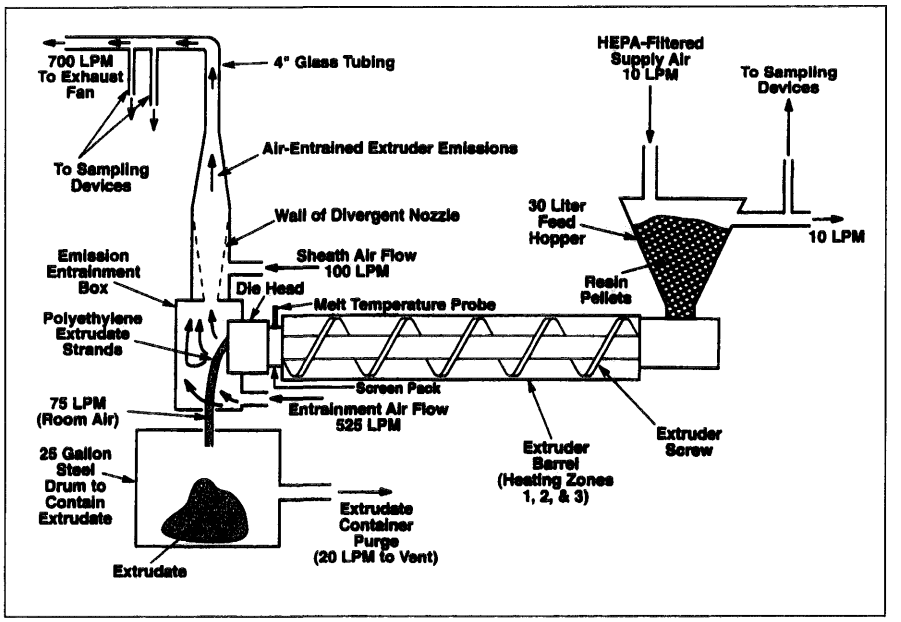


Figure 1. View of the extruder system and the various sampling locations.

Capture and Collection of Emissions

Emissions released at the die head and hopper areas were separately collected for 30 minutes during the extrusion runs. Table 3 shows the sampling strategy employed for the three types of polyethylene resins. Air sampling/collection rates for the various analytical samplers employed are provided in Table 4.

Die Head Emissions. Emissions released at the die head during extrusion were captured at the point of release in a continuous flow of clean

Table 1. Resin type characterization and extrusion temperatures.

Resin Grade	Number of Resins in Composite	Use	Melt Index grams/ 10 minutes	Density g/cc	Extrusion Temperatures °F
LDPE	5	Extrusion Coating	7	0.92	500, 600
LLDPE	6	Blown Film	1	0.92	355, 395 450, 500
HDPE	5	Blow Molding	0.2	0.95	380, 430

Table 2. Experimental process conditions.

	LDPE		LLDPE			HDPE		
Number of Extrusion Runs	2	2[a]	1	1	1	2[b]	1	2
Diehead Melt Temperature, °F	500	600	355[c]	395	450	500	380	430
Zone 3 Temperature, °F	487	610	310	335	425	485	355	415
Zone 2 Temperature, °F	485	590	310	335	400	475	335	375
Zone 1 Temperature, °F	411	450	300	325	350	400	325	325
Pressure, psig	NA[d]	NA[d]	2,000	3,000	1,000	800	1,750	1,500
Resin Throughput lb/hr [gm/min]	38.3/290	38.3/290	37.0/280	36.9/279	38.1/288	38.4/291	37.4/283	34.1/258
Rotor Speed, rpm	96	96	96	96	96	96	96	96
Run Duration, min	30	30	30	30	30	30	30	30

[a] In addition to the duplicate tests at 600 °F, a (third) spiking test was performed at this temperature for benzene-d_6.
[B] In addition to the duplicate tests at 500 °F, a (third) spiking test was performed at this temperature for formaldehyde and formic, acetic and acrylic acids.
[C] Screenpack was removed for 355 °F run with LLDPE to achieve target melt temperature at die head.
[D] NA = Not available.

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air. A portion of this air flow was subsequently sampled downstream as described below. The emissions were initially captured in a stainless-steel enclosure surrounding the die head (see Figure 2). The air stream was immediately drawn through a divergent nozzle entrainment cone which provided a sheath of clean air between the die head emission flow and the walls of the carrier duct. This minimized interaction of the hot exhaust with the cooler duct walls.

The total air flow employed for capturing die head emissions was set at 700 liters per minute. This was comprised of the die head entrainment flow at 525 liters per minute, the sheath flow at 100 liters per minute, and 75 liters per minute of residual air flow which was made up from room air drawn into the open bottom of the stainless-steel die head enclosure. This residual air flow was used to facilitate effective capture of the polymer emissions. These flows are depicted in Figures 1 and 2.

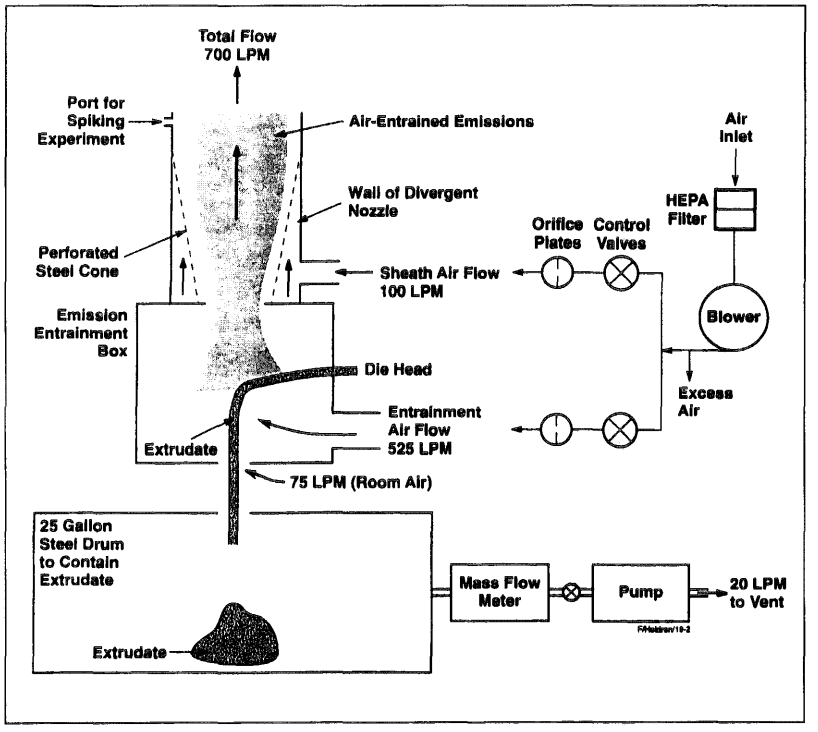


Figure 2. View of emission entrainment area.

Die head emissions were transported by the 700-liter per minute air flow to a sampling point 10 feet downstream of the die head using 4-inch diameter glass tubing. The location for this sampling point (see Figure 1) was based on previous studies performed at Battelle which involved design, engineering, implementation, and proof-of-principle stages for the laboratory system.[4]

Two separate sampling manifolds were used at the sampling location; one for collecting gases and vapors and the other for collecting particulates (see Figure 3). For gases and vapors, a 10-liter per minute substream was diverted from the main emission entrainment stream using a 1/2-inch stainless steel tube (0.425 inch i.d.) wrapped with heating tape

Table 3. Sample collection and analysis scheme.

Substances Monitored	Organic Acids	Aldehydes/ Ketones	Particulates	VOCs			
				HHC[a]	LHC[b]	HHC	LHC
Collection Media	KOH Impregnated Filter	DNPH Tube	Glass Fiber Filter	SUMMA Canister			
Analytical Method	Desorption with Dilute H_2SO_4 and Analysis by Ion Exclusion Chromatography/ UV	Desorption with Acetonitrile and Analysis by HPLC	Gravimetric	Modified TO-14			
				HP-1 Fused Silica Capillary Column	Al_2O_3/ Na_2SO_4 Capillary Column	HP-1 Fused Silica Capillary Column	Al_2O_3/ Na_2SO_4 Capillary Column
				GC/MS GC/FID	GC/FID	GC/MS GC/FID	GC/FID
Sampling Location	Manifold					Hopper	
	Number of Samples Analyzed Per Run						
	2	2	1	1 2	2	1 2	2

[a] HHC = Heavy hydrocarbons - includes C_4 to C_{16} compounds present in canister samples
[b] LHC = Light hydrocarbons - includes ethane, ethylene, propylene

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and maintained at 50 °C. VOCs and oxygenates were sampled from this manifold. Similarly, particulates were sampled from a separate 15-liter per minute substream using a 1/4-inch stainless unheated steel probe (0.1375 inch i.d.).

This study did not include any emissions from the drum collection area as all commercial extrusion processes quench the molten resin shortly after exiting the die. Any emissions from the extrudate in the collection drum were prevented from entering the die head entrainment area by drawing air from the drum at 20 liters per minute and venting to the exhaust duct.

Hopper Emissions. One of the underlying objectives of this study was to determine if substances evolved from the hopper area had any substantial contribution to the overall emissions. Any such emissions would likely be released during the heating and homogenization of the resin pellets in the initial zones of the screw. Since the process temperatures used in this area were substantially lower than those encountered at the die head, the likelihood of generating oxidation products or particulates is low. Therefore, only VOCs were monitored in this area.

Emissions released from the extruder throat of the hopper area were captured using a 30-liter stainless steel enclosure. The enclosure was equipped with a specially designed air-tight lid that would also allow rapid delivery of additional resin material as needed. As shown in Figure 1, a 10-liter per minute air flow was drawn through the enclosure to entrain any emissions and remove them to a downstream location for analytical sampling. The sampling manifold was located 2 feet downstream of the hopper, and a portion of the 10-liter per minute flow was directed to the total VOC analyzer as well as to air sampling canisters (as shown in Figure 3).

Target Analytes

The chemicals measured in this study were selected by cross referencing the substances identified in the thermal emission literature[1] with the EPA's list of Hazardous Air Pollutants (HAPs). Many of these were oxygenated compounds, including acetaldehyde, acrolein, acrylic acid, formaldehyde, methyl ethyl ketone, and propionaldehyde. Although not on the HAPs list, acetic acid, acetone, and formic acid were added to the list of target analytes because they have been

Table 4. Air flow rates for capture and collection of emissions.

PARAMETER	*LDPE (L/min)*	*LLDPE/ HDPE (L/min)*
Total Manifold Flow	700	700
Flow Rate Into Sheath Area	100	100
Flow Rate Into Entrainment Area	525	525
Flow Rate Through Hopper	10	10
Flow Through Tubes for Aldehydes/Ketones	1	0.5
Flow Through Tubes for Organic Acids	10	5
Flow Into Canisters	0.16	0.16
Flow Through 402 THC Analyzer	1	1
Flow Through Filter Holder	15	15

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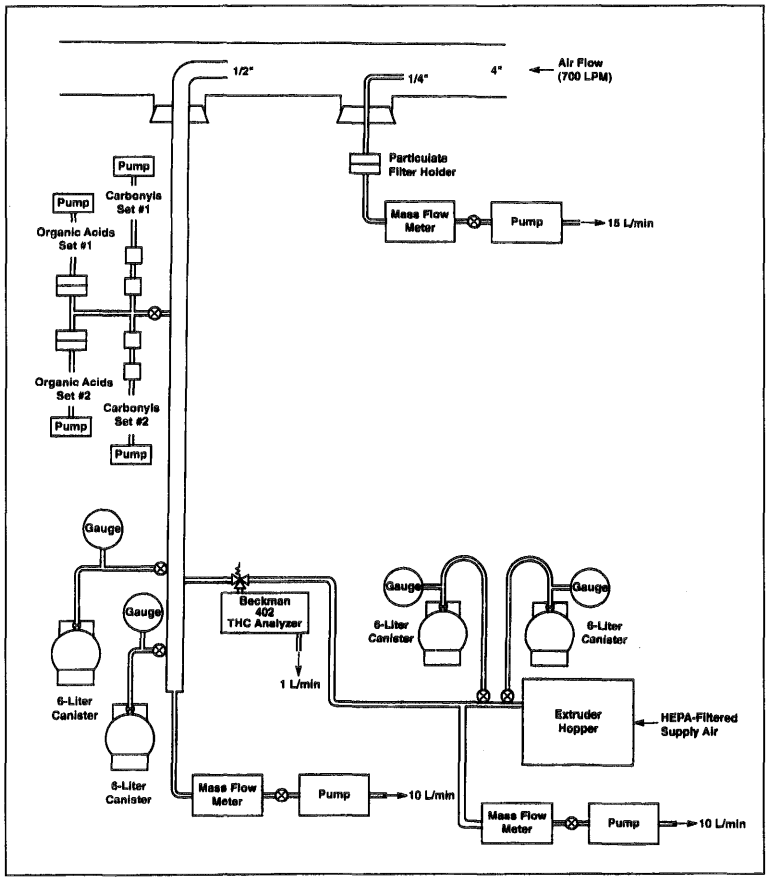


Figure 3. Sampling manifolds for emissions generated at die head and hopper.

commonly reported in the literature as thermal emission components, and they were easily included in the selected analytical protocol.

All gaseous and volatile hydrocarbons were grouped together and monitored as Volatile Organic Compounds (VOCs). This included compounds such as ethane, ethylene, propylene, butane, hexane, and octane. The analytical approach (discussed below) provided a collective measurement for a broad range of volatile hydrocarbons as well as the ability to speciate individual analytes, such as hexane, which is the only hydrocarbon on the HAPs list that is identified in the thermal emission literature associated with polyethylene.

Nonvolatile material (analyzed as "Particulates") was also included as a target substance as this material has been identified in some polyethylene thermal emissions by the study sponsors.

Measurement of Emissions

Emission samples were analyzed as outlined in Table 3. The following classes of materials were measured: volatile organic compounds (VOCs), specific organic acids, specific aldehydes and ketones, and particulates. The emissions from each run were collected over the course of the 30-minute extrusion run and analyzed using the methods described below. VOCs were also monitored in real-time using an on-line heated probe flame ionization detection system.

Volatile Organic Compounds (Time-integrated measurement). Evacuated SUMMA polished 6-liter canisters were used to collect whole air samples. The 6-liter canisters were initially cleaned by placing them in a 50 °C oven, and utilizing a five-step sequence of evacuating to less than 1 torr and filling to ~4 psig using humidified ultra-zero air. A final canister vacuum of 100 mtorr was achieved with an oil-free mechanical pump. Each canister was connected to an orifice/gauge assembly during sampling to assure that an integrated sample was obtained over the 30-minute collection time. The orifice was sized to deliver ~160 mL/min. Canister samples were collected in duplicate at the manifold and hopper locations. After collection, the canister pressure was recorded and the canister was pressurized to 5.0 psig with ultra-zero air to facilitate repeated sampling and analysis of the canister.

Analyses of canister samples were accomplished with two gas chromatographic (GC) systems. The light hydrocarbon (LHC) GC system was used for the analyses of the target compounds ethane, ethylene, and propylene. The GC system was a Varian 3 Model 3600 equipped with a flame ionization detector (FID) and a sample cryogenic preconcentration trap. The trap was a 1/8-inch by 8-inch coiled stainless steel tube packed with 60/80 mesh glass beads. The trap was maintained at -185 °C during sample collection and 100 °C during sample desorption. A six-port valve was used to control sample collection and injection. Analytes were chromatographically resolved with a Chrompack 50 meter by 0.32 mm i.d. Al_2O_3/Na_2SO_4 fused silica capillary column (5-μm film thickness). The column was operated isothermally at 50 °C to resolve the three target species and then ramped to 200 °C to purge the column of the remaining organic species. The sample size was 200 cc.

Propane was the detector calibration gas (traceable to NIST calibration cylinders). The calibration range extended from 0.5 to 1000 parts per billion carbon (ppbC). The ppbC unit is equivalent to part per billion by volume multiplied by the number of carbons in the compound. For the calibrant propane, 1 ppb by volume compound (or 3 ppb carbon) converts to 1.80 nanograms per liter of air (at 25 °C, 1 atm). For this study, an equal per carbon response was used for all hydrocarbon species (i.e., 1 ppbC of benzene will produce the same FID response as 1 ppbC of hexadecane). This procedure permits one calibrant to be used for calculating concentrations of all hydrocarbons species.[4]

A Hewlett Packard Model 5880 GC equipped with parallel flame ionization FID and mass spectrometric detectors MSD was used for the analyses of the heavier hydrocarbons which includes C_4 to C_{16} compounds present in the canister samples. For the heavy hydrocarbons (HHC) analysis,

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canisters were heated to 120°C to assure quantitative recovery of the C_6 to C_{16} organic compounds. The GC contained a similar cryogenic preconcentration trap as described earlier. Analytes were chromatographically resolved on a Hewlett Packard HP-1, 50 m by 0.32 i.d. fused silica capillary column (1 μm film thickness). Optimal analytical results were achieved by temperature programming the GC oven from -50 °C to 200 °C at 8°/min. The column exit flow was split to direct one-third of the flow to the MSD and the remaining flow to the FID. The mass spectrometer was operated in the total ionization mode so that all masses were scanned between 35 and 300 daltons at a rate of 1 scan per 0.6 seconds. Identification of major components were performed by matching the mass spectra acquired from the samples to the mass spectral library from the National Institute of Standards and Technology (NIST). Interpretation also included manual review of all mass spectral data. The sample size was 80cc. Detector calibration was based upon instrument response to known concentrations of dilute benzene calibration gas (traceable to NIST calibration cylinders). The calibration range extended from 1.0 to 1,000 ppbC.

Volatile Organic Compounds (Real-Time). The real-time VOC method involved the Beckman 402 analyzer as an on-line continuous instrument using a heated probe flame ionization detection (FID) system. This method has been frequently used by Battelle to determine total organic concentrations from emission sources[5,6] and is the method specified in the Code of Federal Regulations (CFR) for determining the total hydrocarbon content from automobile exhaust.[7] It is essentially equivalent to EPA method 25A.[8]

A Beckman 402 heated probe (150 °C) flame ionization detector (HFID) was calibrated against a NIST traceable reference cylinder containing 94 ppmC of propane. Challenges with NIST traceable standards have demonstrated instrument linearity from a detection level of 1 ppmC to 1,000 ppmC.

The analyzer was connected to the sampling manifold and the hopper via a three-way solenoid valve. The valve was manually switched during the test runs so that VOC levels could be determined at both hopper and manifold locations. The analyzer was also used to verify the extruder system stability prior to the beginning of each test run.

VOC emission factors were determined using the average of real-time data acquired over the course of the 30-minute run.

Organic Acids (Formic, Acetic, Acrylic). The method for monitoring organic acids was successfully demonstrated by Battelle on an earlier automotive exhaust study for the determination of formic acid.[9]

The target analytes were formic, acetic and acrylic acids. An all-Teflon, three stage, 47-mm diameter filter holder (Berghof/America) was used for sample collection. Potassium hydroxide impregnated filters were prepared by dipping 47-mm diameter Gelman A/E glass fiber filters in a solution of 0.05 N KOH in ethanol. After dipping, the filters were placed individually on a stainless steel rack in a drying oven (45 °C). The oven was continually purged with zero air. Filters were stored in covered petri dishes in a dry box that was also purged with zero air. Each filter holder was loaded with 3 filters. The loaded filter holder was connected to the sampling manifold and the exit side of the holder was connected to a mass flow controller and pump assembly. The flow was set to 10 liters per minute for the LDPE resin runs and to 5 liters per minute for the LLDPE and HDPE test runs. Manifold samplers were collected in duplicate for each test run.

For analyses, filters were taken out of the filter-pack and individually placed into wide mouth jars containing 5 mL of a 3 mM H_2SO_4 solution and 20 μL chloroform (to retard microbial losses). The jar was sonicated for 5 minutes and the solution was pipetted into a centrifuge tube. The tube was centrifuged to separate solid material from solution. A 200 μL aliquot was extracted and analyzed by ion exclusion chromatography with UV detection at 210 nm. A Bio-Rad Aminex HPX-87H HPLC column (7.8 mm i.d. by 300 mm length) was used to resolve the organic acids. The analytical method was shown to be linear for all three acids over a concentration range from the detection limit to 200 μg/mL. These concentrations are expressed in terms of the free organic acid in dilute sulfuric acid solution. The detection limits were 2 μg/mL for formic and acetic acid, and 0.2 μg/mL for acrylic acid. The standards were prepared with neat material (>99 % purity) diluted with a 3 mM H_2SO_4 solution.

Selected Aldehydes and Ketones. The analysis of selected, aldehydes and ketones followed procedures identified in U.S. EPA Method TO-11.[10] The target analytes included formaldehyde, acetaldehyde, acrolein, acetone, propionaldehyde, and methyl ethyl ketone (MEK). C_{18} Sep-Pak cartridges (Waters, Assoc.) coated with dinitrophenylhydrazine (DNPH) were used to collect carbonyl species. The stock reagent contained 0.2 grams of DNPH dissolved in 50 mL of acetonitrile. Orthophosphoric acid (50 μL) was added to provide an acidified solution. Each C_{18} cartridge was precleaned with 2 mL of the acetonitrile and then loaded with 400 μL of DNPH stock reagent. Clean nitrogen gas was used to "dry" the DNPH coated cartridge. The coated cartridges were sealed with polyethylene plugs, placed in 10 cc glass vials and refrigerated until needed. Sample collection was carried out with two cartridges in tandem and a flow control/pump assembly downstream of the cartridges. The flow was set to 1 liter per minute for the LDPE resin runs and to 0.5 liters per minute for the LLDPE and the HDPE test runs. Manifold samples were collected in duplicate for each test run.

For analyses, individual cartridges were backflushed with 2 mL acetonitrile. An aliquot (30 μL) of the extracted solution was analyzed with a Waters Model 600 high performance liquid chromatograph equipped with a UV detector

(360 nm). Carbonyl separations were achieved with two Zorbax ODX (4.6 mm i.d. by 25 cm) columns connected in series. The mobile phase was acetonitrile/water; the flow rate was 0.8 mL/min. The analytical method was shown to be linear for the carbonyl species over a concentration range from the detection limit of 0.1 to 20 μg/mL. These concentrations were expressed in terms of the underivatized aldehyde/ketone in acetonitrile solvent. Standards were prepared with weighed amounts of individual DNPH-derivatives in acetonitrile solution.

Particulate Matter. Particulate emissions were collected under isokinetic conditions on a single in-line 25-mm glass fiber filter (1 μm pore size). The filter was attached to a 0.4 inch i.d. stainless steel sampling probe that was positioned in the 4" glass manifold airstream approximately 12 inches in front of the organic sampling manifold. Gravimetric analyses of the filter before and after sampling were carried out to determine mass loading.

Verification of the Measurement System

The ability of the system to accurately measure emissions was insured in a number of ways including ongoing observation and documentation of system performance as well as manifold spiking tests to measure the recovery of substances released at the die head in known quantities. These are further described below.

Extruder Cleaning. The extruder was thoroughly purged and cleaned[4] prior to extrusion of the polyethylene test resins. The test resins were extruded in order of increasing melt viscosity to minimize cross-contamination.

Homogeneity of Emission Stream. Prior to collection of air samples the air-entrained emissions were verified to be homogeneous at the sampling location for die head emissions. A Beckman 402 hydrocarbon analyzer and a TSI-Aerodynamic Particle Sizer were used for real-time, cross-sectional measurements during the extrusion of LDPE.

Capture Efficiency. Prior to testing, the capture efficiency of the air entrainment system at the die head was visually confirmed with the aid of smoke tubes (Mine Safety Appliance, #458480-Lot 176) prior to testing. The 25-gallon collection drum was also tested to ensure that potential emissions from this area were excluded from the entrainment system.

System Equilibration. Each test resin was extruded for 30 minutes prior to collection of emissions. During this period, total VOCs were monitored by the on-line Beckman 402 Hydrocarbon Analyzer to confirm equilibration of the system.

Confirmation of Critical Operating Parameters. Operating parameters were recorded initially and at 5 minute intervals during the 30-minute test. These include: extruder temperatures, extruder cooling water flow, air flows for the total manifold, sheath and entrainment zones and hopper, and flow settings of all sampling equipment.

Manifold Spiking Tests. Spiking studies were conducted at the outset of the study to verify the recovery efficiencies for each type of target analyte. Compounds representing VOCs, organic acids, and aldehydes were spiked into the sampling manifold about 2 feet downstream of the die head during the extrusion. The spike conditions are provided in Table 5. Additional details about the spiking experiments are provided below.

VOCs (as benzene-d_6). Benzene-d_6 (deuterated benzene) was chosen to represent VOC recoveries in the spiking experiment because (1) its response on the GC/MSD is not prone to interferences from other expected VOC components, and (2) it is generally in the middle of the volatility range of the VOCs likely to be encountered.

A measured amount of benzene-d_6 was injected into a high pressure cylinder through a heated injection port and the cylinder was then filled with zero grade nitrogen to 1000 psig. The cylinder was equipped with a regulator and mass flow controller set at 10 liters per minute. The exit tube was

Table 5. Spike recovery data during extrusion.

Substance	Test Run	Amount Spiked	Amount of Spiked Material Recovered[a]	Percent Recovery and Relative Error[b]
		Pounds Released Per Million Pounds of Polymer Processed ppm(wt/wt)		
Benzene-d_6	LDPE @ 600 °F	0.22	0.21	95 ± 2
Formaldehyde	LLDPE @ 500 °F	3.93	5.10	130 ± 5
Formic Acid	LLDPE @ 500 °F	1.71	2.07	121 ± 18
Acetic Acid	LLDPE @ 500 °F	1.86	2.24	121 ± 12
Acrylic Acid	LLDPE @ 500 °F	1.42	1.51	106 ± 11

[a] The corresponding unspiked run showed a formaldehyde background level of 0.19 lb/million lb. The other species contained background levels less than the detection level.
[B] The relative error was determined as the difference in results from duplicate samples multiplied by 100 and then divided by the average amount.

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inserted into the sampling manifold 2 feet downstream of the die head. The resulting manifold gaseous concentration was 0.092 μg/L. VOC samples were collected using a 6-liter evacuated canister to measure the "spiked" emission concentration as described under Measurement of Emissions.

Organic Acids and Formaldehyde. Aqueous solutions of the three organic acids and formaldehyde were mixed just before the spiking experiment commenced. The solution was dispensed at a rate of 0.57 mL/min using a CADD-PLUS infusion pump. The flow rate was digitally displayed and confirmed by measuring the weight loss of water after the experiment was completed. The water solution was directed through a heated injection system which was inserted into the manifold approximately 2 feet downstream of the die head. Complete evaporation of the water occurred at a temperature of 160 °C.

The spiking apparatus described above has been recently developed at Battelle[11] and has been successfully used for applications which require minimal temperature for the vaporization of liquid material. The vaporizer, shown in Figure 4, consists of a 21-cm length of thin wall 6.35-mm o.d. nickel chamber containing approximately 1 ml of water as the working fluid. A nickel capillary (0.60 mm o.d., 0.35 mm i.d.) coaxially traverses the length of the chamber. The outer surface of the capillary is in contact only with the vapor and liquid phase of the working fluid. The nickel chamber is heated with insulated resistance wire wrapped around and along the length of the chamber. A copper jacket between the resistance heater and the nickel chamber improves temperature uniformity of the chamber and provides additional thermal ballast for the working fluid. The generated gaseous concentrations in the manifold with the vaporizer were: formic acid, 0.60 μg/L; acetic acid, 0.71 μg/L; acrylic acid, 0.59 μg/L; and formaldehyde, 1.63 μg/L.

Calculation of Emission Factors

The emission concentrations in micrograms/L of air were converted to emission factors in micrograms/gram of processed resin using the following equation:

$$Y = C * F/O$$

where:

Y = micrograms of material per gram of processed resin
C = concentration of emissions material in the manifold air (micrograms/L)
F = delivery flow rate in liters per minute (700 liters per minute for manifold, 10 liters per minute for hopper)
O = resin throughput in grams/minute.

The emission factors in units of micrograms/gram (ppm[wt/wt]) are equivalent to pounds of emissions per million pounds of processed resin.

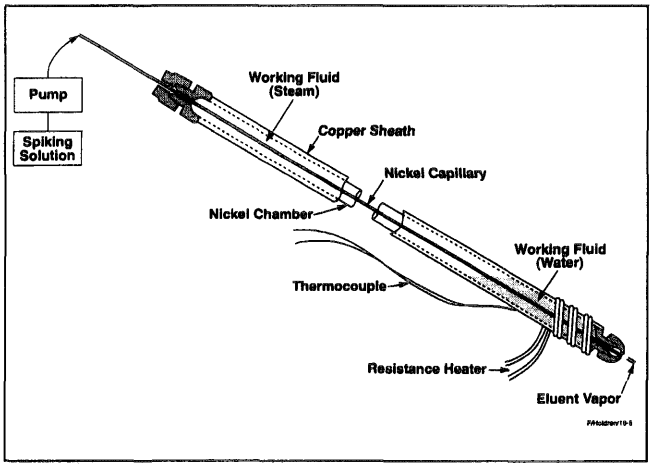


Figure 4. Battelle-developed water vaporizer.

RESULTS AND DISCUSSION

Accuracy and Precision of Emission Measurements

The Manifold Spiking Tests (described earlier) provided a measure of accuracy for the emission factor data. Precision (or relative error) of the data was measured by calculating the relative percent difference (RPD) of the duplicate analysis results. Based on these evaluations, the emission factors generated in this project are, on a conservative basis, expected to be within ±30 percent of the actual values. The accuracy and precision results are further discussed below.

Accuracy. Benzene-d_6 served as the surrogate compound for the hydrocarbon method (i.e., canister sampling and GC/FID analysis). Formaldehyde represented the compounds analyzed with the carbonyl species method, whereas all three acids were used to validate the organic acid method. Spike recoveries for these substances range from 95% to 130% and are presented in Table 5.

Precision. By definition, the relative percent difference (RPD) for duplicate measurements is determined by calculating the absolute difference of the two results, multiplying by 100, and then dividing by the mean. For this study, duplicate samples were collected with the following sampling/analytical methods, light and heavy hydrocarbons (canisters), organic acids (KOH coated filters) and aldehydes/ketones (DNPH impregnated cartridges). Duplicate sampling was not carried out for particulates. Additionally, repeated extrusion runs at one or more of the target die head melt temperatures were carried out for all three types of resins. As a result, there are both within-run and between-run components of precisions.

The within-run precision was calculated as follows. For every analyte which contained duplicate values, a RPD was calculated. An average RPD was then calculated for all analytes within a method. Table 6 shows these within-run average RPD values for each method, along with the range of individual results.

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The between-run precision was calculated as follows. For the repeated extrusion test runs, a RPD value was calculated for each analyte across each repeated extrusion run. An average RPD was then calculated for all analytes within a method. Table 6 shows these between-run average RPD values for each method, along with the range of the individual results.

Emission Factor Results

The emission factor results are presented in Table 7. Overall, VOCs and particulates for all three test resins had much higher emission factors than the oxygenates. VOC emissions for polyethylene ranged from 8 to 157 ppm (wt/wt), while particulates were as high as 242 ppm (wt/wt). The higher test temperatures generally produced higher emission factors, as illustrated for VOCs and particulates in Figures 5 and 6, respectively.

As discussed in the experimental section, two different methods were used to measure VOC emissions. One was the Beckman 402 Hydrocarbon Analyzer which continually analyzed the air emission stream throughout the run and provided a direct reading of all (VOC) substances responding to the flame ionization detector. The other method utilized an evacuated canister for sample collection and gas chromatography for analysis. With this method, total VOCs are determined by summing the Heavy Hydrocarbons and Light Hydrocarbons results.

As can be seen in Table 7, the results between the two methods do not always correlate. For LDPE, the Beckman 402 results are about twice as high as the sum of the HHC and LHC results. However, for LLDPE, the VOC emissions at 355 °F and 395 °F indicate the opposite situation. There are a number of possible explanations for these discrepancies as the techniques are inherently different, but that discussion is beyond the scope of this paper. However, as a conservative measure, it is recommended that the higher result of either VOC method be used when estimating emission quantities.

One advantage of the canister method is that it can provide emission data on total VOCs as well as individual compounds. Based on visual observation of the VOC chromatograms, the VOC measurements were due to the additive response of many individual compounds. Even at the highest test temperature used for each resin, the majority of individual VOCs were below 1 ppm (wt/wt), and no single VOC compound exceeded 6 ppm (wt/wt). Those that exceeded 1 ppm (wt/wt) were aliphatic hydrocarbons in the C_6 to C_{16} range. Hexane, which is listed as a Hazardous Air Pollutant, was present in some of the resin emissions, but never at levels exceeding 1 ppm (wt/wt).

In almost all cases, oxygenates were either present in the emission at levels less than 1 ppm (wt/wt), or they were not detected at all. The exception is LDPE processed at 600 °F. At this temperature, formic acid, formaldehyde, methyl ethyl ketone (or butyraldehyde), acetaldehyde, propionaldehyde, and acetic acid had emission factors of more than 1 ppm (wt/wt). Formic acid was the highest oxygenated compound detected at 12 ppm (wt/wt). The oxygenated compounds on the HAPs list are designated as such in Table 7.

Comparison of VOC Quantities from Hopper and Die Areas

VOCs were measured from both potential emission sources to determine "total" VOCs released during extrusion. The results of this study indicate that the die area of the extruder was the predominant source of VOC emissions. For all three test resins, the emissions collected in the hopper area represent less than 2% of the total VOCs. Hence, the contribution from the hopper area was not included in the calculation of emission factors.

Predicting Emissions Within Experimental Temperature Range

The data in Table 7 were reduced to the following equation that predicts the level of emissions at a specific extrusion temperature:

$$Y = (M * T) + C,$$

where:

Y = emissions in pounds per million pounds of processed resin

T = melt temperature in °F.

M and C constants are shown in Table 8 for each analyte.

Table 6. Within-run and between-run precision.

Method	Within-Run RPD[a] (%)	Range of Individual Results ppm		Between-Run RPD[a] (%)	Range of Individual Results ppm	
		Low	High		Low	High
Heavy Hydrocarbons	16.5 (n[b] = 57)	0.02	6.02	9.6 (n = 40)	0.08	5.94
Light Hydrocarbons	8.5 (n = 27)	0.01	1.66	13.0 (n = 12)	0.01	1.66
Organic Acids	26.9 (n = 5)	0.19	15.6	12.6 (n = 2)	2.0	14.7
Aldehydes/Ketones	14.9 (n = 59)	0.02	8.37	24.7 (n = 23)	0.01	8.32
Particulates	ND[c]	ND[c]	ND[c]	20.9 (n = 4)	22.5	245.1

[a] RPD = Relative percent difference

[b] n = Number of measurements.

[c] ND = Not determined.

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Table 7. Summary of polyethylene emission factors by resin type (lbs/million lbs).

Resin Type	*LDPE*		*LLDPE*			*HDPE*		
	Extrusion Coating			*Blown Film*			*Blow Molding*	
Melt Temperature (°F)	500	600	355	395	450	500	380	430
Particulates	30.9	242.2	2.4	21.7	24.7	59.9	19.6	26.6
Volatile Organic Compounds								
Beckman 402 - THC[a]	35.3	157.4	8.0	9.3	14.2	19.9	21.1	30.7
Heavy Hydrocarbons (HHC)[b]	17.0	76.6	13.9	15.3	15.4	21.3	25.0	38.5
Light Hydrocarbons (LHC)								
Ethane	0.09	1.21	0.02	0.03	0.03	0.04	0.02	0.02
Ethylene	0.05	1.58	0.01	0.03	0.01	0.02	0.02	0.01
Propylene	0.02	0.38	<0.01	0.01	<0.01	<0.01	0.01	<0.01
Aldehydes								
Formaldehyde[c]	0.10	8.11	0.09	0.04	0.14	0.20	0.06	0.06
Acrolein[c]	<0.01	0.07	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Acetaldehyde[c]	0.12	4.43	0.03	0.03	0.09	0.16	0.04	0.05
Propionaldehyde[c]	0.07	3.26	<0.02	<0.02	0.02	0.05	<0.02	0.02
Ketones								
Acetone	0.02	0.04	0.08	0.07	0.08	0.08	0.02	0.03
Methyl ethyl ketone[c]	0.10	5.25	<0.02	<0.02	0.02	0.04	0.05	0.02
Organic acids								
Formic acid	0.34	12.3	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17
Acetic acid	<0.17	2.00	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17
Acrylic acid[c]	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02

[a] THC = Total hydrocarbons.
[B] HHCs are predominantly comprised of C_4 - C_{16} alkanes and alkenes.
[c] Hazardous air pollutants under the Clean Air Act. Methyl ethyl ketone is indistinguishable from butyraldehyde in the HPLC analysis; therefore, any mass reported may be due to the presence of either or both substances.

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These constants were calculated using the data for each run: in some cases duplicate runs were made at the same temperature (see Table 2). In those cases where duplicate runs were made the average analyte emissions are reported in Table 7.

Inserting the melt temperature (°F) into the equation will provide an estimate of the number of pounds of emissions per one million pounds of processed polymer. This equation is only valid within the temperature ranges used in this study and is not recommended for predicting emissions for temperatures outside this range.

Significance of Emission Factors from SPI Study

This study provides emission data collected during extrusion of polyethylene under specific operating conditions. The emission factors developed in this study are two orders of magnitude lower than those reported in an earlier EPA document.[2]

The significance of this data becomes apparent when placed in the context of the 1990 Clean Air Amendment's definition of "major" source for VOC emissions. Categorization of an emission source as a "major" source subjects it to more stringent permitting requirements. The definition of a "major" source varies with the severity of the ozone nonattainment situation of the area where the source is located. The current VOC emission limits are 10 tons/year for an emission source within an extreme ozone nonattainment classification, 25 tons/year for a source in the severe classification, and 50 tons/year for a source in the serious classification. Currently, the only extreme nonattainment area in the U.S. is the Los Angeles area.

The utility of this data can be illustrated in the following example. Based on the emissions data and equations developed in this effort, a processor with equipment similar to that used in this study can extrude up to 125 million pounds of LDPE, 950 million pounds of LLDPE, or 510 million pounds of HDPE using the maximum temperatures employed in this study without exceeding the 10-ton/year limit for an extreme ozone nonattainment area.

Although this information is clearly useful, the reader must realize that these emission factors reflect the quantities obtained from the specific resins and under the conditions and with the specific equipment used in this study. Before using the data in this paper to estimate emissions, one must consider a number of other parameters that may impact the type and quantity of emissions as discussed in the introduction section.

SUMMARY OF FINDINGS

- The emission entrainment, collection and analysis techniques employed in this study provided a representative, accurate and precise method for determining air emissions evolved from thermal extrusion of selected types of LDPE, LLDPE and HDPE on a pilot scale extruder with a 1.5 inch screw fitted with an eight-strand die.

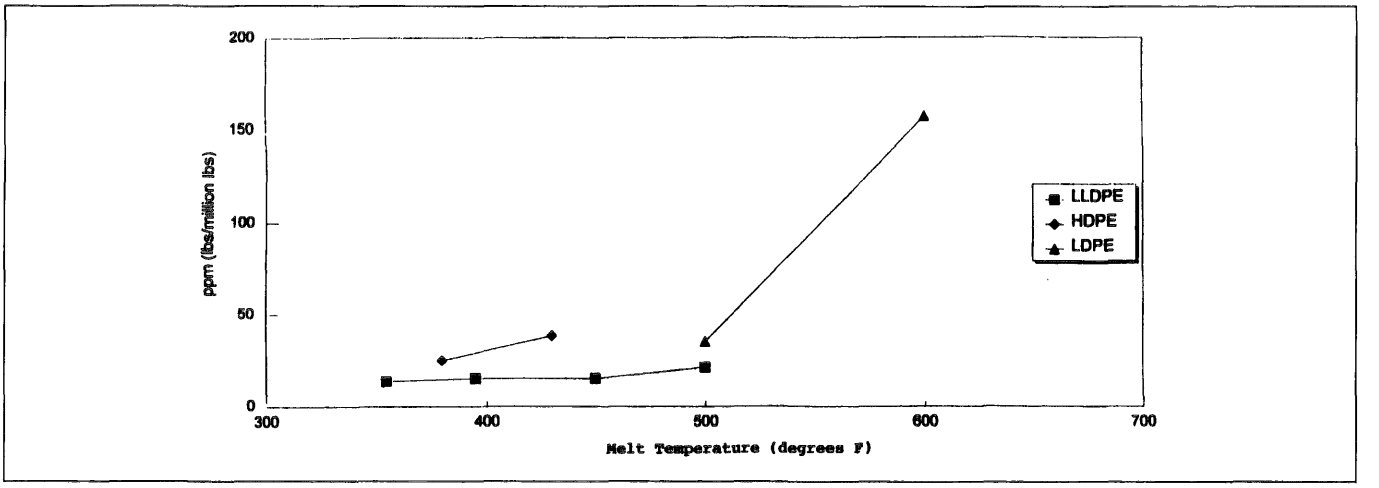


Figure 5. Emissions of VOCs from polyethylene resin composites versus temperature. Note: The equation has not been validated beyond the temperature ranges used in this study. Particular care should be taken when using the equation above the upper test temperature for each resin. Use of this equation to predict emissions above the upper range of this study is not recommended.

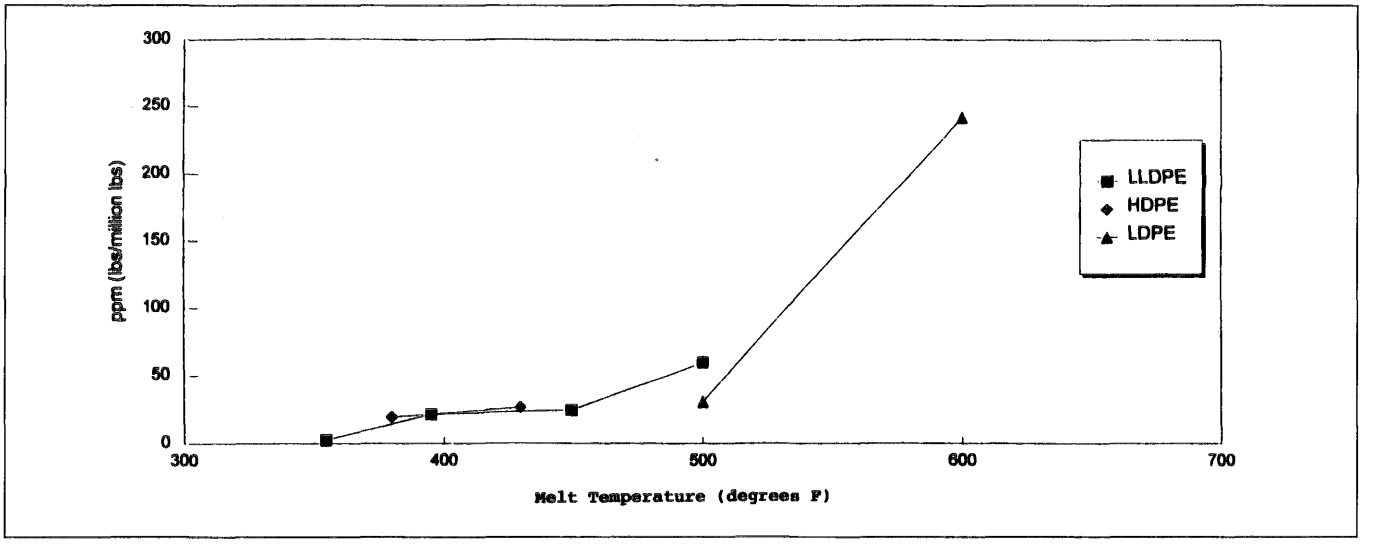


Figure 6. Particulate emissions from polyethylene resin composites versus temperature. Note: The equation has not been validated beyond the temperature ranges used in this study. Particular care should be taken when using the equation above the upper test temperature for each resin. Use of this equation to predict emissions above the upper range of this study is not recommended.

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- For all three resins studied, the major emission components were particulate matter and VOCs. VOC emissions for polyethylene ranged from 8 to 157 ppm (wt/wt), which is equivalent to pounds of emissions per million pounds of processed resin. Particulates ranged as high as 242 ppm (wt/wt). Lower emission levels were measured for the specific aldehydes, ketones and organic acids monitored in this study. VOC emissions measured in this study from polyethylene are two orders of magnitude lower than estimates reported in a 1978 EPA report.
- According to The Clean Air Act Amendments of 1990, a major emission source of VOCs is one that has the potential to emit 10 tons per year of VOC emissions in an extreme ozone nonattainment area. If a processor were to process the same resins and use the same equipment and conditions employed in this study, a total of 125 million pounds of LDPE, 950 million pounds of LLDPE, or 510 million pounds of HDPE could be processed without exceeding the 10-ton/year limit. (Note that the processor must also account for emissions from all additional materials used in the operation and any other activities in the plant.)
- The predominant emission source for VOCs was the die head of the extruder. The emissions from the hopper area contributed 2% or less of the total emissions.
- In general, higher melt temperatures produced higher emissions factors for a given resin.
- Equations for predicting the emissions from LDPE, LLDPE and HDPE as a function of temperature were developed for total VOCs, particulates and the selected oxygenated compounds. Those using these equations must realize that they reflect the emissions generated for the specific resins and conditions. The equations

Table 8. Coefficients for equation predicting emission levels (y = mt+c, where "t" is extrusion temperature (°F) and "y" is emission quantity in lbs per million lbs of resin).

LDPE	*Temperature Range*	*M (slope)*	*C (y Intercept)*
VOCs (402 method)	500 - 600 °F	1.221	-575.2
Particulates	500 - 600 °F	2.112	-1025
Formaldehyde	500 - 600 °F	0.0801	-39.9
Acetaldehyde	500 - 600 °F	0.0433	-21.5
Propionaldehyde	500 - 600 °F	0.0323	-16.1
Methyl Ethyl Ketone	500 - 600 °F	0.0516	-25.7
Acetone	500 - 600 °F	0.00015	-0.055
Formic Acid	500 - 600 °F	0.132	-65.4
Crotonaldehyde was sometimes detected at a maximum of 0.2µg/gm. Compounds that were only detected at higher temperature: Acrolein and Acetic Acid			
LLDPE VOCs (speciation method)	355 - 500 °F	0.046	-3
Particulates	355 - 500 °F	0.3923	-136.9
Formaldehyde	355 - 500 °F	0.00096	-0.281
Acetaldehyde	355 - 500 °F	0.0010	-0.357
Compound that was constant over temperature range: Acetone. Compounds that were only detected at higher temperature: Propionaldehyde, Methyl Ethyl Ketone			
HDPE VOCs (speciation method)	380 - 430 °F	0.27	-77.6
Particulates	380 - 430 °F	0.141	-34.0
Compounds that were constant over temperature range: Formaldehyde, Acetaldehyde, Acetone, Methyl Ethyl Ketone			

Note: The equation has not been validated beyond the temperature ranges used in this study. Particular care should be taken when using the equation above the upper test temperature for each resin. Use of this equation to predict emissions above the upper range of this study is not recommended.

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have not been validated beyond the temperature ranges used in this study and their use above these ranges is not recommended.

- In some cases the emission factors determined in this study may overestimate or under estimate emissions from a particular process. Professional judgment and conservative measures must be exercised as necessary when using the data for estimating emission quantities.

ACKNOWLEDGMENTS

We gratefully acknowledge the technical assistance provided by D.L. Smith, R.N. Smith, G.W. Keigley, J. Frye, T.M. Vinci and M.J. Brooker. We are especially indebted to M.A. Roberts for her help in preparing the tables. Work was funded through The Society of the Plastics Industry, Inc. Companies providing financial support and resin materials are: Chevron Chemical Company, The Dow Chemical Company, DuPont Canada Inc., Exxon Chemical Company, Lyondell Technical Center, Mobil Chemical Company, Novacor Chemical LTD., Quantum Chemical Company, Union Carbide Corporation.

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Ontario

Ministry of the Environment and Climate Change
Ministère de l'Environnement et de l'Action en matière de changement climatique

AMENDED ENVIRONMENTAL COMPLIANCE APPROVAL
NUMBER 9602-A5WQQK
Issue Date: February 3, 2016

Harris Steel ULC
5400 Harvester Road
Burlington, Ontario
L7L 5N5

Site Location: 5400 Harvester Road
Burlington City, Regional Municipality of Halton
L7L 5N5

You have applied under section 20.2 of Part II.1 of the Environmental Protection Act, R.S.O. 1990, c. E. 19 (Environmental Protection Act) for approval of:

Description Section

A low carbon and carbon free machining steel product manufacturing facility, consisting of the following processes and support units:

- coil blasting;

- pickling;
- mesh fabrication;
- drawing machines;
- teurema line;
- galvanizing line;

including the *Equipment* and any other ancillary and support processes and activities, operating at a *Facility Production Limit* of up to **294,000 tonnes of steel bar and wire mesh products per year** discharging to the air as described in the *Original ESDM Report.*

For the purpose of this environmental compliance approval, the following definitions apply:

1. " *Acceptable Point of Impingement Concentration"* means a concentration accepted by the *Ministry* as not likely to cause an adverse effect for a *Compound of Concern* that,

(a) has no *Ministry Point of Impingement Limit* and no *Jurisdictional Screening Level,* or

(b) has a concentration at a *Point of Impingement* that exceeds the *Jurisdictional Screening Level.*

With respect to the *Original ESDM Report,* the *Acceptable Point of Impingement Concentration* for a *Compound of Concern* mentioned above is the concentration set out in the *Original ESDM Report.*

2. "*Acoustic Assessment Report"* means the report, prepared in accordance with *Publication NPC-233* and Appendix A of the *Basic Comprehensive User Guide,* by Dan Bradshaw/HGC Engineering and dated November 04, 2014 submitted in support of the application, that documents all sources of

noise emissions and *Noise Control Measures* present at the *Facility,* as updated in accordance with Condition 5 of this *Approval.*

3. "*Acoustic Assessment Summary Table"* means a table prepared in accordance with the *Basic Comprehensive User Guide* summarising the results of the *Acoustic Assessment Report,* as updated in accordance with Condition 5 of this *Approval.*

4. "*Approval"* means this entire Environmental Compliance Approval and any *Schedules* to it.

5. "*Basic Comprehensive User Guide"* means the *Ministry* document titled "Basic Comprehensive Certificates of Approval (Air) User Guide" dated March 2011, as amended.

6. "*Company"* means **Harris Steel ULC**, operating as **Laurel Steel, a division of Harris Steel ULC** that is responsible for the construction or operation of the *Facility* and includes any successors and assigns in accordance with section 19 of the *EPA.*

7. "*Compound of Concern"* means a contaminant described in paragraph 4 subsection 26 (1) of *O. Reg. 419/05,* namely, a contaminant that is discharged from the *Facility* in an amount that is not negligible.

8. "*Description Section"* means the section on page one of this *Approval* describing the *Company's* operations and the *Equipment* located at the *Facility* and specifying the *Facility Production Limit* for the *Facility.*

9. "*Director"* means a person appointed for the purpose of section 20.3 of the *EPA* by the *Minister* pursuant to section 5 of the *EPA.*

10. "*District Manager"* means the District Manager of the appropriate local district office of the *Ministry,* where the *Facility* is geographically located.

11. "*Emission Summary Table"* means a table described in paragraph 14 of subsection 26 (1) of *O. Reg. 419/05;* namely a table in the *ESDM Report* that compares the *Point of Impingement* concentration for each *Compound of Concern* to the corresponding *Ministry Point of Impingement Limit, Acceptable Point of Impingement Concentration,* or *Jurisdictional Screening Level.*

12. "*Environmental Assessment Act"* means the Environmental Assessment Act, R.S.O. 1990, c.E.18, as amended.

13. "*EPA"* means the Environmental Protection Act, R.S.O. 1990, c.E.19, as amended.

14. "*Equipment"* means equipment or processes described in the *ESDM Report,* this *Approval* and in the *Schedules* referred to herein and any other equipment or processes.

15. "*Equipment with Specific Operational Limits"* means any *Equipment* related to the thermal oxidation of waste or waste derived fuels, fume incinerators or any other *Equipment* that is specifically referenced in any published *Ministry* document that outlines specific operational guidance that must be considered by the *Director* in issuing an *Approval.*

16. "*ESDM Report"* means the most current Emission Summary and Dispersion Modelling Report that describes the *Facility.* The *ESDM Report* is based on the *Original ESDM Report* and is updated after the issuance of this *Approval* in accordance with section 26 of *O. Reg. 419/05* and the *Procedure Document.*

17. "*Facility"* means the entire operation located on the property where the *Equipment* is located.

18. "*Facility Production Limit"* means the production limit placed by the *Director* on the main product(s) or raw materials used by the *Facility.*

19. "*Jurisdictional Screening Level"* means a screening level for a *Compound of Concern* that is listed

in the *Ministry* publication titled "Jurisdictional Screening Level (JSL) List, A Screening Tool for Ontario Regulation 419: Air Pollution - Local Air Quality", dated February 2008, as amended.

20. "*Log"* means a document that contains a record of each change that is required to be made to the *ESDM Report* and *Acoustic Assessment Report,* including the date on which the change occurred. For example, a record would have to be made of a more accurate emission rate for a source of contaminant, more accurate meteorological data, a more accurate value of a parameter that is related to a source of contaminant, a change to a *Point of Impingement* and all changes to information associated with a *Modification* to the *Facility* that satisfies Condition 2**.**

21. "*Minister"* means the Minister of the Environment and Climate Change or such other member of the Executive Council as may be assigned the administration of the *EPA* under the Executive Council Act.

22. "*Ministry"* means the ministry of the *Minister.*

23. "*Ministry Point of Impingement Limit"* means the applicable Standard set out in Schedule 2 or 3 of *O. Reg. 419/05* or a limit set out in the *Ministry* publication titled "Summary of Standards and Guidelines to support Ontario Regulation 419/05: Air Pollution - Local Air Quality (including Schedule 6 of *O. Reg. 419/05* on Upper Risk Thresholds", dated April 2012, as amended.

24. "*Modification"* means any construction, alteration, extension or replacement of any plant, structure, equipment, apparatus, mechanism or thing, or alteration of a process or rate of production at the *Facility* that may discharge or alter the rate or manner of discharge of a *Compound of Concern* to the air or discharge or alter noise or vibration emissions from the *Facility.*

25. "*Noise Control Measures"* means measures to reduce the noise emissions from the *Facility* and/or *Equipment* including, but not limited to, silencers, acoustic louvres, enclosures, absorptive treatment, plenums and barriers.

26. "*O. Reg. 419/05"* means Ontario Regulation 419/05, Air Pollution – Local Air Quality, as amended.

27. "*Original ESDM Report"* means the Emission Summary and Dispersion Modelling Report which was prepared in accordance with section 26 of *O. Reg. 419/05* and the *Procedure Document* by Peter Piersol / ORTECH Consulting Inc. and dated February 12, 2015 submitted in support of the application, and includes any changes to the report made up to the date of issuance of this *Approval.*

28. "*Point of Impingement"* has the same meaning as in section 2 of *O. Reg. 419/05.*

29. *"Point of Reception"* means Point of Reception as defined by *Publication NPC-300.*

30. "*Procedure Document"* means *Ministry* guidance document titled "Procedure for Preparing an Emission Summary and Dispersion Modelling Report" dated March 2009, as amended.

31. "*Processes with Significant Environmental Aspects"* means the *Equipment* which, during regular operation, would discharge one or more contaminants into the air in an amount which is not considered as negligible in accordance with section 26 (1) 4 of *O. Reg. 419/05* and the *Procedure Document.*

32. "*Publication NPC-207"* means the *Ministry* draft technical publication "Impulse Vibration in Residential Buildings", November 1983, supplementing the Model Municipal Noise Control By-Law, Final Report, published by the *Ministry,* August 1978, as amended.

33. "*Publication NPC-233"* means the *Ministry* Publication NPC-233, "Information to be Submitted for Approval of Stationary Sources of Sound", October, 1995, as amended.

34. "*Publication NPC-300"* means the *Ministry* Publication NPC-300, "Environmental Noise Guideline, Stationary and Transportation Sources – Approval and Planning, Publication NPC-300", August 2013,

as amended.

35. "*Schedules"* means the following schedules attached to this *Approval* and forming part of this *Approval* namely:

Schedule A - Supporting Documentation

36. "*Toxicologist"* means a qualified professional currently active in the field of risk assessment and toxicology that has a combination of formal university education, training and experience necessary to assess contaminants.

37. "*Written Summary Form"* means the electronic questionnaire form, available on the *Ministry* website, and supporting documentation, that documents the activities undertaken at the *Facility* in the previous calendar year.

You are hereby notified that this environmental compliance approval is issued to you subject to the terms and conditions outlined below:

TERMS AND CONDITIONS

1. GENERAL

1.1 Except as otherwise provided by this *Approval,* the *Facility* shall be designed, developed, built, operated and maintained in accordance with the terms and conditions of this *Approval* and in accordance with the following *Schedules* attached hereto:

Schedule A - Supporting Documentation

2. LIMITED OPERATIONAL FLEXIBILITY

2.1 Pursuant to section 20.6 (1) of the *EPA* and subject to Conditions 2.2 and 2.3 of this *Approval,* future construction, alterations, extensions or replacements are approved in this *Approval* if the future construction, alterations, extensions or replacements are *Modifications* to the *Facility* that:

(a) are within the scope of the operations of the *Facility* as described in the *Description Section* of this *Approval;*

(b) do not result in an increase of the *Facility Production Limit* above the level specified in the *Description Section* of this *Approval;* and

(c) result in compliance with the performance limits as specified in Condition 4.

2.2 Condition 2.1 does not apply to,

(a) the addition of any new *Equipment with Specific Operational Limits* or to the *Modification* of any existing *Equipment with Specific Operational Limits* at the *Facility;* or

(b) *Modifications* to the *Facility* that would be subject to the *Environmental Assessment Act.*

2.3 Condition 2.1 of this *Approval* shall expire ten (10) years from the date of this *Approval,* unless this *Approval* is revoked prior to the expiry date. The *Company* may apply for renewal of Condition 2.1 of this *Approval* by including an *ESDM Report* and an *Acoustic Assessment Report* that describes the *Facility* as of the date of the renewal application.

3. REQUIREMENT TO REQUEST AN *ACCEPTABLE POINT OF IMPINGEMENT CONCENTRATION*

3.1 Prior to making a *Modification* to the *Facility* that satisfies Condition 2.1 (a) and (b), the *Company* shall prepare a proposed update to the *ESDM Report* to reflect the proposed *Modification.*

3.2 The *Company* shall request approval of an *Acceptable Point of Impingement Concentration* for a *Compound of Concern* if the *Compound of Concern* does not have a *Ministry Point of Impingement Limit* and a proposed update to an *ESDM Report* indicates that one of the following changes with respect to the concentration of the *Compound of Concern* may occur:

(a) The *Compound of Concern* was not a *Compound of Concern* in the previous version of the *ESDM Report* and

(i) the concentration of the *Compound of Concern* is higher than the *Jurisdictional Screening Level* for the contaminant; or

(ii) there is no *Jurisdictional Screening Level* for the contaminant .

(b) The concentration of the *Compound of Concern* in the updated *ESDM Report* is higher than:

(i) the most recent *Acceptable Point of Impingement Concentration,* and

(ii) the *Jurisdictional Screening Level* if a *Jurisdictional Screening Level* exists.

3.3 The request required by Condition 3.2 shall propose a concentration for the *Compound of Concern* and shall contain an assessment, performed by a *Toxicologist,* of the likelihood of the proposed concentration causing an adverse effect at *Points of Impingement.*

3.4 If the request required by Condition 3.2 is a result of a proposed *Modification* described in Condition 3.1, the *Company* shall submit the request, in writing, to the *Director* at least 30 days prior to commencing to make the *Modification.* The *Director* shall provide written confirmation of receipt of this request to the *Company.*

3.5 If a request is required to be made under Condition 3.2 in respect of a proposed *Modification* described in Condition 3.1, the *Company* shall not make the *Modification* mentioned in Condition 3.1 unless the request is approved in writing by the *Director.*

3.6 If the *Director* notifies the *Company* in writing that the *Director* does not approve the request, the *Company* shall,

(a) revise and resubmit the request; or

(b) notify the *Director* that it will not be making the *Modification.*

3.7 The re-submission mentioned in Condition 3.6 shall be deemed a new submission under Condition 3.2.

3.8 If the *Director* approves the request, the *Company* shall update the *ESDM Report* to reflect the *Modification.*

3.9 Condition 3 does not apply if Condition 2.1 has expired.

4. PERFORMANCE LIMITS

4.1. Subject to Condition 4.2, the *Company* shall not discharge or cause or permit the discharge of a *Compound of Concern* into the air if,

(a) the *Compound of Concern* has a *Ministry Point of Impingement Limit* and the discharge results in the concentration at a *Point of Impingement* exceeding the *Ministry Point of Impingement Limit;* or

(b) the *Compound of Concern* does not have a *Ministry Point of Impingement Limit* and the discharge results in the concentration at a *Point of Impingement* exceeding the higher of,

(i) if an *Acceptable Point of Impingement Concentration* exists the most recent *Acceptable Point of Impingement Concentration,* and

(ii) the *Jurisdictional Screening Level* if a *Jurisdictional Screening Level* exists.

4.2 Condition 4.1 does not apply if the *Ministry Point of Impingement Limit* has a 10-minute averaging period and no ambient monitor indicates an exceedance at a *Point of Impingement* where human activities regularly occur at a time when those activities regularly occur.

4.3 The *Company* shall ensure that the noise emissions from the *Facility* comply with the limits set in *Ministry Publication NPC-300.*

4.4 The *Company* shall ensure that the vibration emissions from the *Facility* comply with the limits set out in *Ministry Publication NPC-207.*

4.5 The *Company* shall operate any *Equipment with Specific Operational Limits* approved by this *Approval* in accordance with the *Original ESDM Report.*

5. **DOCUMENTATION REQUIREMENTS**

5.1. The *Company* shall maintain an up-to-date *Log.*

5.2. No later than March 31 in each year, the *Company* shall update the *Acoustic Assessment Report* and shall update the *ESDM Report* in accordance with section 26 of *O. Reg. 419/05* so that the information in the reports is accurate as of December 31 in the previous year.

5.3. The *Company* shall make the *Emission Summary Table* (see section 27 of *O. Reg. 419/05)* and *Acoustic Assessment Summary Table* available for examination by any person, without charge, by posting it on the Internet or by making it available during regular business hours at the *Facility.*

5.4 The *Company* shall, within three (3) months after the expiry of Condition 2.1 of this *Approval,* update the *ESDM Report* and the *Acoustic Assessment Report* such that the information in the reports is accurate as of the date that Condition 2.1 of this *Approval* expired.

5.5. Conditions 5.1 and 5.2 do not apply if Condition 2.1 has expired.

6. REPORTING REQUIREMENTS

6.1 Subject to Condition 6.2, the *Company* shall provide the *Director* no later than June 30 of each year, a *Written Summary Form* to be submitted through the *Ministry's* website that shall include the following:

(a) a declaration of whether the *Facility* was in compliance with section 9 of the *EPA, O. Reg. 419/05* and the conditions of this *Approval;*

(b) a summary of each *Modification* satisfying Condition 2.1 (a) and (b) that took place in the previous calendar year that resulted in a change in the previously calculated concentration at a *Point of Impingement* for any *Compound of Concern* or resulted in a change in the sound levels reported in the *Acoustic Assessment Summary Table* at any *Point of Reception.*

6.2 Condition 6.1 does not apply if Condition 2.1 has expired.

7. OPERATION AND MAINTENANCE

7.1 The *Company* shall prepare and implement, not later than three (3) months from the date of this *Approval,* operating procedures and maintenance programs for all *Processes with Significant Environmental Aspects,* which shall specify as a minimum:

(a) frequency of inspections and scheduled preventative maintenance;

(b) procedures to prevent upset conditions;

(c) procedures to minimize all fugitive emissions;

(d) procedures to prevent and/or minimize odorous emissions;

(e) procedures to prevent and/or minimize noise emissions; and

(f) procedures for record keeping activities relating to the operation and maintenance programs.

7.2 The *Company* shall ensure that all *Processes with Significant Environmental Aspects* are operated and maintained in accordance with this *Approval,* the operating procedures and maintenance programs.

8. COMPLAINTS RECORDING AND REPORTING

8.1 If at any time, the *Company* receives an environmental complaint from the public regarding the operation of the *Equipment* approved by this *Approval,* the *Company* shall take the following steps:

(a) Record and number each complaint, either electronically or in a log book. The record shall include the following information: the time and date of the complaint and incident to which the complaint relates, the nature of the complaint, wind direction at the time and date of the incident to which the complaint relates and, if known, the address of the complainant.

(b) Notify the *District Manager* of the complaint within two (2) business days after the complaint is received, or in a manner acceptable to the *District Manager.*

(c) Initiate appropriate steps to determine all possible causes of the complaint, and take the necessary actions to appropriately deal with the cause of the subject matter of the complaint.

(d) Complete and retain on-site a report written within one (1) week of the complaint date. The report shall list the actions taken to appropriately deal with the cause of the complaint and set out steps to be taken to avoid the recurrence of similar incidents.

9. RECORD KEEPING REQUIREMENTS

9.1 Any information requested by any employee in or agent of the *Ministry* concerning the *Facility* and its operation under this *Approval,* including, but not limited to, any records required to be kept by this *Approval,* shall be provided to the employee in or agent of the *Ministry,* upon request**,** in a timely manner.

9.2 Unless otherwise specified in this *Approval,* the *Company* shall retain, for a minimum of five (5) years from the date of their creation all reports, records and information described in this *Approval,* including,

(a) a copy of the *Original ESDM Report* and each updated version*;*

(b) a copy of each version of the *Acoustic Assessment Report;*

(c) supporting information used in the emission rate calculations performed in the *ESDM Reports* and *Acoustic Assessment Reports;*

(d) the records in the *Log;*

(e) copies of each *Written Summary Form* provided to the *Ministry* under Condition 6.1 of this *Approval;*

(f) records of maintenance, repair and inspection of *Equipment* related to all *Processes with Significant Environmental Aspects;* and

(g) all records related to environmental complaints made by the public as required by Condition 8 of this *Approval.*

10. REVOCATION OF PREVIOUS APPROVALS

This *Approval* replaces and revokes all Certificates of Approval (Air) issued under section 9 *EPA* and Environmental Compliance Approvals issued under Part II.1 *EPA* to the *Facility* in regards to the activities mentioned in subsection 9(1) of the *EPA* and dated prior to the date of this *Approval.*

SCHEDULE A

Supporting Documentation

(a) Environmental Compliance Approval Application, dated April 24, 2015, signed by Mike Caruso and submitted by the *Company;*

(b) Emission Summary and Dispersion Modelling Report, prepared by Peter Piersol and dated February 12, 2015;

(c) *Acoustic Assessment Report,* prepared by Dan Bradshaw/HGC Engineering and dated November 04, 2014**;**

The reasons for the imposition of these terms and conditions are as follows:

GENERAL

1. Condition No. 1 is included to require the *Approval* holder to build, operate and maintain the *Facility* in accordance with the Supporting Documentation in Schedule A considered by the *Director* in issuing this *Approval.*

LIMITED OPERATIONAL FLEXIBILITY, REQUIREMENT TO REQUEST AN *ACCEPTABLE POINT OF IMPINGEMENT CONCENTRATION* AND *PERFORMANCE LIMITS*

2. Conditions No. 2, 3 and 4 are included to limit and define the *Modifications* permitted by this *Approval,* and to set out the circumstances in which the *Company* shall request approval of an *Acceptable Point of Impingement Concentration* prior to making *Modifications.* The holder of the *Approval* is approved for operational flexibility for the *Facility* that is consistent with the description of the operations included with the application up to the *Facility Production Limit.* In return for the operational flexibility, the *Approval* places performance based limits that cannot be exceeded under the terms of this *Approval. Approval* holders will still have to obtain other relevant approvals required to operate the *Facility,* including requirements under other environmental legislation such as the *Environmental Assessment Act.*

DOCUMENTATION REQUIREMENTS

3. Condition No. 5 is included to require the *Company* to maintain ongoing documentation that demonstrates compliance with the *Performance Limits* of this *Approval* and allows the *Ministry* to monitor on-going compliance with these *Performance Limits.* The *Company* is required to have an up to date *ESDM Report* and *Acoustic Assessment Report* that describe the *Facility* at all times and make the *Emission Summary Table* and *Acoustic Assessment Summary Table* from these reports available to the public on an ongoing basis in order to maintain public communication with regard to the

emissions from the *Facility.*

REPORTING REQUIREMENTS

4. Condition No. 6 is included to require the *Company* to provide a yearly *Written Summary Form* to the *Ministry,* to assist the *Ministry* with the review of the site's compliance with the *EPA,* the regulations and this *Approval.*

OPERATION AND MAINTENANCE

5. Condition No. 7 is included to require the *Company* to properly operate and maintain the *Processes with Significant Environmental Aspects* to minimize the impact to the environment from these processes.

COMPLAINTS RECORDING AND REPORTING PROCEDURE

6. Condition No. 8 is included to require the *Company* to respond to any environmental complaints regarding the operation of the *Equipment,* according to a procedure that includes methods for preventing recurrence of similar incidents and a requirement to prepare and retain a written report.

RECORD KEEPING REQUIREMENTS

7. Condition No. 9 is included to require the *Company* to retain all documentation related to this *Approval* and provide access to employees in or agents of the *Ministry,* upon request, so that the *Ministry* can determine if a more detailed review of compliance with the *Performance Limits* is necessary.

REVOCATION OF PREVIOUS APPROVALS

8. Condition No. 10 is included to identify that this *Approval* replaces all Section 9 Certificate(s) of Approval and Part II.1 Approvals in regards to the activities mentioned in subsection 9(1) of the *EPA* and dated prior to the date of this *Approval.*

Upon issuance of the environmental compliance approval, I hereby revoke Approval No(s). 1687-9TKN5M issued on March 9, 2015.

In accordance with Section 139 of the Environmental Protection Act, you may by written Notice served upon me, the Environmental Review Tribunal and in accordance with Section 47 of the Environmental Bill of Rights, 1993 , S.O. 1993, c. 28 (Environmental Bill of Rights), the Environmental Commissioner, within 15 days after receipt of this Notice, require a hearing by the Tribunal. The Environmental Commissioner will place notice of your appeal on the Environmental Registry. Section 142 of the Environmental Protection Act provides that the Notice requiring the hearing shall state:

1. The portions of the environmental compliance approval or each term or condition in the environmental compliance approval in respect of which the hearing is required, and;
2. The grounds on which you intend to rely at the hearing in relation to each portion appealed.

Pursuant to subsection 139(3) of the Environmental Protection Act, a hearing may not be required with respect to any terms and conditions in this environmental compliance approval, if the terms and conditions are substantially the same as those contained in an approval that is amended or revoked by this environmental compliance approval.

The Notice should also include:

3. The name of the appellant;

4. The address of the appellant;
5. The environmental compliance approval number;
6. The date of the environmental compliance approval;
7. The name of the Director, and;
8. The municipality or municipalities within which the project is to be engaged in.

And the Notice should be signed and dated by the appellant.

This Notice must be served upon:

The Secretary* Environmental Review Tribunal 655 Bay Street, Suite 1500 Toronto, Ontario M5G 1E5	AND	The Environmental Commissioner 1075 Bay Street, Suite 605 Toronto, Ontario M5S 2B1	AND The Director appointed for the purposes of Part II.1 of the Environmental Protection Act Ministry of the Environment and Climate Change 135 St. Clair Avenue West, 1st Floor Toronto, Ontario M4V 1P5

*** Further information on the Environmental Review Tribunal's requirements for an appeal can be obtained directly from the Tribunal at: Tel: (416) 212-6349, Fax: (416) 326-5370 or www.ert.gov.on.ca**

This instrument is subject to Section 38 of the Environmental Bill of Rights, 1993, that allows residents of Ontario to seek leave to appeal the decision on this instrument. Residents of Ontario may seek leave to appeal within 15 days from the date this decision is placed on the Environmental Registry. By accessing the Environmental Registry at www.ebr.gov.on.ca , you can determine when the leave to appeal period ends.

The above noted activity is approved under s.20.3 of Part II.1 of the Environmental Protection Act.

DATED AT TORONTO this 3rd day of February, 2016

Rudolf Wan, P.Eng.
Director
appointed for the purposes of Part II.1 of
the *Environmental Protection Act*

KM/
c: District Manager, MOECC Halton-Peel
Peter Piersol, ORTHECH Consulting Inc.

Content Copy Of Original

Ontario

Ministry of the Environment and Climate Change
Ministère de l'Environnement et de l'Action en matière de changement climatique

AMENDED ENVIRONMENTAL COMPLIANCE APPROVAL
NUMBER 1687-9TKN5M
Issue Date: March 9, 2015

Harris Steel ULC
5400 Harvester Road
Burlington, Ontario
L7R 3Y8

Site Location: 5400 Harvester Road
Burlington City, Regional Municipality of Halton
L7R 3Y8

You have applied under section 20.2 of Part II.1 of the Environmental Protection Act, R.S.O. 1990, c. E. 19 (Environmental Protection Act) for approval of:

- one (1) general exhaust system, consisting of eleven (11) roof fans and one (1) wall fan, providing ventilation for the following:

- one (1) baghouse dust collector (Source: DB), serving Draw Bench #106, equipped with a total of 82.7 square metres of polyester felt cloth bags and a mechanical shaker cleaning mechanism, and secondary filtration equipped with a total of 6 square metres of synthetic pleat filters, discharging into the Facility at a maximum volumetric flow rate of 1.7 cubic metres per second;

- one (1) cartridge dust collector (Source: CB), serving the Coil Blaster, equipped with a total of 82.8 square metres of cellulose fibre cartridges and a pulse jet cleaning mechanism, and secondary filtration equipped with a total of 6 square metres of synthetic pleat filters, discharging into the Facility at a volumetric flow rate of 4.7 cubic metres per second;

- one (1) dust collector (Source: ILD1), serving the in-line drawing machine, discharging into the Facility at a volumetric flow rate of 0.6 cubic metre per second;

- one (1) portable dust collector (Source WD1), serving Drawing Machine #68, discharging into the Facility at a maximum volumetric flow rate of 0.4 cubic metre per second;

- one (1) cartridge dust collector (Source: WD2), serving Drawing Machine #75/81, equipped with a total of 335 square metres of cellulose fibre cartridges and a pulse jet cleaning mechanism, and secondary filtration equipped with a total of 6 square metres of synthetic pleat filters, discharging into the Facility at a maximum volumetric flow rate of 2.6 cubic metres per second;

- one (1) cartridge dust collector (Source: WD3), serving Drawing Machine #80, equipped with a total of 250 square metres of cellulose fibre cartridges and a pulse jet cleaning mechanism, and secondary filtration equipped with a total of 6 square metres of synthetic pleat filters, discharging into the Facility at a maximum volumetric flow rate of 2.0 cubic metres per second;

- one (1) cartridge dust collector (Source: MF1), serving Mesh Line #131, equipped with a total of 315 square metres of cellulose fibre cartridges and a pulse jet cleaning mechanism, and secondary filtration equipped with a total of 6 square metres of box filters, discharging into the Facility at a

maximum volumetric flow rate of 3.8 cubic metres per second;

- one (1) cartridge dust collector (Source: TL1), serving the Teurema Line Sanding & Descaling, and Equipment Maintenance Station, equipped with a total of 167 square metres of cellulose fibre cartridges and a pulse jet cleaning mechanism, and secondary filtration equipped with a total of 6 square metres of synthetic pleat filters, discharging into the Facility at a maximum volumetric flow rate of 2.4 cubic metres per second;

- one (1) cartridge dust collector (Source: TL2), serving the Teurema Line Up-ender Tower, equipped with a total of 420 square metres of cellulose fibre cartridges and a pulse jet cleaning mechanism, and secondary filtration equipped with a total of 6 square metres of synthetic pleat filters, discharging into the Facility at a maximum volumetric flow rate of 6.4 cubic metres per second;

- one (1) cartridge dust collector (Source: GL1), serving the Galvanizing Line Sander& Descaler, and Dry Lubricant Application, equipped with a total of 420 square metres of cellulose fibre cartridges and a reverse air pulse jet cleaning mechanism, and secondary filtration equipped with a total of 6 square metres of box filters, discharging into the Facility at a maximum volumetric flow rate of 6.4 cubic metres per second;

discharging to the air at a total maximum volumetric flow rate of 78.4 cubic metres per second;

- one (1) ventilation/exhaust system (Source: CDM), located in the dust collector room, equipped with a high efficiency synthetic media filter to provide tertiary filtration of emissions from:

- three (3) cartridge dust collectors, serving Drawing Machines #97, #124 and #136, each equipped with a total of 240 square metres of cellulose fibre cartridges and a pulse jet cleaning mechanism, and secondary filtration equipped with a total of 6 square metres of synthetic pleat filters, and each discharging to tertiary filtration control at a maximum volumetric flow rate of 2.5 cubic metres per second;

- two (2) cartridge dust collectors, serving Drawing Machines #123 and # 126, each equipped with a total of 320 square metres of cellulose fibre cartridges and a pulse jet cleaning mechanism, and secondary filtration equipped with a total of 6 square metres of synthetic pleat filters, and each discharging to tertiary filtration control at a maximum volumetric flow rate of 3.2 cubic metres per second;

discharging to the air at a maximum volumetric flow rate of 9.1 cubic metres per second through a stack having an exit diameter of 0.8 metre, extending 2 metres above the roof and 10 metes above grade;

- one (1) cartridge dust collector (Source: MF2), serving Mesh Line #139, equipped with a total of 315 square metres of cellulose fibre cartridges and a pulse jet cleaning mechanism, and secondary filtration equipped with a total of 6 square metres of box filters, discharging to the air at a maximum volumetric flow rate of 3.8 cubic metres per second through a stack having an exit diameter of 0.6 metre, extending 2 metres above the roof and 10 metres above grade;

- one (1) exhaust system (Source PS), serving the batch Steel Coil Pickling operation, comprised of four (4) acid dip tanks, two (2) rinsing tanks and two (2) water/lime tanks, all discharging to one (1) packed bed scrubber, having a diameter of 2.74 metres, randomly packed with polypropylene Tellerette packing to a height of 1.83 metres, using water as scrubbing liquid with a maximum volumetric flow rate of 75.7 litres per minute, equipped with a mist eliminator, discharging to the air at a maximum volumetric flow rate o f15.1 cubic metres per second through a stack having an exit diameter of 1.1 metres, extending 2.1 metres above the roof and 10.1 metres above grade;

- one (1) natural gas fired boiler (Source: B) having a maximum heat input of 6.22 million kilojoules per hour discharging to the air at a maximum volumetric flow rate of 0.59 cubic metre per second through a stack having an exit diameter of 0.5 metre, extending 1 metre above the roof and 10 metres above grade;

- one (1) laboratory fumehood discharging to the air at a maximum volumetric flow rate of 0.2 cubic metre per second through a stack having an exit diameter of 0.15 metre, located 2.4 metres above grade;

- various natural gas-fired comfort heating equipment, consisting of thirty-six (36) space heaters and twenty-four (24) infrared heaters, having a total aggregate maximum heat input of 10.64 million kilojoules per hour discharging to the air;

- one (1) induced draft cooling tower (Source: CT-1), serving the Mesh Lines and hydraulic units, having a maximum water recirculation rate of 6.3 litres per second and discharging to the air at an elevation of 7.3 metres above grade;

- two (2) induced draft cooling towers (Source: CT-2 and CT-3), serving the Galvanizing Line, each having a maximum water recirculation rate of 6.3 litres per second and discharging to the air at an elevation of 10.5 meters above grade;

all in accordance with the Environmental Compliance Approval Application submitted by Harris Steel ULC, dated November 5, 2014, and signed by Mike Caruso, Environmental Coordinator; the supporting Emission Summary and Dispersion Modelling report, dated November 7, 2014, prepared by ORTECH Consulting Inc. and signed by Peter Piersol; the revised Emission Summary and Dispersion Modelling report, dated February 12, 2015, prepared by ORTECH Consulting Inc. and signed by Peter Piersol; and the Acoustic Assessment Report prepared by HGC Engineering, dated November 7, 2014 and signed by Dan Bradshaw.

For the purpose of this environmental compliance approval, the following definitions apply:

1. "Approval" means this Environmental Compliance Approval, including the application and supporting documentation listed above;

2. "Company" means Harris Steel ULC, operating as Laurel Steel, a division of Harris Steel ULC, that is responsible for the construction or operation of the Facility and includes any successors and assigns;

3. "District Manager" means the District Manager of the appropriate local district office of the Ministry, where the Facility is geographically located;

4. "EPA" means the Environmental Protection Act , R.S.O. 1990, c.E.19, as amended ;

5. "Equipment" means the equipment and processes described in the Company's application, this Approval and in the supporting documentation submitted with the application, to the extent approved by this Approval;

6. "Facility" means the entire operation located on the property where the Equipment is located;

7. "Manual" means a document or a set of documents that provide written instructions to staff of the Company;

8. "Ministry" means the ministry of the government of Ontario responsible for the EPA and includes all

officials, employees or other persons acting on its behalf ;

9. "Publication NPC-300" means the Ministry Publication NPC-300, "Environmental Noise Guideline, Stationary and Transportation Sources – Approval and Planning, Publication NPC-300", August, 2013, as amended.

You are hereby notified that this environmental compliance approval is issued to you subject to the terms and conditions outlined below:

TERMS AND CONDITIONS

OPERATION AND MAINTENANCE

1. The Company shall ensure that the Equipment is properly operated and maintained at all times. The Company shall:

(1) prepare, not later than three (3) months after the date of this Approval, and update, as necessary, a Manual outlining the operating procedures and a maintenance program for the Equipment, including:

(a) routine operating and maintenance procedures in accordance with good engineering practices and as recommended by the Equipment suppliers;

(b) emergency procedures;

(c) procedures for any record keeping activities relating to operation and maintenance of the Equipment;

(d) all appropriate measures to minimize noise emissions from all potential sources; and

(e) the frequency of inspection and replacement of the filter material in the Equipment;

(2) implement the recommendations of the Manual.

PERFORMANCE REQUIREMENTS

2. The Company shall, at all times, ensure that the noise emissions from the Equipment comply with the limits set out in Publication NPC-300.

3. The following Equipment shall be operated as follows:

(1) the combined drawing machines shall operate the equivalent of three (3) lines in any 24 hour period;

(2) the steel coil blaster shall operate the equivalent of 4 hours in any 24 hour period;

(3) one (1) in-line drawing machine shall operate for only two (2) shifts; and

(4) the steel coil pickling system shall operate for only two (2) shifts.

RECORD RETENTION

4. The Company shall retain, for a minimum of two (2) years from the date of their creation, all records and information related to or resulting from the recording activities required by this Approval, and make

these records available for review by staff of the Ministry upon request. The Company shall retain:

(1) all records on the maintenance, repair and inspection of the Equipment; and

(2) all records of any environmental complaints; including:

(a) a description, time and date of each incident to which the complaint relates;

(b) wind direction at the time of the incident to which the complaint relates; and

(c) a description of the measures taken to address the cause of the incident to which the complaint relates and to prevent a similar occurrence in the future.

NOTIFICATION OF COMPLAINTS

5. The Company shall notify the District Manager, in writing, of each environmental complaint within two (2) business days of the complaint. The notification shall include:

(1) a description of the nature of the complaint; and

(2) the time and date of the incident to which the complaint relates.

The reasons for the imposition of these terms and conditions are as follows:

1. Condition No. 1 is included to emphasize that the Equipment must be maintained and operated according to a procedure that will result in compliance with the EPA, the regulations and this Approval.

2. Conditions No. 2 and 3 are included to provide the minimum performance requirements considered necessary to prevent an adverse effect resulting the operation of the Facility.

3. Condition No. 4 is included to require the Company to keep records and to provide information to staff of the Ministry so that compliance with the EPA, the regulations and this Approval can be verified.

4. Condition No. 5 is included to require the Company to notify staff of the Ministry so as to assist the Ministry with the review of the site's compliance.

Upon issuance of the environmental compliance approval, I hereby revoke Approval No(s). 1399-7AVSHE issued on February 4, 2008.

In accordance with Section 139 of the Environmental Protection Act, you may by written Notice served upon me, the Environmental Review Tribunal and in accordance with Section 47 of the Environmental Bill of Rights, 1993 , S.O. 1993, c. 28 (Environmental Bill of Rights), the Environmental Commissioner, within 15 days after receipt of this Notice, require a hearing by the Tribunal. The Environmental Commissioner will place notice of your appeal on the Environmental Registry. Section 142 of the Environmental Protection Act provides that the Notice requiring the hearing shall state:

1. The portions of the environmental compliance approval or each term or condition in the environmental compliance approval in respect of which the hearing is required, and;
2. The grounds on which you intend to rely at the hearing in relation to each portion appealed.

Pursuant to subsection 139(3) of the Environmental Protection Act, a hearing may not be required with respect to any terms and conditions in this environmental compliance approval, if the terms and conditions are substantially the same as those contained in an approval that is amended or revoked by this environmental compliance approval.

The Notice should also include:

3. The name of the appellant;
4. The address of the appellant;
5. The environmental compliance approval number;
6. The date of the environmental compliance approval;
7. The name of the Director, and;
8. The municipality or municipalities within which the project is to be engaged in.

And the Notice should be signed and dated by the appellant.

This Notice must be served upon:

The Secretary*
Environmental Review Tribunal
655 Bay Street, Suite 1500
Toronto, Ontario
M5G 1E5

AND

The Environmental Commissioner
1075 Bay Street, Suite 605
Toronto, Ontario
M5S 2B1

AND

The Director appointed for the purposes of Part II.1 of the Environmental Protection Act
Ministry of the Environment and Climate Change
2 St. Clair Avenue West, Floor 12A
Toronto, Ontario
M4V 1L5

*** Further information on the Environmental Review Tribunal 's requirements for an appeal can be obtained directly from the Tribunal at: Tel: (416) 212-6349, Fax: (416) 314-4506 or www.ert.gov.on.ca**

This instrument is subject to Section 38 of the Environmental Bill of Rights, 1993, that allows residents of Ontario to seek leave to appeal the decision on this instrument. Residents of Ontario may seek leave to appeal within 15 days from the date this decision is placed on the Environmental Registry. By accessing the Environmental Registry at www.ebr.gov.on.ca , you can determine when the leave to appeal period ends.

The above noted activity is approved under s.20.3 of Part II.1 of the Environmental Protection Act.

DATED AT TORONTO this 9th day of March, 2015

Rudolf Wan, P.Eng.
Director
appointed for the purposes of Part II.1 of the *Environmental Protection Act*

ES/
c: District Manager, MOECC Halton-Peel
Peter Piersol, ORTECH Consulting Inc.

Brammer Standard Company, Inc.

Certificate of Analysis

B.S. 2931

AISI Steel Grade 1018

	Certified Value[1]	Estimate of Uncertainty[2]		Certified Value[1]	Estimate of Uncertainty[2]
		Analysis listed as percent by weight			
C	**0.202**	0.005	**As**	**0.007**	0.001
Mn	**0.75**	0.015	**Ca**	**0.0009**	0.0003
P	**0.012**	0.002	**Co**	**0.009**	0.001
S	**0.025**	0.002	**N**	**0.0119**	0.0005
Si	**0.23**	0.01	**O**	**0.0050**	0.0006
Cu	**0.23**	0.01	**Sn**	**0.010**	0.002
Ni	**0.106**	0.01	**V**	**0.002**	0.0005
Cr	**0.154**	0.01			
Mo	**0.019**	0.004			
Al	**0.002**	0.001			

[1] The certified value listed is the present best estimate of the true value based on the results of an interlaboratory testing program.

[2] The uncertainties listed are based on value judgments of the material inhomogeneity and possible bias in the determined analytical values. No attempt is made to derive exact statistical measurements of imprecision because several methods were used in the determination of most constituents.

The requirements of ISO Guide 31 and ISO Guide 35 were generally followed for the preparation of this reference material and certificate of analysis. This is a reference material as defined by ISO Guide 30.

See reverse side for more information. Certificate Number 2931-122793

Brammer Standard Company, Inc., 14603 Benfer Road, Houston, TX 77069-2895
Telephone (281) 440-9396 Fax (281) 440-4432

BS 2931 Certificate number 2931-122793

Lab	C	Mn	P	S	Si	Cu	Ni	Cr	Mo
1	0.198	0.729	0.0089	0.023	0.212	0.196	0.097	0.146	0.014
2	0.199	0.739	0.0105	0.024	0.219	0.224	0.099	0.150	0.015
3	0.199	0.740	0.011	0.024	0.225	0.224	0.100	0.151	0.016
4	0.199	0.740	0.011	0.025	0.226	0.226	0.103	0.151	0.017
5	0.200	0.749	0.0110	0.0254	0.229	0.228	0.106	0.152	0.017
6	0.201	0.750	0.0111	0.026	0.230	0.229	0.106	0.142	0.017
7	0.2015	0.752	0.0114		0.232	0.230	0.106	0.154	0.017
8	0.202	0.756	0.0116		0.233	0.230	0.107	0.154	0.018
9	0.2045	0.756	0.012		0.236	0.230	0.108	0.155	0.018
10	0.2070	0.756	0.014			0.230	0.108	0.155	0.018
11	0.207	0.758	0.014			0.230	0.108	0.156	0.018
12		0.760				0.231	0.109	0.157	0.020
13		0.768				0.234	0.110	0.159	0.022
14						0.234	0.110	0.161	0.022
15						0.236	0.114	0.169	0.024
16						0.238			0.026
Average	0.2016	0.7502	0.0115	0.0246	0.2269	0.2281	0.1061	0.1541	0.0187
Std Dev	0.0032	0.0107	0.0015	0.0011	0.0075	0.0094	0.0046	0.0063	0.0033
Certified	0.202	0.75	0.012	0.025	0.23	0.23	0.106	0.154	0.019

Lab	Al	As	Ca	Co	N	O	Sn	V
1	0.001	0.0065	0.00058	0.008	0.0115	0.0047	0.008	0.0011
2	0.001	0.0068	0.0007	0.0085	0.0115	0.0048	0.0082	0.0012
3	0.0017	0.007	0.0009	0.009	0.0116	0.0049	0.0087	0.0018
4	0.0018	0.0071	0.00094	0.009	0.0116	0.0050	0.009	0.0019
5	0.0019	0.0078	0.0012	0.009	0.0119	0.0055	0.0096	0.0022
6	0.002			0.0095	0.0120		0.010	0.002
7	0.002			0.0095	0.0120		0.010	
8	0.0024			0.0101	0.0120		0.0101	
9	0.0028			0.0104	0.0120		0.0102	
10				0.0104	0.0124		0.0105	
11							0.011	
Average	0.0018	0.0070	0.0009	0.0093	0.0119	0.0050	0.0096	0.0017
Std Dev	0.0006	0.0005	0.0002	0.0008	0.0003	0.0003	0.0010	0.0004
Certified	0.002	0.007	0.0009	0.009	0.0119	0.0050	0.010	0.002

Analysis: Chemical analyses were made on chips prepared by a lathe from the certified portion of the discs. The laboratories participating in the testing normally followed the requirements of ISO Guide 25. The individual values listed above are the average of each analyst's results. Methods of analysis used were a combination of ASTM Standard Methods E 322, E 350, E 415, E 1019, plus additional ICP, and AA spectrometric methods. The following Certified Reference Materials were used to validate the analytical data listed above: NIST SRM 361 - 365, 125b; JSS 003; ECRM 085-1, 088-1, 096-1, 097-1, 184-1, 481-1

Co-operating Laboratories: Some of the co-operating laboratories were:

Brammer Standard Co., Inc., Houston, Texas
Crucible Specialty Metals, Syracuse, New York
Hoesch Stahl AG, Dortmund, Germany
J. Dirats and Co., Inc., Westfield, Massachusetts
Jessop Steel Company, Washington, Pennsylvania
Lukens Steel, Coatsville, Pennsylvania
Republic Engineered Steels, Canton, Ohio
The Timken Company, Harrison Steel Plant, Canton, Ohio
The Timken Company, Faircrest Steel Plant, Canton, Ohio
VHG Laboratories, Inc., Manchester, New Hampshire

Additional analytical data: This material was used as an unknown test specimen in the ASTM Proficiency Testing Program (PTP) for low-alloy steel. The participating laboratories were instructed to use ASTM Standard Test Methods E 322, E 415, and E 1019. The data shown below are the results from the PTP.

Instrument analysis using ASTM Standard Test Method E 1019

	C	N	O
Number of Labs	36	31	19
Grand Average	0.2034	0.0120	0.0057
Standard Deviation	0.0053	0.0004	0.0016

Optical Emission Spectrometric Analysis using ASTM Standard Test Method E 415

	C	Mn	P	S	Si	Cu	Ni
Number of Labs	55	54	54	49	54	54	54
Grand Average	0.2055	0.7468	0.0118	0.0253	0.2300	0.2281	0.1083
Standard Deviation	0.0090	0.0170	0.0015	0.0029	0.0095	0.0110	0.0064

	Cr	Mo	Al	Co	Sn
Number of Labs	54	52	28	29	45
Grand Average	0.1524	0.0179	0.0025	0.0090	0.0096
Standard Deviation	0.0069	0.0048	0.0012	0.0014	0.0016

X-ray Emission Spectrometric Analysis using ASTM Standard Test Method E 322

	Mn	Cu	Ni	Cr	Mo
Number of Labs	12	11	11	12	11
Grand Average	0.7578	0.2332	0.1077	0.1540	0.0186
Standard Deviation	0.0141	0.0062	0.0027	0.0071	0.0030

Homogeneity: This Reference Material was tested for homogeneity using ASTM Standard Practice E 826 and found acceptable.

Traceability: This Reference Material was also examined by optical emission spectrometry and found to be compatible with the following Certified Reference Materials: NIST SRM C1173, 1261A - 1265A, 1761 - 1767; ECRM 186-1, 191-1; SS 457/1, 458/1; JSS 169-4, 170-6, 171-4

Source: This material was produced by Nucor Steel Corporation, Darlington, South Carolina. The material was made in an electric arc furnace and continuously cast into 8 inch square billets. The billets were hot rolled down to 1.56 inch round bars. The bar stock was cold finished to 1.50 inch diameter.

Available Form: This Reference Material is available only in the form of a disc, approximately 37 mm (1.50") in diameter and 19 mm (0.75") thick.

Use: This Reference Material is intended for use in optical emission and x-ray spectrometric methods of analysis. The entire depth of the disc may be used.

Caution: As with any bar material, avoid optical emission spectrometric burns in the center of the disc (5 mm radius), as some segregation may be present.

Sample Preparation: For best analytical results, use the same method for preparing the analytical surface on all reference materials as you use for production specimens. Avoid overheating the disc during surface preparation.

Safety Notice: A Material Safety Data Sheet (MSDS) is not required for this material. This material will not release or otherwise result in exposure to a hazardous chemical, under normal conditions of use. Inquiries concerning this Reference Material should be directed to:

Brammer Standard Co., Inc. Phone: (281) 440-9396
14603 Benfer Road
Houston, Texas 77069-2895 USA Fax: (281) 440-4432

Certified by: _____ on December 27, 1993
G. R. Brammer

Certificate Number 2931-122793

Referenced Documents

ASTM documents available from ASTM, 1916 Race Street, Philadelphia, PA, 19103.

E 322 - 67 (Reapproved 1990) Standard Method for X-Ray Emission Spectrometric Analysis of Low-Alloy Steels and Cast Irons

E 350 - 90 Standard Test Methods for Chemical Analysis of Carbon Steel, Low-Alloy Steel, Silicon Electrical Steel, Ingot Iron, and Wrought Iron

E 415 - 85 (Reapproved 1989) Standard Test Method for Optical Emission Vacuum Spectrometric Analysis of Carbon and Low-Alloy Steel

E 826 - 85 (Reapproved 1990) Standard Practice for Testing Homogeneity of Materials for the Development of Reference Materials

E 1019-93 Standard Test Methods for Determination of Carbon, Sulfur, Nitrogen, and Oxygen in Steel and in Iron, Nickel, and Cobalt Alloys

ISO Guides available from American National Standards Institute, 11 West 42nd St., 13th Floor, New York, NY 10036.

ISO Guide 25 (Third edition, 1990), General requirements for the competence of calibration and testing laboratories.

ISO Guide 30 (Second edition, 1991), Terms and definitions used in connection with reference materials.

ISO Guide 31 (First edition, 1981), Contents of certificates of reference materials.

ISO Guide 33 (First edition, 1989), Uses of certified reference materials.

ISO Guide 35 (Second edition, 1989), Certification of reference materials - General and statistical principles.

Other useful documents available at no cost from NIST, U.S. Department of Commerce, Gaithersburg, MD 20899.

NBS Special Publication 260-100, Handbook for SRM Users

NIST Special Publication 829, Use of NIST Standard Reference Materials for Decisions on Performance of Analytical Chemical Methods and Laboratories

Air Pollution Control Technology Fact Sheet

Name of Technology: Packed-Bed/Packed-Tower Wet Scrubber

This type of technology is a part of the group of air pollution controls collectively referred to as "wet scrubbers." When used to control inorganic gases, they may also be referred to as "acid gas scrubbers."

Type of Technology: Removal of air pollutants by inertial or diffusional impaction, reaction with a sorbent or reagent slurry, or absorption into liquid solvent.

Applicable Pollutants:

Primarily inorganic fumes, vapors, and gases (e.g., chromic acid, hydrogen sulfide, ammonia, chlorides, fluorides, and SO_2); volatile organic compounds (VOC); and particulate matter (PM), including PM less than or equal to 10 micrometers (μm) in aerodynamic diameter (PM_{10}), PM less than or equal to 2.5 μm in aerodynamic diameter ($PM_{2.5}$), and hazardous air pollutants (HAP) in particulate form (PM_{HAP}).

Absorption is widely used as a raw material and/or product recovery technique in separation and purification of gaseous streams containing high concentrations of VOC, especially water-soluble compounds such as methanol, ethanol, isopropanol, butanol, acetone, and formaldehyde (Croll Reynolds, 1999). Hydrophobic VOC can be absorbed using an amphiphilic block copolymer dissolved in water. However, as an emission control technique, it is much more commonly employed for controlling inorganic gases than for VOC. When using absorption as the primary control technique for organic vapors, the spent solvent must be easily regenerated or disposed of in an environmentally acceptable manner (EPA, 1991). When used for PM control, high concentrations can clog the bed, limiting these devices to controlling streams with relatively low dust loadings (EPA, 1998).

Achievable Emission Limits/Reductions:

Inorganic Gases: Control device vendors estimate that removal efficiencies range from 95 to 99 percent (EPA, 1993).

VOC: Removal efficiencies for gas absorbers vary for each pollutant-solvent system and with the type of absorber used. Most absorbers have removal efficiencies in excess of 90 percent, and packed-tower absorbers may achieve efficiencies greater than 99 percent for some pollutant-solvent systems. The typical collection efficiency range is from 70 to greater than 99 percent (EPA, 1996a; EPA, 1991).

PM: Packed-bed wet scrubbers are limited to applications in which dust loading is low, and collection efficiencies range from 50 to 95 percent, depending upon the application (EPA, 1998).

Applicable Source Type: Point

Typical Industrial Applications:

The suitability of gas absorption as a pollution control method is generally dependent on the following factors: 1) availability of suitable solvent; 2) required removal efficiency; 3) pollutant concentration in the inlet vapor;

4) capacity required for handling waste gas; and, 5) recovery value of the pollutant(s) or the disposal cost of the unrecoverable solvent (EPA, 1996a). Packed-bed scrubbers are typically used in the chemical, aluminum, coke and ferroalloy, food and agriculture, and chromium electroplating industries. These scrubbers have had limited use as part of flue gas desulfurization (FGD) systems, but the scrubbing solution flow rate must be carefully controlled to avoid flooding (EPA, 1998; EPA, 1981).

When absorption is used for VOC control, packed towers are usually more cost effective than impingement plate towers. However, in certain cases, the impingement plate design is preferred over packed-tower columns when either internal cooling is desired, or where low liquid flow rates would inadequately wet the packing (EPA, 1992).

Emission Stream Characteristics:

a. **Air Flow:** Typical gas flow rates for packed-bed wet scrubbers are 0.25 to 35 standard cubic meters per second (sm^3/sec) (500 to 75,000 standard cubic feet per minute (scfm)) (EPA, 1982; EPA, 1998).

b. **Temperature:** Inlet temperatures are usually in the range of 4 to 370°C (40 to 700°F) for waste gases in which the PM is to be controlled, and for gas absorption applications, 4 to 38°C (40 to 100°F). In general, the higher the gas temperature, the lower the absorption rate, and vice-versa. Excessively high gas temperatures also can lead to significant solvent or scrubbing liquid loss through evaporation. (Avallone, 1996; EPA, 1996a).

c. **Pollutant Loading:** Typical gaseous pollutant concentrations range from 250 to 10,000 ppmv (EPA, 1996a). Packed-bed wet scrubbers are generally limited to applications in which PM concentrations are less than 0.45 grams per standard cubic meter (g/sm^3) (0.20 grains per standard cubic foot (gr/scf)) to avoid clogging (EPA, 1982).

d. **Other Considerations:** For organic vapor HAP control applications, low outlet concentrations will typically be required, leading to impractically tall absorption towers, long contact times, and high liquid-gas ratios that may not be cost-effective. Wet scrubbers will generally be effective for HAP control when they are used in combination with other control devices such as incinerators or carbon adsorbers (EPA, 1991).

Emission Stream Pretreatment Requirements:

For absorption applications, precoolers (e.g., spray chambers, quenchers) may be needed to saturate the gas stream or to reduce the inlet air temperature to acceptable levels to avoid solvent evaporation or reduced absorption rates (EPA, 1996a).

Cost Information:

The following are cost ranges (expressed in 2002 dollars) for packed-bed wet scrubbers of conventional design under typical operating conditions, developed using EPA cost-estimating spreadsheets (EPA, 1996a) and referenced to the volumetric flow rate of the waste stream treated. For purposes of calculating the example cost effectiveness, the pollutant used is hydrochloric acid and the solvent is aqueous caustic soda. The costs do not include costs for post-treatment or disposal of used solvent or waste. Costs can be substantially higher than in the ranges shown for applications which require expensive materials, solvents, or treatment methods. As a rule, smaller units controlling a low concentration waste stream will be much more expensive (per unit volumetric flow rate) than a large unit cleaning a high pollutant load flow.

a. **Capital Cost:** $23,000 to $117,000 per sm^3/sec ($11 to $55 per scfm)

b. **O & M Cost:** $32,000 to $104,000 per sm^3/sec ($15 to $49 per scfm), annually

c. **Annualized Cost:** $36,000 to $165,000 per sm^3/sec ($17 to $78 per scfm), annually

d. **Cost Effectiveness:** $110 to $550 per metric ton ($100 to $500 per short ton), annualized cost per ton per year of pollutant controlled

Theory of Operation:

Packed-bed scrubbers consist of a chamber containing layers of variously-shaped packing material, such as Raschig rings, spiral rings, or Berl saddles, that provide a large surface area for liquid-particle contact. The packing is held in place by wire mesh retainers and supported by a plate near the bottom of the scrubber. Scrubbing liquid is evenly introduced above the packing and flows down through the bed. The liquid coats the packing and establishes a thin film. The pollutant to be absorbed must be soluble in the fluid. In vertical designs (packed towers), the gas stream flows up the chamber (countercurrent to the liquid). Some packed beds are designed horizontally for gas flow across the packing (crosscurrent) (EPA, 1998).

Physical absorption depends on properties of the gas stream and liquid solvent, such as density and viscosity, as well as specific characteristics of the pollutant(s) in the gas and the liquid stream (e.g., diffusivity, equilibrium solubility). These properties are temperature dependent, and lower temperatures generally favor absorption of gases by the solvent. Absorption is also enhanced by greater contacting surface, higher liquid-gas ratios, and higher concentrations in the gas stream (EPA, 1991). Chemical absorption may be limited by the rate of reaction, although the rate-limiting step is typically the physical absorption rate, not the chemical reaction rate (EPA, 1996a; EPA, 1996b).

Inorganic Gases Control:

Water is the most common solvent used to remove inorganic contaminants. Pollutant removal may be enhanced by manipulating the chemistry of the absorbing solution so that it reacts with the pollutant. Caustic solution (sodium hydroxide, NaOH) is the most common scrubbing liquid used for acid-gas control (e.g., HCl, SO_2, or both), though sodium carbonate (Na_2CO_3) and calcium hydroxide (slaked lime, $Ca[OH]_2$) are also used. When the acid gases are absorbed into the scrubbing solution, they react with alkaline compounds to produce neutral salts. The rate of absorption of the acid gases is dependent upon the solubility of the acid gases in the scrubbing liquid (EPA, 1996a; EPA, 1996b).

VOC Control:

Absorption is a commonly applied operation in chemical processing. It is used as a raw material and/or a product recovery technique in separation and purification of gaseous streams containing high concentrations of organics (e.g., in natural gas purification and coke by-product recovery operations). In absorption, the organics in the gas stream are dissolved in a liquid solvent. The contact between the absorbing liquid and the vent gas is accomplished in counter current spray towers, scrubbers, or packed or plate columns (EPA, 1995).

The use of absorption as the primary control technique for organic vapors is subject to several limiting factors. One factor is the availability of a suitable solvent. The VOC must be soluble in the absorbing liquid and even then, for any given absorbent liquid, only VOC that are soluble can be removed. Some common solvents that may be useful for volatile organics include water, mineral oils, or other nonvolatile petroleum oils. Another factor that affects the suitability of absorption for organic emissions control is the availability of vapor/liquid equilibrium data for the specific organic/solvent system in question. Such data are necessary for the design of absorber systems; however, they are not readily available for uncommon organic compounds.

The solvent chosen to remove the pollutant(s) should have a high solubility for the vapor or gas, low vapor pressure, low viscosity, and should be relatively inexpensive. Water is used to absorb VOC having relatively high water solubilities. Amphiphilic block copolymers added to water can make hydrophobic VOC dissolve in water. Other solvents such as hydrocarbon oils are used for VOC that have low water solubilities, though only in industries where large volumes of these oils are available (e.g., petroleum refineries and petrochemical plants) (EPA, 1996a).

Another consideration in the application of absorption as a control technique is the treatment or disposal of the material removed from the absorber. In most cases, the scrubbing liquid containing the VOC is regenerated in an operation known as stripping, in which the VOC is desorbed from the absorbent liquid, typically at elevated temperatures and/or under vacuum. The VOC is then recovered as a liquid by a condenser (EPA, 1995).

PM Control:

In packed-bed scrubbers, the gas stream is forced to follow a circuitous path through the packing material, on which much of the PM impacts. The liquid on the packing material collects the PM and flows down the chamber towards the drain at the bottom of the tower. A mist eliminator (also called a “de-mister”) is typically positioned above/after the packing and scrubbing liquid supply. Any scrubbing liquid and wetted PM entrained in the exiting gas stream will be removed by the mist eliminator and returned to drain through the packed bed.

In a packed-bed scrubber, high PM concentrations can clog the bed, hence the limitation of these devices to streams with relatively low dust loadings. Plugging is a serious problem for packed-bed scrubbers because the packing is more difficult to access and clean than other scrubber designs. Mobile-bed scrubbers are available that are packed with low-density plastic spheres that are free to move within the packed bed. These scrubbers are less susceptible to plugging because of the increased movement of the packing material. In general, packed-bed scrubbers are more suitable for gas scrubbing than PM scrubbing because of the high maintenance requirements for control of PM (EPA, 1998).

Advantages:

Advantages of packed-bed towers include (AWMA, 1992):

1. Relatively low pressure drop;
2. Fiberglass-reinforced plastic (FRP) construction permits operation in highly corrosive atmospheres;
3. Capable of achieving relatively high mass-transfer efficiencies;
4. The height and/or type of packing can be changed to improve mass transfer without purchasing new equipment;
5. Relatively low capital cost;
6. Relatively small space requirements; and
7. Ability to collect PM as well as gases.

Disadvantages:

Disadvantages of packed-bed towers include (AWMA, 1992):

1. May create water (or liquid) disposal problem;
2. Waste product collected wet;
3. PM may cause plugging of the bed or plates;
4. When FRP construction is used, it is sensitive to temperature; and

5. Relatively high maintenance costs.

Other Considerations:

For gas absorption, the water or other solvent must be treated to remove the captured pollutant from the solution. The effluent from the column may be recycled into the system and used again. This is usually the case if the solvent is costly (e.g., hydrocarbon oils, caustic solutions, amphiphilic block copolymer). Initially, the recycle stream may go to a treatment system to remove the pollutants or the reaction product. Make-up solvent may then be added before the liquid stream reenters the column (EPA, 1996a).

For PM applications, wet scrubbers generate waste in the form of a slurry. This creates the need for both wastewater treatment and solid waste disposal. Initially, the slurry is treated to separate the solid waste from the water. The treated water can then be reused or discharged. Once the water is removed, the remaining waste will be in the form of a solid or sludge. If the solid waste is inert and nontoxic, it can generally be landfilled. Hazardous wastes will have more stringent procedures for disposal. In some cases, the solid waste may have value and can be sold or recycled (EPA, 1998).

Configuring a control device that optimizes control of more than one pollutant often does not achieve the highest control possible for any of the pollutants controlled alone. For this reason, waste gas flows which contain multiple pollutants (e.g., PM and SO_2, or PM and inorganic gases) are generally controlled with multiple control devices, occasionally more than one type of wet scrubber (EC/R, 1996).

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EPA, 1998. U.S. EPA, Office of Air Quality Planning and Standards, “Stationary Source Control Techniques Document for Fine Particulate Matter,” EPA-452/R-97-001, Research Triangle Park, NC, October, 1998.

Australian Government
Department of Sustainability, Environment, Water, Population and Communities

National Pollutant Inventory

Emission estimation technique manual
for

Galvanizing Version 2.0
July 2012

First published in December 1999

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Disclaimer

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While reasonable efforts have been made to ensure the contents of this manual are factually correct, the Australian Government does not accept responsibility for the accuracy or completeness of the contents and shall not be liable for any loss or damage that may be occasioned directly or indirectly through the use of, or reliance on, the contents of this manual.

EMISSION ESTIMATION TECHNIQUES
FOR
GALVANIZING
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GALVANIZING

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1 Introduction

The purpose of all emission estimation technique (EET) manuals is to assist Australian manufacturing, industrial and service facilities to report emissions of listed substances to the National Pollutant Inventory (NPI). This manual describes the procedures and recommended approaches for estimating emissions and transfers from Australian galvanizing operations.

EET MANUAL	Galvanizing
ANZSIC CODE 2006	2293: Metal coating and finishing

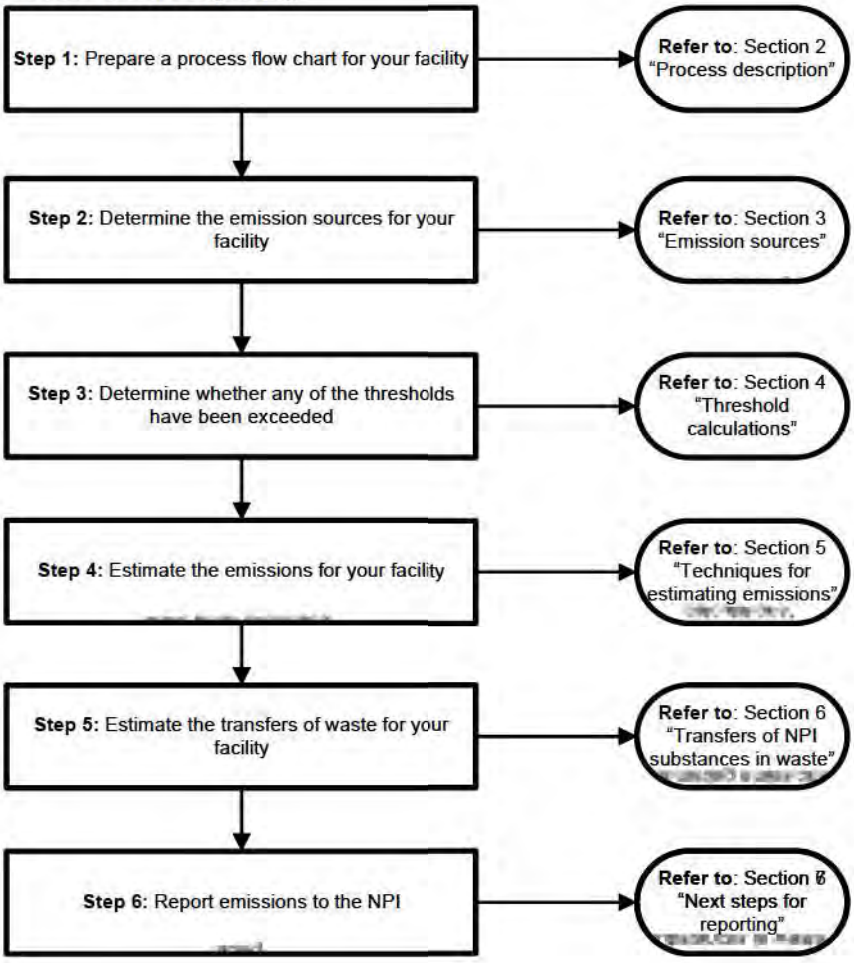
Note that the ANZSIC code is part of NPI reporting requirements. The *NPI Guide* contains an explanation of the ANZSIC code.

This manual has been developed through a process of national consultation involving state and territory environmental agencies and key industry stakeholders. Particular thanks are due to the Galvanizers Association of Australia (GAA)

1.1 Process for NPI reporting

The process for NPI reporting is outlined in the following flow chart:

Figure 1: Process for NPI Reporting



1.2 Information required to produce an annual NPI report

The following information is needed for the reporting period:

- Amount of acid, zinc and other NPI substances used at the facility during the reporting period.

If any fuel burning equipment has been used on the facility, including on-site vehicles, additional data will need to be collated:

- type and amount of fuel burned
- pollution control devices employed, and
- volume and throughput of fuels or organic liquids stored on-site.

1.3 Additional reporting materials

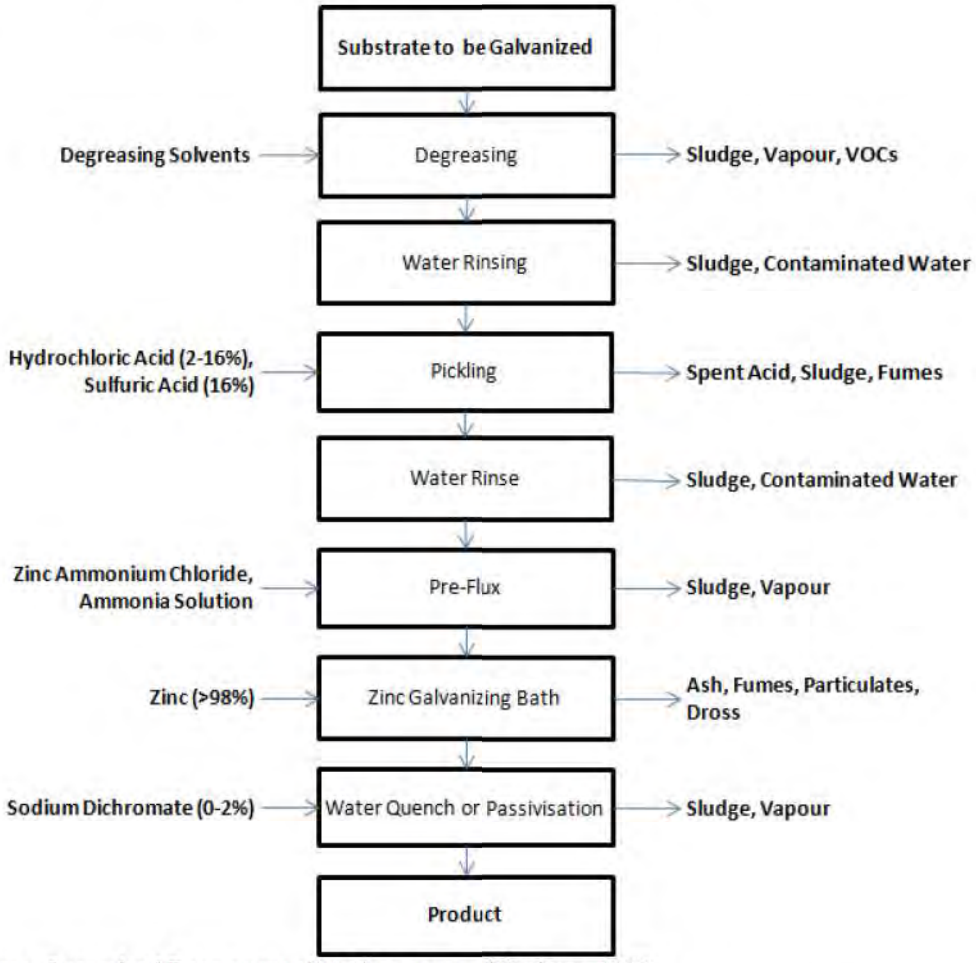
This manual is written to reflect the common practices employed in Australian galvanizing operations. In some cases it may be necessary to refer to other EET manuals to ensure a complete report of the emissions for the facility can be made. Other applicable EET manuals are listed in Section 7.

2 Process description

Galvanizing is a process undertaken to coat ferrous metals and metal products in a layer of zinc to prolong their life. The metal to be coated requires pre-treatment prior to being immersed into the zinc bath in order to remove rust, grease and other materials, and therefore to promote the galvanizing process. Pre-treatment can include treatment of the metal with an alkaline degreasing solution, an acid pickling solution, water rinse, and a pre-flux solution. The pre-flux solution is usually comprised of zinc ammonium chloride ($ZnCl_2.3NH_4Cl$), and is used to promote the zinc-metal bond. After pre-treatment, the metal is immersed in molten zinc followed by a quench bath.

1 shows a basic galvanizing flow diagram and some expected emission points. As each galvanizing facility in Australia is unique, you are encouraged to develop flow diagrams for your operation that detail the input of materials and NPI listed substances and the emissions resulting from the operation of each process.

Figure 2: The basic galvanizing process steps and likely emission points



Source: Queensland Department of Environment and Heritage, 1998.

Many of the emissions produced by the galvanizing process can be contained, captured, treated and/or recycled either back into the process or turned into other useful material.

For example, ash and dross are generally processed on site to extract zinc which is then remelted into galvanizing bath or recycled off-site and made into zinc powders which go into other products, such as paint, make-up, etc.

3 Emission sources

This section describes the raw material inputs, the equipment used and the processes employed that result in emissions of NPI listed substances in the galvanizing process. This section also provides a concise description of the potential fate (to air, land, and water) of these emissions.

Galvanizing generally produces emissions to air as well as waste containing NPI substances. Hydrochloric acid (HCl) and sulfuric acid (H_2SO_4) fumes may be emitted from process tanks, while ammonia and ammonium chloride emissions to air can occur from the pre-flux solution and during the immersion of steel into the galvanizing bath. Zinc and PM_{10} emissions (particulate matter with an equivalent aerodynamic diameter of 10 micrometres or less ie. $\leq 10\mu m$) may result from hot dip metal coating activities.

Waste liquids may be generated from spent pre-treatment solutions and sometimes from quenching activities after galvanizing; it is expected that pollutants are captured on site and transferred off-site under a trade waste agreement or via approved waste disposal contractors (i.e. no emissions are expected). The process tanks usually contain metal salts, acids, bases, and dissolved base materials.

The galvanizing process also generates solid wastes. Solid wastes include a zinc oxide ash that is periodically removed from the surface of the galvanizing bath and zinc iron alloy dross removed from the bottom of the galvanizing bath, as well as solids in spent solutions and wastewater treatment sludge. Characterisation of these wastes may be required when estimating emissions using the mass balance approach (see Section 5).

Table 1 summarises the raw material inputs and the emissions of NPI substances that could be generated during the galvanizing process.

Galvanizing may involve the use and handling of a number of NPI listed substances. These substances commonly include zinc and compounds (e.g. zinc ammonium chloride), chromium (VI) compounds, hydrochloric acid, sulfuric acid, chlorine, and ammonia.

If Category 2a or 2b is tripped, the facility is required to report emissions from the burning of fuel. Emissions from combustion will need to be evaluated at galvanizing facilities where boilers are used, for example to heat a zinc bath. The *Combustion in Boilers EET Manual* can be used to calculate these emissions from boilers. Surface coating emissions that may occur can be evaluated using the *Surface Coating EET Manual*.

Table 1 - Material inputs and emissions from galvanizing processes

Process	Material input	Emissions to air	Solid waste emissions[B]	General Management of Emissions
Degreasing	Substrate to be galvanised, alkaline degreasing solution	• VOCs • steam[A]	Process sludges Caustic sludge containing zinc	Sludges disposed of as controlled/prescribed wastes
Pickling	Substrate to be galvanized Acid pickling solution, hydrochloric acid sulfuric acid	• hydrochloric acid • sulfuric acid	Process sludges	Spent acid disposed of as controlled/prescribed waste[C]
Water rinses	Rinse water and substrate to be galvanised		Zinc and other metal sludges	Sludges disposed of as controlled/prescribed wastes
Pre-flux	Substrate to be galvanized Zinc ammonium chloride ammonia solution	• ammonia, • ammonium chloride • steam[A]	Zinc and other metal sludges	Sludges disposed of as controlled/prescribed wastes
Galvanizing bath	Substrate to be galvanized Zinc, alloys, metal salts, acids	• hydrochloric acid, • ammonia, • ammonium chloride, • zinc oxide, • zinc chloride, • particulate matter, • lead oxide, • copper oxide, • chlorine	Zinc oxide ash, zinc iron alloy dross	Reprocessing of ash and dross for zinc content[D]
Quenching	Sodium dichromate	• Steam[A]	Zinc and other metal sludges	Sludges and solutions disposed of as controlled/prescribed wastes
Heating of galvanizing bath	Fuel	• VOCs, • oxides of nitrogen, • particulate matter, • sulfur dioxide		Released to atmosphere[E]

Source: Queensland Department of Environment and Heritage, 1998.

A. Non NPI substance
B. May result in the transfers of NPI substances
C. There is some but limited collection and treatment of acid fumes and spent acid up to this manual's date.
D. A number of facilities also have a hood over the galvanizing bath capturing emissions to air
E. Some facilities recycle heat to other parts of the galvanizing process

4 Threshold calculations

The NPI has six different threshold categories. The *NPI Guide* outlines each of these. Further information on these thresholds can be found in the *NPI Guide*.

The following example demonstrates how thresholds are related to the reporting requirement for Category 1. The usage of each of the substances listed as Category 1 under the NPI must be estimated to determine whether the 10 tonnes reporting threshold is exceeded. If the threshold of a Category 1 substance is exceeded, emissions of that substance from the facility (for all sources) must be reported, even if the emissions of the substances are very low or zero.

Example 1: Assessing thresholds

A galvanizing facility uses the following NPI substances in the 12 month reporting period:

- 530 tonnes hydrochloric acid
- 400 kg per year of chromium VI compounds (hexavalent chromium), and
- 1,100 tonnes per year of zinc and compounds.

In addition, the facility combusts 18,000,000 MJ natural gas to heat the zinc galvanizing bath.

From the *NPI Guide*, based on the NPI categories and their associated thresholds, the facility is required to estimate and report:

Emissions and transfers of:

- Hydrochloric acid (as ≥10 tonnes of this Category 1 substance is used in the reporting year)'
- Zinc and zinc compounds (as ≥10 tonnes of this Category 1 substance is used in the reporting year), and

Emissions of:

- Category 2a substances as a result of exceeding the combustion threshold (combustion of 400 tonnes, or 17,800,000 MJ natural gas). These substances include carbon monoxide, fluoride and compounds, hydrochloric acid, oxides of nitrogen, particulate matter ≤2.5 µm, particulate matter ≤10 µm, polycyclic aromatic hydrocarbons, sulfur dioxide, and total volatile organic compounds.

The facility is not required to report emissions of chromium VI and compounds as use of this substance does not exceed the reporting threshold (10 tonnes per year).

5 Techniques for estimating emissions

Emissions to air, land and water for every NPI substance that trips a threshold must be reported from all point and fugitive sources at the facility. These are reported as "total point" and "total fugitive" emission sources. The *NPI Guide* provides detailed information on thresholds and identifying emission.

There are five types of emission estimation techniques (EETs) that may be used to estimate emissions from your facility. These are:

- sampling data or direct measurement
- mass balance
- fuel analysis or engineering calculations
- emission factors, *or*
- an approved alternative.

Generally, galvanizing facilities report emissions for hydrochloric acid using the emission factor method, however some facilities report hydrochloric acid emissions using direct measurement, engineering calculations, mass balance calculations or by an approved alternative technique. The emission factor method, engineering calculation and mass balance calculations are briefly described in this section. Information on the other emission estimation techniques can be found in the *NPI Guide*.

If you estimate emissions by using any of these EETs, your data will be displayed on the NPI database as being of "acceptable reliability". Similarly, if your state or territory environmental agency has approved the use of EETs that are not outlined in this manual, your data will also be displayed as being of acceptable reliability.

This manual seeks to provide the most effective emission estimation techniques for the NPI substances relevant to the galvanizing industry. The absence of an EET for a substance in the manual does not imply that an emission should not be reported to the NPI. The obligation to report on all relevant emissions remains if reporting thresholds have been exceeded.

You should note that the EETs presented in this manual relate principally to average process emissions. Emissions resulting from non-routine events are rarely discussed in the literature, and there is a general lack of EETs for such events. However, it is important to recognise that emissions resulting from significant operating excursions and/or accidental situations (e.g. spills) will also need to be estimated. Emissions to land, air and water from spills must be estimated and added to process emissions when calculating total emissions for reporting purposes.

The emission resulting from a spill is the net emission, i.e. the quantity of the NPI reportable substance spilled, less the quantity recovered or consumed immediately (within 24 hours) during clean up operations.

5.1 Direct measurement

Direct measurement involves monitoring and recording emissions of a particular substance at either a point in time or on a continual basis. Many facilities are required to directly measure specific substances as a result of their licensing requirements of their state/territory environment agency. Stack sampling test reports often provide emissions data in terms of kg/hr or grams/m^3 $_{STP\ dry}$ (dry standard cubic metre). Annual emissions for NPI reporting can be calculated from this data using Equations 1 or 2 below.

Stack tests for NPI reporting should be performed under representative (i.e. normal) operating conditions, and in accordance with the methods, or standards, approved by the relevant environmental authority. Tests conducted specifically for the NPI may differ from stack tests undertaken for a State or Territory licence condition, which may require the test be taken under maximum emissions rating (i.e. where emissions are likely to be higher than when operating under normal operating conditions). However, the acceptability of using existing monitoring program data and test methods should be checked with your local environmental regulatory authority.

This Section shows how to calculate emissions in kg/hr based on stack sampling data, and how to convert this to an annual emission figure. Calculations involved in determining PM_{10} emissions are used as an example, although the same general methodology is applicable for most of the substances listed on the NPI.

Equation 1

C_{PM10} = $C_f / V_{m,\ STP}$

where:

C_{PM10} = concentration of PM_{10} or gram loading (g/m^3)
C_f = filter catch (g)
$V_{m,STP}$ = metered volume of sample at STP (m^3), dry.
STP = standard temperature and pressure. 1 atmosphere (101.325) kPa and 273 °K.

If a mass concentration of a gas (C_{gas}) is obtained directly by measurement, results will be in units g/m^3, or converted from units such as g/m^3, or parts per million by volume (ppmv), which may be on a wet or dry basis.)

Equation 2

E_{PM10} = $C_{PM} \times Q_d \times 3.6 \times (1 - CE_{PM10})$

where:

E_{PM10} = hourly emissions of PM_{10} in kg/hr
Q_d = stack gas volumetric flow rate (m^3 STP,dry/s)
3.6 = 3,600 seconds per hour multiplied by 0.001 kilograms per gram
CE_{PM10} = Control efficiency for PM_{10} (%)

Any facility using direct measurement may use this data as the basis of their NPI report.

Efficiency rates for different control devices can be found in the NPI Emission estimation technique manual for combustion in boilers.

5.2 Mass balance

A description of the mass balance method is given in the *NPI Guide.*Calculating emissions from galvanizing facilities using mass balance can be a straightforward approach to emissions estimation. However, it is likely that few Australian facilities consistently track material usage and waste generation with the overall accuracy needed for application of this method. Inaccuracies associated with individual material tracking, or other activities inherent in each material handling stage, can result in large deviations for total facility emissions. As emissions from specific materials are typically below 2% of gross consumption, an error of only ± 5% in any one step of the operation can significantly affect emission estimations.

5.3 Engineering calculations

An engineering calculation is an estimation method based on physical/chemical properties (e.g. vapour pressure) of the substance and mathematical relationships. A more complete discussion of this method is given in the *NPI Guide*.

5.4 Emission factors

An emission factor is a tool that is used to estimate emissions to the environment. In this manual, it relates to the quantity of a substance emitted from the galvanizing process. Emission factors are expressed as kilograms of emission per tonne of activity.

Example 2 illustrates the use of emission factors and control efficiencies in estimating emissions using Equation 3.

Equation 3

$$E_{kpy,i} = A \times EF_i \times CE_i$$

where :

$E_{kpy,i}$	=	annual emissions of pollutant i, kg/yr
A	=	activity rate, tank/yr
EF_i	=	uncontrolled emission factor of pollutant i, kg/tank
CE_i	=	Control efficiency for substance i (%)

Modern galvanizing plants with properly shielded acid baths may use a control efficiency of 75% for acid emissions.

Tables 3 and 4 in Appendix B provide emission factors for the hot dip galvanizing process.

Example 2: Calculating emissions using emission factors

From example 1, Facility A has determined that they have a requirement to report emissions and transfers of hydrochloric acid and zinc and compounds, as well as emissions of Category 2a substances.

Hydrochloric acid:
The facility operates three acid tanks which have a surface area each of 20 m^2, using hydrochloric acid at an average concentration of 12%w/v. The ambient temperature of the solution in the acid tank is 25°C. The facility has proper shielding on the acid tanks to reduce emissions.

Using Equation 3:

EF_{HCl}	=	Emission factor for hydrochloric acid (from Table 3)
A_{HCl}	=	Number of acid tanks
E_{kpyHCl}	=	A_{HCl} x EF_{HCl} x (1 – 75%)
	=	3 x 369.6 x 0.25
	=	278 kg/yr

Zinc and compounds:

EF_{Zinc}	=	Emission factor for zinc and compounds (from Table 5)
A_{Zinc}	=	tonnes of zinc used per year
$E_{kpyZinc}$	=	A_{Zinc} x EF_{Zinc} x (1 – 0%)
	=	1,100 $t_{Zinc/yr}$ x 2.0 kg/t_{Zinc} x 1
	=	2,200 kg/yr

Category 2a substances:
The facility burns natural gas using a boiler with capacity <30MW. Using the *Combustion in Boilers EET manual*, the facility estimates emissions of the Category 2a substance.

The facility is required to report to the NPI:

- Amount of fuel burnt: 18,000,000MJ of natural gas
- Hydrochloric acid: 278 kg/yr
- Zinc and compounds: 2,200 kg/yr, and
- Emissions of Category 2a substances.

As the facility exceeded the reporting threshold for hydrochloric acid (10 tonnes) and zinc and compounds (10 tonnes), the facility must also consult Section 6 to determine if it is necessary to report transfers of waste for these substances.

5.5 Approved alternative

You are able to use emission estimation techniques that are not outlined in this document. You must, however, seek the consent of your state or territory environmental agency. For example, if your company has developed site-specific emission factors, you may use these if they have been approved by your local environmental agency.

6 Transfers of NPI substances

The NPI requires the mandatory reporting of NPI substances that are transferred in waste to a final destination. Transfers are required to be reported if a Category 1, Category 1b or Category 3 reporting threshold is exceeded. For example, if the threshold has been exceeded for a Category 1 substance as a result of use onsite, transfers to a final destination of that substance, as well as emission are reportable. Both emissions and transfers are reportable in kilograms.

There is no requirement to report transfers of substances that are exclusively Category 2a or 2b (i.e. not also listed as Category 1 substances). There is no requirement to report emissions of substances which are both Category 1 and Category 2a or 2b if they have been tripped only by the fuel and energy use threshold. Transfers of NPI substances contained in overburden, waste rock, uncontaminated soil or rock removed in construction or road building, or soil used in capping of landfills are also not reportable.

Reporting of transfers is required if wastes are transported to a destination for containment or destruction which includes:

- a destination for containment including landfill, tailings storage facility, underground injection or other long term purpose-built waste storage facility
- an off-site destination for destruction
- an off-site sewerage system, and
- an off-site treatment facility which leads solely to one or more of the above.

A containment destination may be on site, for example a tailings storage facility on-site, or off-site, for example waste going to landfill. The transport or movement of substances contained in waste to a sewerage system is also included.

The transfer of NPI substances to a destination for reuse, recycling, reprocessing, purification, partial purification, immobilisation, remediation or energy recovery can be reported voluntarily. This is an opportune way for facilities to promote good news stories to their local community.

Further information regarding transfers of waste, including how to estimate and report, can be found in the *NPI Guide and Transfers Information Booklet*.

Table 2: Transfers reporting requirements

Waste stream containing NPI substances	Reporting requirements
Liquid waste discharged to sewer system	Reporting is mandatory Discharge of NPI substance to a mandatory reporting transfer destination.
Solid waste sent to landfill	Reporting is mandatory Discharge of NPI substance to a mandatory reporting transfer destination.
Waste sent for recycling or reprocessing	Reporting is voluntary Reuse of waste containing NPI substances, reporting is voluntary

As previously noted, if transferring waste containing NPI substances to a mandatory reporting destination, it is necessary to determine the amount of the NPI substance(s) in that waste. If the usage threshold for that substance has been tripped (for Categories 1, 1b or 3), and the transfer is to a mandatory reporting transfer destination, then reporting is required.

If your facility has exceeded the threshold and is required to report transfers, only the amount of the actual substance(s) transferred is reportable. You should report only the amount of NPI substances in the waste, not the total waste, for example, a facility generates 1 ton of a waste slurry which is sent off-site for treatment for destruction. The waste slurry contains 1kg of lead oxide with the rest of the slurry made up of non-NPI substance. This means that the facility would need to report 1kg of lead oxide, rather than the entire mass of waste slurry.

Example 3: Reporting transfers of NPI substances in waste

Facility A has exceeded the Category 1 reporting threshold for hydrochloric acid and zinc and compounds, and therefore has a requirement to report both emissions and transfers of this substance.

Facility A transferred the following:

Hydrochloric acid: 150,000 tonnes, and
Zinc and compounds (as ash and dross): 60 tonnes.

Hydrochloric acid is taken by a waste contractor for recycling and reprocessing.
Zinc and compounds is taken by a different waste contractor who disposes of the material to landfill.

It is voluntary to report transfers of hydrochloric acid as it is recycled/reprocessed.

It is mandatory to report transfers of waste of zinc and compounds as this substance has been disposed of with no further use.

7 Additional reporting information

This manual has been written to reflect the common processes employed in galvanizing activities. To ensure a complete report of the emissions and transfers of waste for your facility, it may be necessary to refer to other EET manuals. These include but are not limited to:

- *Combustion in Boilers*
- *Combustion Engines*
- *Fuel and Organic Liquid Storage, and*
- *Fugitive Emissions*

For details on how to report substance emissions and transfers from your facility, refer to *NPI Guide.*

8 References

ANZSIC: Australian and New Zealand Standard Industrial Classification, Australian Bureau of Statistics and Statistics New Zealand 2006, ABS Catalogue 1292.0

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The following Emission Estimation Technique Manuals can be downloaded from the NPI homepage, (http://www.environment.gov.au/epg/npi/home.html) or obtained from your local environmental protection agency (see the front of the NPI Guide for details):

- Emission Estimation Technique Manual for Combustion in Boilers
- Emission Estimation Technique Manual for Combustion Engines
- Emission Estimation Technique Manual for Fuel & Organic Liquid Storage
- Emission Estimation Technique Manual for Surface Coating, and
- Emission Estimation Technique Manual for Electroplating and Anodising.

Appendix A: Definitions and abbreviations

Term	Definition
ANZSIC	Australian and New Zealand Standard Industrial Classification
EET	emission estimation technique
EFR	emission factor rating
Emission	Release of a substances to the environment
Facility	any building or land from which a substance may be emitted, together with any machinery, plant, appliance, equipment, implement, tool or other item used in connection with any activity carried out at the facility
kg	kilogram
tonne	1,000 kilograms

Appendix B: emission factors

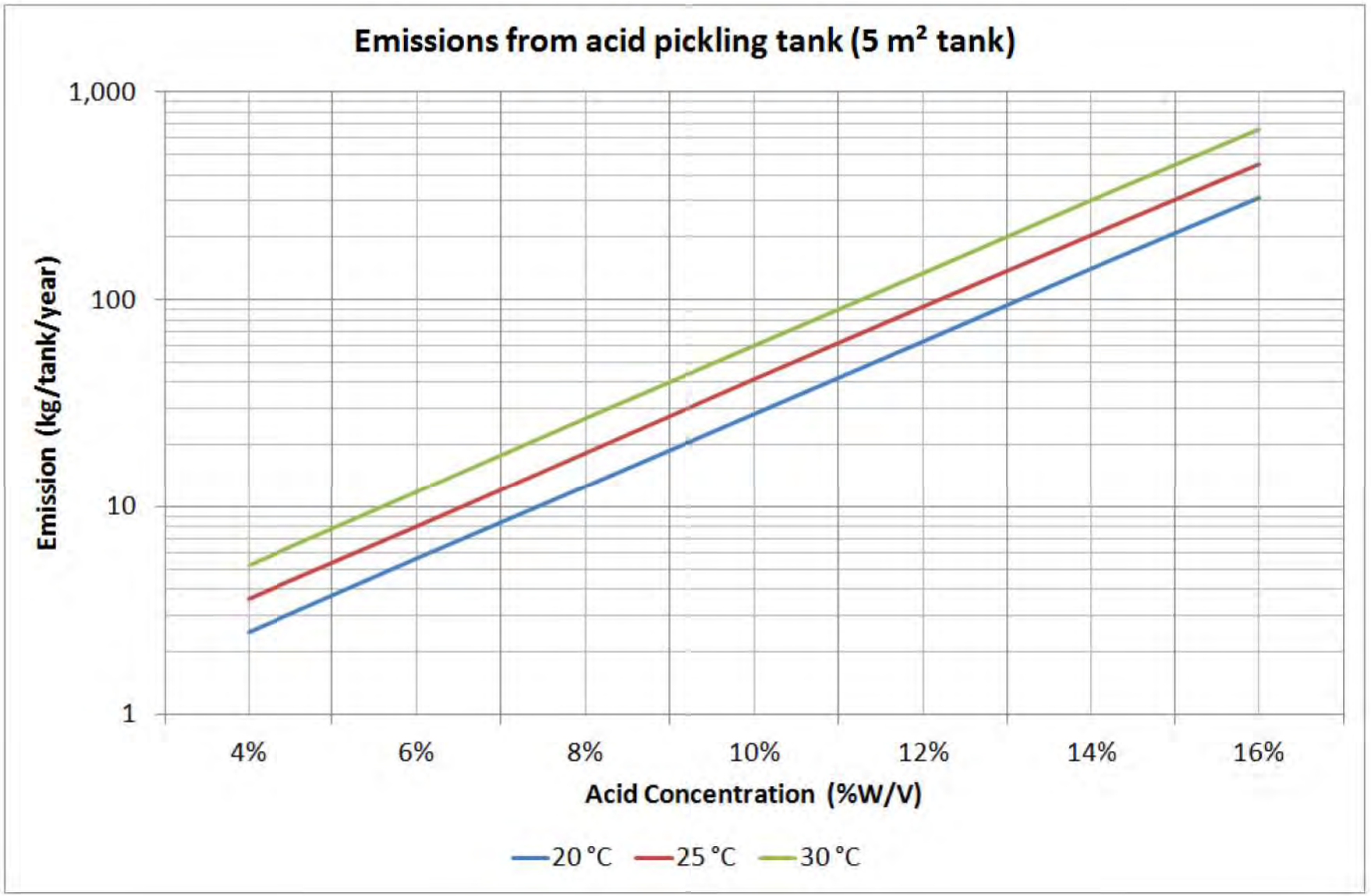
Table 3: Emission factors - acid pickling - hydrochloric acid [A,B,C,D]

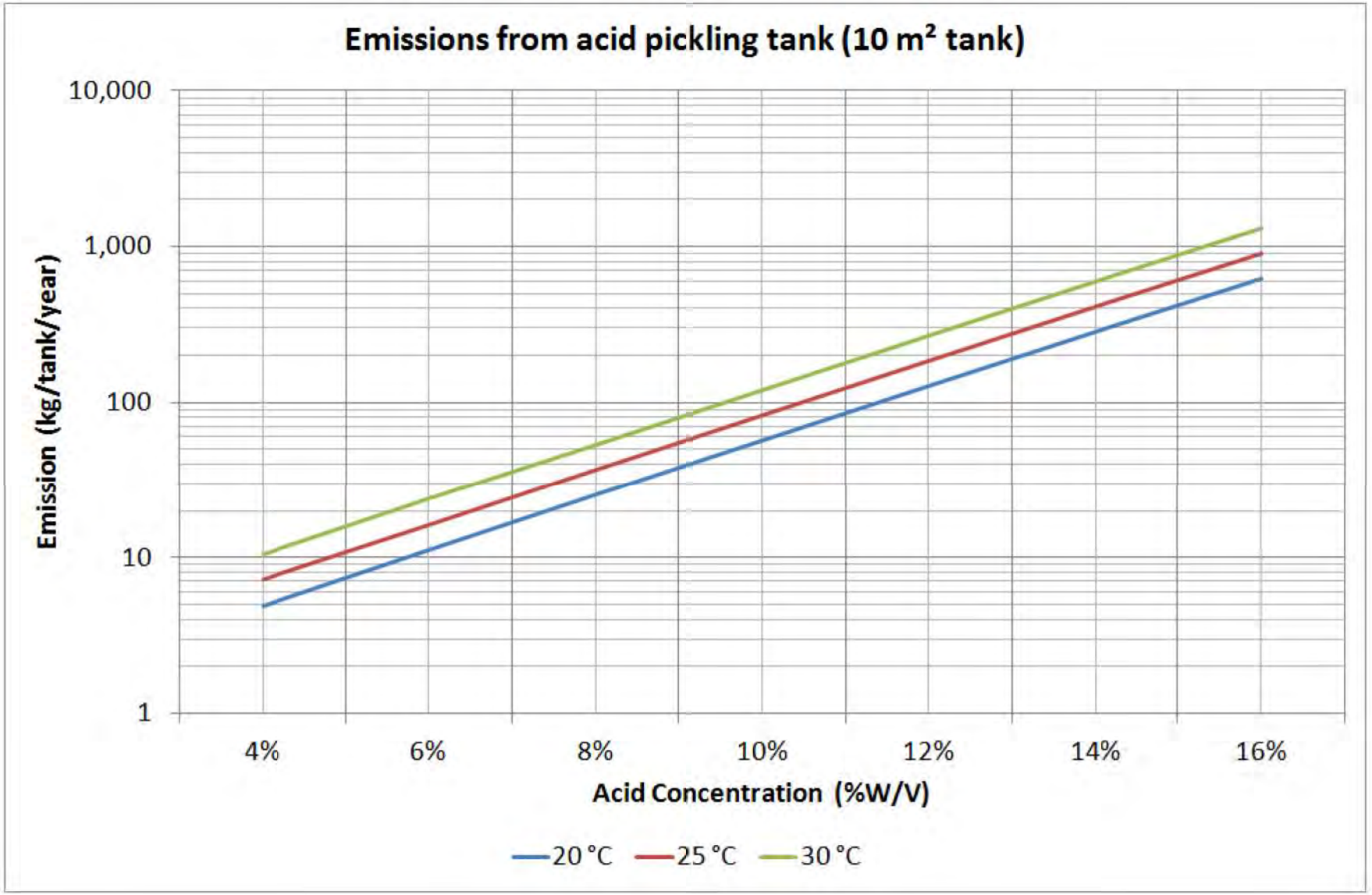
Acid Concentration (% w/v)	Tank Size (m^2)	Solution Temperature (°C)	Emission Factor (kg/tank /year)	Emission Factor (kg/tank /month)
4	5	20	2.5	0.2
4	5	25	3.6	0.3
4	5	30	5.2	0.4
4	10	20	4.9	0.4
4	10	25	7.2	0.6
4	10	30	10.4	0.9
4	15	20	7.4	0.6
4	15	25	10.7	0.9
4	15	30	15.6	1.3
4	20	20	9.9	0.8
4	20	25	14.3	1.2
4	20	30	20.8	1.7
4	25	20	12.3	1
4	25	25	17.9	1.5
4	25	30	26	2.2
6	5	20	5.6	0.5
6	5	25	8.1	0.7
6	5	30	11.8	1
6	10	20	11.2	0.9
6	10	25	16.3	1.4
6	10	30	23.7	2
6	15	20	16.8	1.4
6	15	25	24.4	2
6	15	30	35.5	3
6	20	20	22.4	1.9
6	20	25	32.6	2.7
6	20	30	47.4	4
6	25	20	28	2.3
6	25	25	40.7	3.4
6	25	30	59.2	4.9
8	5	20	12.7	1.1
8	5	25	18.4	1.5
8	5	30	26.8	2.2
8	10	20	25.3	2.1
8	10	25	36.8	3.1
8	10	30	53.6	4.5
8	15	20	38	3.2
8	15	25	55.2	4.6
8	15	30	80.3	6.7
8	20	20	50.6	4.2
8	20	25	73.6	6.1
8	20	30	107.1	8.9
8	25	20	63.3	5.3
8	25	25	92	7.7
8	25	30	133.9	11.2

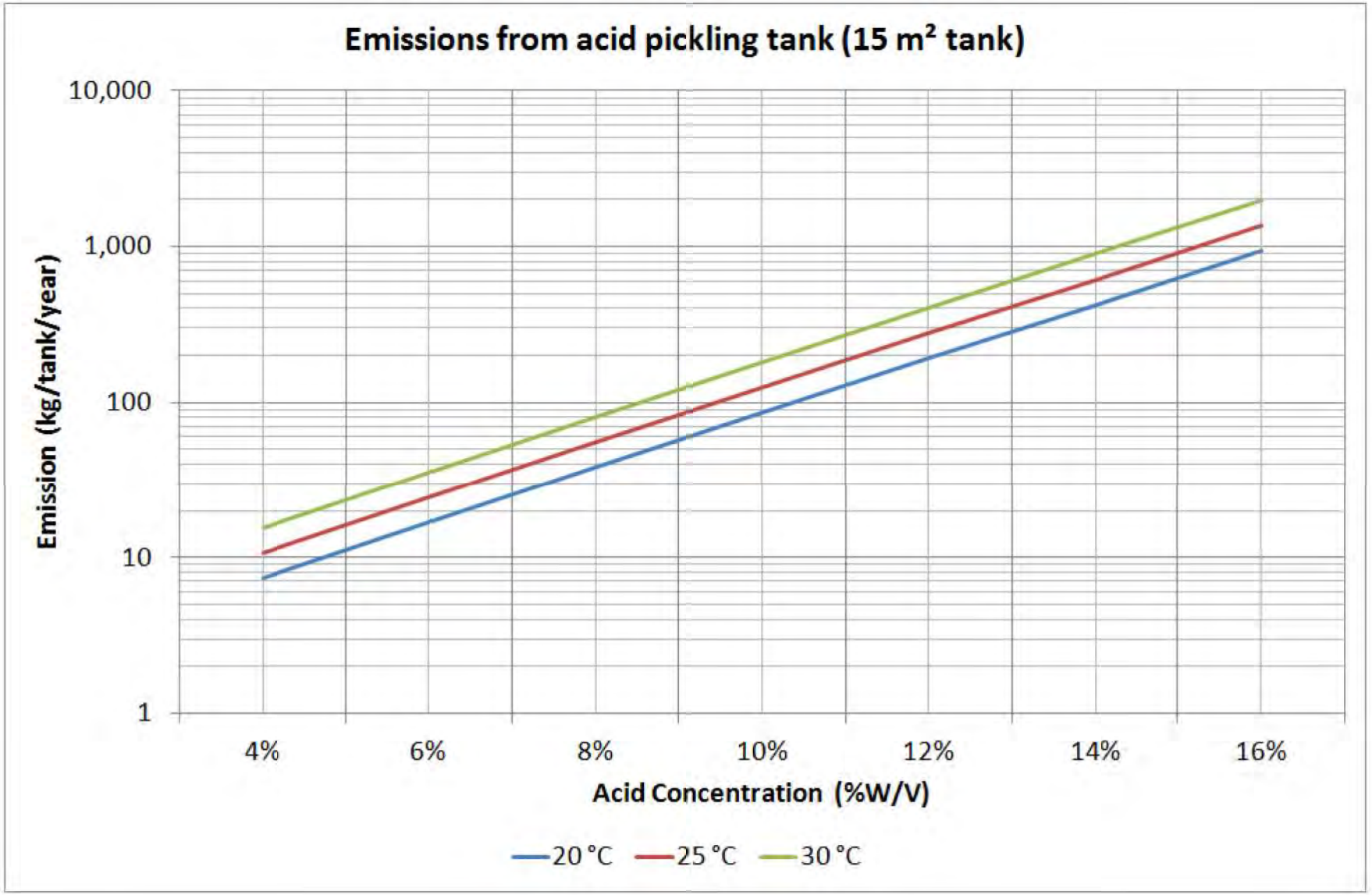
Acid Concentration (% w/v)	Tank Size (m^2)	Solution Temperature (°C)	Emission Factor (kg/tank /year)	Emission Factor (kg/tank /month)
10	5	20	28.4	2.4
10	5	25	41.4	3.5
10	5	30	60.2	5
10	10	20	56.8	4.7
10	10	25	82.7	6.9
10	10	30	120.4	10
10	15	20	85.2	7.1
10	15	25	124.1	10.3
10	15	30	180.6	15.1
10	20	20	113.6	9.5
10	20	25	165.5	13.8
10	20	30	240.8	20.1
10	25	20	142.1	11.8
10	25	25	206.8	17.2
10	25	30	301	25.1
12	5	20	63.4	5.3
12	5	25	92.4	7.7
12	5	30	134.6	11.2
12	10	20	126.9	10.6
12	10	25	184.8	15.4
12	10	30	269.1	22.4
12	15	20	190.3	15.9
12	15	25	277.2	23.1
12	15	30	403.6	33.6
12	20	20	253.7	21.1
12	20	25	369.6	30.8
12	20	30	538.2	44.9
12	25	20	317.2	26.4
12	25	25	462	38.5
12	25	30	672.7	56.1
14	5	20	140.8	11.7
14	5	25	205.2	17.1
14	5	30	299	24.9
14	10	20	281.6	23.5
14	10	25	410.4	34.2
14	10	30	597.9	49.8
14	15	20	422.4	35.2
14	15	25	615.6	51.3
14	15	30	896.9	74.7
14	20	20	563.2	46.9
14	20	25	820.8	68.4
14	20	30	1195.9	99.7
14	25	20	704	58.7
14	25	25	1026	85.5
14	25	30	1494.8	124.6

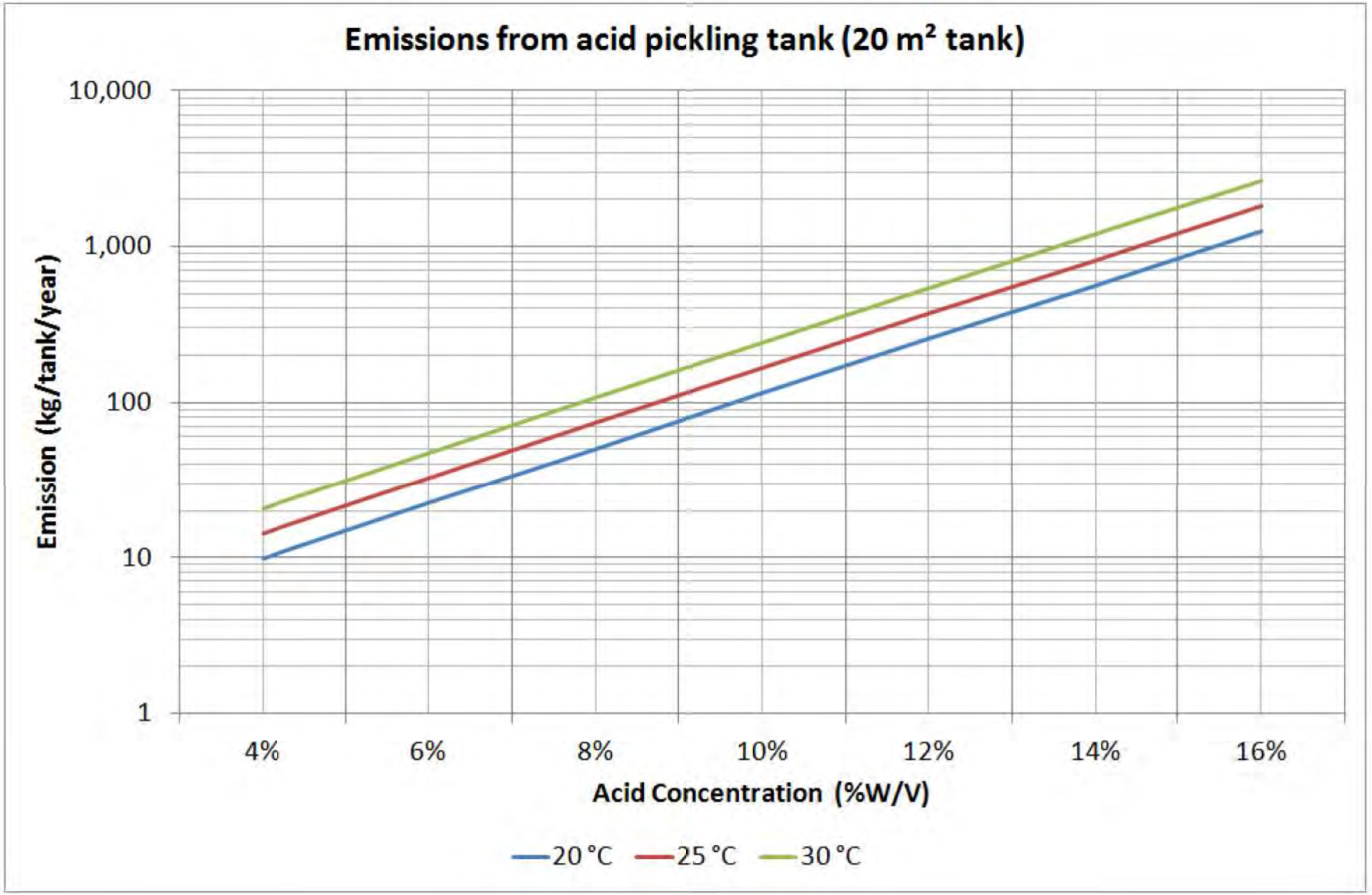
Acid Concentration (% w/v)	Tank Size (m^2)	Solution Temperature (°C)	Emission Factor (kg/tank /year)	Emission Factor (kg/tank /month)
16	5	20	310.8	25.9
16	5	25	453.1	37.8
16	5	30	660.6	55.1
16	10	20	621.5	51.8
16	10	25	906.2	75.5
16	10	30	1321	110.1
16	15	20	932.3	77.7
16	15	25	1359.3	113.3
16	15	30	1981.6	165.1
16	20	20	1243	103.6
16	20	25	1812.5	151
16	20	30	2642.1	220.2
16	25	20	1553.8	129.5
16	25	25	2265.6	188.8
16	25	30	3302.6	275.2

A. Derived from Texas Commission on Environmental Quality (TCEQ), Calculations Package, Hot Dip Galvanizing, and Based on lab work by Esco Engineering, the equation was derived from a similar associative equation in a 1980 paper by R.M. Hudson and C.J. Warning called "Factors influencing the Pickling Rate of Hot-Rolled Low-Carbon Steel in Sulfuric and Hydrochloric Acids". The constants used were calculated using correlative data from 24 samples of experiments conducted by Esco Engineering
B. All emission factors are rated U
C. Emissions factors are per tank per year.
D. Emission factors are uncontrolled. If controls are used (such as suppressants, hoods of other abatement), the emission factor should be adjusted by the percentage efficiency of any such control. Modern galvanizing plants with properly shielded acid baths may use a control efficiency of 75% for acid emissions.
E. Emissions factors assume a constant concentration; facilities should use the average concentration in the tanks to determine which factor to use. (For example, the starting concentration of the tank may be 14%, however due to the consumption of acid during the process, the average concentration in the tank over the year may be 10%)


Emissions from acid pickling tank (5 m² tank)
1,000
100
10
1
Emission (kg/tank/year)
4%
6%
8%
10%
12%
14%
16%
Acid Concentration (%W/V)
20 °C
25 °C
30 °C


Emissions from acid pickling tank (10 m² tank)
10,000
1,000
100
10
1
Emission (kg/tank/year)
4%
6%
8%
10%
12%
14%
16%
Acid Concentration (%W/V)
20 °C
25 °C
30 °C


Emissions from acid pickling tank (15 m² tank)
10,000
1,000
100
10
1
Emission (kg/tank/year)
4%
6%
8%
10%
12%
14%
16%
Acid Concentration (%W/V)
20 °C
25 °C
30 °C


Emissions from acid pickling tank (20 m² tank)
10,000
1,000
100
10
1
Emission (kg/tank/year)
4%
6%
8%
10%
12%
14%
16%
Acid Concentration (%W/V)
20 °C
25 °C
30 °C

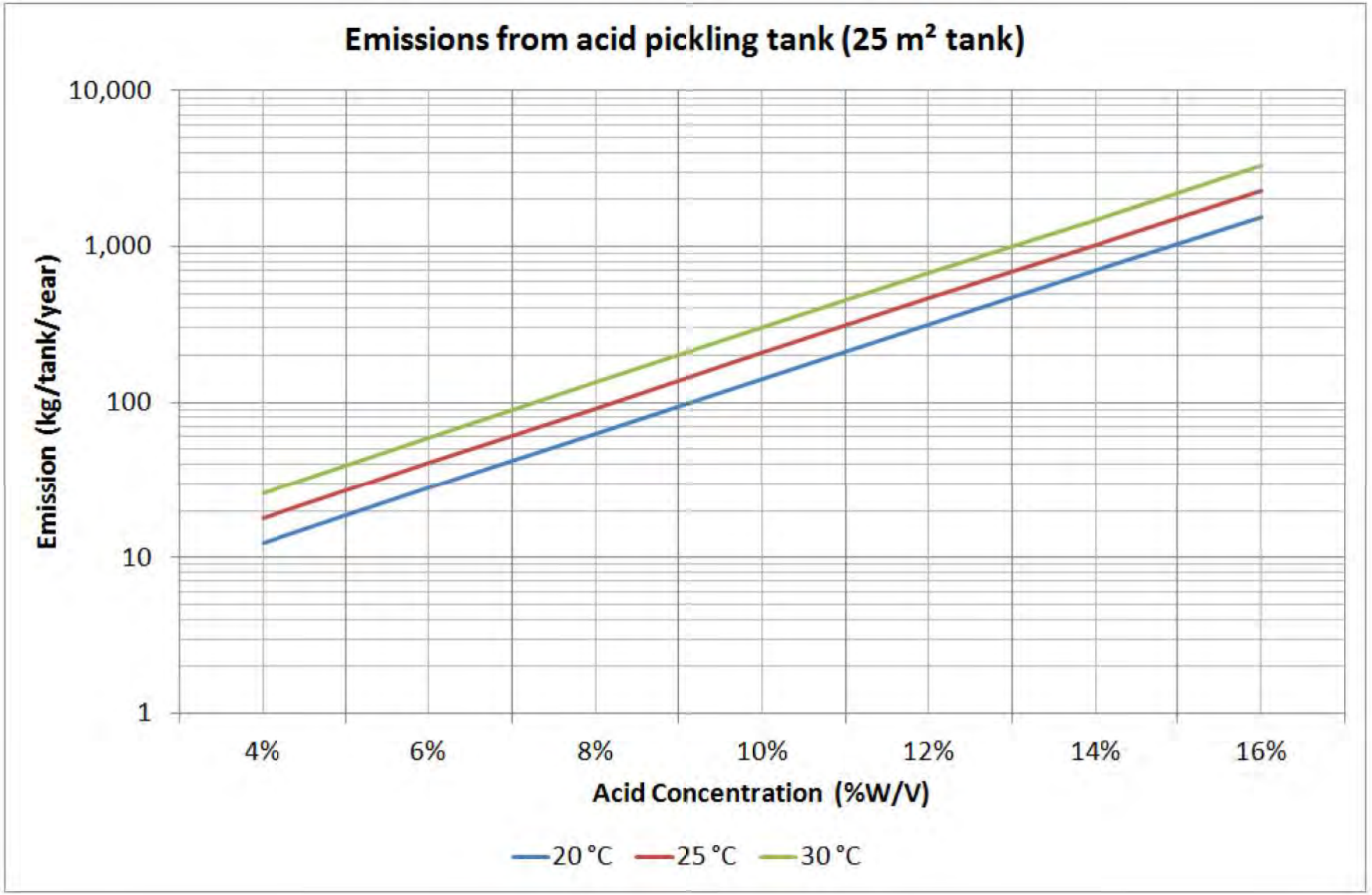

Emissions from acid pickling tank (25 m² tank)
10,000
1,000
100
10
1
Emission (kg/tank/year)
4%
6%
8%
10%
12%
14%
16%
Acid Concentration (%W/V)
20 °C
25 °C
30 °C

Table 4: Emission factors - acid picking - sulfuric acid

Substance	Uncontrolled emission factor EF (kg/per tank/year)	Emission factor rating
Sulfuric acid	134	U

Derived from Texas Commission on Environmental Quality (TCEQ), Calculations Package, Hot Dip Galvanizing
Assumptions:
Tank size is approximately 21 square metres in size
Tank operating temperature is ambient
Acid concentration is approximately 16%
Emissions factors are per tank per year.
Emission factors are uncontrolled. If controls are used (such as suppressants, hoods of other abatement), the emission factor should be adjusted by the percentage efficiency of any such control.

Table 5: Emission factors - zinc galvanizing bath

Substance	Uncontrolled emission factor EF (kg/tonne of zinc used)[c]	Emission factor rating
Particulate matter less than or equal to 10 microns (PM_{10}) [a]	2.5	C
Zinc and compounds[b]	2.0	C

[a] Based on Particulate Matter emission factor in Table 2.3-1 of USEPA *AP-42 Section 12.14*, 1985. Table 2 above assumes that all particulate matter is classed as PM_{10}.
[b] Based on assumption that particulate matter (PM) consists entirely of zinc oxide (ZnO). Based on the molecular weight of ZnO and its components, 2.5 kg of ZnO contains 2.0 kg of Zn.
[c] Units are kg of substance emitted/tonne of zinc used and emission factors are for uncontrolled emissions.

Appendix C: Modifications to the galvanizing emission estimation technique (EET) manual (Version 2.0 July 2012)

Page	Outline of alteration
Throughout	Updated manual to reflect discussions with Galvanizers Association of Australia
Section 4	Provided example for threshold calculation
Section 5	Provided up to date example for emissions calculations
Section 4	Removed emissions to water guidance
Section 4	Removed sampling data
Section 4	Removed emissions to land guidance
Section 4	Removed guidance on fugitive chemicals leaks and replacement with emission factors for acids
Section 6	Addition of transfers guidance

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Artificial Neural Network Modeling for Al–Zn–Sn Sacrificial Anode protection of Low Carbon Steel in Saline Media

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American Journal of Materials Science 2012, 2(3): 62-65
DOI: 10.5923/j.materials.20120203.05

Artificial Neural Network Modeling for Al-Zn-Sn Sacrificial Anode protection of Low Carbon Steel in Saline Media

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Abstract This work presents the artificial neural network(ANN) modeling for sacrificial anode cathodic protection of low carbon steel using Al-Zn-Sn alloys anodes in saline media. Corrosion experiments were used to obtain data for developing a neural network model. The Feed forward Levenberg-Marquadt training algorithm with passive time, pH, conductivity,% metallic composition used in the input layer and the corrosion potential measured against a silver/silver chloride(Ag/AgCl) reference electrode used as the target or output variable. The modeling results obtained show that the network with 4 neurons in the input layer, 10 neurons in the hidden layer and 1 neuron in the output layer had a high correlation coefficient (R-value) of 0.850602 for the test data, and a low mean square error (MSE) of 0.0261294. 9

Keywords Cathodic Protection, Sacrificial Anodes, Artificial Neural Networks

1. Introduction

Corrosion is the destruction of material resulting from exposure and interaction with the environment[1]. While common usage typically associates corrosion with metals, the destruction of non-metallic materials as a result of exposure to sunlight can be considered as corrosion[1]. The economic cost of corrosion was estimated some years ago by the US Department of Commerce to be approximately 5% of the Gross National Product[2]. However corrosion not only has an economic cost it can present a threat to life through the collapse of a structure or to the environment through the leak of toxic chemicals[3]. To control corrosion effectively, the accurate modeling and prediction of corrosion behaviour is a fundamental requirement[4]. Artificial neural networks are computational systems that simulate the Neurons or simple processors of a biological nervous system and have been used to solve complex engineering problems like corrosion [4,5]. Basically, all ANNs have a similar topological structure or architecture[5]. The interaction of the neurons in the network is roughly based on the principles of neural science. The neural network can learn both static and dynamic properties autonomously based on the past history of the measurement data and then act in such a way that a better solution can be obtained under unknown environmental conditions. Hence they are suitable for problems where pattern recognition is important and precise computational answers are not required[4,5].

Different researchers have attempted at various times to deploy the neural network technique for the prediction of corrosion rate, which have yielded very good prediction results compared to mechanistic models[4,5,8].

Yu Sun et al[9] studied the microstructure-property relationship of a titanium (Ti-6Al-4V) alloy with Artificial neural networks. His results showed very good agreements between experimental and ANN model. Tomislav Rolic et al[10] estimated the corrosion of steel guitar strings in the artificial sweat solution using neural networks. From measurements and training results a high correlation coefficient and low mean absolute error between measured and estimated output values were observed. As opposed to a deterministic approach corrosion potential data (polarization curves) on metallic glasses, corrosion rate and weight loss data on carbon and alloy steel and crevice corrosion data on grade-2 titanium have been used for comparison and future prediction of the alloys' corrosion behavior using ANN[11, 12].

Artificial neural networks have also found increasing usage along side mechanistic approaches in determining evolution of corrosion rate and yield strength in certain Mg-Rare Earth alloys[13] and modeling pit growths in high strength aluminum alloys[14].

However, some of these applications are advanced modeling techniques that are not readily available to the corrosion engineer who may be interested in creating his/her own neural network model for the corrosion problem at hand. Hence this paper seeks to demonstrate an attempt to create a

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successful neural network model for an Al-Zn-Sn sacrificial anode protection system using a simple and straightforward modeling strategy.

2. Materials and Method

2.1. Material

The chemical composition of the low carbon steel sample used is presented in Table 1. The cast aluminum anodes used were Al-Zn(5%)-Sn(0.1%), Al-Zn(7%)-Sn(0.1%) and Al-Zn(10%)-Sn(0.1%).

In this work, the Levenberg-Marquadt training algorithm was used to develop a network for predicting the corrosion potential of low carbon steel in saline media. Corrosion experiments were mounted to obtain the necessary data for training the networks.

2.2. Methods

2.2.1. Preparation of Samples

The low carbon steel specimen with dimensions of 50mm x 50mm x 1mm (eight pieces) were neatly cut and polished in a sequence of emery papers until a smooth finish was obtained. They were cleaned by rinsing under running tap water, distilled water and acetone. This was done a number of times to ensure that there were no traces of corrosion products on the metal surface

Table 1. Chemical composition of low carbon steel

Element	% Composition
C	0.0329
Si	0.0077
S	0.0186
P	0.0109
Mn	0.2918
Ni	0.0209
Cr	0.0182
Mo	0.004
V	0.0011
Cu	0.0405
W	0.0065
Co	0.0025
Al	0.0172
Pb	0.0072
Zn	0.0049
Fe	99.5268

2.2.2. Experimental Data

Electrochemical measurements were carried out on the low carbon steel specimens with 25 cm^2 exposed geometric surface, protected with the aluminum alloy anodes immersed in 1M and 0.5M NaCl solutions. The potentials were measured against an Ag/AgCl saturated reference electrode using a DT9205A digital multimeter. All measurements were carried out at a temperature of 298 K. The pH and conductivity were measured. The experiment run lasted for 630 hours.

2.3. Neural Network Application for the Sacrificial Anode Protection System

The MATLAB ® neural network toolbox was used for the ANN modeling. The system was used to assess the potential difference required to control sacrificial anode cathodic protection systems and to predict corrosion rate. A network with two hidden layers was used. This number is chosen randomly as the selection of the number of neurons was specified by trial and error. For the potential difference assessment, the input layer received the variables (time of exposure, pH, conductivity, metal composition of the anode). The output layer gave the potential difference as network result.

The tan-sigmoid transformation function was used in the first hidden and in the second layer, a pure line function. The Levenberg Marquadt feed forward neural network training algorithm was used with 107 samples.

3. Results and Discussion

3.1. Results

Table 2 shows the correlation results and mean square errors using neural networks.

Figure 1 shows the bar chart chart of the mean square errors and the corresponding network structure revealing that structure 10 had the best performance.

Figure 2 Shows the plot of electrode potentials versus exposure time for the steel samples Immersed in 1M NaCl solution and protected with different aluminium anodes. It shows that the steel sample protected with Al-Zn(0.5%)-Sn(0.1%) had the best performance of the three anodes throughout the experiment run.

Figure 3 shows the plot of electrode potentials versus exposure time for the steel samples immersed in 0.5M NaCl solution. It shows that the steel sample protected with Al-Zn(10%)-Sn(0.1%) performed best of the three anodes.

Figures 4 and 5 show a comparison between the experimental and modeled potential values for the low carbon steel sample in 1M NaCl solution.

3.2. Discussion of Results

3.2.1. Effect of Exposure Time on Potential

Within the first 72 hours of the experiment the low carbon steel samples protected with Al-Zn-Sn anodes with varying compositions gave negative potentials. The steel sample protected with Al-Zn(10%)-Sn(0.1%) had a more negative potential of up to -0.97V after about 350 hours of exposure in 1M NaCl and -0.73V after 300 hours in 0.5M NaCl though the anode showed some form of fluctuations possibly due to uneven corrosion[7]. The more electronegative values of low carbon steel show that the Al-Zn(10%)-Sn(0.1%) anode is corroding quite fast in 1M solution. However the steel sample protected Al-Zn(5%)-Sn(0.1%) had a less negative potential of -0.87V after 350 hours of exposure, implying that the anode is not corroding as fast as that containing 10% Zn and hence a better anode material in 1M NaCl solution and that with 5% Zn performing better in 0.5M NaCl.

Table 2. Correlation and MSE for different Network Structures

	No. of Iterations	Correlation Coefficient(R-Value)			Mean Square Error (MSE) e-2		
		Training	Validation	Testing	Training	Validation	Testing
2-5-1	24	0.800092	0.811596	0.770030	3.83112	5.85046	4.33157
2-10-1	11	0.771729	0.742407	0.861787	4.78746	4.07154	2.75595
2-15-1	48	0.846507	0.717939	0.798170	3.73605	5.19064	5.46547
2-20-1	22	0.798150	0.766909	0.851286	3.20208	8.20451	3.01428
3-5-1	13	0.817244	0.796208	0.772418	2.90510	8.69564	4.36268
3-10-1	19	0.797581	0.813279	0.812208	3.66967	5.19056	3.79440
3-15-1	9	0.828406	0.813750	0.729404	4.26745	3.19910	3.67971
3-20-1	10	0.831410	0.804441	0.754775	3.55374	4.62663	4.72951
4-5-1	13	0.776210	0.817973	0.846558	3.99940	4.71449	3.77262
4-10-1	9	0.799574	0.840233	0.850602	4.51663	2.61294	2.75250
4-15-1	17	0.800274	0.809670	0.823734	3.61581	3.62052	3.79745
4-20-1	21	0.819010	0.809670	0.823734	3.61581	3.62052	3.79745

3.2.2. ANN Modeling Results

From the results of the performance of twelve network structures are presented in table 2 and fig 1 it is evident that of all twelve structures used the 4-10-1 structure had the best R-value for test data set (0.850602), training data set (0.0799574), and validation data set (0.840233). The accuracy of this prediction is further indicated by the low mean square error (MSE) which ranged from 0.0261294 to 0.0451663. The number of iterations for the five structures ranged from 9 to 24.

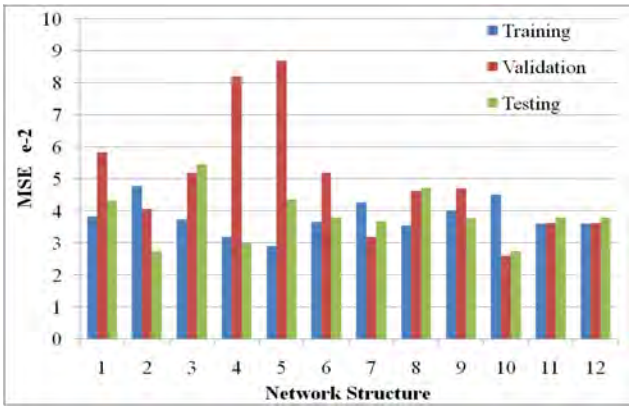


Figure 1. Plot of Mean Square Error (MSE) Vs Network Structure

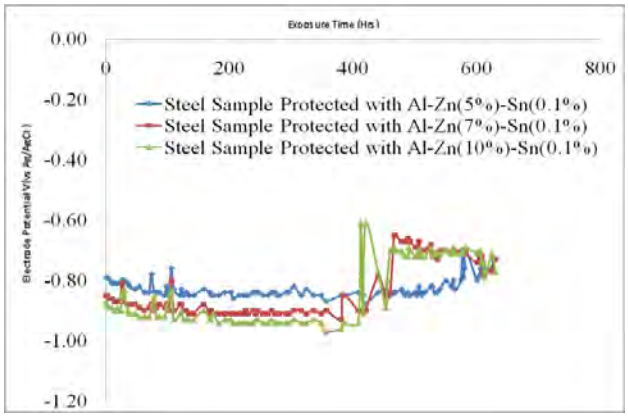


Figure 2. Plot of Electrode Potentials versus Exposure Time for Low Carbon Steels Immersed in 1M NaCl solution

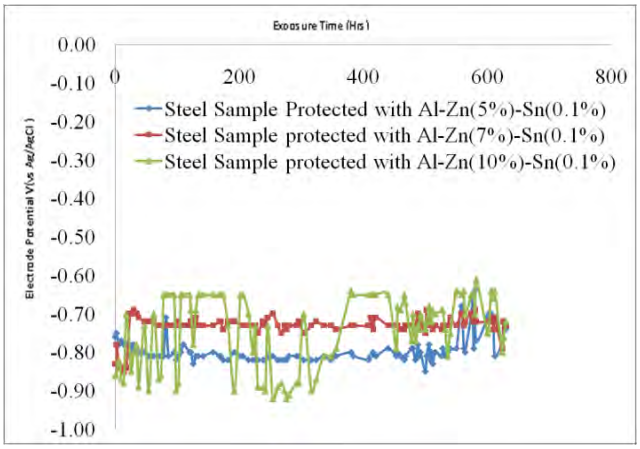


Figure 3. Plot of Electrode Potentials versus Exposure Time for Low Carbon Steels Immersed in 0.5M NaCl solution

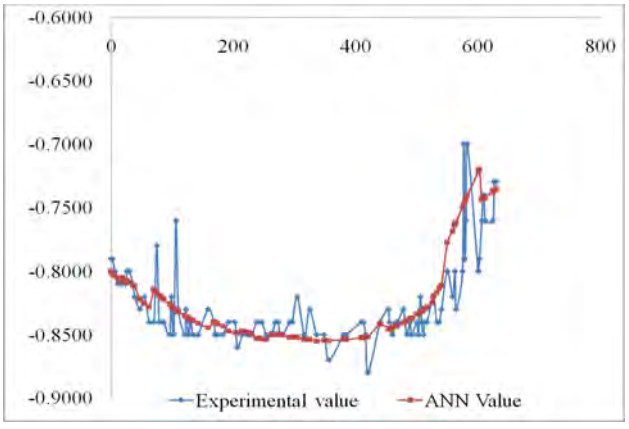


Figure 4. ANN Modeling results compared with Experimental Results for steel protected with Al-Zn(5%)-Sn(0.1%) anode in 1M NaCl

The 4-10-1 structure which was chosen as the one with the best predictive ability converged in nine (9) iterations with four (4) variables in its input layer ten (10) number of neurons in the hidden layer and an output layer. The structure was so selected as the R-value of a network reflects the ability of a network to predict well[6] i.e. its value should be as close to unity (1) as possible. Hence more importance is attached to the R-value than to the speed of the network in making the prediction.

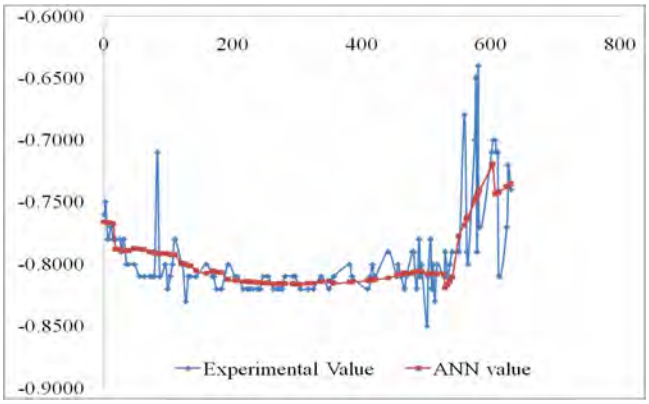


Figure 5. ANN Modeling results compared with Experimental Results for steel protected with Al-Zn(5%)-Sn(0.1%) anode in 0.5M NaCl

4. Conclusions

Based on the experimental data this work has shown that;

1) An effective neural network model for an Al-Zn-Sn sacrificial anode system was created using a standard commercial package with nearly all the trends noticed in the experimental data captured by the network.

2) Artificial neural networks can be used to predict quite accurately the corrosion potential of low carbon steel in saline media.

3) There is a need to conduct further experiments, use a larger data set and apply other neural network techniques to test their performance over the Levenberg Marquadt technique.

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Characterization of Fine Particles from Machining in Automotive Plants

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Sampling of the full range of particle sizes was carried out on 16 processes in six different General Motors plants over a period of 2.5 years. This article deals with particle characterization from five of the processes that relate to machining, specifically, wet machining with water-based fluids from old and new technology processes, grinding with straight oils from old and new technology processes, and dry machining. The concentrations measured by different instruments were in reasonable agreement, although the light-scattering instrument generally produced higher values than filters. Of the processes studied, the old technology grinding using straight oils generated the highest particle concentrations. The new technology controls (enclosed, vented machines) were highly effective but more so for large particles than small particles. The particle size distribution was shifted to smaller particles with enclosed processes. Dry machining generated the largest particles of all processes studied.

Keywords aerosols, machining, manufacturing, particle emissions, particle size, particles

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Over the years, the Environmental Protection Agency (EPA) has changed the focus of its particulate standards from total airborne particles in 1971 to particulate matter less than 10 μm (PM_{10}) in 1987 and then to a proposed $PM_{2.5}$ standard in 1997.[1] The shift toward regulating smaller particles is related to their longer residence time in the air, their chemistry, and their deeper penetration into the respiratory system. For similar reasons, particles in workplace air are increasingly sampled according to particle size rather than total particle mass to aid in understanding the fate of particle fractions in the air and respiratory system of workers. During this period, the United Auto Workers-GM National Joint Committee on Health & Safety became interested in fine particles and sponsored a study to evaluate fine particles from a variety of processes in the automotive industry, including casting, machining, heat-treat, and assembly. This article deals with the characterization of airborne particles in the vicinity of machining processes at General Motors plants.

Earlier studies have focused on various aspects of airborne particles in machining plants. Chan et al.[2] characterized particles from six machining areas and found a bimodal particle distribution. They attributed the particle generation mechanism to fluid spray for particles >2 μm and high shear forces for the small particles. Woskie et al.[3] measured worker exposures to airborne particles and found correlations with the type of machining operation and the type of metal removal fluid (MRF), with grinding and straight oils producing the highest exposures. Sioutas[4] studied particles smaller than 3.2 μm in diameter from machining operations and measured 0.1 mg/m^3 from grinding and 0.2 mg/m^3 from machining with a mass median aerodynamic diameter (MMAD) of about 0.5 μm.

The Occupational Safety and Health Administration (OSHA) has a permissible exposure limit (PEL) of 5 mg/m^3 for mineral oil mist in the air, averaged over an 8-hour period. The United Auto Workers (UAW) petitioned OSHA in 1993 to establish a new standard of 0.5 mg/m^3 for metalworking fluid, regardless of the mineral oil content. In response, the National Institute for Occupational Safety and Health (NIOSH) issued a *Criteria for a Recommended Standard: Occupational Exposure to Metalworking Fluids* in 1998, where they included a recommended exposure level (REL) of 0.5 mg/m^3 for total metalworking fluid aerosol or 0.4 mg/m^3 for metalworking fluid aerosol meeting the thoracic particulate size definition. However, to date, OSHA has concentrated on increasing awareness of good metalworking fluid management rather than lowering the mist standard.

A variety of machining processes were evaluated in this study. Two processes were studied in which water-based MRFs were used: a traditional high-volume machining operation on aluminum transmission cases with retrofitted mist controls at an older plant and newer, enclosed equipment machining

aluminum engine heads. Hands et al.[5] showed that original equipment enclosures are more effective in controlling airborne mist than retrofitted enclosures.

The vast majority of machining in GM operations is done using water-based MRFs. Only 10% of MRFs used are straight oils, but those have a higher potential for creating airborne mist.[6] Therefore, two machining operations were studied in which straight oils were used as MRFs: a traditional grinding operation for transmission output shafts and a newer high-speed grinding process using plated-CBN (cubic boron nitride) grinding wheels on engine camshafts.

The final process studied was the dry machining of a cast iron engine block at a GM engine plant. Dry machining is expected to become more important in the future as plants try to avoid the problems inherent with MRFs. Although dry machining eliminates *mist*, other particles are generated, primarily metal fines produced during machining.[3]

EXPERIMENTAL PROCEDURES

The processes and plants were chosen and the project was introduced to the plant personnel to help gain access to the site. PM_{10} and $PM_{1.0}$ concentrations were measured throughout the process area, and two maps of concentration by location were prepared for each site. Based on the mapped concentrations, an intensive sampling site was chosen to monitor particle size and temporal variation during the plant's first shift of operation. Samplers were also operated outdoors upwind of the plant to evaluate background particle concentrations.

Mapping

Two DustTrak (TSI Inc., Shoreview, Minn.) real-time aerosol monitors were fitted with PM_{10} and $PM_{1.0}$ inlets and were used to map the spatial distribution of coarse and fine particles within the process area using a technique developed by D'Arcy.[7] The procedure involves taking readings with each instrument at designated locations in the plant using a 20-sec averaging time. The data are arranged into a geographic format and a spatial representation is created using DeltaGraph (version 3.5, Red Rock Software) software. A map of particle counts, as measured with the P-Trak using a 20-sec averaging time (TSI Inc.), was also made at one location. The color palettes used for PM_{10} and $PM_{1.0}$ are shown in Figure 1A and for particle count are shown in Figure 1B. The DustTraks were zeroed and calibrated using the factory calibration each day.

Based on the mapping, a site within the process area was chosen for intensive sampling based on the following criteria:

- A location with high, fine-particle concentrations
- Visual analysis of the process area
- Input from workers in the area and plant engineering
- Minimal inconvenience for production workers
- Lack of conflict with material handling needs
- Access to 120 VAC electrical power
- Safety of the researchers

Intensive Sampling

The final step in the process evaluation was the detailed characterization of the particulate matter present in the work environment. This involved the collection of temporal data on aerosol concentration as well as cumulative concentration and aerosol size distribution (0.014–10 μm) for the approximately 7-hour sampling period during the plant's first shift of operation. For one process, sampling was conducted over 3 consecutive days to assess day-to-day variation. Background concentrations were also collected outdoors upwind of the plant.

A variety of instruments were used to characterize aerosols over a broad range of particle sizes. The samplers are listed in Table I. Two DustTrak monitors, one with the normal PM_{10} inlet and the other with a $PM_{1.0}$ inlet, were used for both mapping and temporal sampling during intensive sampling. During temporal sampling, they were set to collect data averaged over 1-min periods, so that a typical 7-hour sample included about 420 sample points from each sampler. Concentrations were measured over a particle size range of approximately 0.3 μm to 10 μm or 0.3 μm to 1 μm, respectively. DustTrak monitors are light-scattering nephelometers calibrated using ISO 12103-1, A1 test method ("Arizona Road Dust"), which has a larger size distribution than $PM_{1.0}$. Since particles scatter light differently depending on their size, all particle size distributions would not be expected to have the same calibration as road dust.

The Aerodynamic Particle Sizer (APS) (model 3320,TSI Inc.) is a particle time-of-flight spectrometer that determines a particle's aerodynamic diameter by measuring the particle velocity following acceleration through a nozzle. Particles with less mass have less inertia and therefore experience a greater acceleration. Velocity is characterized by particle time of flight between two fixed points; time of flight is used to calculate particle aerodynamic diameter using an empirical calibration function.

The P-Trak (TSI Inc.), a portable condensation particle counter with a nominal size range of 0.015 μm to 1 μm and an upper concentration level of 5×10^5 particles/cm^3, was added to the study for one process. This instrument provided temporal particle number concentration data and allowed us to map total particle numbers in the vicinity of the processes.

The Micro-Orifice Uniform Deposit Impactor (model 110 MOUDI; MSP Corp., Shoreview, Minn.), the principal instrument for collecting aerosol mass distribution data, operated at 30 L/min for the 7-hour period and provided size segregation from >20 μm down to 0.06 μm.[8] The unique micro-orifice design accomplishes this size segregation with low pressure drops across stages, allowing the collection of size-segregated samples of semivolatile compounds down to a very small size range. Traditional PVC filters were used for the MOUDI impaction substrates and backup filter. The upper cutpoint on particles that could enter the impactor was arbitrarily taken as 40 μm.

Because recent EPA sampling has focused on $PM_{2.5}$ for compliance with National Ambient Air Quality Standards, we used cyclones with a 2.5-μm aerodynamic cutpoint (model URG-2000-30EN, URG Corp., Chapel Hill, N.C.) in front of

TABLE I. Aerosol Sampling Instruments

Instrument	Type	Size Range	Purpose
Area: Direct-reading			
TSI DustTrak	RPA[A]	0.3–1.0 μm	Mapping, temporal mass
TSI DustTrak	RPA	0.3–10 μm	Mapping, temporal mass
TSI Aerodynamic Particle Sizer	RPA	0.2–20 μm	Real-time size distribution/concentration
TSI P-Trak[B]	RPA	0.015–1 μm	Mapping, real-time particle number concentration
Area: Integrated			
MOUDI	CI[C]	0.06–20 μm	Mass distribution
$PM_{2.5}$ filter	SS[D]	$<$2.5 μm	Mass concentration, plant and background
Personal: Integrated[E]			
37-mm closed face	Filter	$\approx$ $<$20 μm	"Total particulate matter"

[A] RPA: Real-time particle analyzer.
[B] Used for one process.
[C] CI: Cascade impactor.
[D] SS: Cyclone (model URG-2000-30EN; URG Corp., Chapel Hill, N.C.) on size-selective sampler for $PM_{2.5}$.
[E] Traditional industrial hygiene sampler used as area sampler.

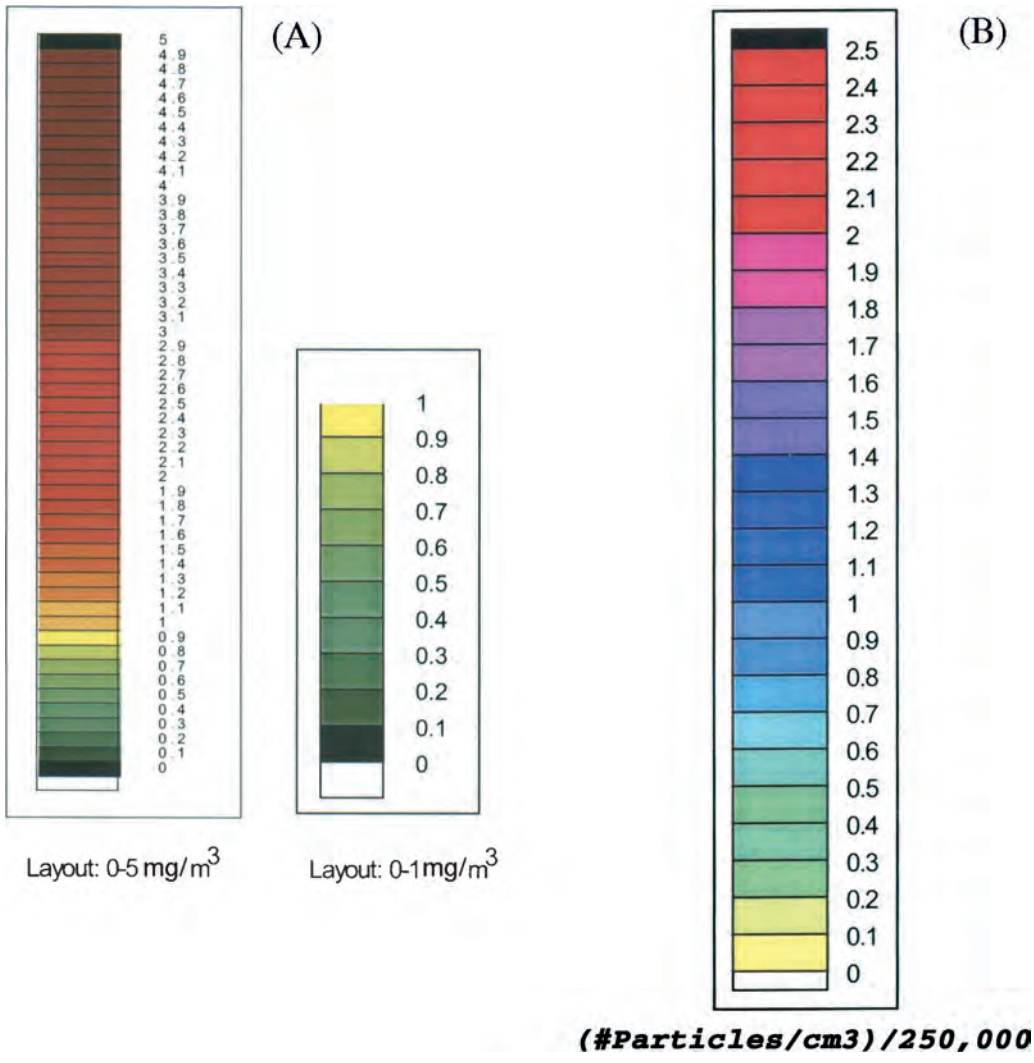


FIGURE 1. (A) Color palette used for PM_{10} and $PM_{1.0}$ (B) Color palette used for particle count

47-mm, 0.4 μm pore size polycarbonate filters, operating at 10 L/min for the 7-hour period. Polycarbonate filters, which have a low trace-metal content, were used for mass determination and later chemical analysis. However, due to difficulty weighing the polycarbonate filters, PVC filters were usually preferred for mass analyses. EPA sample collection and analysis procedures were followed for these samples.[9]

Finally, total particulate matter personal samples were collected at 2.0 L/min on a 37-mm, closed-face filter cassette with a 5.0 μm pore size, PVC filter to provide reference data for comparison with historical "total particulate" exposure data at GM.

An effort was also made to obtain background samples, that is, samples collected outside and upwind of the plant. Two $PM_{2.5}$ samplers were running outdoors for the entire intensive sampling period. In addition, the two DustTrak monitors and the APS were taken outdoors at the end of the intensive sampling period and allowed to measure outdoor air for a 30-min period.

RESULTS

Wet Machining, Old Technology

Process Description

An old technology, wet machining process was studied at a transmission plant in January 2001. To help assess day-to-day variability, intensive sampling was conducted on 3 days, January 17, 18, and 19. The area studied was the transmission case area, consisting of 16 machining cells arranged in a 4 $\times$ 4 array. Aluminum 380 alloy was drilled, reamed, tapped, and milled using carbide and diamond tools.

The machining fluid used in the entire case area was a soluble oil, Eppert T-Kool 149a, used at a concentration of 5.2%. T-Kool concentrate is a high-oil product containing over 75% heavy naphthenic oil in the concentrate. An antimisting polymer, Addco Lo-Mist D from Gateway, was added to the sump to reduce mist levels, a change that had been implemented in January 2000.[10,11]

The plant was operating on two shifts at the time of sampling, from 5:00 a.m. to 3:30 p.m. and 4:40 p.m. to past midnight. Our intensive sampling period was from 7:25 a.m. to 3:00 p.m. During the lunch break (10:30 a.m. to 11:00 a.m.) and between shifts (2:30 p.m. to 3:30 p.m.), the workers left the area but machining continued unless a problem arose. During the first shift of the sampling day, 3746 transmission cases were machined. The maximum possible is 4800 per shift.

The plant was older and utilized old technology mist control. Machine operations took place on transfer lines that were not enclosed. Plastic panels were positioned around machining areas in an effort to contain splash and mist. Hoods located above the operations routed air to a number of small mist collectors. Seven air supply houses on the roof supplied 315,000 CFM (8900 m^3/min) of outside air to the 150,000 ft^2 (13,900 m^2) transmission case area, providing a ventilation and fresh air makeup rate of approximately 2 CFM/ft^2(0.61 m^3/min/m^2). An air diffuser supplying fresh air was located within 9 m of the sampler area. In the area close to the intensive sampling site, a Monroe mist collector (Monroe Environmental Corp., Monroe, Mich.) drew in 3000 CFM (85 m^3/min) of air and exhausted it vertically through the top about 2.4 m above the floor and 3 m from the samplers.

Mapping Data

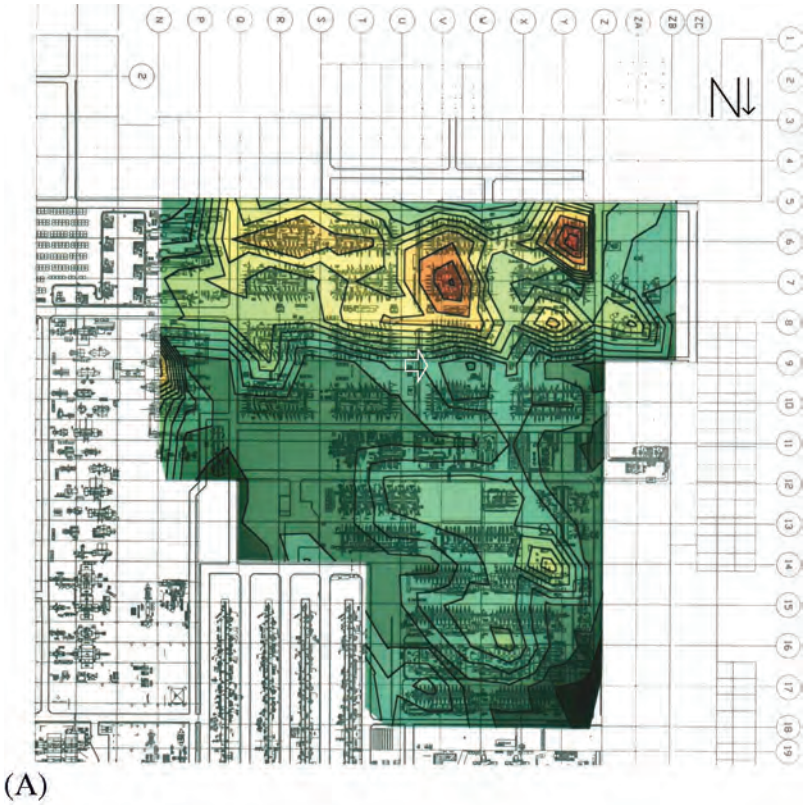
The PM_{10} and $PM_{1.0}$ maps, as measured with DustTrak monitors, are shown in Figure 2. The correlation coefficient between PM_{10} and $PM_{1.0}$ at various locations is 0.93, which is highly significant for the 150 data locations ($p < 0.0005$). Maximum values measured during mapping were 1.8 mg/m^3 PM_{10} and 0.64 mg/m^3 $PM_{1.0}$. The arrows in the figures represent the site chosen for intensive sampling. The PM_{10} concentration measured during mapping at the intensive sampling location was 0.43 mg/m^3, which fell at the 49% frequency level of the mapping measurements or close to the median value.

A P-Trak was used in addition to the DustTrak monitors to map particle numbers and the resulting map is shown in Figure 3. Note that the color palette is different from that for particle mass (see Figure 1). As might be expected, the particle number map is similar to the particle mass map with the higher levels at the top of each. The correlation coefficient of the P-Trak particle number concentration was 0.63 with PM_{10} mass and 0.68 with $PM_{1.0}$ mass, both highly significant at the $p < 0.0005$ level. The maximum particle number concentration was 406,000 particles/cm^3. The particle count at the intensive sampling location was 62,600 particles/cm^3, which fell at the 44% frequency level of the mapping data.

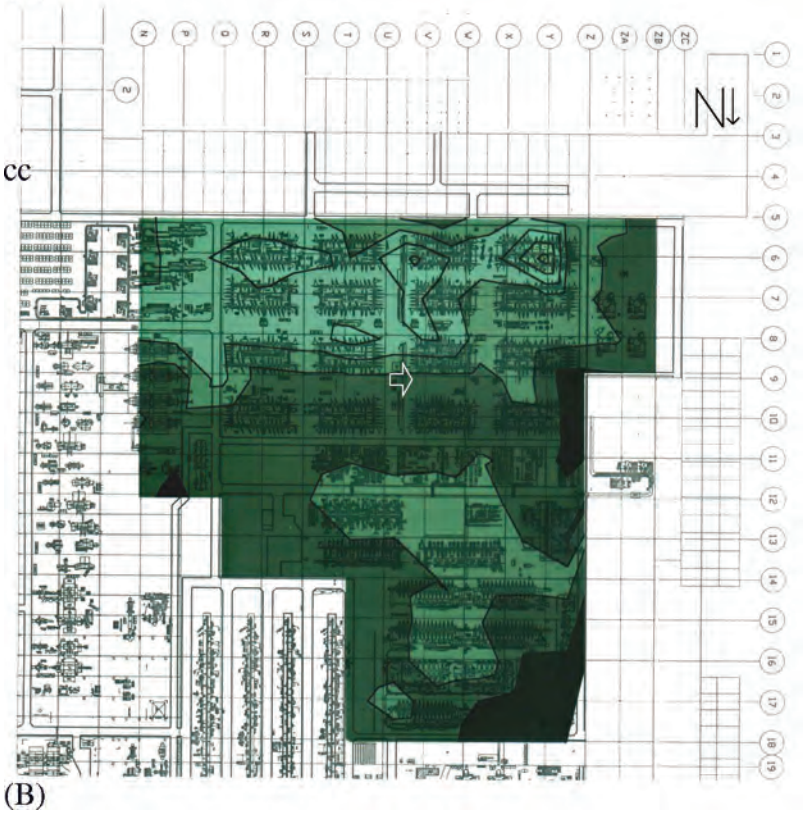
Intensive Sampling Data

The temporal concentrations of PM_{10} and $PM_{1.0}$ as measured with two DustTrak monitors on 3 consecutive days are shown in Figure 4. The 3 days of sampling yielded very similar profiles in terms of both size distribution and temporal variation. On average, two times more particle mass was found in the PM_{10} fraction than in the $PM_{1.0}$. The correlation coefficient between the two traces on a given day is 0.86, highly significant for >400 data points ($p < 0.0005$). Outdoor background concentrations were measured at the end of the sampling day and averaged 13 times lower for $PM_{1.0}$ and 16 times lower for PM_{10} than plant concentrations (Figure 4).

A mass and size distribution data table will be presented for each process and will include data from a variety of measurement devices. Table II presents the average mass concentration and standard deviation for various size fractions of aerosols for wet machining over 3 consecutive days. MOUDI and APS concentrations are presented for size fractions that match the other instruments. APS and DustTrak values represent the average values from the sampling period. "Filter" values are presented for total particulate collected by a personal sampler and the $PM_{2.5}$ sample. Reasonable agreement was observed between different methods with the one exception that the DustTrak measured higher $PM_{1.0}$ levels than the MOUDI or APS on all days. The plant $PM_{2.5}$ level was 6 to 12 times



(A)



(B)

FIGURE 2. (A) Map of PM_{10}, as measured with DustTrak monitors, from wet machining, old technology, January 2001 (B) Map of $PM_{1.0}$, as measured with DustTrak monitors, from wet machining, old technology, January 2001

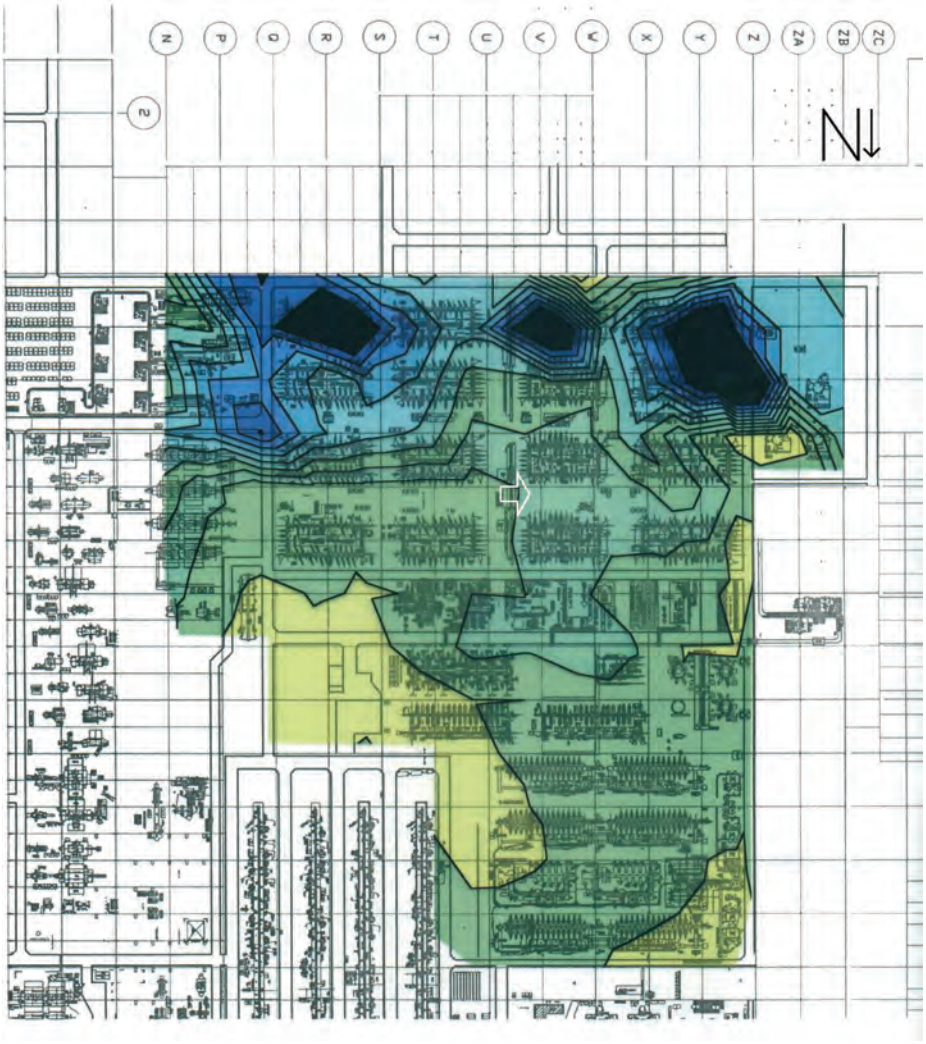


FIGURE 3. Map of particle number as measured with P-Trak, from wet machining, old technology, January 2001

the outdoor background level, indicating that most of the particulate measured in the process was produced in the plant.

The standard deviation over the 3-day period was usually less than 10% of the average indicating that the concentrations varied little over the 3 consecutive days of sampling. The MOUDI relative standard deviation was higher than the others, as high as 50% for the MOUDI $PM_{1.0}$ sample.

TABLE II. Particle Mass Concentrations and Standard Deviations (mg/m^3) in Different Size Fractions from Wet Machining, Old Technology

Location	Method	Total	PM_{10}	$PM_{5.0}$	$PM_{2.5}$	$PM_{1.0}$
Plant	MOUDI	0.56 ± 0.07	0.49 ± 0.07	0.37 ± 0.05	0.24 ± 0.05	0.097 ± 0.047
	Filter	0.40 ± 0.08			0.23 ± 0.01	
	APS		0.38 ± 0.03	0.25 ± 0.02	0.15 ± 0.01	0.042 ± 0.001
	DustTrak		0.62 ± 0.03			0.28 ± 0.02
Background	Filter				0.029 ± 0.004	
	APS[A]					
	DustTrak		0.043 ± 0.006			0.036 ± 0.004

Note: Sampling was conducted on January 17, 18, and 19, 2001.
[A]The APS was not used at this site for a background measurement due to the very cold conditions.

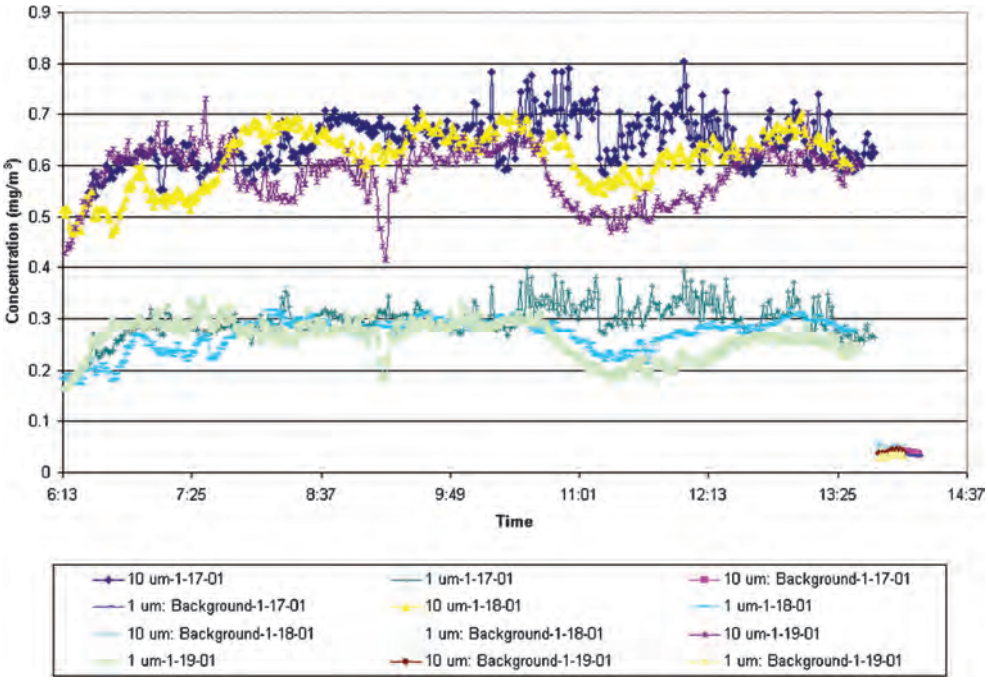


FIGURE 4. Temporal variations in PM_{10} and $PM_{1.0}$ during the intensive sampling period of wet machining, old technology, during 3 sequential sampling days in January 2001, as measured with DustTrak monitors

The particle size distribution as determined with the MOUDI impactor on January 17, 2001, is shown in Figure 5, where the particle mass per collector stage (normalized to the difference in logarithms of the aerodynamic diameters [Dar]) is plotted versus Dar. The wet machining particles have a unimodal distribution with the mode in particle mass centered between 2.5 and 5 μm and a MMAD of 3.3 μm, σ_g 2.5 (geometric standard deviation). The January 18 and 19 particle size distributions were similar unimodal distributions with MMADs of 2.8 and 3.2 μm, respectively.

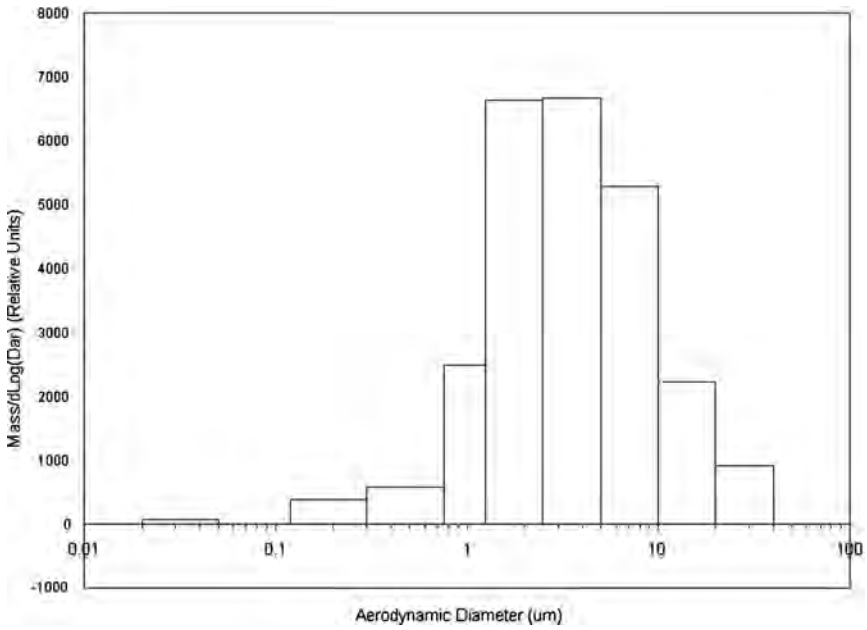


FIGURE 5. Particle size distribution, as measured with the MOUDI, from wet machining, old technology, January 17, 2001

Wet Machining, New Technology

Process Description

A new technology, wet machining process was studied in June 2000. Cast aluminum (Al 319 alloy) engine blocks were machined in a 38,500-ft^2 (3600-m^2) area on Thyssen Huller machines, and engine heads were machined in a 36,000-ft^2 (3300-m^2) area on Grob machines. Both areas operated with one 10-hour shift with target production of 821 heads and 313 blocks.

All machines were totally enclosed and the enclosures were vented to five Monroe spiral tube mist collectors, each with an 18,000 CFM (510 m^3) capacity. The cleaned air was recirculated back into the plant. The machining fluid was a Castrol WS3-908E semisynthetic fluid used at 10% concentration by volume. For a semisynthetic, it had a high oil content, up to 30% naphthenic oils in the concentrate. Separate 80,000-gal (303,000-L) sumps fed the block and head areas. Two Durr washers, located in the block area, had a 2200-gal (8300-L) capacity and used Permatreat 435 cleaner at a 2% concentration. The washers were vented outdoors through the roof. The intensive sampling instruments were located in the engine head area.

Mapping Data

The PM_{10} and $PM_{1.0}$ maps, as measured with DustTrak monitors, are shown in Figure 6. The PM_{10} and $PM_{1.0}$ values had a correlation coefficient of 0.98, which is highly significant for 120 data points ($p < 0.0005$). The maximum values measured during mapping were 0.69 mg/m^3 PM_{10} and 0.26 mg/m^3 $PM_{1.0}$. The intensive sampling site chosen was in an aisle between Grob machines where the PM_{10} concentration was 0.33 mg/m^3, which fell at the 88% frequency level of the mapping measurements.

Intensive Sampling Data

The temporal concentrations of PM_{10} and $PM_{1.0}$ as measured with two DustTrak monitors in Figure 7 showed considerable variation over the course of the day, as expected because the machining operation itself was frequently not operational. Overall, the PM_{10} concentration was 1.6 times the $PM_{1.0}$, compared with 2.3 times for the old technology, wet machining process. There was close agreement between the two traces with a correlation coefficient of 0.99, highly significant for over 400 sample points ($p < 0.0005$). The average PM_{10} and $PM_{1.0}$ plant air concentrations, which unfortunately were highly variable over the course of the day, were four to five times the background levels measured at the end of the day.

The mass distributions measured with the MOUDI impactor, filters, the APS, and DustTrak monitors are shown in Table III. Good agreement was observed between most samplers, with the exception that the concentrations measured by the DustTrak monitors were 2 to 4 times the other instruments, both in the plant and background samples. The filter $PM_{2.5}$ levels were only 50% higher in the plant than outdoors.

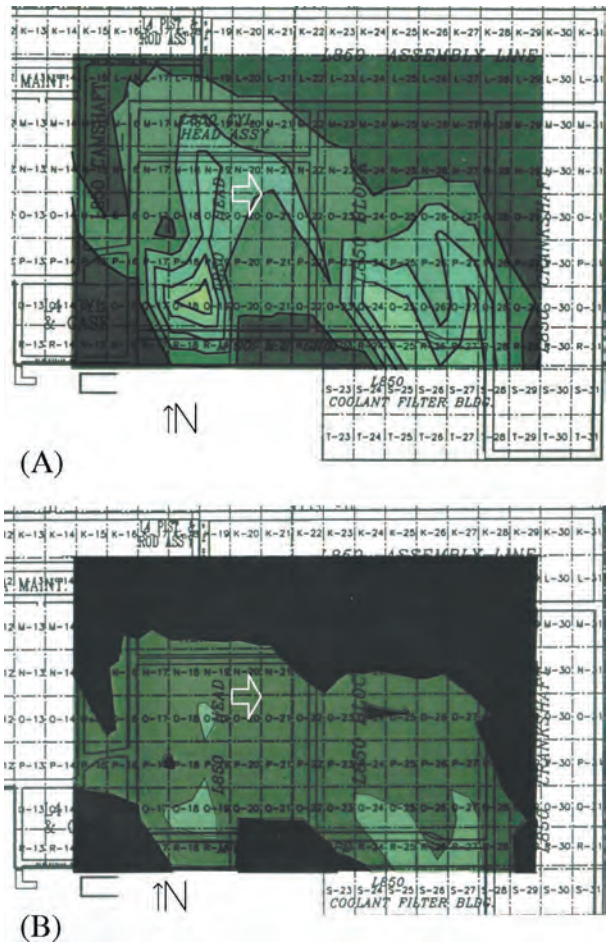


FIGURE 6. (A) Map of PM_{10}, as measured with DustTrak monitors, from wet machining, new technology, June 2000 (B) Map of $PM_{1.0}$, as measured with DustTrak monitors, from wet machining, new technology, June 2000

The MOUDI particle size distribution in Figure 8 is unimodal with the mode centered near 1 μm. The MMAD is 1.25 μm, σ_g 3.2. The old technology, wet machining particle distribution, shown earlier in Figure 5, was also unimodal, but the mode occurred at larger particle sizes, between 2.5 and 5 μm.

TABLE III. Particle Mass Concentrations (mg/m^3) in Different Size Fractions from Wet Machining, New Technology, June 2000

Location	Method	Total	PM_{10}	$PM_{5.0}$	$PM_{2.5}$	$PM_{1.0}$
Plant	MOUDI	0.081	0.075	0.067	0.057	0.029
	Filter	0.070			0.062	
	APS		0.054	0.040	0.031	0.022
	DustTrak		0.18			0.11
Background	Filter				0.044	
	APS		0.011	0.008	0.007	0.005
	DustTrak		0.045			0.023

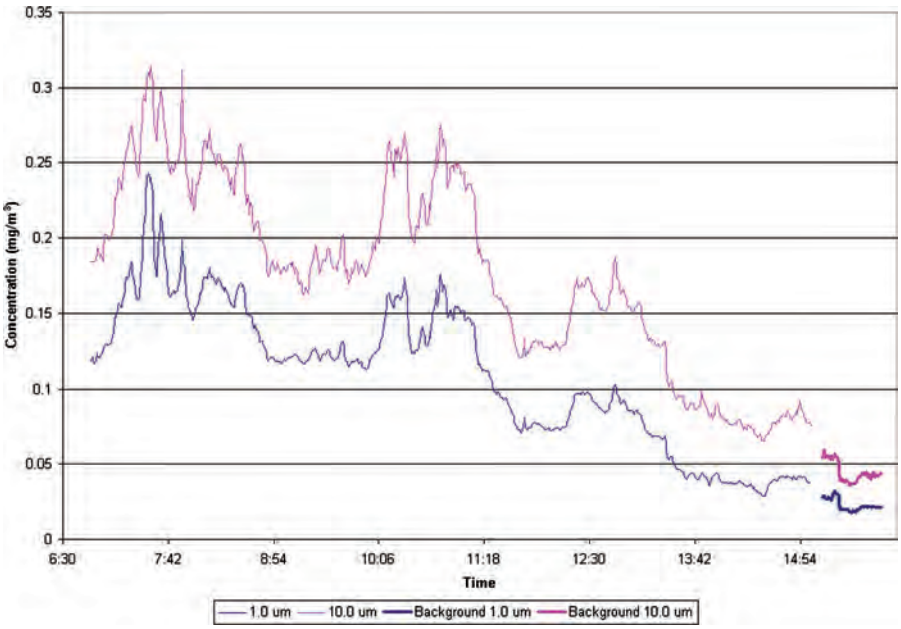


FIGURE 7. Temporal variations in PM_{10} and $PM_{1.0}$ during the intensive sampling period at the wet machining, new technology process, as measured with DustTrak monitors, June 2000

Grinding with Oil, Old Technology

Process Description

An old technology grinding process using straight oil as a MRF was studied in October 2000. Steel transmission output shafts were ground on Cincinnati centerless grinders using Norton and Cincinnati grinding wheels. Five grinders were performing the rough and finish grind, with two using a water-based fluid (5% Tech-Cool 5720) and three using a straight oil (Texaco 737). The cycle time was about 2 min/shaft such that the three grinders could machine about 3000 shafts in an 8-hour shift. Only one shift was operating. Air supply ducts were located above each of the oil grinders. The grinders had partial enclosures that were vented to Heli-flo mist collectors. The intensive air sampler was located directly beside one of the oil grinders.

Mapping Data

The PM_{10} and $PM_{1.0}$ maps, as measured with DustTrak monitors, are shown in Figure 9. The values shown on the two maps had a correlation coefficient of 0.84, which is highly significant ($p < 0.0005$) for the 15 sample locations. The area covered by the map is 6000 ft^2. Maximum values measured during mapping were 0.89 mg/m^3 PM_{10} and 0.51 mg/m^3 $PM_{1.0}$. The PM_{10} concentration measured at the intensive sampling location during mapping was 0.89 mg/m^3, the highest mapped value for this process.

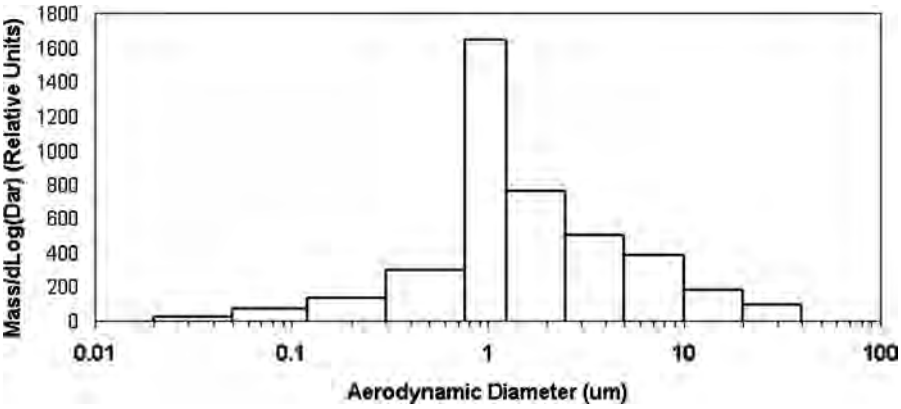


FIGURE 8. Particle size distribution, as measured with the MOUDI, from wet machining, new technology, June 2000

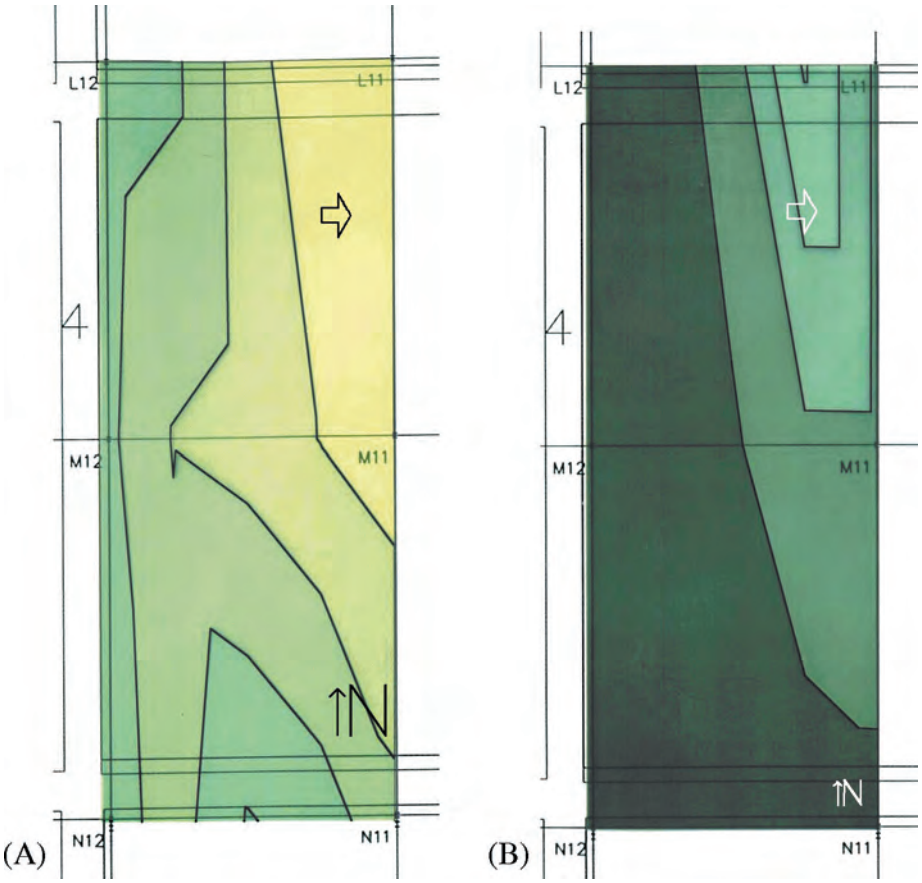


FIGURE 9. (A) Map of PM_{10}, as measured with DustTrak monitors, from grinding with oil, old technology, October 2000 (B) Map of $PM_{1.0}$, as measured with DustTrak monitors, from grinding with oil, old technology, October 2000

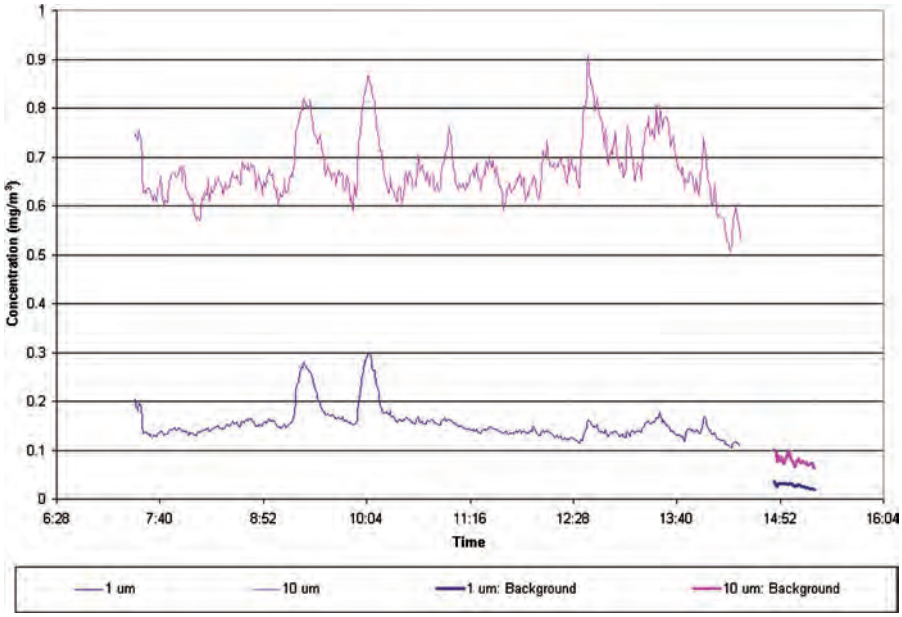


FIGURE 10. Temporal variations in PM_{10} and $PM_{1.0}$ during the intensive sampling period at the oil grinding, old technology process, as measured with DustTrak monitors, October 2000

TABLE IV. Particle Mass Concentrations (mg/m^3) in Different Size Fractions from Oil Grinding, Old Technology, October 2000

Location	Method	Total	PM_{10}	$PM_{5.0}$	$PM_{2.5}$	$PM_{1.0}$
Plant	MOUDI	1.1	0.85	0.59	0.23	0.060
	Filter	1.1			0.35	
	APS		0.60	0.39	0.17	0.045
	DustTrak		0.68			0.15
Background	Filter				0.032	
	APS		0.085	0.038	0.021	0.012
	DustTrak		0.073			0.025

Intensive Sampling Data

The temporal concentrations of PM_{10} and $PM_{1.0}$ as measured with two DustTrak monitors are shown in Figure 10. The two traces do not track as well as for other processes with a correlation coefficient of 0.84, although still highly significant for the >400 sample points ($p < 0.0005$). There is a large difference between the two, with the PM_{10} being 4.5 times the $PM_{1.0}$. The background PM_{10} and $PM_{1.0}$ levels, measured at the end of the day, were clearly lower than in the plant, averaging one-sixth ($PM_{1.0}$) to one-ninth (PM_{10}) of plant levels.

Mass distributions measured with the MOUDI impactor, filters, the APS, and DustTrak monitors in Table IV showed good agreement between different methods, although $PM_{1.0}$ measured by the DustTrak was again higher than measured by other methods. The $PM_{2.5}$ concentration measured by the filter was 11 times the background level collected the same way, indicating that most of the particulate measured was contributed by the process.

The MOUDI particle size distribution in Figure 11 was bimodal, with the primary mode between 2.5 μm to 5.0 μm and a large-particle mode greater than 20 μm. The MMAD was 4.8 μm, σ_g 2.6. The mode centered at 4 μm is similar to that seen from wet machining, old technology and probably consists of oil mist. The larger particles mode >20 μm could be mechanically generated grinding dust from the steel parts or wheel.

Grinding with Oil, New Technology

Process Description

A new technology, oil grinding process was studied in June 2000. Gray cast iron camshafts were rough and finish ground on a Landis grinder using high-speed plated CBN wheels. Straight oil was used on this one operation for high-performance cams. The process was on single-shift operation, producing about 450 cams per shift with an ultimate goal of 1050.

The grinder was totally enclosed and vented, along with several other machines, to a 12,000 CFM (3400 m^3/min) Monroe spiral tube mist collector. A straight oil, BenzGrind HP15, from Benz Oil was used for the grinding operation, although other fluids in use on the cam line included Clearedge 6510, WS3-091A, Hysol X, Honilo 480 straight oil from Castrol, and Aquaquench 3600 hardener from Houghton. Open windows in the roof and air supply vents to the east and west of the area provided general ventilation.

Mapping Data

The PM_{10} and $PM_{1.0}$ maps, as measured with DustTrak monitors, are shown in Figure 12. The grinding area indicated by the box represents 4800 ft^2 (440 m^2). The values measured on the two maps have a correlation coefficient of 0.70, which is not significant for the few sampling points in this small area. The maximum values measured during mapping were 0.26 mg/m^3 PM_{10} and 0.14 mg/m^3 $PM_{1.0}$. The PM_{10} concentration measured during mapping at the intensive sampling location was 0.22 mg/m^3, which fell at the 60% frequency level of the mapping measurements.

Intensive Sampling Data

The temporal concentrations of PM_{10} and $PM_{1.0}$ as measured with two DustTrak monitors are shown in Figure 13.

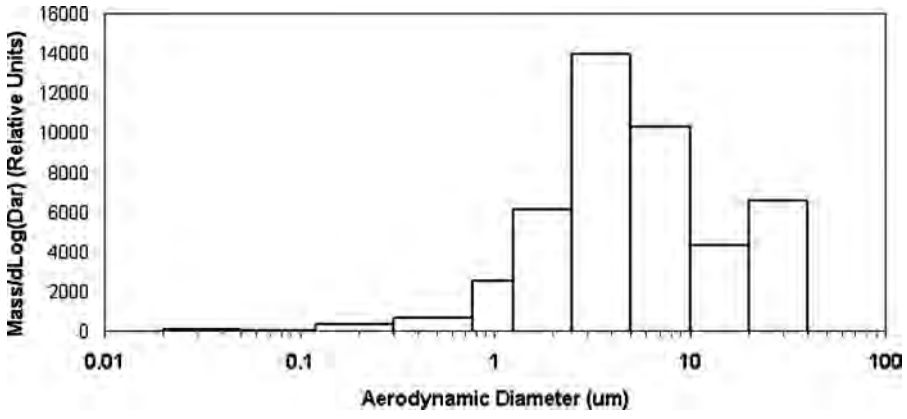


FIGURE 11. Particle size distribution, as measured with the MOUDI, from oil grinding, old technology, October 2000

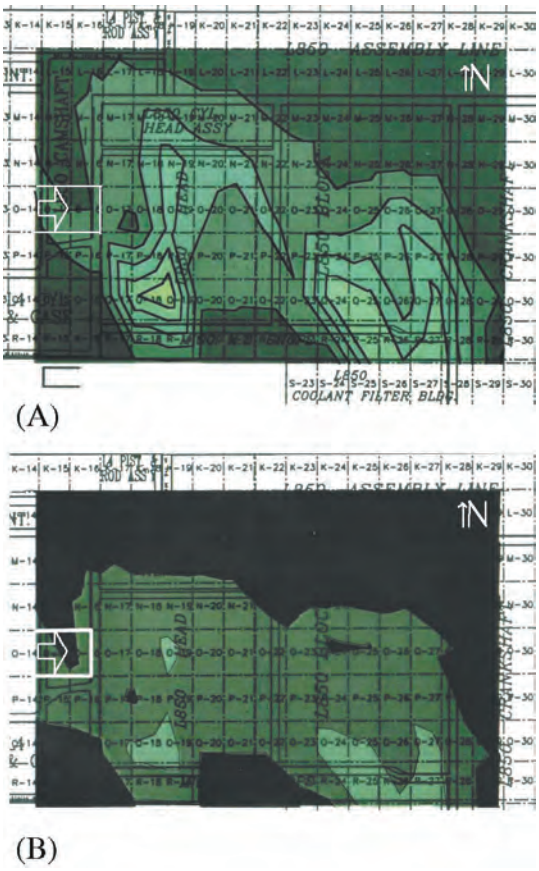


FIGURE 12. (A) Map of PM_{10}, as measured with DustTrak monitors, from grinding with oil, new technology, June 2000 (B) Map of $PM_{1.0}$, as measured with DustTrak monitors, from grinding with oil, new technology, June 2000

There appeared to be almost a cyclic variation with a period of 5 to 10 min that may be due to periods when the enclosure door opened allowing mist to escape. Overall, the PM_{10} mass was about 2.5 times the $PM_{1.0}$ as measured with the DustTrak monitors. The background PM_{10} and $PM_{1.0}$, measured at the end of the day, are shown in Figure 13 and are clearly lower than in the plant, averaging one-third to one-half of plant concentrations.

Comparing the temporal variations in concentration from the old technology oil grinding (Figure 10) with the new technology oil grinding (Figure 13) shows clearly that there is far less difference between the PM_{10} and the $PM_{1.0}$ with new technology enclosed equipment than with old technology partial enclosures. Concentrations also track much better as evidenced by the higher correlation coefficient of 0.90, which is highly significant ($p < 0.0005$).

The mass distribution measured with the MOUDI impactor, filters, the APS, and DustTrak monitors are shown in Table V. The mass concentration measured by the MOUDI was about twice that measured by the filter. The reason for the poor agreement is unknown. However, since the concentration

TABLE V. Particle Mass Concentrations (mg/m^3) in Different Size Fractions from Oil Grinding, New Technology, June 2000

Location	Method	Total	PM_{10}	$PM_{5.0}$	$PM_{2.5}$	$PM_{1.0}$
Plant	MOUDI	0.18	0.16	0.14	0.089	0.024
	Filter	0.082			0.099	
	APS		0.12	0.087	0.060	0.026
	DustTrak		0.25			0.11
Background	Filter				0.034	
	APS		0.031	0.023	0.020	0.014
	DustTrak		0.089			0.057

measured by the total filter is less than measured by the $PM_{2.5}$ filter, it is reasonable to trust the MOUDI value over the filter value. The DustTrak measured higher PM_{10} and $PM_{1.0}$ levels than the MOUDI or APS. The $PM_{2.5}$ concentration was three times the background levels.

The MOUDI particle size distribution in Figure 14 is unimodal, with the mode in the 1.25 μm to 2.5 μm region. The MMAD is 2.5 μm, σ_g 2.5. In comparison, the old technology oil grinding process showed a small-particle mode at larger diameters and a large-particle mode that is not present in new-technology distribution for the enclosed machine. The MMAD in that case was 4.8 μm.

Dry Machining of Cast Iron, Old Technology

Process Description

Dry machining was studied in June 2000. Gray cast iron engine blocks were dry machined on a transfer line consisting primarily of unenclosed Lamb machines. Some areas of the line had mini-enclosures with air vented to mist collectors. The line was running a two-shift operation with approximately 1050 blocks machined per shift. Although not enclosed, hoods above the operations drew the air to about eight different air cleaners throughout the area. Several overhead air vents also provided general ventilation. A number of personal fans were also located in the vicinity of the process. Since the machines were not enclosed, the controls would be classified as old technology.

Mapping Data

The PM_{10} and $PM_{1.0}$ maps, as measured with DustTraks (Figure 15), cover 93,600 ft^2 of plant area. The values measured on the two maps have a correlation coefficient of 0.85, which is highly significant for 53 sample locations ($p < 0.0005$). Maximum values on the map are 0.35 mg/m^3 PM_{10} and 0.14 mg/m^3 $PM_{1.0}$. The PM_{10} concentration measured during mapping at the intensive sampling location was 0.35 mg/m^3, equal to the highest mapped value measured in this area.

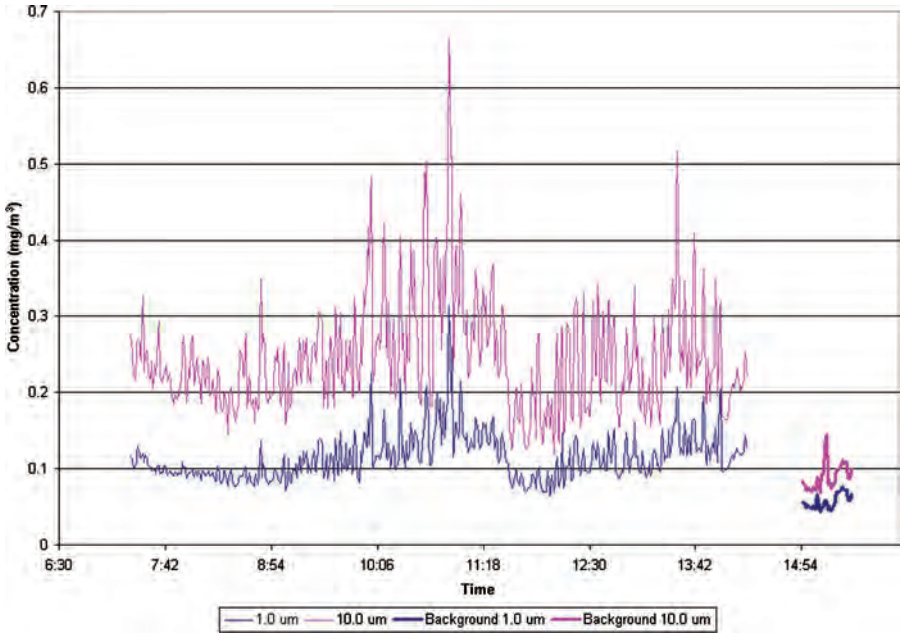


FIGURE 13. Temporal variations in PM_{10} and $PM_{1.0}$ during the intensive sampling period at the oil grinding, new technology process, as measured with DustTrak monitors, June 2000

Intensive Sampling Data

The temporal concentrations of PM_{10} and $PM_{1.0}$ as measured with two DustTrak monitors are shown in Figure 16. The two traces indicate that PM_{10} and $PM_{1.0}$ tracked closely with a correlation coefficient of 0.94, which is highly significant ($p < 0.0005$). The PM_{10} is 2.3 times the $PM_{1.0}$ on average. The background PM_{10} and $PM_{1.0}$ concentrations were measured at the end of the day and were about half of plant concentrations.

The mass distribution measured with the MOUDI impactor, filters, the APS, and DustTrak monitors are shown in Table VI. Good agreement was seen between the different measurement methods, with the usual exception that the $PM_{1.0}$ DustTrak read considerably more than the other samplers during plant sampling, and data from both DustTrak monitors were higher than other samplers during background sampling. The plant concentrations were 3.7 times the background levels as measured with the $PM_{2.5}$ filters.

The MOUDI particle size distribution in Figure 17 shows the peak of particle mass on the first impactor stage, indicating particles >20 μm. The MMAD is 10 μm, σ_g 5.5. These are the largest particles seen of all the processes and suggest particles generated by mechanical processes.

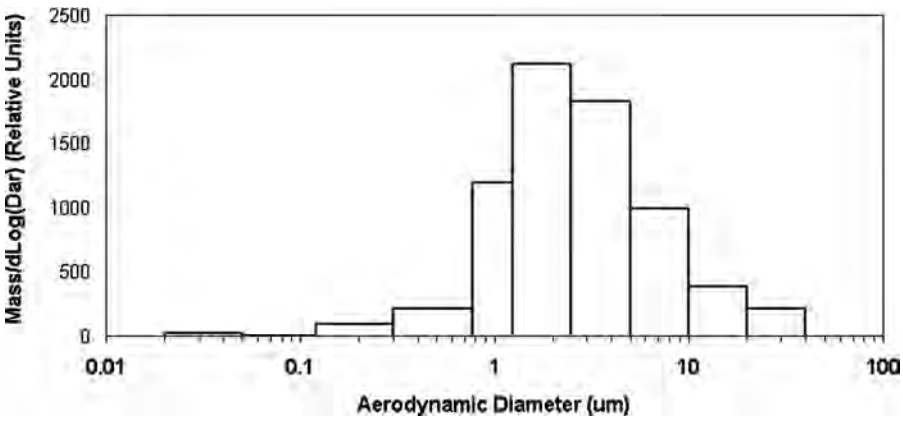


FIGURE 14. Particle size distribution, as measured with the MOUDI, from oil grinding, new technology, June 2000

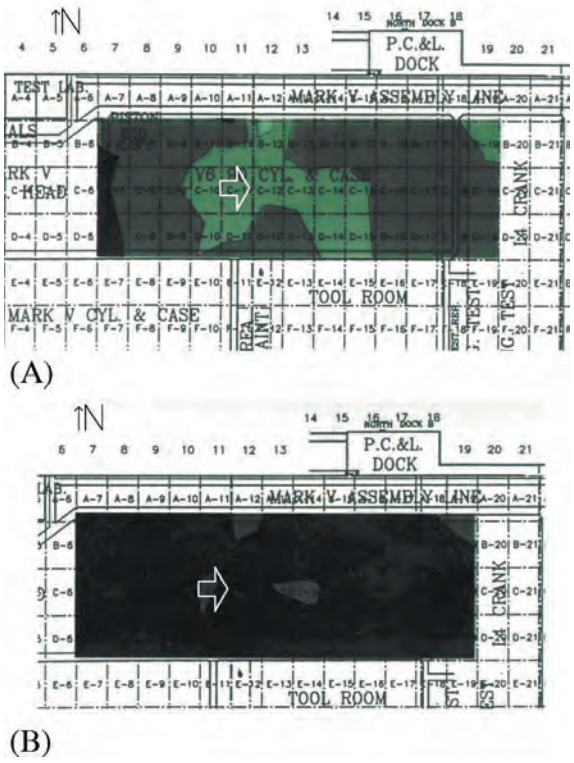


FIGURE 15. (A) Map of PM_{10}, as measured with DustTrak monitors, from dry machining of cast iron, old technology, June 2000 (B) Maps of $PM_{1.0}$, as measured with DustTrak monitors, from dry machining of cast iron, old technology, June 2000

TABLE VI. Particle Mass Concentrations (mg/m^3) in Different Size Fractions from Dry Machining of Cast Iron, Old Technology, June 2000

Location	Method	Total	PM_{10}	$PM_{5.0}$	$PM_{2.5}$	$PM_{1.0}$
Plant	MOUDI	0.56	0.28	0.19	0.13	0.048
	Filter	0.47			0.16	
	APS		0.18	0.094	0.054	0.027
	DustTrak		0.34			0.15
Background	Filter				0.043	
	APS		0.024	0.019	0.016	0.013
	DustTrak		0.15			0.10

DISCUSSION AND CONCLUSIONS

Airborne particles were studied from five machining processes in automotive manufacturing plants as part of a UAW-GM sponsored study. For each process, the PM_{10} and $PM_{1.0}$ concentrations were determined at locations throughout the process area, the data were mapped, and a site was selected for intensive measurements. Temporal variations in PM_{10} and $PM_{1.0}$ and particle size fractions were measured at the intensive sites over the course of one working shift using a variety of measurement equipment, including a personal sampler collecting total mass on a filter, $PM_{2.5}$ filters, a MOUDI impactor, an aerodynamic particle sizer, and DustTrak monitors measuring PM_{10} and $PM_{1.0}$.

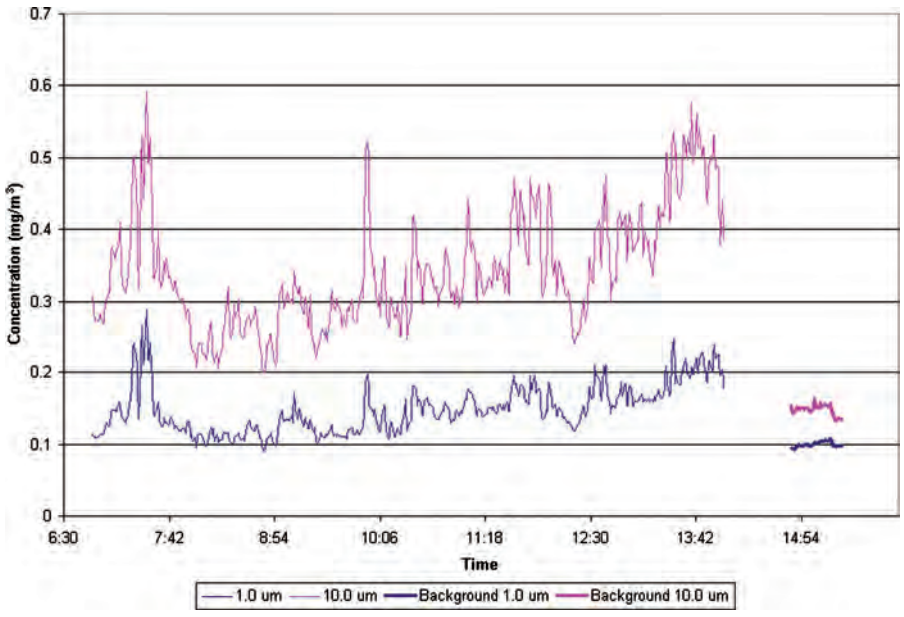


FIGURE 16. Temporal variations in PM_{10} and $PM_{1.0}$ during the intensive sampling period at the dry machining of cast iron, old technology process, as measured with DustTrak monitors, June 2000

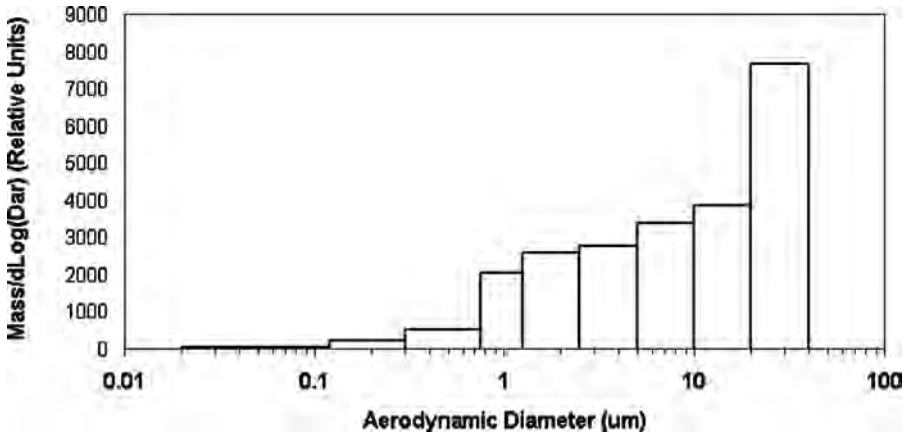


FIGURE 17. Particle Size Distribution, as measured with the MOUDI, from dry machining of cast iron, old technology, June 2000

Samples taken at a single location on 3 consecutive days showed good reproducibility, indicating that particle concentrations and sizes will be stable if the process is stable. The highest relative standard deviation between samples taken on consecutive days was from the MOUDI samples. Processing a MOUDI sample requires making 20 weight measurements in the microgram range with greater opportunity for experimental errors, leading to greater variance between samples. Yet it is considered the most accurate of the methods since it relies on gravimetric methods rather than indirect methods such as light scattering.

Most instruments were in reasonable agreement with one another for the various size ranges. The greatest consistently recorded difference was $PM_{1.0}$ as measured with the DustTrak, which was always higher than other methods (2.5 to 5.1 times higher than MOUDI). Volckens et al.[12] compared different measurement methods for MRF mist and found that light-scattering instruments overestimated mist compared with gravimetric methods when the MMAD was less than 2 μm. Their explanation was that light-scattering instruments are calibrated using aerosols of different sizes than found in machining. DustTrak monitors are light-scattering instruments calibrated against Arizona Road Dust, which has a larger size distribution than typical MRF mist. Therefore, light-scattering instruments should be calibrated against known, local particle concentrations or used as relative monitors, such as for mapping or temporal sampling.

A summary of the data for five machining operations as measured in this study are shown in Table VII, including median concentrations from mapping and the MOUDI MMAD. In considering the table, some summary statements can be made. Median aerosol concentrations near oil grinding were higher than near machining operations using water-based fluids, both for old and new technology equipment, similar to the results of Woskie et al.[3] Median aerosol concentrations near old technology controls, as characterized by open transfer lines, were higher than those near new technology controls, as characterized by enclosed machining centers. The new technology controls appeared to effectively reduce particle concentration levels. Median dry machining aerosol concentrations were lower than from the other processes, even with old technology controls.

A comparison of particle size distributions for old and new technologies is shown in Figure 18 and the MMADs are listed in Table VII. The solid and dashed lines in the top two plots represent the old and new technology processes overlaid. The new technology processes are obviously much lower in concentration and the primary mode has shifted to smaller particles. Comparing the different size fractions, it is obvious that the new technology controls are more effective at removing

TABLE VII. Airborne Particle Values from Five Machining Operations

Operation	Fluid	Material	Technology	Mapping Median PM_{10} (mg/m^3)	Mapping Median $PM_{1.0}$ (mgm^3)	MMD (μm)
Grinding	Oil	Steel	Old	0.67	0.17	4.8
Wet machining	WB[A]	Aluminum	Old	0.43	0.19	3.3
Grinding	Oil	Steel	New	0.21	0.12	2.5
Wet machining	WB	Aluminum	New	0.17	0.091	1.25
Dry	None	Cast Iron	Old	0.16	0.072	10

[A]WB: Water-based metal removal fluid.

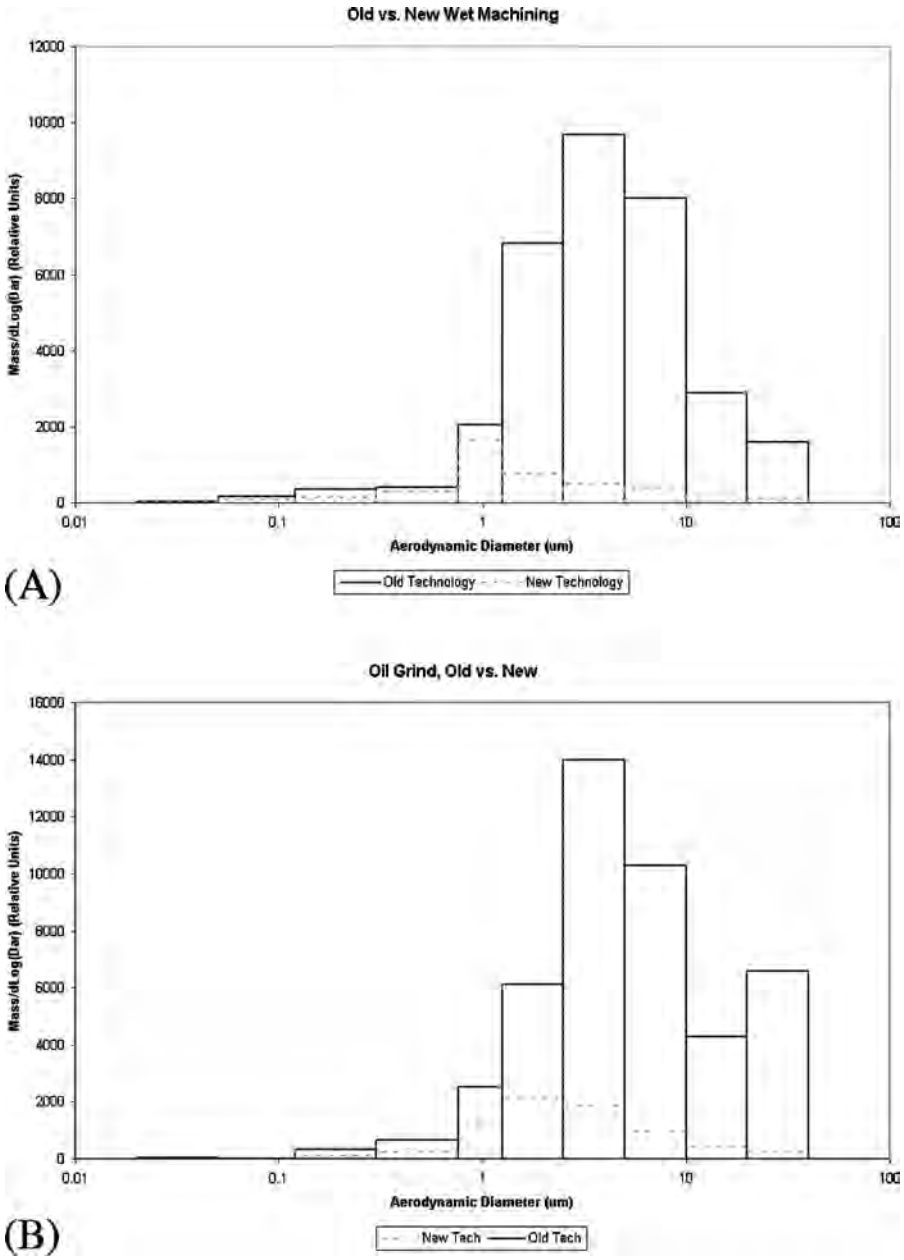


FIGURE 18. MOUDI size distribution plots for old technology (solid line) and new technology (dashed line) processes. (A) Wet Machining and (B) Grinding with Oil.

the large particles than the small particles. The large-particle mode (>20 μm) observed for grinding has disappeared with new technology controls.

The old technology, wet machining process has the major particle mode between 1 μm and 10 μm. Grinding shows a similar mode as well as a large-particle mode >20 μm, possibly from grinding dust. Particles were larger for grinding with oil than machining with water-based fluids, both for old and new technologies. Since water-based fluids produce aerosols that lose water to evaporation, they produce smaller aerosols. Dry machining of cast iron generated the largest particles of all processes studied (Figure 17). A submicron particle mode was not observed in these wet machining tests, although it has been observed in some machining operations that generate high heat and has been attributed to evaporation of oil and recondensation as submicron particles.[6]

This study has shown that each manufacturing process, even within related machining operations, generates a signature aerosol, that is, an aerosol with a size profile specific to that process. The signature is determined by the operation, the type of fluid, and the enclosure and control devices. This signature is lost when collecting an integrated sample, whatever cutoff

diameter is chosen. The generation and removal of aerosols from a particular process can be understood only if a complete size characterization of the aerosol is performed.

ACKNOWLEDGMENTS

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QUICK**FACTS**

GO Trains

AUGUST 2014

GO Transit trains are now pulled (or pushed) by MP40 locomotives.

The MP40 locomotives have the ability to pull 12 bi-level coaches, instead of the standard 10. This means greater passenger capacity on trains, delivering more people on time.

MP40 LOCOMOTIVE

New to GO's rail fleet as of 2008.

Total in fleet	67
Length	20.73 m (68ft)
Width	3.24 m (10ft 7 1/2 in)
Height	4.97 m (16ft 3 1/2 in)
Gross weight	129 tons (289,000 lb)
Fuel capacity	up to 8,410 L (1,850 Imp. gal)
Horsepower	4000

- Maximum operating speed: 150 km/h (93 mph)
- Can move a maximum of 12 bi-level railcars

BI-LEVEL COACH

Total in GO's fleet	598
Seating capacity	up to 162 passengers
Length	25.9 m (85 ft)
Width	3.0 m (9 ft 10 in)
Height	4.85 m (15 ft 11 in)
Weight (empty)	49 tons (109,000 lb)

- Up to four bicycles can be accommodated on each railcar, outside of rush hour
- Seating available on upper and lower levels, as well as middle "mezzanine" level at each end of railcar

CUSTOMER SERVICE

Customer Service Ambassadors (CSAs) on GO Trains announce station stops, upcoming service changes, and reminders about passenger safety, as well as attending to the needs and questions of customers.

CSAs are specially focused on the interaction with passengers and on providing the latest information about service status. They are linked directly to GO's operations centre and always have the latest information.

ACCESSIBILITY

All GO Trains are equipped with accessibility features that allow passengers with disabilities to enter and exit the trains easily, as well as having Priority and Courtesy Seating areas.

GO TRAIN MAINTENANCE FACILITY

Willowbrook

Willowbrook is GO Transit's 18,600 square-metre train maintenance depot located just west of downtown Toronto. This modern commuter train service facility has four progressive maintenance bays for train equipment, a locomotive shop, a railcar shop and storage tracks for 21 trains. Innovative features include an efficient waste management system and energy-saving equipment in the main building. All of these features combine to make Willowbrook one of the most modern and efficient commuter train facilities in North America.



See what we're doing to make your ride better.
gotransit.com/promise

Burloak Grade Separation Transit Air Quality Assessment
Existing GO Train Schedule (2017)

2017 Weekday Schedule
Appleby

Arrival Time	Time between each train arrival (mins)	Arrival Time	Time between each train arrival (mins)
Eastbound		**Westbound**	
5:16	30	6:33	30
5:46	30	7:03	34
6:16	20	7:37	35
6:36	10	8:12	30
6:46	20	8:42	25
7:06	10	9:07	35
7:16	20	9:42	30
7:36	10	10:12	25
7:46	20	10:37	30
8:06	10	11:07	30
8:16	15	11:37	30
8:31	18	12:07	30
8:49	30	12:37	30
9:19	25	13:07	30
9:44	35	13:37	30
10:19	30	14:07	30
10:49	25	14:37	30
11:14	30	15:07	30
11:44	30	15:37	37
12:14	30	16:14	20
12:44	30	16:34	10
13:14	30	16:44	20
13:44	30	17:04	10
14:14	30	17:14	20
14:44	27	17:34	10
15:11	30	17:44	20
15:41	33	18:04	10
16:14	24	18:14	20
16:38	36	18:34	40
17:14	30	19:14	20
17:44	30	19:34	33
18:14	35	20:07	30
18:49	25	20:37	30
19:14	30	21:07	30
19:44	30	21:37	30
20:14	30	22:07	30
20:44	30	22:37	30
21:14	30	23:07	30
21:44	30	23:37	30
22:14	30	0:07	30
22:44	30	0:37	60
23:14		1:37	
Number of EB trains/day		Number of WB trains/day	
42		42	

Burloak Grade Separation Transit Air Quality Assessment
Future GO Train Schedule (2018)

2018 Weekend Schedule
Appleby

Arrival Time	Time between each train arrival (mins)	Arrival Time	Time between each train arrival (mins)
Eastbound		**Westbound**	
7:14	30	7:37	30
7:44	30	8:07	30
8:14	30	8:37	30
8:44	30	9:07	30
9:14	30	9:37	30
9:44	30	10:07	30
10:14	30	10:37	30
10:44	30	11:07	30
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18:44	30	18:37	30
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20:44	30	20:37	30
21:14	30	21:07	30
21:44	30	21:37	30
22:14	30	22:07	30
22:44	30	22:37	30
23:14		23:07	30
		23:37	30
		0:07	30
		0:37	30
		1:07	30
		1:37	

Number of EB trains/day: 32
Number of WB trains/day: 37

Total number of trains per day: 69

Technical Highlights

Emission Factors for Locomotives

The Environmental Protection Agency (EPA) has established emission standards for oxides of nitrogen (NOx), hydrocarbons (HC), carbon monoxide (CO), particulate matter (PM) and smoke for newly manufactured and remanufactured locomotives. These standards, which are codified at 40 CFR part 1033, include several sets of emission standards with applicability dependent on the date a locomotive is first manufactured. The first set of standards (Tier 0) applies to most locomotives originally manufactured before 2001. The most stringent set of standards (Tier 4) applies to locomotives originally manufactured in 2015 and later. This fact sheet describes EPA's estimates of the typical in-use emission rates for locomotives subject to these standards, as well as the previous standards.

It is important to emphasize that this fact sheet relies on many simplifying assumptions. Thus emission rates calculated as described in this fact sheet should be considered as approximations.

Estimated Locomotive Emission Rates by Tier

EPA has estimated average emission rates, given in grams per brake horsepower-hour (g/bhp-hr), for uncontrolled locomotives and those required to meet the various emission standards. Emissions were estimated for two different types of operation: a low power cycle representing operation in a switch yard, and a higher power cycle representative of general line-haul operation. These estimates are shown in Tables 1 and 2. Note that plus signs in the table indicate that a given tier of standards was revised in a 2008 rulemaking (73 FR 37096, June 30, 2008). For example, locomotives originally manufactured in years 2002-2004 were initially subject to the original Tier 1 standards, but will be required to meet revised Tier 1 standards (also known as Tier 1+ standards) when remanufactured. See the regulatory text for a more precise explanation of which standards apply to which locomotives.

EPA United States Environmental Protection Agency

Office of Transportation and Air Quality
EPA-420-F-09-025
April 2009

It is important to note that there can be significant variability in in-use emission rates, especially for uncontrolled locomotives. Also, a single locomotive's emission rate can vary throughout its life as the engine ages and as ambient conditions change. Thus the values presented here are intended to reflect the average emission rates. It is also worth noting that these emission estimates were developed in the context of adopting new emission standards. This is especially important for the CO emission factors. Because EPA's CO emission standards were intended to cap CO emissions at pre-control levels (which were relatively low), we have not projected any reductions in CO emission factors. However, recent testing indicates that emission controls designed to reduce PM and HC emissions are also reducing CO emissions. Thus the CO emission rates presented here may be too high and should be used with some caution. A similar effect may also apply for HC emissions from Tier 0 and Tier 1 locomotives (but not the Tier 0+ and Tier 1+ locomotives).

Table 1 - Line-Haul Emission Factors (g/bhp-hr)

	PM_{10}	HC	NO_x	CO
UNCONtrOlled	0.32	0.48	13.00	1.28
tier 0	0.32	0.48	8.60	1.28
tier 0+	0.20	0.30	7.20	1.28
tier 1	0.32	0.47	6.70	1.28
tier 1+	0.20	0.29	6.70	1.28
tier2	0.18	0.26	4.95	1.28
tier 2+ & tier 3	0.08	0.13	4.95	1.28
tier 4	0.015	0.04	1.00	1.28
+ iNdiCa tes tHa t tHese are tHe revised st aNdards iN 40 CFr P ar t 1033				

Table 2 - Switch Emission Factors (g/bhp-hr)

	PM_{10}	HC	NO_x	CO
UNCONtrOlled	0.44	1.01	17.40	1.83
tier 0	0.44	1.01	12.60	1.83
tier 0+	0.23	0.57	10.60	1.83
tier 1	0.43	1.01	9.90	1.83
tier 1+	0.23	0.57	9.90	1.83
tier2	0.19	0.51	7.30	1.83
tier 2+	0.11	0.26	7.30	1.83
tier 3	0.08	0.26	4.50	1.83
tier 4	0.015	0.08	1.00	1.83
+ iNdiCa tes tHa t tHese are tHe revised st aNdards iN 40 CFr P ar t 1033				

Conversion to Gram per Gallon Emission Factors

It is often useful to express emission rates as grams of pollutant emitted per gallon of fuel consumed (g/gal). This can be done by multiplying the emission rates in Table 1 or 2 by a conversion factor relating the fuel consumption (gal/hr) and the usable power (bhp) of the engine. EPA has estimated different conversion factors for different types of locomotive service as shown in Table 3. The two primary reasons for the differences are variations in locomotive age and duty cycle. Fuel efficiency tends to be worse for older locomotive designs and for locomotives used in low power applications such as switching. Note that the g/gal emission factors presented at the end of this fact sheet can be converted back to g/bhp-hr by dividing them by the conversion factors shown here.

Table 3
Conversion Factors (bhp-hr/gal)

locomotive application	Conversion Factor (bhp-hr/gal)
lar ge line-Haul and Passenger	20.8
small line-Haul	18.2
switching	15.2

Conversion to Gram per Ton-Mile Emission Factors

In some cases, it can be helpful to express emission factors as grams emitted per ton-mile of freight hauled. However, this can also be very problematic because the amount of engine work required for each ton-mile varies significantly with a variety of factors. For example, it takes more work to haul freight through mountainous terrain than across flat areas. Since EPA does not have detailed information about these variations, we cannot provide accurate g/ton-mile emission rates. However, very approximate national average values can be calculated based on data collected by the Association of American Railroads for revenue ton-miles and fuel consumption, which show that about one gallon of fuel is consumed by the railroads to haul 400 tons-miles of freight. Thus dividing g/gal emission rates by 400 ton-miles/gal gives approximate g/ton-mile emission rates.

Emission Inventory Estimation

Total emissions can be calculated by multiplying the emission factors (in g/gal) by the fuel consumption rates (in million-gal/yr) to give annual emission rates (in metric tons per year). Multiplying this metric estimate by 1.102 gives standard U.S. tons (or short tons) per year.

EPA has estimated that locomotives consume approximately 4 billion gallons of diesel fuel each year. This includes national/regional freight service, switching, local freight service, and passenger service. The relative amounts of fuel used in the United States for these four different types of operation are shown in Table 4. The great majority of fuel consumed by locomotives each year is used in line-haul freight service by the largest railroads. Smaller amounts are also used in

switching and passenger service, and by very small railroads. For the purpose of this fact sheet, we are aggregating the largest railroads with smaller railroads that are fully subject to EPA's emission requirements. This includes regional railroads as well as other railroads such as those that are owned by large businesses. The local freight category includes only those railroads that meet our regulatory definition of "small railroad" (40 CFR 1033.901) to qualify for small business allowances under our regulations. These railroads are included in this fact sheet as local whether or not they are truly local in nature. The passenger category includes local commuter railroads and AMTRAK.

Table 4 - Locomotive Fuel Consumption by Service Category	
National and regional Freight line-haul	88%
National Freight switching	7%
local Freight	<2%
Passenger	3%

Other Pollutants

The preceding emission factors include those pollutants for which EPA has set emission standards. However, other pollutants may also be of interest.

The broad category of volatile organic compounds (VOC) is a slightly different way of aggregating the organic pollutants controlled by our HC emission standards. In our rulemaking analysis (http://www.epa.gov/otaq/regs/nonroad/420r08001a.pdf), we estimated that VOC emissions can be assumed to be equal to 1.053 times the HC emissions. Similarly, PM emissions can be expressed as PM_{10} (which includes all particles up to 10 microns in diameter) or $PM_{2.5}$ (which includes only those particles up to 2.5 microns in diameter). $PM_{2.5}$ emissions can be estimated as 0.97 times the PM_{10} emissions, meaning that nearly all of the PM is less than 2.5 microns in diameter.

Gram per gallon emissions of sulfur dioxide (SO_2) and carbon dioxide (CO_2) are largely independent of engine parameters and are primarily dependent on fuel properties. Locomotive-specific emission rates are not presented here. Instead, SO_2 and CO_2 emission rates should be calculated based on the properties of the specific fuel being used by the locomotives. These emission rates can also be assumed to be the same as for other diesel engines operating on similar fuel. Note that special caution should be used when estimating SO_2 emission rates since the sulfur content of diesel fuel varies much more than the carbon content. Also, while the vast majority of sulfur in the fuel is typically converted to SO_2, up to 5 percent of the sulfur is oxidized further to sulfate (and forms particulate matter), so that the fraction of fuel sulfur emitted as SO_2 may be as low as 95 percent. Examples of these calculations are shown below based on inputs described in the NONROAD technical document NR-009c (http://www.epa.gov/otaq/models/nonrdmdl/nonrdmdl2004/420p04009.pdf).

sO_2 (g/gal) = (fuel density) × (conversion factor) × (64 g sO_2/32 g s) × (s content of fuel)

Consider the example where the density of diesel fuel is 3200 g/gal, the fraction of fuel sulfur converted to sO_2 is 97.8 percent, and the sulfur content of the fuel is 300 ppm.

sO_2 (g/gal) = (3200) × (0.978) × (2.00) × (300×10^{-6}) = 1.88 g/gal

CO_2 (g/gal) = (fuel density) × (44 g CO_2/12 g C) × (C content of fuel)

Consider the example where the density of diesel fuel is 3200 g/gal and the carbon content of the fuel is 87 percent by mass.

CO_2 (g/gal) = (3200) × (3.67) × (0.87) = 10,217 g/gal

Other trace pollutants such as N_2O, methane, and many air toxics are more dependent on engine parameters. At this time, however, EPA does not have detailed emission rates for these pollutants from locomotives. Where estimates are needed for N_2O or methane, you may assume that emissions of these pollutants from locomotives are similar to those of other diesel engines with similar technology. For N_2O, you may assume the emissions are proportional to total NOx. For methane, you may assume the emissions are proportional to total hydrocarbons. Note however, that the presence of catalyzed components in the exhaust can significantly affect these ratios. So it is best to compare emissions from uncatalyzed locomotives to emissions from other uncatalyzed diesel engines. While this same approach could be used for air toxics (assuming that air toxic emissions are proportional to total hydrocarbons), EPA has estimated air toxic emissions from locomotives. These estimates are described in the National Emission Inventory documentation (see ftp://ftp.epa.gov/EmisInventory/2002finalnei/documentation/mobile/2002nei_mobile_nonroad_methods.pdf - appendix C).

Projected Future Emission Factors

Tables 5-7 give the expected fleet average NOx, PM_{10}, and HC emission factors by calendar year for the four categories of locomotives (the same four categories as are shown in Table 4). The steady decline in these emission factors reflects the penetration of the various tiers of locomotives into the fleet over time. More detail regarding the assumptions on which these projections were based can be found in the Regulatory Impact Analysis for the 2008 rulemaking (http://www.epa.gov/otaq/regs/nonroad/420r08001a.pdf)

For More Information

You can access the rule and related documents on EPA's Office of Transportation and Air Quality (OTAQ) Web site at: www.epa.gov/otaq/locomotives.htm.

For more information on this rule, please contact the Assessment and Standards Division information line at:

U.S. Environmental Protection Agency
Office of Transportation and Air Quality
2000 Traverwood Drive
Ann Arbor, MI 48105
Voicemail: (734) 214-4636
E-mail: asdinfo@epa.gov

Table 5 – NOx Emission Factors (g/gal)

Calendar Year	lar ge line-haul	lar ge switch	small railroads	Passenger/Commuter	Overall a verage
2006	180	250	242	244	188
2007	175	249	242	229	183
2008	169	243	242	214	177
2009	165	241	242	200	172
2010	157	236	242	183	165
2011	149	235	242	167	157
2012	144	227	242	157	152
2013	139	225	242	147	147
2014	135	217	242	138	143
2015	129	215	240	131	137
2016	121	208	239	119	129
2017	114	206	237	112	122
2018	108	202	236	105	117
2019	103	200	233	98	112
2020	99	187	231	93	107
2021	94	185	228	88	102
2022	89	177	225	83	97
2023	84	172	223	78	92
2024	79	162	220	73	87
2025	74	150	217	68	81
2026	69	144	215	64	77
2027	65	138	212	60	72
2028	61	132	209	56	68
2029	57	126	206	52	64
2030	53	119	203	49	60
2031	49	112	200	46	56
2032	46	105	197	42	52
2033	43	98	193	39	49
2034	40	91	190	36	46
2035	37	84	187	33	43
2036	35	77	184	30	40
2037	33	71	180	28	38
2038	31	67	177	26	36
2039	29	63	174	24	34
2040	28	60	171	23	32

Table 6 – PM_{10} Emission Factors (g/gal)

Calendar Year	lar ge line-haul	lar ge switch	small railroads	Passenger/Commuter	Overall a verage
2006	6.4	6.5	6.5	6.5	6.4
2007	6.3	6.5	6.5	6.4	6.3
2008	5.1	5.5	5.7	5.1	5.1
2009	4.9	5.5	5.7	5.0	4.9
2010	4.7	5.4	5.7	4.8	4.7
2011	4.4	5.3	5.7	4.5	4.5
2012	4.1	5.1	5.7	4.2	4.2
2013	3.8	5.0	5.6	3.9	3.9
2014	3.6	4.8	5.6	3.6	3.7
2015	3.4	4.8	5.5	3.4	3.5
2016	3.1	4.6	5.5	3.1	3.3
2017	2.9	4.5	5.4	2.8	3.0
2018	2.7	4.4	5.4	2.6	2.8
2019	2.5	4.4	5.4	2.3	2.6
2020	2.3	4.1	5.3	2.1	2.5
2021	2.2	4.0	5.3	2.0	2.4
2022	2.0	3.9	5.3	1.8	2.2
2023	1.9	3.7	5.2	1.7	2.1
2024	1.7	3.5	5.2	1.5	1.9
2025	1.6	3.2	5.1	1.4	1.8
2026	1.5	3.1	5.1	1.2	1.6
2027	1.4	3.0	5.1	1.1	1.5
2028	1.3	2.8	5.0	1.0	1.4
2029	1.1	2.7	5.0	0.9	1.3
2030	1.0	2.5	4.9	0.8	1.2
2031	1.0	2.4	4.8	0.7	1.1
2032	0.9	2.2	4.8	0.7	1.0
2033	0.8	2.1	4.7	0.6	0.9
2034	0.7	1.9	4.6	0.6	0.9
2035	0.7	1.7	4.6	0.5	0.8
2036	0.6	1.6	4.5	0.5	0.7
2037	0.6	1.5	4.4	0.4	0.7
2038	0.5	1.4	4.4	0.4	0.6
2039	0.5	1.3	4.3	0.4	0.6
2040	0.4	1.2	4.2	0.3	0.5

Table 7 - HC Emission Factors (g/gal)

Calendar Year	lar ge line-haul	lar ge switch	small railroads	Passenger/Commuter	Overall a verage
2006	9.5	15.0	11.7	9.7	10.0
2007	9.3	15.0	11.7	9.5	9.8
2008	9.0	14.5	11.7	9.3	9.5
2009	8.7	14.5	11.7	9.1	9.1
2010	8.3	14.1	11.7	8.6	8.8
2011	7.7	14.0	11.7	8.1	8.2
2012	7.1	13.3	11.7	7.5	7.6
2013	6.5	13.3	11.7	6.9	7.1
2014	6.1	12.7	11.7	6.3	6.7
2015	5.7	12.6	11.7	5.8	6.3
2016	5.1	12.0	11.7	5.2	5.7
2017	4.6	11.8	11.7	4.6	5.2
2018	4.2	11.5	11.7	4.1	4.8
2019	3.9	11.4	11.7	3.5	4.5
2020	3.6	10.5	11.7	3.1	4.2
2021	3.4	10.4	11.7	2.9	4.0
2022	3.2	9.8	11.7	2.7	3.8
2023	3.0	9.5	11.7	2.4	3.6
2024	2.8	8.9	11.7	2.2	3.4
2025	2.6	8.0	11.7	2.0	3.1
2026	2.5	7.6	11.7	1.8	2.9
2027	2.3	7.3	11.7	1.6	2.8
2028	2.1	6.9	11.7	1.5	2.6
2029	2.0	6.5	11.7	1.3	2.4
2030	1.9	6.2	11.7	1.2	2.3
2031	1.7	5.8	11.7	1.1	2.2
2032	1.6	5.5	11.7	1.0	2.0
2033	1.5	5.1	11.7	0.9	1.9
2034	1.4	4.7	11.7	0.8	1.8
2035	1.3	4.4	11.7	0.7	1.7
2036	1.2	4.0	11.7	0.7	1.6
2037	1.2	3.7	11.7	0.6	1.5
2038	1.1	3.6	11.7	0.6	1.4
2039	1.1	3.4	11.7	0.5	1.4
2040	1.0	3.2	11.7	0.5	1.3

13.2.1 Paved Roads

13.2.1.1 General

Particulate emissions occur whenever vehicles travel over a paved surface such as a road or parking lot. Particulate emissions from paved roads are due to direct emissions from vehicles in the form of exhaust, brake wear and tire wear emissions and resuspension of loose material on the road surface. In general terms, resuspended particulate emissions from paved roads originate from, and result in the depletion of, the loose material present on the surface (i.e., the surface loading). In turn, that surface loading is continuously replenished by other sources. At industrial sites, surface loading is replenished by spillage of material and trackout from unpaved roads and staging areas. Figure 13.2.1-1 illustrates several transfer processes occurring on public streets.

Various field studies have found that public streets and highways, as well as roadways at industrial facilities, can be major sources of the atmospheric particulate matter within an area.[1-9] Of particular interest in many parts of the United States are the increased levels of emissions from public paved roads when the equilibrium between deposition and removal processes is upset. This situation can occur for various reasons, including application of granular materials for snow and ice control, mud/dirt carryout from construction activities in the area, and deposition from wind and/or water erosion of surrounding unstabilized areas. In the absence of continuous addition of fresh material (through localized track out or application of antiskid material), paved road surface loading should reach an equilibrium value in which the amount of material resuspended matches the amount replenished. The equilibrium surface loading value depends upon numerous factors. It is believed that the most important factors are: mean speed of vehicles traveling the road; the average daily traffic (ADT); the number of lanes and ADT per lane; the fraction of heavy vehicles (buses and trucks); and the presence/absence of curbs, storm sewers and parking lanes.[10]

The particulate emission factors presented in a previous version of this section of AP-42, dated October 2002, implicitly included the emissions from vehicles in the form of exhaust, brake wear, and tire wear as well as resuspended road surface material. EPA included these sources in the emission factor equation for paved roads since the field testing data used to develop the equation included both the direct emissions from vehicles and emissions from resuspension of road dust.

This version of the paved road emission factor equation only estimates particulate emissions from resuspended road surface material[28]. The particulate emissions from vehicle exhaust, brake wear, and tire wear are now estimated separately using EPA's MOVES[29] model. This approach eliminates the possibility of double counting emissions. Double counting results when employing the previous version of the emission factor equation in this section and MOVES to estimate particulate emissions from vehicle traffic on paved roads. It also incorporates the decrease in exhaust emissions that has occurred since the paved road emission factor equation was developed. Earlier versions of the paved road emission factor equation includes estimates of emissions from exhaust, brake wear, and tire wear based on emission rates for vehicles in the 1980 calendar year fleet. The amount of PM released from vehicle exhaust has decreased since 1980 due to lower new vehicle emission standards and changes in fuel characteristics.

13.2.1.2 Emissions And Correction Parameters

Dust emissions from paved roads have been found to vary with what is termed the "silt loading" present on the road surface. In addition, the average weight and speed of vehicles traveling the road influence road dust emissions. The term silt loading (sL) refers to the mass of silt-size material (equal to or less than 75 micrometers [µm] in physical diameter) per unit area of the travel surface. The total road surface dust loading consists of loose material that can be collected by broom sweeping and vacuuming of the traveled portion of the paved road. The silt fraction is determined by measuring the proportion of the loose dry surface dust that passes through a 200-mesh screen, using the ASTM-C-136 method. Silt loading is the product of the silt fraction and the total loading, and is abbreviated "sL". Additional details on the sampling and analysis of such material are provided in AP-42 Appendices C.1 and C.2.

The surface sL provides a reasonable means of characterizing seasonal variability in a paved road emission inventory. In many areas of the country, road surface loadings [11-21] are heaviest during the late winter and early spring months when the residual loading from snow/ice controls is greatest. As noted earlier, once replenishment of fresh material is eliminated, the road surface loading can be expected to reach an equilibrium value, which is substantially lower than the late winter/early spring values.

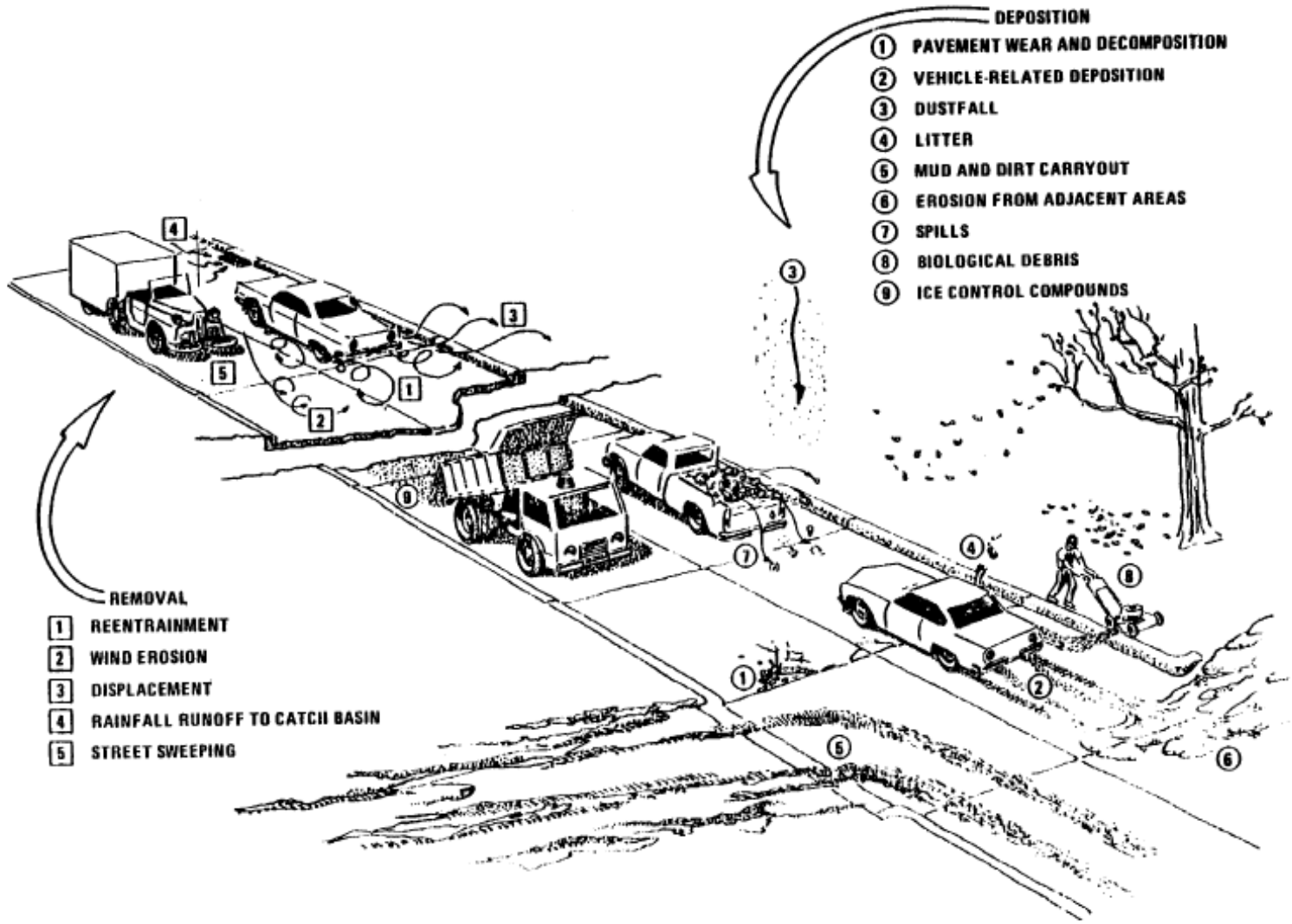


Figure 13.2.1-1. Deposition and removal processes.

13.2.1.3 Predictive Emission Factor Equations[10,29]

The quantity of particulate emissions from resuspension of loose material on the road surface due to vehicle travel on a dry paved road may be estimated using the following empirical expression:

$$E = k\,(sL)^{0.91} \times (W)^{1.02} \quad (1)$$

where: E = particulate emission factor (having units matching the units of k),
k = particle size multiplier for particle size range and units of interest (see below),
sL = road surface silt loading (grams per square meter) (g/m^2), and
W = average weight (tons) of the vehicles traveling the road.

It is important to note that Equation 1 calls for the average weight of all vehicles traveling the road. For example, if 99 percent of traffic on the road are 2 ton cars/trucks while the remaining 1 percent consists of 20 ton trucks, then the mean weight "W" is 2.2 tons. More specifically, Equation 1 is *not* intended to be used to calculate a separate emission factor for each vehicle weight class. Instead, only one emission factor should be calculated to represent the "fleet" average weight of all vehicles traveling the road.

The particle size multiplier (k) above varies with aerodynamic size range as shown in Table 13.2.1-1. To determine particulate emissions for a specific particle size range, use the appropriate value of k shown in Table 13.2.1-1.

To obtain the total emissions factor, the emissions factors for the exhaust, brake wear and tire wear obtained from either EPA's MOBILE6.2 [27] or most recent MOVES [29] software model should be added to the emissions factor calculated from the empirical equation.

Table 13.2.1-1. PARTICLE SIZE MULTIPLIERS FOR PAVED ROAD EQUATION

Size range[a]	Particle Size Multiplier k[b]		
	g/VKT	g/VMT	lb/VMT
PM-2.5[c]	0.15	0.25	0.00054
PM-10	0.62	1.00	0.0022
PM-15	0.77	1.23	0.0027
PM-30[d]	3.23	5.24	0.011

[a] Refers to airborne particulate matter (PM-x) with an aerodynamic diameter equal to or less than x micrometers.

[b] Units shown are grams per vehicle kilometer traveled (g/VKT), grams per vehicle mile traveled (g/VMT), and pounds per vehicle mile traveled (lb/VMT). The multiplier k includes unit conversions to produce emission factors in the units shown for the indicated size range from the mixed units required in Equation 1.

[c] The k-factors for $PM_{2.5}$ were based on the average $PM_{2.5}$:PM_{10} ratio of test runs in Reference 30.

[d] PM-30 is sometimes termed "suspendable particulate" (SP) and is often used as a surrogate for TSP.

Equation 1 is based on a regression analysis of 83 tests for PM-10.[3, 5-6, 8, 27-29, 31-36] Sources tested include public paved roads, as well as controlled and uncontrolled industrial paved roads. The majority of tests involved freely flowing vehicles traveling at constant speed on relatively level roads. However, 22 tests of slow moving or "stop-and-go" traffic or vehicles under load were available for inclusion in the data base.[32-36] Engine exhaust, tire wear and break wear were subtracted from the emissions measured in the test programs prior to stepwise regression to determine Equation 1.[37, 39] The equations retain the quality rating of A (D for PM-2.5), if applied within the range of source conditions that were tested in developing the equation as follows:

Silt loading:	0.03 - 400 g/m^2 0.04 - 570 grains/square foot (ft^2)
Mean vehicle weight:	1.8 - 38 megagrams (Mg) 2.0 - 42 tons
Mean vehicle speed:	1 - 88 kilometers per hour (kph) 1 - 55 miles per hour (mph)

The upper and lower 95% confidence levels of equation 1 for PM_{10} is best described with equations using an exponents of 1.14 and 0.677 for silt loading and an exponents of 1.19 and 0.85 for weight. Users are cautioned that application of equation 1 outside of the range of variables and operating conditions specified above, e.g., application to roadways or road networks with speeds above 55 mph and average vehicle weights of 42 tons, will result in emission estimates with a higher level of uncertainty. In these situations, users are encouraged to consider an assessment of the impacts of the influence of extrapolation to the overall emissions and alternative methods that are equally or more plausible in light of local emissions data and/or ambient concentration or compositional data.

To retain the quality rating for the emission factor equation when it is applied to a specific paved road, it is necessary that reliable correction parameter values for the specific road in question be determined. With the exception of limited access roadways, which are difficult to sample, the collection and use of site-specific silt loading (sL) data for public paved road emission inventories are strongly recommended. The field and laboratory procedures for determining surface material silt content and surface dust loading are summarized in Appendices C.1 and C.2. In the event that site-specific values cannot be obtained, an appropriate value for a paved public road may be selected from the values in Table 13.2.1-2, but the quality rating of the equation should be reduced by 2 levels.

Equation 1 may be extrapolated to average uncontrolled conditions (but including natural mitigation) under the simplifying assumption that annual (or other long-term) average emissions are inversely proportional to the frequency of measurable (> 0.254 mm [0.01 inch]) precipitation by application of a precipitation correction term. The precipitation correction term can be applied on a daily or an hourly basis [26, 38].

For the daily basis, Equation 1 becomes:

$$E_{ext} = [\, k\,(sL)^{0.91} \times (W)^{1.02} \,]\,(1 - P/4N) \qquad (2)$$

where k, sL, W, and S are as defined in Equation 1 and

E_{ext} = annual or other long-term average emission factor in the same units as k,

P = number of "wet" days with at least 0.254 mm (0.01 in) of precipitation during the averaging period, and

N = number of days in the averaging period (e.g., 365 for annual, 91 for seasonal, 30 for monthly).

Note that the assumption leading to Equation 2 is based on analogy with the approach used to develop long-term average unpaved road emission factors in Section 13.2.2. However, Equation 2 above incorporates an additional factor of "4" in the denominator to account for the fact that paved roads dry more quickly than unpaved roads and that the precipitation may not occur over the complete 24-hour day.

For the hourly basis, equation 1 becomes:

$$E_{ext} = [\, k\,(sL)^{0.91} \times (W)^{1.02} \,]\,(1 - 1.2P/N) \qquad (3)$$

where k, sL, W, and S are as defined in Equation 1 and

E_{ext} = annual or other long-term average emission factor in the same units as k,
P = number of hours with at least 0.254 mm (0.01 in) of precipitation during the averaging period, and
N = number of hours in the averaging period (e.g., 8760 for annual, 2124 for season 720 for monthly)

Note: In the hourly moisture correction term (1-1.2P/N) for equation 3, the 1.2 multiplier is applied to account for the residual mitigative effect of moisture. For most applications, this equation will produce satisfactory results. Users should select a time interval to include sufficient "dry" hours such that a reasonable emissions averaging period is evaluated. For the special case where this equation is used to calculate emissions on an hour by hour basis, such as would be done in some emissions modeling situations, the moisture correction term should be modified so that the moisture correction "credit" is applied to the first hours following cessation of precipitation. In this special case, it is suggested that this 20% "credit" be applied on a basis of one hour credit for each hour of precipitation up to a maximum of 12 hours.

Note that the assumption leading to Equation 3 is based on analogy with the approach used to develop long-term average unpaved road emission factors in Section 13.2.2.

Figure 13.2.1-2 presents the geographical distribution of "wet" days on an annual basis for the United States. Maps showing this information on a monthly basis are available in the *Climatic Atlas of the United States*[23] . Alternative sources include other Department of Commerce publications (such as local climatological data summaries). The National Climatic Data Center (NCDC) offers several products that provide hourly precipitation data. In particular, NCDC offers *Solar and Meteorological Surface Observation Network 1961-1990* (SAMSON) CD-ROM, which contains 30 years worth of hourly meteorological data for first-order National Weather Service locations. Whatever meteorological data are used, the source of that data and the averaging period should be clearly specified.

It is emphasized that the simple assumption underlying Equations 2 and 3 has not been verified in any rigorous manner. For that reason, the quality ratings for Equations 2 and 3 should be downgraded one letter from the rating that would be applied to Equation 1.

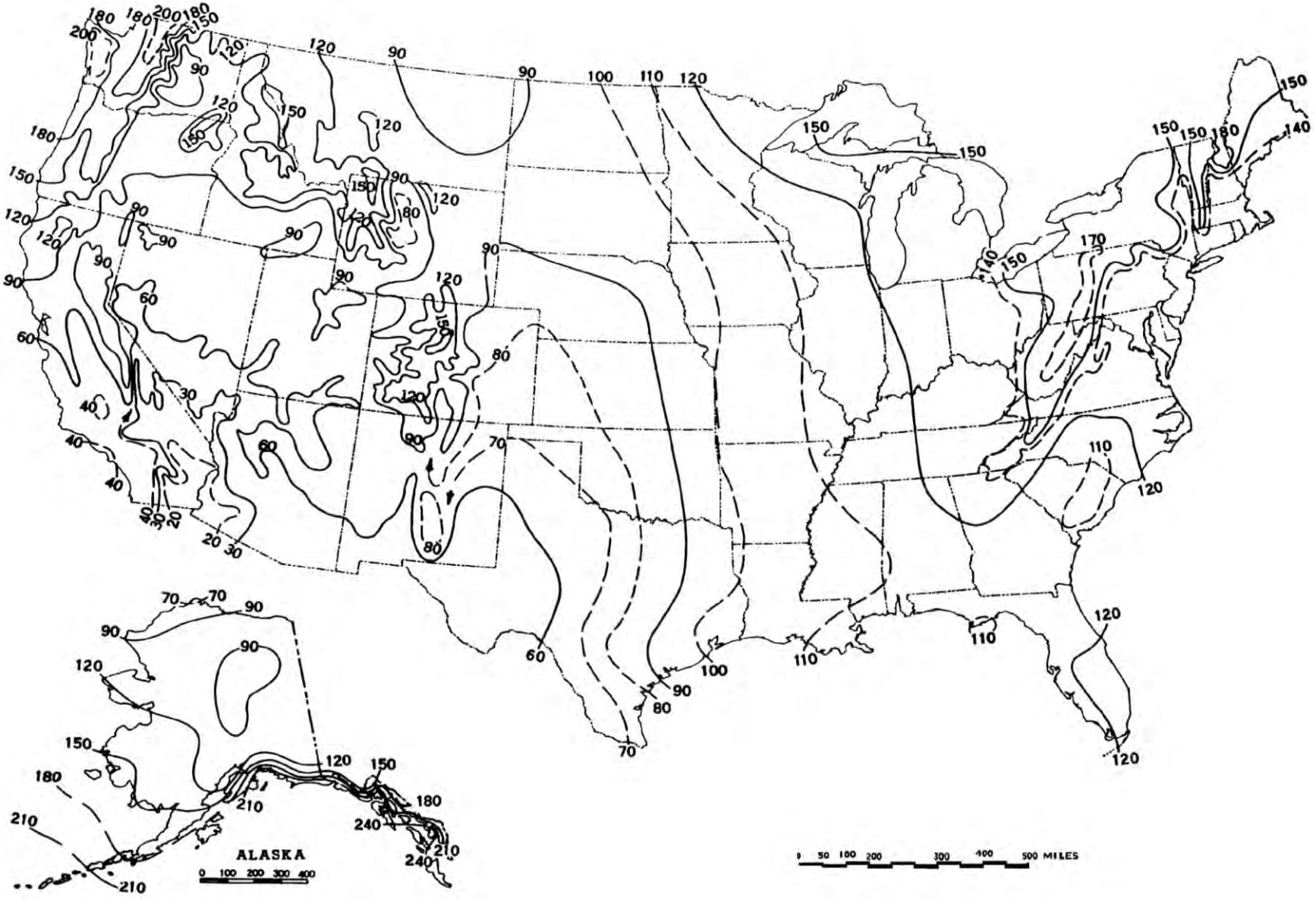


Figure 13.2.1-2. Mean number of days with 0.01 inch or more of precipitation in the United States.

Table 13.2.1-2 presents recommended default silt loadings for normal baseline conditions and for wintertime baseline conditions in areas that experience frozen precipitation with periodic application of antiskid material[24]. The winter baseline is represented as a multiple of the non-winter baseline, depending on the ADT value for the road in question. As shown, a multiplier of 4 is applied for low volume roads (< 500 ADT) to obtain a wintertime baseline silt loading of 4 X 0.6 = 2.4 g/m^2.

Table 13.2.1-2. Ubiquitous Silt Loading Default Values with Hot Spot Contributions from Anti-Skid Abrasives (g/m^2)

ADT Category	< 500	500-5,000	5,000-10,000	> 10,000
Ubiquitous Baseline g/m^2	0.6	0.2	0.06	0.03 0.015 limited access
Ubiquitous Winter Baseline Multiplier during months with frozen precipitation	X4	X3	X2	X1
Initial peak additive contribution from application of antiskid abrasive (g/m^2)	2	2	2	2
Days to return to baseline conditions (assume linear decay)	7	3	1	0.5

It is suggested that an additional (but temporary) silt loading contribution of 2 g/m^2 occurs with each application of antiskid abrasive for snow/ice control. This was determined based on a typical application rate of 500 lb per lane mile and an initial silt content of 1 % silt content. Ordinary rock salt and other chemical deicers add little to the silt loading, because most of the chemical dissolves during the snow/ice melting process.

To adjust the baseline silt loadings for mud/dirt trackout, the number of trackout points is required. It is recommended that in calculating PM_{10} emissions, six additional miles of road be added for each active trackout point from an active construction site, to the paved road mileage of the specified category within the county. In calculating $PM_{2.5}$ emissions, it is recommended that three additional miles of road be added for each trackout point from an active construction site.

It is suggested the number of trackout points for activities other than road and building construction areas be related to land use. For example, in rural farming areas, each mile of paved road would have a specified number of trackout points at intersections with unpaved roads. This value could be estimated from the unpaved road density (mi/sq. mi.).

The use of a default value from Table 13.2.1-2 should be expected to yield only an order-of-magnitude estimate of the emission factor. Public paved road silt loadings are dependent

upon: traffic characteristics (speed, ADT, and fraction of heavy vehicles); road characteristics (curbs, number of lanes, parking lanes); local land use (agriculture, new residential construction) and regional/seasonal factors (snow/ice controls, wind blown dust). As a result, the collection and use of site-specific silt loading data is highly recommended. In the event that default silt loading values are used, the quality ratings for the equation should be downgraded 2 levels.

Limited access roadways pose severe logistical difficulties in terms of surface sampling, and few silt loading data are available for such roads. Nevertheless, the available data do not suggest great variation in silt loading for limited access roadways from one part of the country to another. For annual conditions, a default value of 0.015 g/m^2 is recommended for limited access roadways.[9,22] Even fewer of the available data correspond to worst-case situations, and elevated loadings are observed to be quickly depleted because of high traffic speeds and high ADT rates. A default value of 0.2 g/m^2 is recommended for short periods of time following application of snow/ice controls to limited access roads.[22]

The limited data on silt loading values for industrial roads have shown as much variability as public roads. Because of the variations of traffic conditions and the use of preventive mitigative controls, the data probably do not reflect the full extent of the potential variation in silt loading on industrial roads. However, the collection of site specific silt loading data from industrial roads is easier and safer than for public roads. Therefore, the collection and use of site-specific silt loading data is preferred and is highly recommended. In the event that site-specific values cannot be obtained, an appropriate value for an industrial road may be selected from the mean values given in Table 13.2.1-3, but the quality rating of the equation should be reduced by 2 levels.

The predictive accuracy of Equation 1 requires thorough on-site characterization of road silt loading. Road surface sampling is time-consuming and potentially hazardous because of the need to block traffic lanes. In addition, large number of samples is required to represent spatial and temporal variations across roadway networks. Mobile monitoring is a new alternative silt loading or road dust emission characterization method for either paved or unpaved roads. It utilizes a test vehicle that generates and monitors its own dust plume concentration (mass basis) at a fixed sampling probe location. A calibration factor is needed for each mobile monitoring configuration (test vehicle and sampling system), to convert the relative dust emission intensity to an equivalent silt loading or emission factor. Typically, portable continuous particle concentration monitors do not comply with Federal Reference Method (FRM) standards. Therefore, a controlled study must be performed to correlate the portable monitor response to the road silt loading or size specific particle concentration measured with an approved FRM sampling system. In the calibration tests, multiple test conditions should be performed to provide an average correlation with known precision and to accommodate variations in road silt loading, vehicle speed, road dust characteristics and other road conditions that may influence mobile monitoring measurements or emissions characteristics. Because the paved road dust emissions are also dependent on the average vehicle weight for the road segment, it is important that the weight of the test vehicle correspond closely to the average vehicle weight for the road segment or be adjusted using the average vehicle weight relationship in Equation 1. In summary, it is believed that the Mobile Monitoring Method will provide improved capabilities to provide reliable temporally and spatially resolved silt loading or emissions factors with increased coverage, improved safety, reduced traffic interference and decreased cost.[40, 41, 42]

Table 13.2.1-3 (Metric And English Units). TYPICAL SILT CONTENT AND LOADING VALUES FOR PAVED ROADS AT INDUSTRIAL FACILITIES [a]

Industry	No. of Sites	No. Of Samples	Silt Content (%)		No. of Travel Lanes	Total Loading x 10^{-3}			Silt Loading (g/m^2)	
			Range	Mean		Range	Mean	Units[b]	Range	Mean
Copper smelting	1	3	15.4-21.7	19.0	2	12.9 - 19.5 45.8 - 69.2	15.9 55.4	kg/km lb/mi	188-400	292
Iron and steel production	9	48	1.1-35.7	12.5	2	0.006 - 4.77 0.020 -16.9	0.495 1.75	kg/km lb/mi	0.09-79	9.7
Asphalt batching	1	3	2.6 - 4.6	3.3	1	12.1 - 18.0 43.0 - 64.0	14.9 52.8	kg/km lb/mi	76-193	120
Concrete batching	1	3	5.2 - 6.0	5.5	2	1.4 - 1.8 5.0 - 6.4	1.7 5.9	kg/km lb/mi	11-12	12
Sand and gravel processing	1	3	6.4 - 7.9	7.1	1	2.8 - 5.5 9.9 - 19.4	3.8 13.3	kg/km lb/mi	53-95	70
Municipal solid waste landfill	2	7		-	2	-			1.1-32.0	7.4
Quarry	1	6		-	2	-			2.4-14	8.2
Corn wet mills	3	15		-	2	-			0.05 – 2.9	1.1

[a] References 1-2,5-6,11-13. Values represent samples collected from *industrial* roads. Public road silt loading values are presented in Table-13.2.1-2. Dashes indicate information not available. [b] Multiply entries by 1000 to obtain stated units; kilograms per kilometer (kg/km) and pounds per mile (lb/mi).

13.2.1.4 Controls[6,25]

Because of the importance of the silt loading, control techniques for paved roads attempt either to prevent material from being deposited onto the surface (preventive controls) or to remove from the travel lanes any material that has been deposited (mitigative controls). Covering of loads in trucks, and the paving of access areas to unpaved lots or construction sites, are examples of preventive measures. Examples of mitigative controls include vacuum sweeping, water flushing, and broom sweeping and flushing. Actual control efficiencies for any - of these techniques can be highly variable. Locally measured silt loadings before and after the application of controls is the preferred method to evaluate controls. It is particularly important to note that street sweeping of gutters and curb areas may actually increase the silt loading on the traveled portion of the road. Redistribution of loose material onto the travel lanes will actually produce a short-term increase in the emissions.

In general, preventive controls are usually more cost effective than mitigative controls. The cost-effectiveness of mitigative controls falls off dramatically as the size of an area to be treated increases. The cost-effectiveness of mitigative measures is also unfavorable if only a short period of time is required for the road to return to equilibrium silt loading condition. That is to say, the number and length of public roads within most areas of interest preclude any widespread and routine use of mitigative controls. On the other hand, because of the more limited scope of roads at an industrial site, mitigative measures may be used quite successfully (especially in situations where truck spillage occurs). Note, however, that public agencies could make effective use of mitigative controls to remove sand/salt from roads after the winter ends.

Because available controls will affect the silt loading, controlled emission factors may be obtained by substituting controlled silt loading values into the equation. (Emission factors from controlled industrial roads were used in the development of the equation.) The collection of surface loading samples from treated, as well as baseline (untreated), roads provides a means to track effectiveness of the controls over time. The use of Mobile Monitoring Methodologies provide an improved means to track progress in controlling silt loading values.

13.2.1.5 Changes since Fifth Edition

The following changes were made since the publication of the Fifth Edition of AP-42:

October 2002

1) The particle size multiplier for $PM_{2.5}$ was revised to 25% of PM_{10}. The approximately 55% reduction was a result of emission testing using FRM monitors. The monitoring was specifically intended to evaluate the PM-2.5 component of the emissions.

2) Default silt loading values were included in Table 13.2.1-2 replacing the Tables and Figures containing silt loading statistical information.

3) Editorial changes within the text were made indicating the possible causes of variations in the silt loading between roads within and among different locations. The uncertainty of using the default silt loading value was discussed.

4) Section 13.2.1.1 was revised to clarify the role of dust loading in resuspension. Additional minor text changes were made.

5) Equations 2 and 3, Figure 13.2.1-2, and text were added to incorporate natural mitigation into annual or other long-term average emission factors.

December 2003

1) The emission factor equation was adjusted to remove the component of particulate emissions- from exhaust, brake wear, and tire wear. A parameter C representing these emissions was included in the predictive equation. The parameter C varied with aerodynamic size range of the particulate matter. Table 13.2.1-2 was added to present the new coefficients.

2) The default silt loading values in Table 13.2.1-3 were revised to incorporate the results from a recent analysis of silt loading data.

November 2006

1) The $PM_{2.5}$ particle size multiplier was revised to 15% of PM_{10} as the result of wind tunnel studies of a variety of dust emitting surface materials.

2) References were rearranged and renumbered.

January 2011

1) The empirical predictive equation was revised. The revision is based upon stepwise regression of 83 profile emissions tests and an adjustment of individual test data for the exhaust; break wear and tire wear emissions prior to regression of the data.

2) The C term is removed from the empirical predictive equation and Table 13.2.1-2 with the C term values is removed since the exhaust; break wear and tire wear emissions were no longer part of the regressed data.

3) The $PM_{2.5}$ particle size multiplier was revised to 25% of PM_{10} since the PM_{10} test data used to develop the equation did not meet the necessary PM_{10} concentrations for a ratio of 15%.

4) The lower speed of the vehicle speed range supported by the empirical predictive equation was revised to 1 mph.

5) Information was added on an improved methodology to develop spatially and temporally resolved silt loadings or emissions factors by Mobile Monitoring Methodologies.

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Burloak Grade Separation Air Quality Assessment

RQQ-2015-EC-058

Metrolinx

Project number: 60512842

October, 2017

Table 5-9: Road Traffic Data – Existing Conditions

Link Description	AADT	% Light duty	% Med Truck	% Heavy Truck	Speed[1] (km/hr)
Harvester Road, 500 m west of Burloak Drive	12,877	95.71%	3.14%	1.15%	60
Wyecroft Road, 500 m east of Burloak Drive	7,820	59.00%	1.20%	0.53%	60
Burloak Drive from Superior Court to Harvester Road	23,502	96.93%	1.70%	1.37%	60
Vehicle queue southbound on Burloak Drive at Rail crossing	1,758	96.93%	1.70%	1.37%	0
Vehicle queue northbound on Burloak Drive at Rail crossing	1,637	96.93%	1.70%	1.37%	0
Prince William Drive, west of Burloak Drive	3,292	98.20%	1.01%	0.79%	40
Superior Court, 500 m east of Burloak Drive	5,564	98.93%	0.87%	0.20%	60

Note [1]: Based on posted speed limit or stopping due rail crossing queue

Table 5-10: Road Traffic Data – Future No-Build Conditions

Link Description	AADT	% Light duty	% Med Truck	% Heavy Truck	Speed[1] (km/hr)
Harvester Road, 500 m west of Burloak Drive	15,940	95.71%	3.14%	1.15%	60
Wyecroft Road, 500 m east of Burloak Drive	9,680	59.00%	1.20%	0.53%	60
Burloak Drive from Superior Court to Harvester Road	29,092	96.93%	1.70%	1.37%	60
Vehicle queue southbound on Burloak Drive at Rail crossing	1,862	96.93%	1.70%	1.37%	0
Vehicle queue northbound on Burloak Drive at Rail crossing	1,734	96.93%	1.70%	1.37%	0
Prince William Drive, west of Burloak Drive	3,292	98.20%	1.01%	0.79%	40
Superior Court, 500 m east of Burloak Drive	6,887	98.93%	0.87%	0.20%	60

Note [1]: Based on posted speed limit or stopping due rail crossing queue

Table 5-11: Road Traffic Data – Future Build-Out Conditions

Link Description	AADT	% Light duty	% Med Truck	% Heavy Truck	Speed[1] (km/hr)
Harvester Road, 500 m west of Burloak Drive	16,995	95.71%	3.14%	1.15%	60
Wyecroft Road, 500 m east of Burloak Drive	9,680	59.00%	1.20%	0.53%	60
Burloak Drive from Superior Court to Harvester Road	31,016	96.93%	1.70%	1.37%	60
Vehicle queue southbound on Burloak Drive at Rail crossing	3,292	98.20%	1.01%	0.79%	40
Vehicle queue northbound on Burloak Drive at Rail crossing	6,887	98.93%	0.87%	0.20%	60
Prince William Drive, west of Burloak Drive	16,995	95.71%	3.14%	1.15%	60
Superior Court, 500 m east of Burloak Drive	9,680	59.00%	1.20%	0.53%	60

Note [1]: Based on posted speed limit or stopping due rail crossing queue

5.3.2 Modelling Inputs

5.3.2.1 Meteorology

Five years of pre-processed regional meteorological data from 1996 – 2000 for Central Region (Toronto, York-Durham, Halton-Peel) were obtained from the Ministry of Environment (MOECC) website. The meteorological data (surface) was collected at Pearson Airport in Toronto and the upper data was collected at the Buffalo, New York station. The data is accepted by the MOECC for Environmental Assessment and Air Quality Assessment purposes.

Summary of AERMOD Input: Maximum Emission Rate (g/s)

PollutantID **2**

													Line Sources (free-flow)				Area Sources (idling)		
LINK ID	AERMOD ID	Avg. Speed ID	AADT	Max Hourly Traffic (vehicles/hr)	Car%	MT %	HT %	Max Car_ER (g/VMT)	Max MT_ER (g/VMT)	Max HT_ER (g/VMT)	Comb_ER (g/VMT)	Road Dust (g/VMT)	Link Length (km)	Link Length (miles)	Veh-Miles Traveled (VMT/hr)	AERMOD Emisison Rate (g/s)	Idling Speed Bin Upper Bound (mile/hr)	Veh. Idling per hour (Veh.)	AERMOD Emisison Rate (g/s/m^2)
CURRENT CONDITIONS (2016)																			
1-S1	SLINE1	8	12,877	1,180	95.71%	3.14%	1.15%	1.981251187	4.288972789	1.177214893	2.044482258	0	0.511	0.318	374.5188245	0.212693637	--	--	--
1-S2	SLINE2	8	7,820	716	59.00%	1.20%	0.53%	1.981251187	4.288972789	1.177214893	1.226514491	0	0.500	0.311	222.6709215	0.075863642	--	--	--
1-S3	SLINE3	8	23,502	2,153	96.93%	1.70%	1.37%	1.981251187	4.288972789	1.177214893	2.009467157	0	0.617	0.384	825.8450154	0.460974565	--	--	--
1-A1	ARLN1	1	1,758	161	96.93%	1.70%	1.37%	8.407864476	19.97492911	7.300330518	8.589331359	0	--	--	--	--	2.5	73	0.000126119
1-A2	ARLN2	1	1,637	150	96.93%	1.70%	1.37%	8.407864476	19.97492911	7.300330518	8.589331359	0	--	--	--	--	2.5	68	0.000125779
1-S4	SLINE4	6	3,292	302	98.20%	1.01%	0.79%	2.261876035	5.267793058	1.462535244	2.286067543	0	0.270	0.168	50.56870752	0.032112078	--	--	--
1-S5	SLINE5	8	5,564	510	98.93%	0.87%	0.20%	1.981251187	4.288972789	1.177214893	1.999655637	0	0.526	0.327	166.5979482	0.09253848	--	--	--
FUTURE NO-BUILD (2032)																			
2-S1	2SLINE1	8	15,940	1,460	95.71%	3.14%	1.15%	0.726271685	0.808336419	0.258185607	0.723453299	0	0.511	0.318	463.6045485	0.093165622	--	--	--
2-S2	2SLINE2	8	9,680	887	59.00%	1.20%	0.53%	0.726271685	0.808336419	0.258185607	0.439544757	0	0.500	0.311	275.6370182	0.033654113	--	--	--
2-S3	2SLINE3	8	29,092	2,665	96.93%	1.70%	1.37%	0.726271685	0.808336419	0.258185607	0.721254006	0	0.617	0.384	1022.273985	0.204810891	--	--	--
2-A1	2ARLN1	1	1,862	171	96.93%	1.70%	1.37%	2.624926345	4.115614266	1.723985339	2.637925147	0	--	--	--	--	2.5	78	4.10308E-05
2-A2	2ARLN2	1	1,734	159	96.93%	1.70%	1.37%	2.624926345	4.115614266	1.723985339	2.637925147	0	--	--	--	--	2.5	72	4.092E-05
2-S4	2SLINE4	6	3,292	302	98.20%	1.01%	0.79%	0.771576536	0.985408226	0.315291886	0.770145299	0	0.270	0.168	50.56870752	0.010818126	--	--	--
2-S5	2SLINE5	8	6,887	631	98.93%	0.87%	0.20%	0.726271685	0.808336419	0.258185607	0.72604659	0	0.526	0.327	206.2261268	0.041591604	--	--	--
FUTURE BUILD-OUT (2032)																			
3-S1	3SLINE1	8	16,995	1,557	95.71%	3.14%	1.15%	0.726271685	0.808336419	0.258185607	0.723453299	0	0.511	0.318	494.2650446	0.099327133	--	--	--
3-S2	3SLINE2	8	9,680	887	59.00%	1.20%	0.53%	0.726271685	0.808336419	0.258185607	0.439544757	0	0.500	0.311	275.6370182	0.033654113	--	--	--
3-S3	3SLINE3	8	31,016	2,841	96.93%	1.70%	1.37%	0.726271685	0.808336419	0.258185607	0.721254006	0	0.617	0.384	1089.848603	0.218349353	--	--	--
3-S4	3SLINE4	6	3,292	302	98.20%	1.01%	0.79%	0.771576536	0.985408226	0.315291886	0.770145299	0	0.270	0.168	50.56870752	0.010818126	--	--	--
3-S5	3SLINE5	8	6,887	631	98.93%	0.87%	0.20%	0.726271685	0.808336419	0.258185607	0.72604659	0	0.526	0.327	206.2261268	0.041591604	--	--	--

Notes:

(1) Road Dust only is contributed if Pollutant ID = 9100 (PM10) or 9110 (PM2.5); based on AADT per link

(2) Area source emissions are reduced based on the maximum time spent idling in one hour, based on 12 GO/VIA train crossings at 2 minutes each, and 1 CN train crossing at 5 minutes.

(3) Area source A1 = 12 m x 139.5 m
Area source A2 = 12 m x 130.3 m

(4) Pollutant IDs as follows: 2 (CO); 3 (NOx); 20 (Benzene); 24 (1,3-Butadiene); 25 (Formaldehyde); 26 (Acetaldehyde); 27 (Acrolein); 974 (Benzo(a)pyrene); 9100 (PM_{10}); 9110 ($PM_{2.5}$)

Calculation Methodology:

Combined Emission Rate = ∑ Car_ER x Car% + Medium Truck (MT)_ER x MT% + Heavy Truck (HT)_ER x HT%

Vehicle Miles Traveled per hour = Maximum hourly traffic volumn (vehicle/hr) x total miles travelled per link (VMT/hr)

Free-Flow link Emission Rate = Combined Emission rate + Road Dust (VMT/hr) x Vehicle miles travelle per hour (VMT/hr) / 3600 seconds per hour

Vehicles Idling per hour = Total AADT for Burloak (Southbound or Northbound) x % of time spent idling due to train passing during a day / 24 hrs per day

Idling (Area source) Emission Rate = Cumulative Emission Rate (g/VMT) (speed bin 1 = 0 - 2.5 miles/hr) x 2.5 miles per hour x Vehicles idling per hour (vehicle/hr) x % time spent idling during one hour (29 mins of total train crossing per hour) / 3600 seconds per hour / Total area of queue (m^2)

Profile Type	Profile Number	Profile Name	Master Pollutant	Particle Size Range	Pollutant Name	Pollutant Symbol	Weight %	Uncertainty %
Particulate Matter (PM)	4113030	Paved Road Dust - Composite	PM	0 µm to 30 µm	Aluminum	Al	1.649	0.255
Particulate Matter (PM)	4113030	Paved Road Dust - Composite	PM	0 µm to 30 µm	Antimony	Sb	0.008	0.014
Particulate Matter (PM)	4113030	Paved Road Dust - Composite	PM	0 µm to 30 µm	Arsenic	As	0.015	0.005
Particulate Matter (PM)	4113030	Paved Road Dust - Composite	PM	0 µm to 30 µm	Barium	Ba	0.028	0.053
Particulate Matter (PM)	4113030	Paved Road Dust - Composite	PM	0 µm to 30 µm	Cadmium	Cd	0.004	-99
Particulate Matter (PM)	4113030	Paved Road Dust - Composite	PM	0 µm to 30 µm	Calcium	Ca	0.887	0.184
Particulate Matter (PM)	4113030	Paved Road Dust - Composite	PM	0 µm to 30 µm	Chromium	Cr	0.005	-99
Particulate Matter (PM)	4113030	Paved Road Dust - Composite	PM	0 µm to 30 µm	Copper	Cu	0.051	0.016
Particulate Matter (PM)	4113030	Paved Road Dust - Composite	PM	0 µm to 30 µm	Gallium	Ga	0	-99
Particulate Matter (PM)	4113030	Paved Road Dust - Composite	PM	0 µm to 30 µm	Indium	In	0.002	-99
Particulate Matter (PM)	4113030	Paved Road Dust - Composite	PM	0 µm to 30 µm	Iron	Fe	1.03	0.153
Particulate Matter (PM)	4113030	Paved Road Dust - Composite	PM	0 µm to 30 µm	Lead	Pb	0.204	0.049
Particulate Matter (PM)	4113030	Paved Road Dust - Composite	PM	0 µm to 30 µm	Magnesium	Mg	0	-99
Particulate Matter (PM)	4113030	Paved Road Dust - Composite	PM	0 µm to 30 µm	Manganese	Mn	0.024	0.003
Particulate Matter (PM)	4113030	Paved Road Dust - Composite	PM	0 µm to 30 µm	Mercury	Hg	0	-99
Particulate Matter (PM)	4113030	Paved Road Dust - Composite	PM	0 µm to 30 µm	Molybdenum	Mo	0	-99
Particulate Matter (PM)	4113030	Paved Road Dust - Composite	PM	0 µm to 30 µm	Nickel	Ni	0.002	-99
Particulate Matter (PM)	4113030	Paved Road Dust - Composite	PM	0 µm to 30 µm	Nitrate	NO3-	0	-99
Particulate Matter (PM)	4113030	Paved Road Dust - Composite	PM	0 µm to 30 µm	Organic carbon	OC	0	-99
Particulate Matter (PM)	4113030	Paved Road Dust - Composite	PM	0 µm to 30 µm	Palladium	Pd	0	-99
Particulate Matter (PM)	4113030	Paved Road Dust - Composite	PM	0 µm to 30 µm	Phosphorus	P	0.032	0.013
Particulate Matter (PM)	4113030	Paved Road Dust - Composite	PM	0 µm to 30 µm	Potassium	K	0.268	0.046
Particulate Matter (PM)	4113030	Paved Road Dust - Composite	PM	0 µm to 30 µm	Rubidium	Rb	0	-99
Particulate Matter (PM)	4113030	Paved Road Dust - Composite	PM	0 µm to 30 µm	Selenium	Se	0	-99
Particulate Matter (PM)	4113030	Paved Road Dust - Composite	PM	0 µm to 30 µm	Silicon	Si	5.274	0.825
Particulate Matter (PM)	4113030	Paved Road Dust - Composite	PM	0 µm to 30 µm	Silver	Ag	0	-99
Particulate Matter (PM)	4113030	Paved Road Dust - Composite	PM	0 µm to 30 µm	Sodium	Na	0	-99
Particulate Matter (PM)	4113030	Paved Road Dust - Composite	PM	0 µm to 30 µm	Strontium	Sr	0.008	-99
Particulate Matter (PM)	4113030	Paved Road Dust - Composite	PM	0 µm to 30 µm	Sulfate	SO4=	0.075	0.057
Particulate Matter (PM)	4113030	Paved Road Dust - Composite	PM	0 µm to 30 µm	Sulfur	S	0.111	0.033
Particulate Matter (PM)	4113030	Paved Road Dust - Composite	PM	0 µm to 30 µm	Tin	Sn	0.011	0.01
Particulate Matter (PM)	4113030	Paved Road Dust - Composite	PM	0 µm to 30 µm	Titanium	Ti	0.112	0.016
Particulate Matter (PM)	4113030	Paved Road Dust - Composite	PM	0 µm to 30 µm	Vanadium	V	0.007	-99
Particulate Matter (PM)	4113030	Paved Road Dust - Composite	PM	0 µm to 30 µm	Zinc	Zn	0.129	0.019
Particulate Matter (PM)	4113030	Paved Road Dust - Composite	PM	0 µm to 30 µm	Zirconium	Zr	0.001	0.006
Particulate Matter (PM)	4113030	Paved Road Dust - Composite	PM	0 µm to 30 µm	Chlorine atom	Cl	0.021	0.007
Particulate Matter (PM)	4113030	Paved Road Dust - Composite	PM	0 µm to 30 µm	Bromine Atom	Br	0.004	-99
Particulate Matter (PM)	4113030	Paved Road Dust - Composite	PM	0 µm to 30 µm	Fluoride ion	F-	0	-99
Particulate Matter (PM)	4113030	Paved Road Dust - Composite	PM	0 µm to 30 µm	Elemental Carbon	EC	0	-99

Profile Type	Profile Number	Profile Name	Master Pollutant	Particle Size Range	Pollutant Name	Pollutant Symbol	Weight %	Uncertainty %
Total Organic Compounds (TOC)	2540	Vehicle Emissions: Roadway: Busy Intersection		N/A	Unidentified	UNID	54.33	-99
Total Organic Compounds (TOC)	2540	Vehicle Emissions: Roadway: Busy Intersection		N/A	Acetylene (or ethyne)	ACETYL	5.72	-99
Total Organic Compounds (TOC)	2540	Vehicle Emissions: Roadway: Busy Intersection		N/A	Benzene	BENZE	2.96	-99
Total Organic Compounds (TOC)	2540	Vehicle Emissions: Roadway: Busy Intersection		N/A	Ethane	ETHANE	1.77	-99
Total Organic Compounds (TOC)	2540	Vehicle Emissions: Roadway: Busy Intersection		N/A	Ethylbenzene	ETBZ	1.23	-99
Total Organic Compounds (TOC)	2540	Vehicle Emissions: Roadway: Busy Intersection		N/A	Ethylene (or ethene)	ETHENE	7.03	-99
Total Organic Compounds (TOC)	2540	Vehicle Emissions: Roadway: Busy Intersection		N/A	Isopentane (or 2-Methylbutane)	IPENTA	6.04	-99
Total Organic Compounds (TOC)	2540	Vehicle Emissions: Roadway: Busy Intersection		N/A	M & p-xylene	MP_X	4.14	-99
Total Organic Compounds (TOC)	2540	Vehicle Emissions: Roadway: Busy Intersection		N/A	N-butane	N_BUTA	3.14	-99
Total Organic Compounds (TOC)	2540	Vehicle Emissions: Roadway: Busy Intersection		N/A	N-pentane	N_PENT	2.89	-99
Total Organic Compounds (TOC)	2540	Vehicle Emissions: Roadway: Busy Intersection		N/A	O-xylene	O_XYL	1.32	-99
Total Organic Compounds (TOC)	2540	Vehicle Emissions: Roadway: Busy Intersection		N/A	Propane	N_PROP	0.84	-99
Total Organic Compounds (TOC)	2540	Vehicle Emissions: Roadway: Busy Intersection		N/A	Propylene (or Propene; 1-Propene)	PROPE	2.51	-99
Total Organic Compounds (TOC)	2540	Vehicle Emissions: Roadway: Busy Intersection		N/A	Toluene	TOLUE	6.08	-99

Methods to Find the Cost-Effectiveness of Funding Air Quality Projects

For Evaluating
Motor Vehicle Registration Fee Projects
and
Congestion Mitigation and
Air Quality Improvement (CMAQ) Projects

Emission Factor Tables
November 2021

CALIFORNIA
AIR RESOURCES BOARD

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Preface

This document contains updated emission factors to be used with the "Methods to Find the Cost-Effectiveness of Funding Air Quality Projects" document published in May 2005 (the Methods document). The emission factors below are the latest available as of the publication date, and in most cases are based on the California Air Resources Board's on-road emission factor model EMFAC, or in the case of off-road emissions data, the Board's emission rate model OFFROAD.

Please note that even though the emission factors have changed since the original publication of the Methods document, the actual methods to apply the rates in that document remain valid.

Summary of Changes by Table.

Table 1	Updated emission rates to reflect EMFAC2017. Eliminated model year ranges with no vehicles.
Table 2	Updated Table 2.
Table 3/3A	Updated emission rates to reflect EMFAC2017.
Table 4	Updated emission rates to reflect EMFAC2017.
Table 5	Updated emission rates to reflect EMFAC2017.

Table 1 Diesel Bus Emission Factors
(through Model Year 2020)

Pollutant	Calendar Year	Model Year	Emission Factor (gram/mile) Average	Emission Factor (gram/mile) 45 MPH
ROG	2020	Entire Fleet	0.003	0.003
	2020	2003 - 2006	0.010	0.003
	2020	2007 - 2009	0.005	0.001
	2020	2010 - 2014	0.003	0.003
	2020	2015 - 2020	0.003	0.003
	2020	2020	0.009	0.003
CO	2020	Entire Fleet	0.23	0.06
	2020	2003 - 2006	0.60	0.35
	2020	2007 - 2009	0.56	0.09
	2020	2010 - 2014	0.14	0.05
	2020	2015 - 2020	0.13	0.04
	2020	2020	0.13	0.04
NOx	2020	Entire Fleet	2.03	0.79
	2020	2003 - 2006	7.60	4.31
	2020	2007 - 2009	5.90	3.66
	2020	2010 - 2014	0.79	0.13
	2020	2015 - 2020	0.78	0.12
	2020	2020	0.70	0.11
PM2.5 - Exhaust*	2020	Entire Fleet	0.007	0.007
	2020	2003 - 2006	0.01	0.008
	2020	2007 - 2009	0.01	0.006
	2020	2010 - 2014	0.006	0.008
	2020	2015 - 2020	0.006	0.007
	2020	2020	0.005	0.007
PM2.5 – Tire Wear	All Years	All Years	0.008	Not Speed Dependent
PM2.5 – Brake Wear	All Years	All Years	0.033	Not Speed Dependent
PM2.5 – Road Dust**	All Years	All Years	0.028	Not Speed Dependent

Source: EMFAC2017 V1.0.3, average annual emissions, statewide vehicle fleet, 50% humidity, temperature 75 °F.

* Statewide average annual PM2.5 emission factor, weighted by VMT per road category.

** The PM10 road dust emission factor was calculated using US EPA's Compilation of Air Pollutant Emission Factors, Vol. 5 (AP-42, Chapter 13.2.1, Jan. 2011), and ARB's Miscellaneous Process Methodology 7.9, Entrained Paved Road Travel, Paved Road Dust (updated Jan. 2013). [PM2.5 = 0.15*PM10]

Table 2 Emission Factors for Cleaner Vehicles for Light-Duty and Medium-Duty Trucks/SUVs (Chassis-Certified)

Baseline (Older) Technology Vehicles:
Average New Truck in 2010 (note: emission factor units are grams/mile)

Weight[1]	ROG	NOx	PM2.5 Exhaust	PM2.5 Total[2]	CO
Up to 8,500	0.051	0.060	0.010	0.056	2.1
8,501-10,000	0.148	0.195	0.068	0.132	6.2
10,001-14,000	0.173	0.390	0.068	0.137	7.1

Replacement (Newer) Technology Cleaner Vehicles:
Projected Average New Trucks in 2020 (note: emission factor units are grams per mile)

Weight[1]	ROG	NOx	PM2.5 Exhaust	PM2.5 Total[2]	CO
Up to 8,500	0.043	0.054	0.003	0.049	1.8
8,501-10,000	0.104	0.149	0.008	0.072	5.7
10,001-14,000	0.155	0.245	0.010	0.079	6.4

Replacement (Newer) Technology Cleaner Vehicles:
Zero-emission light-duty and medium-duty vehicle (ZEV) (note: emission factor units are grams per mile)

Weight[1]	ROG	NOx	PM2.5 Exhaust	PM2.5 Total[2]	CO
Up to 8,500	0	0	0	0.046	0
8,501-10,000	0	0	0	0.064	0
10,001-14,000	0	0	0	0.069	0

See notes next page

[1] Gross vehicle weights can be associated with payload capacity as follows: 5751-8500 lb, roughly 1-ton payload; 8501-10,000 lb, roughly 1.8-ton payload; 10,001-14,000 lb, 2.5-ton payload.

[2] Total PM2.5 factors include motor vehicle exhaust, tire wear, brake wear, and entrained road dust.

Sources:

Baseline is California Vehicle Exhaust Standards ("LEV II") for average chassis-certified trucks for model year 2010. Factors assume emissions at 50,000 mile standard for the first 50,000 miles of the car's life (assumed to be 120,000 miles) and emissions at the 120,000 mile standard for the last 70,000 miles of the car's life.

Cleaner Vehicle Emission Factors are from the California Vehicle Exhaust Standards for MYs after 2016 ("LEV III") evaluated for calendar year 2020.

The PM2.5 factors have been adjusted from total PM by the fraction of the size distribution less than 2.5 µm. These were taken from EPA size distribution measurements tabulated in EPA's PART5 model. See the EMFAC 2000 Technical Support Document Table 4.12-5. The road dust portion of the PM2.5 emission factor was calculated from equation 1 of Chapter 13.2.1.3 of AP-42 Compilation of Air Pollutant Emission Factors Vol 5. US EPA Jan 1995. The silt loading and other parameters for the equation came from MRI, 1996. Improvement of Specific Emission Factors, (BACM Project No 1). Vehicle Trip reductions may have little if any effect on road dust emissions from high volume facilities thought to be in equilibrium, i.e., the dust is fully entrained due to the heavy traffic. The road dust PM factor, however, may be multiplied by the total VMT reductions as it has been scaled down to reflect emissions from lower-volume local and collector roads only. The brake wear emission factors came from a review of recent non-asbestos brake emissions (Section 9 of the EMFAC2011 Technical Documentation).

Table 3 Average Auto Emission Factors

(Fleet of Light-Duty Passenger Vehicles, Light-Duty Trucks and Motor Cycles)

Analysis Period or Project Life	1-5 Years (2019-2023)	6-10 Years (2019-2028)	11-15 Years (2019-2033)	16-20 Years (2019-2038)
ROG				
VMT (g/mile)	0.079	0.071	0.065	0.060
commute trip ends (g/trip end)	0.295	0.244	0.208	0.180
average trip ends (g/trip end)	0.471	0.397	0.343	0.303
NOx				
VMT (g/mile)	0.075	0.059	0.050	0.044
commute trip ends (g/trip end)	0.083	0.065	0.053	0.044
average trip ends (g/trip end)	0.245	0.208	0.184	0.168
$PM_{2.5}$				
VMT (g/mile)	0.047	0.047	0.047	0.046
running exhaust only (g/mile)	0.0016	0.0014	0.0013	0.0011
tire and brake wear (g/mile)	0.0177	0.0177	0.0177	0.0177
road dust (g/mile)	0.028	0.028	0.028	0.028
commute trip ends (g/trip end)	0.005	0.004	0.004	0.004
average trip ends (g/trip end)	0.002	0.002	0.002	0.001
CO				
VMT (g/mile)	1.004	0.856	0.765	0.705
commute trip ends (g/trip end)	2.154	1.788	1.526	1.328
average trip ends (g/trip end)	2.537	2.335	2.171	2.046

Source: EMFAC2017 V1.0.3, average annual emissions, statewide vehicle fleet, 50% humidity, temperature 75 °F.

PM2.5, road dust: statewide average annual PM2.5 emission factor is based on US EPA's Compilation of Air Pollutant Emission Factors, Vol. 5 (AP-42, Chapter 13.2.1, Jan. 2011), and CARB's Miscellaneous Process Methodology 7.9, Entrained Paved Road Travel, Paved Road Dust (updated Nov. 2016).

[PM2.5 = 0.15*PM10]

Table 3A Average Auto Emission Factors

(Fleet of Light-Duty Passenger Vehicles, Light-Duty Trucks and Motor Cycles)

Analysis Period or Project Life	**1 Year 2019**	**1 Year 2020**	**1 Year 2021**
ROG			
VMT (g/mile)	0.090	0.083	0.078
commute trip ends (g/trip end)	0.355	0.320	0.291
average trip ends (g/trip end)	0.554	0.507	0.466
NOx			
VMT (g/mile)	0.096	0.083	0.073
commute trip ends (g/trip end)	0.106	0.092	0.081
average trip ends (g/trip end)	0.287	0.264	0.243
$PM_{2.5}$			
VMT (g/mile)	0.047	0.047	0.047
running exhaust only (g/mile)	0.002	0.002	0.002
tire and brake wear (g/mile)	0.018	0.018	0.018
road dust (g/mile)	0.028	0.028	0.028
commute trip ends (g/trip end)	0.005	0.005	0.005
average trip ends (g/trip end)	0.002	0.002	0.002
CO			
VMT (g/mile)	1.201	1.083	0.988
commute trip ends (g/trip end)	2.592	2.332	2.121
average trip ends (g/trip end)	2.709	2.617	2.532

Source: EMFAC2017 V1.0.3, average annual emissions, statewide vehicle fleet, 50% humidity, temperature 75 °F.

PM2.5, road dust: statewide average annual PM2.5 emission factor is based on US EPA's Compilation of Air Pollutant Emission Factors, Vol. 5 (AP-42, Chapter 13.2.1, Jan. 2011), and CARB's Miscellaneous Process Methodology 7.9, Entrained Paved Road Travel, Paved Road Dust (updated Nov. 2016).

[PM2.5 = 0.15*PM10]

Table 4 Emission Factors (grams per mile) by Speed (mph)

Project Life 1-5 years (2019-2023)

Speed	ROG	CO	NOx	PM2.5 Ex		Speed	ROG	CO	NOx	PM2.5 Ex
5	**0.25**	**2.30**	**0.83**	**0.02**		***35***	**0.04**	**1.14**	**0.27**	**0.004**
6	0.23	2.23	0.79	0.02		*36*	0.04	1.12	0.26	0.004
7	0.22	2.16	0.76	0.01		*37*	0.03	1.10	0.26	0.004
8	0.20	2.10	0.73	0.01		*38*	0.03	1.09	0.25	0.003
9	0.18	2.03	0.70	0.01		*39*	0.03	1.07	0.25	0.003
10	**0.17**	**1.97**	**0.67**	**0.01**		***40***	**0.03**	**1.05**	**0.24**	**0.003**
11	0.15	1.92	0.63	0.01		*41*	0.03	1.04	0.24	0.003
12	0.14	1.86	0.60	0.01		*42*	0.03	1.03	0.23	0.003
13	0.13	1.81	0.56	0.01		*43*	0.03	1.01	0.23	0.003
14	0.12	1.75	0.53	0.01		*44*	0.03	1.00	0.23	0.003
15	**0.11**	**1.70**	**0.50**	**0.01**		***45***	**0.03**	**0.99**	**0.22**	**0.003**
16	0.10	1.66	0.48	0.01		*46*	0.03	0.98	0.22	0.004
17	0.09	1.62	0.47	0.01		*47*	0.03	0.96	0.22	0.004
18	0.09	1.58	0.45	0.01		*48*	0.03	0.95	0.22	0.004
19	0.08	1.54	0.43	0.01		*49*	0.03	0.94	0.22	0.004
20	**0.07**	**1.50**	**0.42**	**0.01**		***50***	**0.03**	**0.93**	**0.22**	**0.004**
21	0.07	1.47	0.40	0.01		*51*	0.03	0.93	0.22	0.004
22	0.07	1.44	0.39	0.01		*52*	0.03	0.92	0.22	0.004
23	0.06	1.41	0.38	0.01		*53*	0.03	0.91	0.22	0.004
24	0.06	1.38	0.37	0.00		*54*	0.03	0.90	0.22	0.004
25	**0.06**	**1.35**	**0.36**	**0.00**		***55***	**0.03**	**0.89**	**0.22**	**0.004**
26	0.05	1.33	0.34	0.00		*56*	0.03	0.89	0.22	0.004
27	0.05	1.31	0.33	0.00		*57*	0.03	0.88	0.23	0.004
28	0.05	1.28	0.33	0.00		*58*	0.03	0.88	0.23	0.004
29	0.05	1.26	0.32	0.00		*59*	0.03	0.88	0.23	0.004
30	**0.04**	**1.23**	**0.31**	**0.004**		***60***	**0.03**	**0.87**	**0.23**	**0.005**
31	0.04	1.21	0.30	0.004		*61*	0.03	0.87	0.24	0.005
32	0.04	1.19	0.29	0.004		*62*	0.03	0.87	0.24	0.005
33	0.04	1.17	0.28	0.004		*63*	0.03	0.87	0.25	0.005
34	0.04	1.15	0.28	0.004		*64*	0.03	0.87	0.25	0.005
						65	**0.03**	**0.87**	**0.26**	**0.005**

Source: EMFAC2017 V1.0.3, average annual emissions, statewide vehicle fleet, 50% humidity, temperature 75 °F.

ROG includes running exhaust and running evaporative emissions. PM2.5 Ex includes running exhaust emissions only.

Table 4 Emission Factors (grams per mile) by Speed (mph) (continued)

Project Life 6-10 years (2019-2028)

Speed	ROG	CO	NOx	PM2.5 Ex		Speed	ROG	CO	NOx	PM2.5 Ex
5	**0.20**	**1.94**	**0.77**	**0.01**		***35***	**0.03**	**0.96**	**0.22**	**0.003**
6	0.18	1.89	0.73	0.01		*36*	0.03	0.95	0.21	0.003
7	0.17	1.83	0.70	0.01		*37*	0.03	0.93	0.21	0.003
8	0.16	1.77	0.67	0.01		*38*	0.03	0.92	0.20	0.003
9	0.14	1.72	0.64	0.01		*39*	0.03	0.91	0.19	0.003
10	**0.13**	**1.67**	**0.61**	**0.01**		***40***	**0.03**	**0.89**	**0.19**	**0.003**
11	0.12	1.62	0.57	0.01		*41*	0.02	0.88	0.18	0.003
12	0.11	1.57	0.54	0.01		*42*	0.02	0.87	0.18	0.003
13	0.10	1.53	0.51	0.01		*43*	0.02	0.86	0.18	0.003
14	0.09	1.48	0.48	0.01		*44*	0.02	0.85	0.17	0.003
15	**0.09**	**1.44**	**0.45**	**0.01**		***45***	**0.02**	**0.83**	**0.17**	**0.003**
16	0.08	1.40	0.43	0.01		*46*	0.02	0.82	0.17	0.003
17	0.07	1.37	0.42	0.01		*47*	0.02	0.82	0.17	0.003
18	0.07	1.33	0.40	0.00		*48*	0.02	0.81	0.17	0.003
19	0.06	1.30	0.39	0.00		*49*	0.02	0.80	0.16	0.003
20	**0.06**	**1.27**	**0.37**	**0.00**		***50***	**0.02**	**0.79**	**0.16**	**0.003**
21	0.05	1.24	0.36	0.004		*51*	0.02	0.78	0.16	0.003
22	0.05	1.22	0.34	0.004		*52*	0.02	0.77	0.16	0.003
23	0.05	1.19	0.33	0.004		*53*	0.02	0.77	0.16	0.003
24	0.05	1.17	0.32	0.004		*54*	0.02	0.76	0.16	0.003
25	**0.04**	**1.15**	**0.31**	**0.003**		***55***	**0.02**	**0.75**	**0.17**	**0.003**
26	0.04	1.12	0.30	0.003		*56*	0.02	0.75	0.17	0.003
27	0.04	1.10	0.29	0.003		*57*	0.02	0.74	0.17	0.003
28	0.04	1.08	0.28	0.003		*58*	0.02	0.74	0.17	0.003
29	0.04	1.06	0.27	0.003		*59*	0.02	0.74	0.18	0.003
30	**0.03**	**1.05**	**0.26**	**0.003**		***60***	**0.02**	**0.73**	**0.18**	**0.003**
31	0.03	1.03	0.25	0.003		*61*	0.02	0.73	0.18	0.004
32	0.03	1.01	0.24	0.003		*62*	0.02	0.73	0.19	0.004
33	0.03	0.99	0.23	0.003		*63*	0.03	0.73	0.19	0.004
34	0.03	0.98	0.23	0.003		*64*	0.03	0.72	0.20	0.004
						65	**0.03**	**0.72**	**0.20**	**0.004**

Source: EMFAC2017 V1.0.3, average annual emissions, statewide vehicle fleet, 50% humidity, temperature 75 °F.

ROG includes running exhaust and running evaporative emissions. PM2.5 Ex includes running exhaust emissions only

Table 5 Statewide Calendar Year 2021 On-Road Emission Factors for Heavy-Duty Cleaner Vehicle Projects (grams per mile)

BEFORE PROJECT Baseline Emission Factors – New Diesel Vehicles

Vehicle Type	GVWR[1] (lbs)	Model Year	ROG	CO	NOx	PM2.5	Conversion Factors	ROG	CO	NOx	PM2.5
Urban Transit Buses	> 33,000	2007-2009	0.005	0.56	5.90	0.05	4.0	0.001	0.139	1.476	0.0133
		2010-2012	0.005	0.15	0.78	0.04	4.0	0.001	0.037	0.196	0.0111
		2013-2015	0.001	0.13	0.79	0.04	4.0	0.0003	0.032	0.197	0.0111
		2016+	0.003	0.13	0.78	0.04	4.0	0.0007	0.033	0.194	0.0112
Transit Buses[1], School Buses, and Trucks[2]	14,001-33,000	2007-2009	0.34	0.95	6.27	0.22	1.8	0.187	0.530	3.481	0.121
		2010-2012	0.03	0.19	2.61	0.08	1.8	0.017	0.106	1.452	0.044
		2013-2015	0.01	0.14	1.78	0.07	1.8	0.006	0.080	0.988	0.040
		2016+	0.01	0.13	1.29	0.07	1.8	0.005	0.070	0.718	0.038
Class 8 Trucks[3]	> 33,000	2007-2009	0.46	1.42	10.43	0.18	2.9	0.159	0.489	3.596	0.061
		2010-2012	0.16	0.97	5.94	0.08	2.9	0.054	0.334	2.049	0.028
		2013-2015	0.06	0.84	3.24	0.06	2.9	0.022	0.289	1.118	0.021
		2016+	0.06	0.78	2.29	0.05	2.9	0.020	0.271	0.789	0.018

Source: EMFAC2017 v1.0.3, Annual, Statewide (No pre-2003 Urban Transit Buses)

1 – Gross Vehicle Weight Rating 2 – Other Buses 3 – Medium Heavy-Duty Trucks 4 – Heavy Heavy-Duty Trucks

Cleaner vehicles could be compressed natural gas (CNG), liquefied natural gas (LNG), or cleaner diesel with after-treatment technology to reduce NOx and PM. The "After Project" emission factors are based on typical CNG vehicles; however, after-treatment applied to CNG vehicles has been shown to reduce even more PM and also, formaldehyde.

Table 5 Statewide Calendar Year 2021 On-Road Emission Factors for Heavy-Duty Cleaner Vehicle Projects (grams per mile) (Continued)

Retrofit Diesel Vehicles

Vehicle Type	GVWR[1] (lbs)	Model Year	ROG	CO	NOx	PM2.5	Conversion Factors	ROG	CO	NOx	PM2.5
Urban Transit Buses	>33,000	2003-2006	0.01	0.60	7.60	0.06	4.0	0.002	0.151	1.901	0.015
		2007-2009	0.005	0.56	5.90	0.05	4.0	0.001	0.139	1.476	0.013
Transit Buses[1], School Buses, and Trucks[2]	14,001-33,000	1994-1997	0.72	1.81	16.01	0.42	1.8	0.400	1.004	8.893	0.235
		1998-2002	1.08	2.58	15.78	0.47	1.8	0.602	1.434	8.769	0.263
		2003-2006	0.80	2.54	8.50	0.50	1.8	0.444	1.410	4.720	0.280
		2007-2009	0.34	0.95	6.27	0.22	1.8	0.187	0.530	3.481	0.121
Class 8 Trucks[3]	>33,000	1994-1997	1.15	3.66	20.66	0.44	2.9	0.395	1.261	7.125	0.153
		1998-2002	1.42	3.69	24.43	0.46	2.9	0.488	1.272	8.423	0.159
		2003-2006	0.94	3.36	13.14	0.59	2.9	0.323	1.158	4.532	0.205
		2007-2009	0.46	1.42	10.43	0.18	2.9	0.159	0.489	3.596	0.061

Source: EMFAC2017 v1.0.3, Annual, Statewide (No pre-2003 Urban Transit Buses)

1 – Gross Vehicle Weight Rating 2 – Other Buses 3 – Medium Heavy-Duty Trucks 4 – Heavy Heavy-Duty Trucks

Cleaner vehicles could be compressed natural gas (CNG), liquefied natural gas (LNG), or cleaner diesel with after-treatment technology to reduce NOx and PM. The "After Project" emission factors are based on typical CNG vehicles; however, after-treatment applied to CNG vehicles has been shown to reduce even more PM and also, formaldehyde.

Table 5 Statewide Calendar Year 2021 On-Road Emission Factors for Heavy-Duty Cleaner Vehicle Projects (grams per mile) (Continued)

AFTER PROJECT Emission Factors – New Cleaner Vehicle Purchase or Repowers

Vehicle Type	GVWR[1] (lbs)	Model Year	ROG	CO	NOx	PM2.5	Conversion Factors	ROG	CO	NOx	PM2.5
Urban Transit Buses	> 33,000	2012-2014	0.001	0.13	0.79	0.04	4.0	0.0003	0.032	0.199	0.0110
		2015-2017	0.003	0.13	0.79	0.04	4.0	0.0006	0.033	0.197	0.0110
		2018+	0.003	0.13	0.76	0.05	4.0	0.0007	0.032	0.190	0.0114
Transit Buses[1] School Buses, and Trucks[2]	14,001 - 33,000	2012-2014	0.011	0.05	2.15	0.07	1.8	0.006	0.026	1.194	0.041
		2015-2017	0.01	0.13	1.46	0.07	1.8	0.005	0.074	0.809	0.039
		2018+	0.01	0.12	1.19	0.07	1.8	0.005	0.067	0.659	0.037
Class 8 Trucks[3]	> 33,000	2012-2014	0.16	0.97	5.94	0.08	2.9	0.054	0.334	2.049	0.028
		2015-2017	0.06	0.81	2.52	0.06	2.9	0.021	0.278	0.870	0.020
		2018+	0.06	0.76	2.03	0.05	2.9	0.020	0.263	0.699	0.017

Source: EMFAC2017 v1.0.3, Annual, Statewide (No pre-2003 Urban Transit Buses)

1 – Gross Vehicle Weight Rating 2 – Other Buses 3 – Medium Heavy-Duty Trucks 4 – Heavy Heavy-Duty Trucks

Cleaner vehicles could be compressed natural gas (CNG), liquefied natural gas (LNG), or cleaner diesel with after-treatment technology to reduce NOx and PM. The "After Project" emission factors are based on typical CNG vehicles; however, after-treatment applied to CNG vehicles has been shown to reduce even more PM and also, formaldehyde.

Table 6 Off-Road Emission Factors for Cleaner Vehicle Projects

In Table 6, find the horsepower (hp) and model year for the engine that best describes the engine being replaced to determine the "before project" baseline emission factors. In Table 6, find the hp and model year for the newer engine to determine the "after project" cleaner engine baseline emission factors.

To calculate an engine's emission factor taking into account deterioration from the engine's cumulative operating hours:

1. First multiply the engine's cumulative operating hours by the deterioration rate (DR).
2. Then add that to the emission factor (EF).

Equation 1:

$EF_{DR} = (Hrs_{Cumulative} * DR) + EF$

EF_{DR} = Emission factor with deterioration rate (to be calculated)
$Hrs_{Cumulative}$ = Total operating hours to date
DR = Deterioration Rate (from Table 6)

For example, based on Equation 1 and data presented in Table 6, a pre-1988 25 horsepower engine that has 1,000 operating hours to date would have the following NOx emission factor:

$$6.608 = (1{,}000 * 0.000098) + 6.51$$

To estimate the reduction in annual emissions (in grams) from replacing the engine, use the equation below, obtained from the Carl Moyer Guidelines, Appendix D (https://www.arb.ca.gov/regact/2010/offroadlsi10/offroadappd.pdf):

Equation 2:

$Annual\ Reductions = (EF_{Before\ Project} - EF_{After\ Project}) * (Hours/Year) * hp * (LF)$

LF = Load Factor (unitless, see Carl Moyer Guidelines Appendix D for values https://www.arb.ca.gov/regact/2010/offroadlsi10/offroadappd.pdf)

Table 6 Uncontrolled Off-Road Diesel Engines
Emission Factors (g/bhp-hr) (EF) and Deterioration Rates (g/bhp-hr-hr) (DR)

Before Project: Baseline Emission

Horsepower	Model Year	NOx EF	NOx DR	ROG EF	ROG DR	PM2.5 EF	PM2.5 DR
25-49	Pre-1988	6.51	0.000098	1.68	0.000210	0.503	0.0000390
	1988+	6.42	0.000097	1.64	0.000210	0.503	0.0000390
50-119	Pre-1988	12.09	0.00028	1.31	0.000061	0.557	0.0000405
	1988+	8.14	0.00019	0.90	0.000042	0.457	0.0000332
120+	Pre-1970	13.02	0.00030	1.20	0.000056	0.510	0.0000371
	1970-1979	11.16	0.00026	0.91	0.000042	0.364	0.0000265
	1980-1987	10.23	0.00024	0.80	0.000037	0.364	0.0000265
	1988+	7.60	0.00018	0.62	0.000029	0.252	0.0000183

Source: The Carl Moyer program Guidelines 2017 Revisions, Appendix D, Table D-8
For use in calculating cost effectiveness of diesel engines: PM2.5 = PM10 X 0.92
(https://www.arb.ca.gov/msei/ordiesel/pm25_pm10reference.pdf)

Table 6 Uncontrolled Off-Road Diesel Engines (continued)
Emission Factors (g/bhp-hr) (EF) and Deterioration Rates (g/bhp-hr-hr) (DR)

After Project: Cleaner Engine

Horsepower	Tier	NOx EF	NOx DR	ROG EF	ROG DR	PM2.5 EF	PM2.5 DR
25-49	1	5.26	0.0000980	1.32	0.000170	0.442	0.0000342
	2	4.63	0.0000930	0.22	0.000050	0.258	0.0000201
	4 (Interim)	4.55	0.0000950	0.09	0.000036	0.118	0.0000088
	4 (Final)	2.75	0.0000570	0.09	0.000036	0.008	0.0000009
50-74	1	6.54	0.0001500	0.90	0.000042	0.508	0.0000370
	2	4.75	0.0000710	0.17	0.000025	0.177	0.0000130
	3	2.74	0.0000360	0.09	0.000023	0.177	0.0000130
	4 (Interim)	2.74	0.0000360	0.09	0.000023	0.103	0.0000074
	4 (Final)	2.74	0.0000360	0.09	0.000023	0.008	0.0000008
75-99	1	6.54	0.0001500	0.90	0.000042	0.508	0.0000370
	2	4.75	0.0000710	0.17	0.000025	0.177	0.0000130
	3	2.74	0.0000360	0.09	0.000023	0.103	0.0000074
	4 (Phase-Out)	2.74	0.0000360	0.09	0.000030	0.008	0.0000008
	(Phase-In or Alt. NOx)	2.15	0.0000270	0.08	0.000021	0.008	0.0000008
	4 (Final)	0.26	0.0000035	0.05	0.000015	0.008	0.0000008
100-174	1	6.54	0.0001500	0.62	0.000029	0.280	0.0000203
	2	4.15	0.0000600	0.15	0.000023	0.118	0.0000086
	3	2.32	0.0000300	0.09	0.000030	0.103	0.0000074
	4 (Phase-Out)	2.32	0.0000300	0.09	0.000030	0.008	0.0000004
	(Phase-In or Alt. NOx)	2.15	0.0000270	0.08	0.000020	0.008	0.0000004
	4 (Final)	0.26	0.0000040	0.05	0.000011	0.008	0.0000004
175-299	1	5.93	0.0001400	0.29	0.000013	0.110	0.0000059
	2	4.15	0.0000600	0.11	0.000022	0.081	0.0000042
	3	2.32	0.0000300	0.09	0.000023	0.081	0.0000042
	4 (Phase-Out)	2.32	0.0000300	0.09	0.000023	0.008	0.0000003
	(Phase-In or Alt. NOx)	1.29	0.0000170	0.06	0.000017	0.008	0.0000003
	4 (Final)	0.26	0.0000036	0.05	0.000011	0.008	0.0000003
300-750	1	5.93	0.0000990	0.29	0.000010	0.110	0.0000059
	2	3.79	0.0000500	0.09	0.000023	0.081	0.0000040
	3	2.32	0.0000300	0.09	0.000023	0.081	0.0000040
	4 (Phase-Out)	2.32	0.0000300	0.09	0.000023	0.008	0.0000003
	(Phase-In or Alt. NOx)	1.29	0.0000170	0.06	0.000017	0.008	0.0000003
	4 (Final)	0.26	0.0000036	0.05	0.000011	0.008	0.0000003
751+	1	5.93	0.0000990	0.29	0.000010	0.110	0.0000059
	2	3.79	0.0000500	0.09	0.000023	0.081	0.0000040
	4 (Interim)	2.24	0.0000280	0.06	0.000017	0.047	0.0000019
	4 (Final)	2.24	0.0000280	0.05	0.000011	0.016	0.0000008

APPENDIX 3
DISPERSION MODELLING AND ZONING INFORMATION

Conservative Factor Dispersion Modelling

Minimum Source/Receptor Separation Distance: 20 m

Factor		
1	Hourly	10,000.0 µg/m^3 per g/s emission
24	24-Hour	4,107.2 µg/m^3 per g/s emission
0.167	10 Minute	16,505.9 µg/m^3 per g/s emission
0.5	1/2-Hour	12,141.9 µg/m^3 per g/s emission
720	30-day	1,584.7 µg/m^3 per g/s emission
8760	Annual	787.2 µg/m^3 per g/s emission

Distance From Source (m)	Urban Dispersion Factor (µg/m^3 per g/s)	Rural Dispersion Factor (µg/m^3 per g/s)
20	8700	10000
40	6300	8100
60	4600	5900
80	3400	5100
100	2600	4500
150	1400	3500
200	900	2800
250	600	2300
300	450	1900
350	350	1700
400	300	1500
450	250	1300
500	200	1150
600	150	950
700	120	800
800	90	650
900	80	575
1000	70	500

Emission Threshold Comparison and Dispersion Factor Modelling

Contaminant	CAS	POI Limit ($\mu g/m^3$)	Limiting Effect	Averaging Period (hours)	Limit Source	50% POI Limit ($\mu g/m^3$)	Calculated Emission Threshold (g/s)	Facility Emission Rate (g/s)	Significance (Er>Et)	Modelling Required?
1,2,3-Trimethylbenzene	526-73-8	220	Health	24	Standard	110	2.68E-02	2.45E-04	Insig.	No
1,3,5-Trimethylbenzene	108-67-8	220	Health	24	Standard	110	2.68E-02	6.54E-04	Insig.	No
1,3-butadiene	106-99-0	2	Health	8760	Standard	1	1.27E-03	7.72E-06	Insig.	No
1-hexene	592-41-6	850	Health	24	SL-JSL	425	1.03E-01	6.14E-06	Insig.	No
1-pentene	109-67-1	2050	Health	24	SL-JSL	1025	2.50E-01	9.22E-06	Insig.	No
Isooctane	540-84-1	1750	Health	24	SL-JSL	875	2.13E-01	3.20E-05	Insig.	No
2,2-dimethylpentane	590-35-2	175	Health	24	SL-JSL	87.5	2.13E-02	2.24E-06	Insig.	No
2,3,3-trimethylpentane	560-21-4	0.1	de minimus	24	de minimus	0.05	1.22E-05	1.57E-05	Sig.	Yes
2,3,4-trimethylpentane	565-75-3	175	Health	24	SL-JSL	87.5	2.13E-02	1.89E-05	Insig.	No
2,3-dimethylpentane	565-59-3	1750	Health	24	SL-JSL	875	2.13E-01	1.21E-05	Insig.	No
2,4-dimethylpentane	108-08-7	1750	Health	24	SL-JSL	875	2.13E-01	1.51E-05	Insig.	No
2,5-Dimethylbenzaldehyde	5779-94-2	0.5	Health	24	SL-JSL	0.25	6.09E-05	2.17E-05	Insig.	No
2,6-dimethylheptane	1072-05-5	175	Health	24	SL-JSL	87.5	2.13E-02	4.11E-06	Insig.	No
2-Butanone	78-93-3	1000	Health	24	Standard	500	1.22E-01	2.86E-04	Insig.	No
2-methyl-1-butene	563-46-2	300	Health	24	SL-JSL	150	3.65E-02	2.36E-05	Insig.	No
2-methyl-1-pentene	763-29-1	85	Health	24	SL-JSL	42.5	1.03E-02	6.14E-06	Insig.	No
2-methyl-2-butene	513-35-9	530	Health	24	SL-JSL	265	6.45E-02	1.23E-05	Insig.	No
2-Methylnaphthalene	91-57-6	35.5	Health	24	SL-JSL	17.75	4.32E-03	1.24E-02	Sig.	Yes
2-methylpentane (isohexane)	107-83-5	1750	Health	24	SL-JSL	875	2.13E-01	9.08E-06	Insig.	No
3-methylheptane	589-81-1	175	Health	24	SL-JSL	87.5	2.13E-02	7.94E-06	Insig.	No
3-methyloctane	2216-33-3	175	Health	24	SL-JSL	87.5	2.13E-02	8.23E-06	Insig.	No
3-methylpentane	96-14-0	1750	Health	24	SL-JSL	875	2.13E-01	1.54E-06	Insig.	No
4-methyl-1-pentene	691-37-2	85	Health	24	SL-JSL	42.5	1.03E-02	1.59E-05	Insig.	No
Acenaphthene	83-32-9	Assessed using B(a)P as the surrogate as per the guidance provided by the ACB List (v 2.0)								
Acenaphthylene	208-96-8	Assessed using B(a)P as the surrogate as per the guidance provided by the ACB List (v 2.0)								
Acetaldehyde	75-07-0	500	Health	24	Standard	250	6.09E-02	8.11E-03	Insig.	No
	75-07-0	500	Health	24	Standard	250	6.09E-02	1.87E-02	Insig.	No
Acetic Acid	64-19-7	2500	Odour	24	Guideline	1250	3.04E-01	1.92E-04	Insig.	No
Acetone	67-64-1	11880	Health	24	Standard	5940	1.45E+00	3.57E-04	Insig.	No
Acetylene	74-86-2	56000	Odour	24	Guideline	28000	6.82E+00	7.50E-04	Insig.	No
Acrolein	107-02-8	0.4	Health	24	Standard	0.2	4.87E-05	1.23E-04	Sig.	Yes
	107-02-8	4.5	Health	1	Standard	2.25	2.25E-04	1.61E-04	Insig.	No
Acrylic Acid	79-10-7	12	Health	24	SL-PA	6	1.46E-03	2.26E-05	Insig.	No
Aluminum	7429-90-5	12	Health	24	SL-JSL	6	1.46E-03	9.86E-04	Insig.	No
Anthracene	120-12-7	Assessed using B(a)P as the surrogate as per the guidance provided by the ACB List (v 2.0)								
Antimony	7440-36-0	25	Health	24	Standard	12.5	3.04E-03	8.91E-06	Insig.	No
Arsenic and compounds	7440-38-2	0.3	Health	24	Guideline	0.15	3.65E-05	5.13E-05	Sig.	Yes
Barium	7440-39-3	10	Health	24	Guideline	5	1.22E-03	1.51E-04	Insig.	No
Benzaldehyde	100-52-7	2	Health	24	SL-JSL	1	2.43E-04	3.04E-03	Sig.	Yes
Benzene	71-43-2	0.45	Health	8760	Standard	0.225	2.86E-04	2.88E-03	Sig.	Yes
Benzo(a)anthracene	56-55-3	Assessed using B(a)P as the surrogate as per the guidance provided by the ACB List (v 2.0)								
Benzo(a)pyrene	50-32-8	0.00001	Health	8760	Standard	0.000005	6.35E-09	2.28E-08	Sig.	Yes
Benzo(b)fluoranthene	205-99-2	Assessed using B(a)P as the surrogate as per the guidance provided by the ACB List (v 2.0)								

Emission Threshold Comparison and Dispersion Factor Modelling

Contaminant	CAS	POI Limit ($\mu g/m^3$)	Limiting Effect	Averaging Period (hours)	Limit Source	50% POI Limit ($\mu g/m^3$)	Calculated Emission Threshold (g/s)	Facility Emission Rate (g/s)	Significance (Er>Et)	Modelling Required?
Benzo(e)pyrene	192-97-2	Assessed using B(a)P as the surrogate as per the guidance provided by the ACB List (v 2.0)								
Benzo(g,h,i)perylene	191-24-2	Assessed using B(a)P as the surrogate as per the guidance provided by the ACB List (v 2.0)								
Benzo(k)fluoranthene	207-08-9	Assessed using B(a)P as the surrogate as per the guidance provided by the ACB List (v 2.0)								
Bromomethane	74-83-9	1350	Health	24	Guideline	675	1.64E-01	2.88E-05	Insig.	No
Butyraldehyde	123-72-8	7	Health	24	SL-JSL	3.5	8.52E-04	2.26E-05	Insig.	No
Butyraldehyde/isobutyraldehyde	78-84-2	160	Health	24	SL-JSL	80	1.95E-02	7.29E-04	Insig.	No
C9-c12 isoalkanes	64742-82-1	2600	Health	24	SL-MD	1300	3.17E-01	2.52E-04	Insig.	No
Cadmium	7440-43-9	0.025	Health	24	Standard	0.0125	3.04E-06	1.19E-05	Sig.	Yes
Calcium	1305-78-8	10	Corrosion	24	Standard	5	1.22E-03	5.30E-04	Insig.	No
Carbon	7440-44-0	15	Health & Particulate	24	SL-JSL	7.5	1.83E-03	8.49E-04	Insig.	No
Carbon Disulfide	75-15-0	330	Odour	24	Guideline	165	4.02E-02	9.39E-05	Insig.	No
Carbon Monoxide	630-08-0	6000	Health	0.5	Standard	3000	2.47E-01	2.31E+01	Sig.	Yes
Chloroethane	75-00-3	5600	Health	24	Standard	2800	6.82E-01	2.35E-05	Insig.	No
Chloromethane	74-87-3	320	Health	24	Standard	160	3.90E-02	1.35E-04	Insig.	No
Chromium (di, tri and metallic)	7440-47-3	0.5	Health	24	Standard	0.25	6.09E-05	7.77E-04	Sig.	Yes
Chrysene	218-01-9	Assessed using B(a)P as the surrogate as per the guidance provided by the ACB List (v 2.0)								
Cobalt	7440-48-4	0.1	Health	24	Guideline	0.05	1.22E-05	3.84E-05	Sig.	Yes
Copper	7440-50-8	50	Health	24	Standard	25	6.09E-03	1.07E-03	Insig.	No
Crotonaldehyde	4170-30-3	1.25	Health	24	SL-JSL	0.625	1.52E-04	8.02E-04	Sig.	Yes
Cumene	92-82-8	0.1	de minimus	24	de minimus	0.05	1.22E-05	4.70E-07	Insig.	No
Dibenz(a,h)anthracene	53-70-3	Assessed using B(a)P as the surrogate as per the guidance provided by the ACB List (v 2.0)								
Diethylbenzene	25340-17-4	30	Health	24	SL-JSL	15	3.65E-03	2.93E-04	Insig.	No
Ethane	74-84-0	14500	Health	24	SL-JSL	7250	1.77E+00	2.40E-04	Insig.	No
Ethylbenzene	100-41-4	1000	Health	24	Standard	500	1.22E-01	5.15E-02	Insig.	Yes
	100-41-4	1900	Odour	0.167	Guideline	950	5.76E-02	1.24E-01	Sig.	Yes
Ethylene	74-85-1	40	Vegetation	24	Guideline	20	4.87E-03	8.09E-03	Sig.	Yes
Ethyltoluene	620-14-4	62.5	Health	24	SL-JSL	31.25	7.61E-03	2.67E-03	Insig.	No
Ferric Oxide	1309-37-1	25	Health & Soiling	24	Standard	12.5	3.04E-03	2.06E-01	Sig.	Yes
Fluoranthene	206-44-0	Assessed using B(a)P as the surrogate as per the guidance provided by the ACB List (v 2.0)								
Fluorene	86-73-7	Assessed using B(a)P as the surrogate as per the guidance provided by the ACB List (v 2.0)								
Formaldehyde	50-00-0	65	Health	24	Standard	32.5	7.91E-03	2.27E-02	Sig.	Yes
Formic Acid	64-18-6	500	Health	24	Standard	250	6.09E-02	1.92E-04	Insig.	No
Heavy Hydrocarbons (aliphatic hydrocarbon blend)	69430-33-7	122.5	Health	24	SL-JSL	61.25	1.49E-02	4.35E-02	Sig.	Yes
Hexanal	66-25-1	10	Health	24	SL-JSL	5	1.22E-03	5.56E-04	Insig.	No
Hexavalent Chromium	18540-29-9	0.00014	Health	8760	Standard	0.00007	8.89E-08	2.85E-06	Sig.	Yes
Hydrogen Chloride	7647-01-0	20	Health	24	Standard	10	2.43E-03	9.85E-03	Sig.	Yes
Indeno(1,2,3-cd)pyrene	193-39-5	Assessed using B(a)P as the surrogate as per the guidance provided by the ACB List (v 2.0)								
Indium	7440-74-6	0.5	Health	24	SL-JSL	0.25	6.09E-05	1.19E-06	Insig.	No
Iron	7439-89-6	4	Health & Soiling	24	Standard	2	4.87E-04	2.07E-01	Sig.	Yes
Isobutane	75-28-5	3550	Health	24	SL-JSL	1775	4.32E-01	2.72E-05	Insig.	No
Isobutyl benzene	538-93-2	62.5	Health	24	SL-JSL	31.25	7.61E-03	1.10E-04	Insig.	No
Isopentane	78-78-4	35500	Health	24	SL-JSL	17750	4.32E+00	7.43E-04	Insig.	No
Isopropyl Alcohol	67-63-0	7300	Health	24	Standard	3650	8.89E-01	2.69E-03	Insig.	No

Emission Threshold Comparison and Dispersion Factor Modelling

Contaminant	CAS	POI Limit ($\mu g/m^3$)	Limiting Effect	Averaging Period (hours)	Limit Source	50% POI Limit ($\mu g/m^3$)	Calculated Emission Threshold (g/s)	Facility Emission Rate (g/s)	Significance (Er>Et)	Modelling Required?
Lead and compounds	7439-92-1	0.5	Health	24	Standard	0.25	6.09E-05	1.66E-04	Sig.	Yes
	7439-92-1	0.2	Health	720	Standard	0.1	6.31E-05	1.66E-04	Sig.	Yes
Manganese and compounds	7439-96-5	0.4	Health	24	Standard	0.2	4.87E-05	3.34E-03	Sig.	Yes
Mercury	7439-97-6	2	Health	24	Standard	1	2.43E-04	5.56E-06	Insig.	No
Methane	74-82-8	37330	Health	24	SL-PA	18665	4.54E+00	2.01E-03	Insig.	No
Methylbenzaldehyde	104-87-0	45	Health	24	SL-JSL	22.5	5.48E-03	3.77E-05	Insig.	No
Methylcyclopentane	96-37-7	3500	Health	24	SL-JSL	1750	4.26E-01	2.24E-06	Insig.	No
Methylene Chloride	75-09-2	220	Health	24	Standard	110	2.68E-02	1.58E-06	Insig.	No
Molybdenum	7439-98-7	120	Particulate	24	Guideline	60	1.46E-02	7.98E-05	Insig.	No
Naphthalene	91-20-3	22.5	Health	24	Guideline	11.25	2.74E-03	4.54E-03	Sig.	Yes
	91-20-3	50	Odour	0.167	Guideline	25	1.51E-03	1.98E-02	Sig.	Yes
N-butane	106-97-8	3550	Health	24	SL-JSL	1775	4.32E-01	4.09E-04	Insig.	No
n-Hexane	110-54-3	7500	Health	24	Standard	3750	9.13E-01	8.02E-04	Insig.	No
Nickel and compounds	7440-02-0	0.04	Health	8760	Standard	0.02	2.54E-05	8.46E-04	Sig.	Yes
Nitrogen Oxides	10102-44-0	200	Health	24	Standard	100	2.43E-02	1.40E+00	Sig.	Yes
	10102-44-0	400	Health	1	Standard	200	2.00E-02	2.43E+00	Sig.	Yes
N-octane	111-65-9	61800	Odour	0.167	Guideline	30900	1.87E+00	1.27E-05	Insig.	No
N-pentane	109-66-0	35500	Health	24	SL-JSL	17750	4.32E+00	4.20E-04	Insig.	No
n-Propylbenzene	103-65-1	1250	Health	24	SL-JSL	625	1.52E-01	4.83E-04	Insig.	No
N-undecane	1120-21-4	175	Health	24	SL-JSL	87.5	2.13E-02	3.15E-05	Insig.	No
Perylene	198-55-0	Assessed using B(a)P as the surrogate as per the guidance provided by the ACB List (v 2.0)								
Phenanthrene	85-01-8	Assessed using B(a)P as the surrogate as per the guidance provided by the ACB List (v 2.0)								
Phenol	108-95-2	30	Health	24	Standard	15	3.65E-03	3.39E-06	Insig.	No
Phosphorus	7723-14-0	0.5	Health	24	SL-MD	0.25	6.09E-05	7.18E-04	Sig.	Yes
Potassium	7440-09-7	10	Health	24	SL-MD	5	1.22E-03	1.59E-04	Insig.	No
Propane	74-98-6	215000	Health	24	SL-JSL	107500	2.62E+01	1.10E-04	Insig.	No
Propionaldehyde	123-38-6	10	Odour	0.167	Guideline	5	3.03E-04	1.32E-04	Insig.	No
Propylcyclopentane	2040-96-2	175	Health	24	SL-JSL	87.5	2.13E-02	4.11E-06	Insig.	No
Propylene	115-07-1	4000	Health	24	Standard	2000	4.87E-01	4.03E-04	Insig.	No
Pyrene	129-00-0	Assessed using B(a)P as the surrogate as per the guidance provided by the ACB List (v 2.0)								
Quinone	106-51-4	15	Health	24	Guideline	7.5	1.83E-03	6.25E-03	Sig.	Yes
Selenium	7782-49-2	10	Health	24	Guideline	5	1.22E-03	8.10E-06	Insig.	No
Silicon	7440-21-3	27	Health	24	SL-PA	13.5	3.29E-03	4.09E-03	Sig.	Yes
Silver	7440-22-4	1	Health	24	Standard	0.5	1.22E-04	1.11E-05	Insig.	No
Strontium	7440-24-6	120	Particulate	24	Guideline	60	1.46E-02	4.74E-06	Insig.	No
Styrene	100-42-5	400	Health	24	Standard	200	4.87E-02	3.17E-05	Insig.	No
Sulphur	7704-34-9	25	Health	24	SL-JSL	12.5	3.04E-03	1.71E-04	Insig.	No
Sulphur dioxide	7446-09-5	10	Health & Vegetation	8760	Standard	5	6.35E-03	5.00E-02	Sig.	Yes
	7446-09-5	100	Health & Vegetation	1	Standard	50	5.00E-03	3.47E-01	Sig.	Yes
Suspended Particulate Matter	N/A(9)	120	Visibility	24	Standard	60	1.46E-02	2.04E+00	Sig.	Yes
Suspended Particulate Matter - PM10	NA-M09	50	Health	24	AAQC - Interim	25	6.09E-03	9.80E-01	Sig.	Yes
Suspended Particulate Matter - PM2.5	NA-M10	27	Health	24	CWS	13.5	3.29E-03	4.66E-01	Sig.	Yes
Tetrachloroethene	127-18-4	360	Health	24	Standard	180	4.38E-02	3.29E-08	Insig.	No

Emission Threshold Comparison and Dispersion Factor Modelling

Contaminant	CAS	POI Limit ($\mu g/m^3$)	Limiting Effect	Averaging Period (hours)	Limit Source	50% POI Limit ($\mu g/m^3$)	Calculated Emission Threshold (g/s)	Facility Emission Rate (g/s)	Significance (Er>Et)	Modelling Required?
Thallium	7440-28-0	0.5	Health	24	SL-JSL	0.25	6.09E-05	9.49E-08	Insig.	No
Tin	7440-31-5	10	Health	24	Standard	5	1.22E-03	4.85E-05	Insig.	No
Titanium	7440-32-6	120	Particulate	24	Standard	60	1.46E-02	6.64E-05	Insig.	No
Toluene	108-88-3	2000	Odour	24	Guideline	1000	2.43E-01	2.53E-02	Insig.	No
Trans-2-pentene	646-04-8	300	Health	24	SL-JSL	150	3.65E-02	2.21E-05	Insig.	No
Trichlorofluoromethane	75-69-4	6000	Health	24	Guideline	3000	7.30E-01	5.55E-09	Insig.	No
Valeraldehyde	110-62-3	900	Health	24	SL-JSL	450	1.10E-01	7.68E-06	Insig.	No
Vanadium	7440-62-2	2	Health	24	Standard	1	2.43E-04	1.26E-05	Insig.	No
Xylene	1330-20-7	730	Health	24	Standard	365	8.89E-02	6.51E-02	Insig.	Yes
	1330-20-7	3000	Odour	0.167	Guideline	1500	9.09E-02	1.56E-01	Sig.	Yes
Zinc	7440-66-6	120	Particulate	24	Standard	60	1.46E-02	3.35E-02	Sig.	Yes
Zirconium	7440-67-7	25	Health	24	SL-JSL	12.5	3.04E-03	5.93E-07	Insig.	No

Results Summary

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2,3,3-trimethylpentane - Concentration - Source Group: ALL

Averaging Period	Rank	Peak	Units	X (m)	Y (m)	ZELEV (m)	ZFLAG (m)	ZHILL (m)	Peak Date, Start Hour
24-HR	1ST	0.00217	ug/m^3	601232.63	4804853.97	106.00	1.00	106.00	1/5/1998, 24
MONTH	1ST	0.00107	ug/m^3	601232.63	4804853.97	106.00	1.00	106.00	
ANNUAL		0.00082	ug/m^3	601232.63	4804853.97	106.00	1.00	106.00	

2-Methylnaphthalene - Concentration - Source Group: ALL

Averaging Period	Rank	Peak	Units	X (m)	Y (m)	ZELEV (m)	ZFLAG (m)	ZHILL (m)	Peak Date, Start Hour
24-HR	1ST	0.39276	ug/m^3	601191.18	4804756.17	105.00	20.70	105.00	
MONTH	1ST	0.11283	ug/m^3	601180.19	4804755.85	105.00	1.00	105.00	
ANNUAL		0.08841	ug/m^3	601180.19	4804755.85	105.00	1.00	105.00	

Acrolein - Concentration - Source Group: ALL

Averaging Period	Rank	Peak	Units	X (m)	Y (m)	ZELEV (m)	ZFLAG (m)	ZHILL (m)	Peak Date, Start Hour
24-HR	1ST	0.01146	ug/m^3	601232.63	4804853.97	106.00	1.00	106.00	1/5/1998, 24
MONTH	1ST	0.00563	ug/m^3	601232.63	4804853.97	106.00	1.00	106.00	
ANNUAL		0.00433	ug/m^3	601232.63	4804853.97	106.00	1.00	106.00	

Results Summary

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Arsenic and compounds - Concentration - Source Group: ALL

Averaging Period	Rank	Peak	Units	X (m)	Y (m)	ZELEV (m)	ZFLAG (m)	ZHILL (m)	Peak Date, Start Hour
24-HR	1ST	0.00730	ug/m^3	601354.99	4804827.21	105.00	1.00	105.00	1/5/1998, 24
MONTH	1ST	0.00380	ug/m^3	601354.99	4804827.21	105.00	1.00	105.00	
ANNUAL		0.00290	ug/m^3	601354.99	4804827.21	105.00	1.00	105.00	

Benzaldehyde - Concentration - Source Group: ALL

Averaging Period	Rank	Peak	Units	X (m)	Y (m)	ZELEV (m)	ZFLAG (m)	ZHILL (m)	Peak Date, Start Hour
24-HR	1ST	0.02220	ug/m^3	601192.96	4804745.89	105.00	27.10	105.00	12/17/1999, 24
MONTH	1ST	0.00676	ug/m^3	601180.19	4804755.85	105.00	1.00	105.00	
ANNUAL		0.00447	ug/m^3	601188.93	4804782.61	105.66	1.00	105.66	

Benzene - Concentration - Source Group: ALL

Averaging Period	Rank	Peak	Units	X (m)	Y (m)	ZELEV (m)	ZFLAG (m)	ZHILL (m)	Peak Date, Start Hour
24-HR	1ST	0.30554	ug/m^3	601354.99	4804827.21	105.00	1.00	105.00	1/5/1998, 24
MONTH	1ST	0.15899	ug/m^3	601354.99	4804827.21	105.00	1.00	105.00	
ANNUAL		0.12179	ug/m^3	601354.99	4804827.21	105.00	1.00	105.00	

Results Summary

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Benzo(a)pyrene - Concentration - Source Group: ALL

Averaging Period	Rank	Peak	Units	X (m)	Y (m)	ZELEV (m)	ZFLAG (m)	ZHILL (m)	Peak Date, Start Hour
24-HR	1ST	0.00000	ug/m^3	601192.96	4804745.89	105.00	14.30	105.00	1/6/1998, 24
MONTH	1ST	0.00000	ug/m^3	601191.18	4804756.17	105.00	14.30	105.00	
ANNUAL		0.00000	ug/m^3	601180.19	4804755.85	105.00	1.00	105.00	

Cadmium - Concentration - Source Group: ALL

Averaging Period	Rank	Peak	Units	X (m)	Y (m)	ZELEV (m)	ZFLAG (m)	ZHILL (m)	Peak Date, Start Hour
24-HR	1ST	0.00192	ug/m^3	601354.99	4804827.21	105.00	1.00	105.00	1/5/1998, 24
MONTH	1ST	0.00100	ug/m^3	601354.99	4804827.21	105.00	1.00	105.00	
ANNUAL		0.00077	ug/m^3	601354.99	4804827.21	105.00	1.00	105.00	

Carbon Monoxide - Concentration - Source Group: ALL

Averaging Period	Rank	Peak	Units	X (m)	Y (m)	ZELEV (m)	ZFLAG (m)	ZHILL (m)	Peak Date, Start Hour
24-HR	1ST	299.05588	ug/m^3	601354.99	4804827.21	105.00	1.00	105.00	1/5/1998, 24
MONTH	1ST	162.45717	ug/m^3	601354.99	4804827.21	105.00	1.00	105.00	
ANNUAL		130.87337	ug/m^3	601354.99	4804827.21	105.00	1.00	105.00	

Results Summary

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Chromium (di, tri and metallic) - Concentration - Source Group: ALL

Averaging Period	Rank	Peak	Units	X (m)	Y (m)	ZELEV (m)	ZFLAG (m)	ZHILL (m)	Peak Date, Start Hour
24-HR	1ST	0.01014	ug/m^3	601191.18	4804756.17	105.00	20.70	105.00	10/23/1997, 24
MONTH	1ST	0.00284	ug/m^3	601191.18	4804756.17	105.00	17.50	105.00	
ANNUAL		0.00188	ug/m^3	601192.96	4804745.89	105.00	11.10	105.00	

Cobalt - Concentration - Source Group: ALL

Averaging Period	Rank	Peak	Units	X (m)	Y (m)	ZELEV (m)	ZFLAG (m)	ZHILL (m)	Peak Date, Start Hour
24-HR	1ST	0.00057	ug/m^3	601191.18	4804756.17	105.00	20.70	105.00	10/23/1997, 24
MONTH	1ST	0.00016	ug/m^3	601191.18	4804756.17	105.00	17.50	105.00	
ANNUAL		0.00010	ug/m^3	601192.96	4804745.89	105.00	11.10	105.00	

Crotonaldehyde - Concentration - Source Group: ALL

Averaging Period	Rank	Peak	Units	X (m)	Y (m)	ZELEV (m)	ZFLAG (m)	ZHILL (m)	Peak Date, Start Hour
24-HR	1ST	0.01811	ug/m^3	601232.63	4804853.97	106.00	1.00	106.00	1/5/1998, 24
MONTH	1ST	0.00923	ug/m^3	601232.63	4804853.97	106.00	1.00	106.00	
ANNUAL		0.00742	ug/m^3	601232.63	4804853.97	106.00	1.00	106.00	

Results Summary

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Ethylbenzene - Concentration - Source Group: ALL

Averaging Period	Rank	Peak	Units	X (m)	Y (m)	ZELEV (m)	ZFLAG (m)	ZHILL (m)	Peak Date, Start Hour
24-HR	1ST	0.37744	ug/m^3	601192.96	4804745.89	105.00	27.10	105.00	12/17/1999, 24
MONTH	1ST	0.11321	ug/m^3	601191.18	4804756.17	105.00	27.10	105.00	
ANNUAL		0.07912	ug/m^3	601354.99	4804827.21	105.00	1.00	105.00	

Ethylene - Concentration - Source Group: ALL

Averaging Period	Rank	Peak	Units	X (m)	Y (m)	ZELEV (m)	ZFLAG (m)	ZHILL (m)	Peak Date, Start Hour
24-HR	1ST	0.76001	ug/m^3	601354.99	4804827.21	105.00	1.00	105.00	1/5/1998, 24
MONTH	1ST	0.39155	ug/m^3	601354.99	4804827.21	105.00	1.00	105.00	
ANNUAL		0.29884	ug/m^3	601354.99	4804827.21	105.00	1.00	105.00	

Ferric Oxide - Concentration - Source Group: ALL

Averaging Period	Rank	Peak	Units	X (m)	Y (m)	ZELEV (m)	ZFLAG (m)	ZHILL (m)	Peak Date, Start Hour
24-HR	1ST	3.08213	ug/m^3	601191.18	4804756.17	105.00	20.70	105.00	10/23/1997, 24
MONTH	1ST	0.84181	ug/m^3	601191.18	4804756.17	105.00	17.50	105.00	
ANNUAL		0.55284	ug/m^3	601192.96	4804745.89	105.00	11.10	105.00	

Results Summary

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Formaldehyde - Concentration - Source Group: ALL

Averaging Period	Rank	Peak	Units	X (m)	Y (m)	ZELEV (m)	ZFLAG (m)	ZHILL (m)	Peak Date, Start Hour
24-HR	1ST	0.22735	ug/m^3	601191.18	4804756.17	105.00	14.30	105.00	
MONTH	1ST	0.11582	ug/m^3	601188.93	4804782.61	105.66	1.00	105.66	
ANNUAL		0.09813	ug/m^3	601188.93	4804782.61	105.66	1.00	105.66	

Heavy Hydrocarbons (aliphatic hydrocarbon blend) - Concentration - Source Group: ALL

Averaging Period	Rank	Peak	Units	X (m)	Y (m)	ZELEV (m)	ZFLAG (m)	ZHILL (m)	Peak Date, Start Hour
24-HR	1ST	2.86623	ug/m^3	601197.67	4804791.53	105.56	1.00	105.56	1/5/1998, 24
MONTH	1ST	1.42755	ug/m^3	601215.15	4804818.29	105.58	1.00	105.58	
ANNUAL		1.09780	ug/m^3	601215.15	4804818.29	105.58	1.00	105.58	

Hexavalent Chromium - Concentration - Source Group: ALL

Averaging Period	Rank	Peak	Units	X (m)	Y (m)	ZELEV (m)	ZFLAG (m)	ZHILL (m)	Peak Date, Start Hour
24-HR	1ST	0.00002	ug/m^3	601192.96	4804745.89	105.00	27.10	105.00	12/17/1999, 24
MONTH	1ST	0.00001	ug/m^3	601191.18	4804756.17	105.00	27.10	105.00	
ANNUAL		0.00000	ug/m^3	601191.18	4804756.17	105.00	27.10	105.00	

Results Summary

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Hydrogen Chloride - Concentration - Source Group: ALL

Averaging Period	Rank	Peak	Units	X (m)	Y (m)	ZELEV (m)	ZFLAG (m)	ZHILL (m)	Peak Date, Start Hour
24-HR	1ST	0.29729	ug/m^3	601218.83	4804725.09	105.00	23.90	105.00	
MONTH	1ST	0.06076	ug/m^3	601191.18	4804756.17	105.00	17.50	105.00	
ANNUAL		0.03099	ug/m^3	601192.96	4804745.89	105.00	20.70	105.00	

Iron - Concentration - Source Group: ALL

Averaging Period	Rank	Peak	Units	X (m)	Y (m)	ZELEV (m)	ZFLAG (m)	ZHILL (m)	Peak Date, Start Hour
24-HR	1ST	3.08387	ug/m^3	601191.18	4804756.17	105.00	20.70	105.00	10/23/1997, 24
MONTH	1ST	0.84449	ug/m^3	601191.18	4804756.17	105.00	17.50	105.00	
ANNUAL		0.55614	ug/m^3	601192.96	4804745.89	105.00	11.10	105.00	

Lead and compounds - Concentration - Source Group: ALL

Averaging Period	Rank	Peak	Units	X (m)	Y (m)	ZELEV (m)	ZFLAG (m)	ZHILL (m)	Peak Date, Start Hour
24-HR	1ST	0.09803	ug/m^3	601354.99	4804827.21	105.00	1.00	105.00	1/5/1998, 24
MONTH	1ST	0.05101	ug/m^3	601354.99	4804827.21	105.00	1.00	105.00	
ANNUAL		0.03888	ug/m^3	601354.99	4804827.21	105.00	1.00	105.00	

Results Summary

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800 Burloak Drive

Manganese and compounds - Concentration - Source Group: ALL

Averaging Period	Rank	Peak	Units	X (m)	Y (m)	ZELEV (m)	ZFLAG (m)	ZHILL (m)	Peak Date, Start Hour
24-HR	1ST	0.04776	ug/m^3	601191.18	4804756.17	105.00	20.70	105.00	10/23/1997, 24
MONTH	1ST	0.01318	ug/m^3	601191.18	4804756.17	105.00	17.50	105.00	
ANNUAL		0.00870	ug/m^3	601192.96	4804745.89	105.00	11.10	105.00	

MULTI - Concentration - Source Group: ALL

Averaging Period	Rank	Peak	Units	X (m)	Y (m)	ZELEV (m)	ZFLAG (m)	ZHILL (m)	Peak Date, Start Hour
24-HR	1ST	0.30579	ug/m^3	601354.99	4804827.21	105.00	1.00	105.00	1/5/1998, 24
MONTH	1ST	0.15912	ug/m^3	601354.99	4804827.21	105.00	1.00	105.00	8/31/1996, 24
ANNUAL		0.12190	ug/m^3	601354.99	4804827.21	105.00	1.00	105.00	
ANNUAL Y1		0.12721	ug/m^3	601354.99	4804827.21	105.00	1.00	105.00	
ANNUAL Y2		0.12471	ug/m^3	601354.99	4804827.21	105.00	1.00	105.00	
ANNUAL Y3		0.12594	ug/m^3	601354.99	4804827.21	105.00	1.00	105.00	
ANNUAL Y4		0.11544	ug/m^3	601354.99	4804827.21	105.00	1.00	105.00	
ANNUAL Y5		0.11618	ug/m^3	601354.99	4804827.21	105.00	1.00	105.00	

Results Summary

AERMOD Dispersion Modelling Assessment
800 Burloak Drive

Naphthalene - Concentration - Source Group: ALL

Averaging Period	Rank	Peak	Units	X (m)	Y (m)	ZELEV (m)	ZFLAG (m)	ZHILL (m)	Peak Date, Start Hour
24-HR	1ST	0.13616	ug/m^3	601191.18	4804756.17	105.00	20.70	105.00	
MONTH	1ST	0.03915	ug/m^3	601180.19	4804755.85	105.00	1.00	105.00	
ANNUAL		0.03085	ug/m^3	601180.19	4804755.85	105.00	1.00	105.00	

Nickel and compounds - Concentration - Source Group: ALL

Averaging Period	Rank	Peak	Units	X (m)	Y (m)	ZELEV (m)	ZFLAG (m)	ZHILL (m)	Peak Date, Start Hour
24-HR	1ST	0.00816	ug/m^3	601191.18	4804756.17	105.00	23.90	105.00	10/23/1997, 24
MONTH	1ST	0.00241	ug/m^3	601191.18	4804756.17	105.00	17.50	105.00	
ANNUAL		0.00163	ug/m^3	601180.19	4804755.85	105.00	1.00	105.00	

Nitrogen Oxides - Concentration - Source Group: ALL

Averaging Period	Rank	Peak	Units	X (m)	Y (m)	ZELEV (m)	ZFLAG (m)	ZHILL (m)	Peak Date, Start Hour
24-HR	1ST	30.51121	ug/m^3	601232.63	4804853.97	106.00	1.00	106.00	1/5/1998, 24
MONTH	1ST	14.80944	ug/m^3	601232.63	4804853.97	106.00	1.00	106.00	
ANNUAL		11.70767	ug/m^3	601232.63	4804853.97	106.00	1.00	106.00	

Results Summary

AERMOD Dispersion Modelling Assessment
800 Burloak Drive

Phosphorus - Concentration - Source Group: ALL

Averaging Period	Rank	Peak	Units	X (m)	Y (m)	ZELEV (m)	ZFLAG (m)	ZHILL (m)	Peak Date, Start Hour
24-HR	1ST	0.01556	ug/m^3	601354.99	4804827.21	105.00	1.00	105.00	1/5/1998, 24
MONTH	1ST	0.00830	ug/m^3	601354.99	4804827.21	105.00	1.00	105.00	
ANNUAL		0.00653	ug/m^3	601354.99	4804827.21	105.00	1.00	105.00	

Quinone - Concentration - Source Group: ALL

Averaging Period	Rank	Peak	Units	X (m)	Y (m)	ZELEV (m)	ZFLAG (m)	ZHILL (m)	Peak Date, Start Hour
24-HR	1ST	0.04598	ug/m^3	601192.96	4804745.89	105.00	27.10	105.00	12/17/1999, 24
MONTH	1ST	0.01352	ug/m^3	601191.18	4804756.17	105.00	27.10	105.00	
ANNUAL		0.00719	ug/m^3	601191.18	4804756.17	105.00	27.10	105.00	

Silicon - Concentration - Source Group: ALL

Averaging Period	Rank	Peak	Units	X (m)	Y (m)	ZELEV (m)	ZFLAG (m)	ZHILL (m)	Peak Date, Start Hour
24-HR	1ST	2.53391	ug/m^3	601354.99	4804827.21	105.00	1.00	105.00	1/5/1998, 24
MONTH	1ST	1.31844	ug/m^3	601354.99	4804827.21	105.00	1.00	105.00	
ANNUAL		1.00463	ug/m^3	601354.99	4804827.21	105.00	1.00	105.00	

Results Summary

AERMOD Dispersion Modelling Assessment
800 Burloak Drive

Sulphur Dioxide - Concentration - Source Group: ALL

Averaging Period	Rank	Peak	Units	X (m)	Y (m)	ZELEV (m)	ZFLAG (m)	ZHILL (m)	Peak Date, Start Hour
24-HR	1ST	0.95431	ug/m^3	601191.18	4804756.17	105.00	17.50	105.00	10/23/1997, 24
MONTH	1ST	0.33980	ug/m^3	601191.18	4804756.17	105.00	14.30	105.00	
ANNUAL		0.25845	ug/m^3	601180.19	4804755.85	105.00	1.00	105.00	

Suspended Particulate Matter - Concentration - Source Group: ALL

Averaging Period	Rank	Peak	Units	X (m)	Y (m)	ZELEV (m)	ZFLAG (m)	ZHILL (m)	Peak Date, Start Hour
24-HR	1ST	62.24823	ug/m^3	601354.99	4804827.21	105.00	1.00	105.00	1/5/1998, 24
MONTH	1ST	31.73540	ug/m^3	601354.99	4804827.21	105.00	1.00	105.00	
ANNUAL		24.39273	ug/m^3	601354.99	4804827.21	105.00	1.00	105.00	

Suspended Particulate Matter - PM10 - Concentration - Source Group: ALL

Averaging Period	Rank	Peak	Units	X (m)	Y (m)	ZELEV (m)	ZFLAG (m)	ZHILL (m)	Peak Date, Start Hour
24-HR	1ST	23.74851	ug/m^3	601191.18	4804756.17	105.00	14.30	105.00	1/6/1998, 24
MONTH	1ST	9.03514	ug/m^3	601180.19	4804755.85	105.00	1.00	105.00	
ANNUAL		7.06342	ug/m^3	601180.19	4804755.85	105.00	1.00	105.00	

Results Summary

AERMOD Dispersion Modelling Assessment
800 Burloak Drive

Suspended Particulate Matter - PM2.5 - Concentration - Source Group: ALL

Averaging Period	Rank	Peak	Units	X (m)	Y (m)	ZELEV (m)	ZFLAG (m)	ZHILL (m)	Peak Date, Start Hour
24-HR	1ST	8.92118	ug/m^3	601192.96	4804745.89	105.00	14.30	105.00	1/6/1998, 24
MONTH	1ST	3.47803	ug/m^3	601354.99	4804827.21	105.00	1.00	105.00	
ANNUAL		2.70079	ug/m^3	601354.99	4804827.21	105.00	1.00	105.00	

Xylene - Concentration - Source Group: ALL

Averaging Period	Rank	Peak	Units	X (m)	Y (m)	ZELEV (m)	ZFLAG (m)	ZHILL (m)	Peak Date, Start Hour
24-HR	1ST	0.56258	ug/m^3	601354.99	4804827.21	105.00	1.00	105.00	1/5/1998, 24
MONTH	1ST	0.31248	ug/m^3	601354.99	4804827.21	105.00	1.00	105.00	
ANNUAL		0.25811	ug/m^3	601354.99	4804827.21	105.00	1.00	105.00	

Zinc - Concentration - Source Group: ALL

Averaging Period	Rank	Peak	Units	X (m)	Y (m)	ZELEV (m)	ZFLAG (m)	ZHILL (m)	Peak Date, Start Hour
24-HR	1ST	0.44908	ug/m^3	601192.96	4804745.89	105.00	20.70	105.00	3/24/1998, 24
MONTH	1ST	0.12728	ug/m^3	601191.18	4804756.17	105.00	17.50	105.00	
ANNUAL		0.08492	ug/m^3	601192.96	4804745.89	105.00	11.10	105.00	

Results Summary

AERMOD Dispersion Modelling Assessment
800 Burloak Drive

Acrolein - Concentration - Source Group: ALL

Averaging Period	Rank	Peak	Units	X (m)	Y (m)	ZELEV (m)	ZFLAG (m)	ZHILL (m)	Peak Date, Start Hour
1-HR	1ST	0.01463	ug/m^3	601191.18	4804756.17	105.00	11.10	105.00	6/20/1998, 6
24-HR	1ST	0.01211	ug/m^3	601215.15	4804818.29	105.58	1.00	105.58	1/5/1998, 24
ANNUAL		0.00451	ug/m^3	601215.15	4804818.29	105.58	1.00	105.58	

Benzene - Concentration - Source Group: ALL

Averaging Period	Rank	Peak	Units	X (m)	Y (m)	ZELEV (m)	ZFLAG (m)	ZHILL (m)	Peak Date, Start Hour
1-HR	1ST	0.35886	ug/m^3	601354.99	4804827.21	105.00	1.00	105.00	1/3/1997, 15
24-HR	1ST	0.30993	ug/m^3	601354.99	4804827.21	105.00	1.00	105.00	1/5/1998, 24
ANNUAL		0.12607	ug/m^3	601354.99	4804827.21	105.00	1.00	105.00	

Benzo(a)pyrene - Concentration - Source Group: ALL

Averaging Period	Rank	Peak	Units	X (m)	Y (m)	ZELEV (m)	ZFLAG (m)	ZHILL (m)	Peak Date, Start Hour
1-HR	1ST	0.00001	ug/m^3	601191.18	4804756.17	105.00	14.30	105.00	6/20/1998, 6
24-HR	1ST	0.00000	ug/m^3	601192.96	4804745.89	105.00	14.30	105.00	1/6/1998, 24
ANNUAL		0.00000	ug/m^3	601180.19	4804755.85	105.00	1.00	105.00	

Results Summary

AERMOD Dispersion Modelling Assessment
800 Burloak Drive

Carbon Monoxide - Concentration - Source Group: ALL

Averaging Period	Rank	Peak	Units	X (m)	Y (m)	ZELEV (m)	ZFLAG (m)	ZHILL (m)	Peak Date, Start Hour
1-HR	1ST	332.22882	ug/m^3	601354.99	4804827.21	105.00	1.00	105.00	8/21/1996, 7
24-HR	1ST	298.25912	ug/m^3	601354.99	4804827.21	105.00	1.00	105.00	1/5/1998, 24
ANNUAL		130.57678	ug/m^3	601354.99	4804827.21	105.00	1.00	105.00	

Ethylbenzene - Concentration - Source Group: ALL

Averaging Period	Rank	Peak	Units	X (m)	Y (m)	ZELEV (m)	ZFLAG (m)	ZHILL (m)	Peak Date, Start Hour
1-HR	1ST	1.61420	ug/m^3	601191.18	4804756.17	105.00	27.10	105.00	
24-HR	1ST	0.90838	ug/m^3	601192.96	4804745.89	105.00	27.10	105.00	12/17/1999, 24
ANNUAL		0.17931	ug/m^3	601354.99	4804827.21	105.00	1.00	105.00	

Hexavalent Chromium - Concentration - Source Group: ALL

Averaging Period	Rank	Peak	Units	X (m)	Y (m)	ZELEV (m)	ZFLAG (m)	ZHILL (m)	Peak Date, Start Hour
1-HR	1ST	0.00014	ug/m^3	601191.18	4804756.17	105.00	27.10	105.00	
24-HR	1ST	0.00008	ug/m^3	601192.96	4804745.89	105.00	27.10	105.00	12/17/1999, 24
ANNUAL		0.00001	ug/m^3	601191.18	4804756.17	105.00	27.10	105.00	

Results Summary

AERMOD Dispersion Modelling Assessment
800 Burloak Drive

Naphthalene - Concentration - Source Group: ALL

Averaging Period	Rank	Peak	Units	X (m)	Y (m)	ZELEV (m)	ZFLAG (m)	ZHILL (m)	Peak Date, Start Hour
1-HR	1ST	2.63469	ug/m^3	601191.18	4804756.17	105.00	17.50	105.00	
24-HR	1ST	0.65104	ug/m^3	601191.18	4804756.17	105.00	20.70	105.00	
ANNUAL		0.14611	ug/m^3	601180.19	4804755.85	105.00	1.00	105.00	

Nickel and compounds - Concentration - Source Group: ALL

Averaging Period	Rank	Peak	Units	X (m)	Y (m)	ZELEV (m)	ZFLAG (m)	ZHILL (m)	Peak Date, Start Hour
1-HR	1ST	0.02656	ug/m^3	601192.96	4804745.89	105.00	20.70	105.00	6/22/1998, 2
24-HR	1ST	0.01243	ug/m^3	601192.96	4804745.89	105.00	27.10	105.00	2/10/1997, 24
ANNUAL		0.00283	ug/m^3	601180.19	4804755.85	105.00	1.00	105.00	

Nitrogen Oxides - Concentration - Source Group: ALL

Averaging Period	Rank	Peak	Units	X (m)	Y (m)	ZELEV (m)	ZFLAG (m)	ZHILL (m)	Peak Date, Start Hour
1-HR	1ST	96.40298	ug/m^3	601191.18	4804756.17	105.00	14.30	105.00	6/20/1998, 6
24-HR	1ST	37.06797	ug/m^3	601197.67	4804791.53	105.56	1.00	105.56	1/5/1998, 24
ANNUAL		14.82963	ug/m^3	601197.67	4804791.53	105.56	1.00	105.56	

Results Summary

AERMOD Dispersion Modelling Assessment
800 Burloak Drive

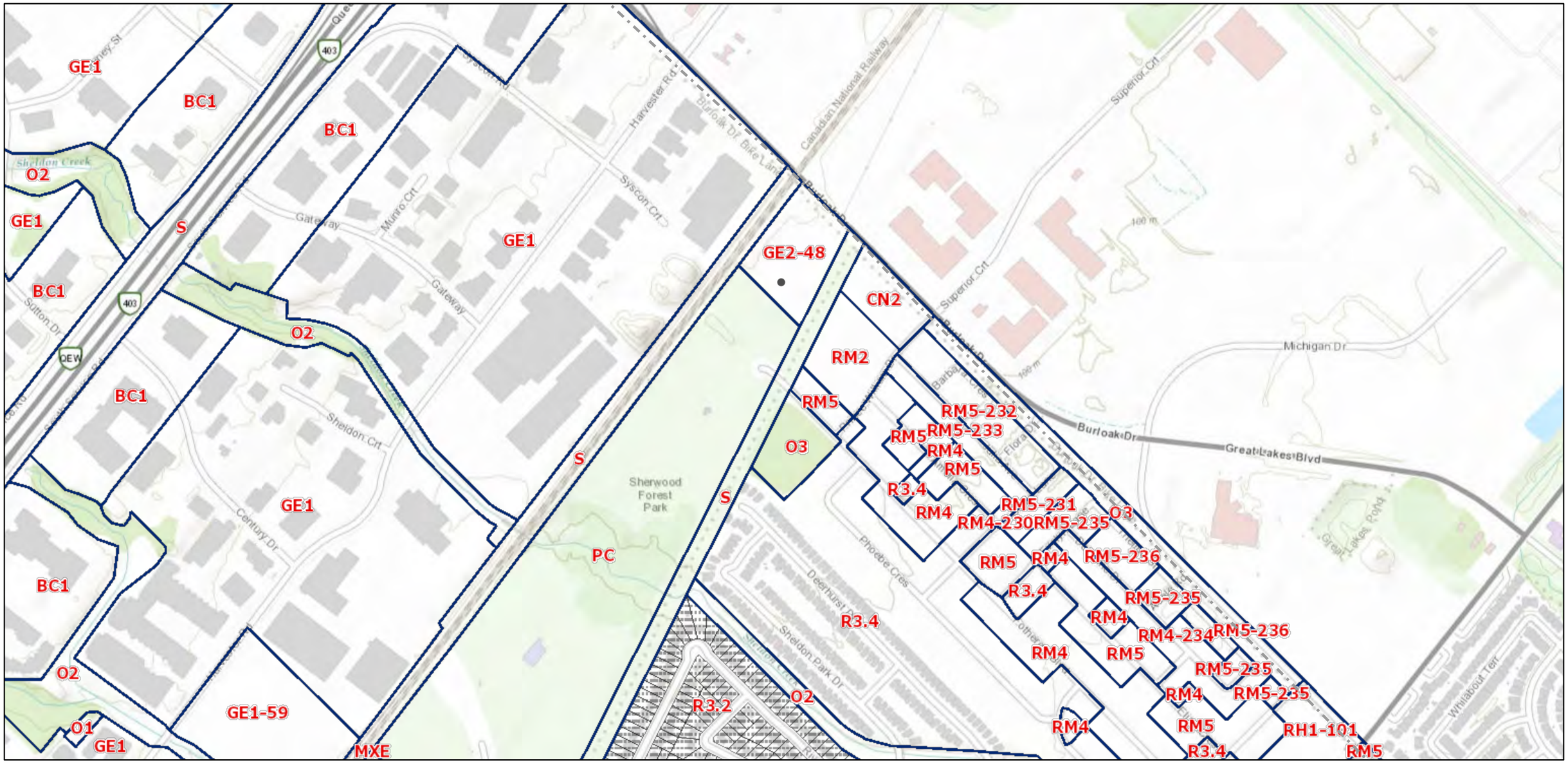
Sulphur Dioxide - Concentration - Source Group: ALL

Averaging Period	Rank	Peak	Units	X (m)	Y (m)	ZELEV (m)	ZFLAG (m)	ZHILL (m)	Peak Date, Start Hour
1-HR	1ST	13.88275	ug/m^3	601191.18	4804756.17	105.00	17.50	105.00	6/20/1998, 6
24-HR	1ST	4.63387	ug/m^3	601191.18	4804756.17	105.00	17.50	105.00	10/23/1997, 24
ANNUAL		1.27549	ug/m^3	601180.19	4804755.85	105.00	1.00	105.00	

Xylene - Concentration - Source Group: ALL

Averaging Period	Rank	Peak	Units	X (m)	Y (m)	ZELEV (m)	ZFLAG (m)	ZHILL (m)	Peak Date, Start Hour
1-HR	1ST	2.03330	ug/m^3	601191.18	4804756.17	105.00	27.10	105.00	
24-HR	1ST	1.23009	ug/m^3	601354.99	4804827.21	105.00	1.00	105.00	1/5/1998, 24
ANNUAL		0.57196	ug/m^3	601354.99	4804827.21	105.00	1.00	105.00	

City of Burlington Mapping



4/2/2019, 2:28:51 PM

City Outline

Designated area for lot coverage

Zoning Bylaw

Shoreacres

Roseland

Indian Point

NEC Development Control

1:9,028

0 0.07 0.15 0.3 mi

0 0.13 0.25 0.5 km

Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User

1.4 ZONE DESIGNATIONS

The City of Burlington is hereby divided into several zones, each zone representing a class of land use permitted by this By-law. The land use classifications and zoning designations are shown in Table 1.4.1:

Table 1.4.1

Residential Zones - Low Density	**Holding Zone**
R1, R2, R3, R4, R5	H (prefix)
Residential Zones - Medium Density	**Mixed Use Corridor Zones**
RM1, RM2, RM3, RM4, RM5	MXG, MXC, MXE, MXT
Residential Zones - High Density	**Downtown Centre Zones**
RH1, RH2, RH3, RH4, RH5	DC, DW, DL-A, DL-B, DL-C, DRH, DRM, DRL and DI
Residential Zones - Orchard Community	**Uptown Centre Zones**
RO1, RO2, RO3, RO4	UCR1, UCR2, UC, UE, UCR3, URH, UMXE, UOP, URM
Residential Zones - Alton Community	**Rural Zones**
RAL1, RAL2, RAL3, RAL4	RA, RG, ME
Employment Zones	**North Aldershot Zones**
BC1, BC2, GE1, GE2	RNA1, RNA2, RNA3, SNA, MRNA, CNA, ONA, DNA
Commercial Zones	**Development Zone**
CR, CC1, CC2, CE, CN1, CN2	D
Park Zones	**Utility Services Zone**
P, PC	S
Open Space Zones	
O1, O2, O3	