SNAP CODE: **040611**

SOURCE ACTIVITY TITLE: **PROCESSES IN WOOD, PAPER PULP, FOOD, DRINK AND OTHER INDUSTRIES**
Road Paving with Asphalt

NOSE CODE: **105.16.31**

NFR CODE: **2 A 6**

1 ACTIVITIES INCLUDED

Asphalt surfaces and pavements are composed of compacted aggregate and an asphalt binder. The asphalt binder may consist of heated asphalt cement (hot mix) or liquefied asphalts (cutback or emulsified). This section covers emissions from asphalt paving operations as well as subsequent releases from the paved surfaces.

2 CONTRIBUTIONS TO TOTAL EMISSIONS

Information on U.S. and Canadian NMVOC emissions are not available at this time. Estimates based on U.S. asphalt sales in 1991 as reported by the Asphalt Institute (1992) and the maximum available emission factors (please see section 8) indicate a maximum emission of approximately 460,000 Mg VOC from liquefied asphalt paving, which would represent about 0.2% of total estimated emissions from all sources (U.S. EPA 1993a).

Table 1: Contribution to total emissions of the CORINAIR90 inventory (*28 countries*)

Source-activity	SNAP-code	Contribution to total emissions [%]								
		SO_2	NO_x	NMVOC	CH_4	CO	CO_2	N_2O	NH_3	PM*
Road Paving with Asphalt	040611	-	-	0.1	-	-	-	-	-	-

0 = emissions are reported, but the exact value is below the rounding limit (0.1 per cent)
- = no emissions are reported
* = PM (inclusive of TSP, PM_{10} and $PM_{2.5}$) is <0.1% of total PM emissions

3 GENERAL

3.1 Description

Asphalt roads are a compacted mixture of aggregate and an asphalt binder. Natural gravel, manufactured stone (from quarries) or byproducts from metal ore refining are used as aggregates. Asphalt cement or liquefied asphalt may be used as the asphalt binder.

3.1.1 Asphalt Cement

Asphalt cement is semisolid, and must be heated prior to mixing with the aggregate. This is done in hot mix plants, which, are considered to be potential sources of common and toxic pollutants. Hot mix plants are normally fixed bulk manufacturing plants. After the hot mix is produced, the mixture is very low in volatile hydrocarbons and is not thought to be a significant source of NMVOC during paving operations (U.S. EPA 1985).
In order of development, hot mix asphalt paving materials can be manufactured by: batch mix plants; continuous mix plants; parallel flow plants; and counterflow plants. Continuous mix plants are thought to constitute a small portion of production.

In the batch process aggregate is dried, sorted, stored and then mixed in a separate pug mill with heated asphalt cement.

In the parallel flow drum mix process, the dryer is used to not only dry the aggregate but also mix the heated and dried aggregates with the liquid asphalt cement. This combined mixing process means that mixing in the discharge end captures a substantial portion of the aggregate dust. The disadvantage is that, because the mixing of aggregate and liquid asphalt occurs in the hot combustion product flow, organic emission (gaseous and liquid aerosol) may be greater than in other processes.

In the counterflow plant, the material flow in the drum is opposite to the direction of exhaust gases. Because the liquid asphalt cement, and aggregate are mixed in a zone removed from the exhaust gas stream, counterflow drum mix plants are likely to have organic emissions (gaseous and liquid aerosol) that are lower than parallel flow drum mix plants, in addition to greater capacity to accomodate recycled pavement and improved thermal efficiencies.

3.1.2 Liquefied Asphalt

Liquefied asphalts may be used as a pavement sealant, as a tack coat, in priming roadbeds for hot mix application and for operations up to several inches thick. Liquefied asphalts are considered to be significant sources of NMVOCs during the mixing and subsequent paving operations. The two types of liquefied asphalt used for road paving are cutback asphalt and emulsified asphalt.

Cutback asphalt is prepared by blending or “cutting back” asphalt cement with various blends of petroleum distillates. The three categories of cutback asphalt are rapid cure (RC), medium cure (MC) and slow cure (SC). SC, MC and RC cutbacks are prepared by blending asphalt cement with heavy residual oils, kerosene-type solvents, or naphtha and gasoline solvents, respectively. Depending on the viscosity desired, the proportions of solvent generally range from 25 to 45 percent by volume. (U.S.EPA 1985)

Emulsified asphalts are prepared with a blend of water with an emulsifier, which is generically referred to as a soap. The blend consists of 94 to 98 percent water and 2 to 6 percent soaps. As for cutback asphalts, emulsified asphalts can be classified as rapid set (RS), medium set (MS) or slow set (SS) depending on the application and blend percentage. The blend proportions are dependent upon the specific application and operating parameters. It has been reported that emulsified asphalts may have as high as 12 percent VOC content

(U.S. EPA 1993b). Emulsified asphalts may also be classified as either anionic (highfloat) or cationic through the use of particle charge testing. (U.S.EPA 1993a)

3.2 Definitions

Asphalt - this is commonly called bitumen in some European countries. Macadam is another term for as laid asphalt.

3.3 Techniques

3.4 Emissions

3.4.1 Hot Mix Plants

The most significant source of ducted emissions from batch mix plants is the dryer, which emits particulate matter and small amounts of VOCs derived from combustion exhaust gases. Aggregate dust, VOCs and a fine aerosol of liquids are also emitted from the hot-side conveying, classifying and mixing equipment. Vented emissions from these areas may be controlled by equipment ranging from dry mechanical collectors to scrubbers and fabric collectors. Organic vapour and its associated aerosol are also emitted directly to the atmosphere as process fugitives during truck loadout and from the bed of the truck during transport. In addition to low molecular weight VOC, these organic emission streams may contain small amounts of polycyclic compounds. The ducted emissions from the heated asphalt storage tanks may include VOC and combustion products from the tank heater. Other fugitive sources of particulate include vehicular traffic and aggregate materials handling.

In parallel flow drum mix plants, the most significant ducted source of emissions is the rotary drum dryer. Emissions include particulate and small amounts of VOCs resulting from incomplete combustion and from the heating and mixing of liquid asphalt cement inside the drum.

Counterflow plants have similar emissions to parallel flow drum mix plants, although VOC emissions are likely to be lower because liquid asphalt cement and aggregate are not in contact with the hot exhaust gas stream. The organic compounds that are emitted are likely to be the result of inefficient combustion.

Process fugitive emissions for parallel and counterflow plants are much lower than batch plants. However VOC emissions from transport, handling and loadout of the hot mix are likely to be similar.

3.4.2 Liquefied Asphalt

For any given amount of asphalt, total emissions are believed to be the same, regardless of stockpiling, mixing and application times. The major source of NMVOCs from the use of liquefied asphalts is the cutback asphalt.

For cutback asphalt, the two major variables affecting both the quantity of NMVOC emitted and the time over which emissions occur are the type and quantity of petroleum distillate used as a diluent. Long term emissions from cutback asphalts can be estimated by assuming that

95 percent of the diluent evaporates from rapid cure (RC) cutback asphalts, 70 percent from medium cure (MC) cutbacks, and about 25 percent from slow cure (SC) asphalts, by weight percent.

Limited test data suggest that, from RC asphalt, 75 percent of the total diluent loss occurs on the first day after application, 90 percent with the first month and 95 in three to four months. For MC, evaporation is slower, with about 20 percent loss in the first day, 50 percent in the first week and 70 percent after three to four months. Although no data is available for SC, the total losses are believed to be in the order of 25 percent, considerably less than for RC or MC, and occur over a considerably longer period of time. (U.S.EPA 1985)

3.5 Controls

3.5.1 Hot Mix Plants

Dryer exhaust and vent line control equipment ranges from dry mechanical collectors to scrubbers and fabric collectors. Attempts to use electrostatic precipitators have been largely unsuccessful.

The dryer and other potential sources may also be routed to primary dust collection equipment with large diameter cyclones, skimmers or settling chambers. These chambers are often used as classifiers to return collected material to the process. To capture the remaining particulate matter, the primary collector is ducted to a secondary collection device such as a baghouse or a venturi scrubber**.**

3.5.2 Liquefied Asphalts

Emulsions are typically used in place of cutback asphalts to eliminate emissions of NMVOC. Limits on the volatile hydrocarbon content of emulsions can be put in place to limit NMVOC emissions.

4 SIMPLER METHODOLOGY

It is important to obtain information on asphalt sales for the purposes of paving that are broken down into hot mix, cutback and emulsified classifications. This then permits a generally realistic emission estimation based on reasonable emission factors for each category.
The selection of average emission factors for each of hot mix, cutback and emulsified asphalt will then depend on the level of regulation in the inventory area. For example, for liquefied asphalt, levels of VOCs in the asphalt may be regulated and emission factors used would reflect the upper limits of the allowable practice. In the case of hot mix plants, a knowledge of the industry and its controls would permit the selection of the most appropriate emission factor from those presented in Section 8. In the absence of any such information, however, the emission factors for batch mix plants should be selected.

If only total asphalt sales are available, it should be assumed that the entire amount is rapid cure cutback asphalt at 45% percent by volume of diluent , with the appropriate emission factor from Section 8.

N.B There are no emission factors available for $PM_{2.5}$. The source is <0.1% of the total PM emissions for most countries.

5 DETAILED METHODOLOGY

Detailed information on the use of each of hot mix, cutback asphalt and emulsified asphalt should be obtained. These may be available from paving associations.

For hot mix asphalt, emission factors are based on total product, which includes the weight of the aggregate. Therefore, a survey of the types of hot mix plants by production (or at the very least capacity) and type of control, would facilitate the breakdown of hot mix asphalt use into categories matching the available emission factors. If this detailed production survey is not possible, then the production can be estimated by assuming that the total asphalt cement used represents 8 percent of the total product. (U.S. EPA 1994)

For liquefied asphalts, the detailed emission estimation methodology is to estimate emissions from basic principles using detailed product specification and use information. It is assumed that, over the long term, 95 % of the diluent in RC evaporates. Similarly 70% of MC and 25% of SC are assumed to evaporate. If the product specification is given that specifies the weight percent of VOCs in asphalt the calculation of VOCs is fairly straight forward. It is common, however, to specify the diluent content on a percent by volume basis. An example calculation for this situation follows (U.S.EPA 1985):

Example: Local records indicate that 10,000 kg of RC cutback asphalt, containing 45 percent diluent by volume, was applied in a given area during the year. Cutback asphalt is a mixture of diluent and asphalt cement. To determine the VOC emissions, the volume of diluent present in the cutback asphalt must first be determined. Because the density of naphtha (0.7 kg/l) differs from that of asphalt cement (1.1 kg/l), the following equations must be solved to determine the volume of diluent (x) and the volume of asphalt cement (y) in the cutback cement:

10,000 kg cutback asphalt = (x l diluent) (0.7 kg/l) + (y l asphalt cement)(1.1 kg/l)

and

x liter diluent = 0.45 (x litre diluent + y l asphalt cement)

From these equations, the volume of diluent present in the cutback asphalt is determined to be about 4900 litres, or about 3400 kg. Assuming that 95 percent of this is evaporative VOC, emissions are the 3400 kg x 0.95 = 3200 kg (i.e., 32% by weight, of the cutback asphalt eventually evaporates).

These equations can be used for MC and SC asphalts by assuming typical diluent densities of 0.8 and 0.9 kg/litre, respectively, unless actual density values are available from local records. If actual diluent contents are not known, a typical value of 35 percent may be assumed for inventory purposes.

Should a key source analysis indicate this to be a major source of particulate matter (TSP, PM_{10} or $PM_{2.5}$) then installation level data should be collected using a measurement protocol such as that illustrated in Measurement Protocol Annex.

6 RELEVANT ACTIVITY STATISTICS

The annual weight of asphalt used in road paving is required as a minimum to prepare estimates of maximum likely emissions of NMVOCs from this source. If more detailed information is available on the breakdown of this total annual usage (i.e. cement asphalt for hot mix, cutback asphalt and emulsified asphalt) and the diluent contents of the same, then progressively more accurate emissions estimates may be done. Details on the type of information that may be obtained are provided in Section 5.

7 POINT SOURCE CRITERIA

It is not likely that hot mix plants will qualify as point sources of common pollutants. Therefore road paving with asphalt should be inventoried as an area source.

8 EMISSION FACTORS, QUALITY CODES AND REFERENCES

8.1 Hot Mix Plants

The U.S. Environmental Protection Agency has recently completed a detailed review of the hot mix industry (U.S.EPA 1994). Emission factors for particulate matter, CO, NOx, SO2 and total organic compounds (TOC) from this review are summarized in Tables 2 and 3. The organic emissions are reported as TOC as methane, based on EPA Method 25A test data. Detailed organic compound emission factors are provided in Tables 4 and 5. It can be seen that NMVOCs generally represent less than half of the TOC, depending on the type of control.

8.2 Liquefied Asphalt

Emission factors can be developed for the use of liquefied asphalts if sufficient information is available, as described in section 5. Alternatively, default emission factors are provided in Table 6 (U.S. EPA 1985).

Table 2: Emission Factors for Batch Mix Hot Mix Asphalt Plants (kg/Mg of Product) [c]

Process	Particulate[b] Matter	CO	NOx	SO_2	TOC[c]
Natural gas-fired dryer					
Uncontrolled	16 (E)	0.17 (D)	0.013 (D)	0.0025 (D)	0.0084 (D)
Fabric Filter	0.02 (D)				
Oil-fired dryer					
Uncontrolled	16 (E)	0.035 (D)	0.084 (D)	0.12 (D)	0.023 (D)
Fabric Filter	0.04 (D)				

[a]The emission factor rating is supplied in brackets after the emission factor.
[b]The sum of filterable PM and total condensible PM emission factor.
[c]Factors represent TOC as methane, based on EPA Method 25A test data.

Table 3: Emission Factors for Drum Mix Hot Mix Asphalt Plants (kg/Mg of Product) [c]

Process	Particulate[b] Matter	CO	NOx	SO_2	TOC[c]
Natural gas-fired dryer					
Uncontrolled	9.4	0.028	0.015	0.0017	0.025[d]
Fabric Filter	0.0089				
Oil-fired dryer					
Uncontrolled	9.4	0.018	0.038	0.028	0.035[d]
Fabric Filter	0.020				

[a]The emission factor rating is D for all factors. Drum Mix refers to both parallel flow and counterflow plants. Tests included dryers that were processing reclaimed asphalt pavement (RAP). Because of limited data, the affect of RAP processing on emissions could not be determined.
[b]The sum of filterable PM and total condensible PM emission factor.
[c]Factors represent TOC as methane, based on EPA Method 25A test data.
[d]Organic compound flows are expected to be smaller.

Table 4: Emission Factors for Organic Pollutant Emissions from Batch Mix Hot Mix Asphalt Plants[a]

Emission Factor Rating: D

Process / Pollutant	Emission Factor kg/Mg	% of TOC
Natural Gas-fired dryer		
2-Methylnaphthalene[b]		0.00
Acenaphthene[b]		0.0041333
Acenaphthylene[b]		0.00
Acetaldehyde		2.13
Acetone		21.33
Anthracene[b]	1.50e-07	0.000133
Benzaldehyde	6.40e-05	0.43
Benzene	1.70e-04	1.13
Benzo(a)anthracene[b]	2.30e-09	0.000015
Benzo(b)fluoranthene[b]	2.30e-09	0.000015
Benzo(k)fluoranthene[b,c]	1.20e-08	0.000080
Butyraldehyde/Isobutyraldehyde	1.50e-05	0.10
Chrysene[b]	3.10e-09	0.000021
Crotonaldehyde	1.50e-05	0.10
Ethyl benzene	1.60e-03	10.67
Fluoranthene[b]	1.60e-07	0.000067

Process **Pollutant**	**Emission Factor kg/Mg**	**% of TOC**
Natural Gas-fired dryer		
Fluorene[b]	9.80e-07	0.01
Formaldehyde	4.30e-04	2.87
Hexanal	1.20e-05	0.08
Methane	6.00e-03	40.00
Naphthalene[b]	2.10e-05	0.14
Phenanthrene[b]	1.60e-06	0.01
Pyrene[b]	3.10e-08	0.00021
Quinone	1.40e-04	0.93
Toluene	8.80e-04	5.87
Xylene	2.10e-03	14.00
Total for Natural gas-fired dryer	1.50e-02	99.80

Oil-fired dryer		
2-Methylnaphthalene[b]	3.00e-05	0.77
Fluoranthene[b]	1.20e-05	0.31
Formaldehyde[c]	1.60e-03	40.92
Methane	2.20e-03	56.27
Naphthalene[b]	2.20e-05	0.56
Phenanthrene[b,c]	1.80e-05	0.46
Pyrene[b]	2.70e-05	0.69
Total for Oil-fired dryer	3.91e-03	99.97

[a]Factors kg/Mg of hot mix asphalt produced. Factors represent uncontrolled emissions, unless noted.
[b]Controlled by a fabric filter. Compound is classified as polycyclic organic matter (POM).
[c]Emission Factor Rating: E

Table 5: Emission Factors for Organic Pollutant Emissions from Drum Hot Mix Asphalt Plants[a]

Emission Factor Rating: D

Process **Pollutant**	**Emission Factor kg/Mg**	**% of TOC**
Natural Gas-fired dryer		
2-Chloronaphthalene[c]	8.90e-07	0.00086
2-Methylnaphthalene[c]		0.03558
Acenaphthene[c]	3.80e-05	0.000615
Acenaphthylene[c]	6.20e-07	0.00000
Anthracene[c]	4.30e-07	0.000096
Benzene	3.20e-04	0.58
Benzo(a)anthracene[c]	3.20e-03	0.000096
Benzo(a)pyrene[c]	4.60e-09	0.000004
Benzo(b)fluoranthene[c]	5.10e-08	0.000049
Benzo(e)pyrene[c]	5.20e-08	0.000050
Benzo(g,h,i)perylene[c]	1.90e-08	0.000018
Benzo(k)fluoranthene[c]	2.60e-08	0.000025
Chrysene[c]	1.80e-07	0.000173
Dibenz(a,h)anthracene[c,e]	1.30e-09	0.000001
Ethyl benzene[e]	1.50e-04	0.14
Fluoranthene[c]	3.00e-07	0.0003
Fluorene[c]	2.70e-06	0.000
Formaldehyde	1.80e-03	1.73
Formaldehyde[d,e]	7.90e-04	0.76
Ideno(1,2,3-cd)pyrene[c]	3.60e-09	0.000003
Methane	1.00e-01	96.15
Methyl chloroform[e]	2.50e-04	0.24
Naphthalene[c]	2.50e-05	0.02
Perylene[c,e]	6.20e-09	0.00001
Phenanthrene[c]	4.20e-06	0.000
Pyrene[c]	2.30e-07	0.00022
Toluene	1.00e-04	0.10
Xylene	2.00e-04	0.19
Total for Natural gas-fired dryer	1.04e-01	99.96

Oil-fired dryer[c]		
2-Methylnaphthalene[c]	8.50e-05	0.63
Acenaphthylene[c]	1.10e-05	0.08
Acetaldehyde	6.50e-04	4.78
Acetone	4.20e-04	3.09
Acrolein	1.30e-05	0.10
Anthracene[c]	1.80e-06	0.01
Benzaldehyde	5.50e-05	0.40
Benzene	2.00e-04	1.47
Butyraldehyde/Isobutyraldehyde	8.00e-05	0.59
Crotonaldehyde	4.30e-05	0.32
Ethylbenzene	1.90e-04	1.40
Fluorene[c]	8.50e-06	0.06
Formaldehyde	1.20e-03	8.82
Formaldehyde[d,e]	2.60e-04	1.91
Hexanal	5.50e-05	0.40
Isovaleraldehyde	1.60e-05	0.12
Methane	9.60e-03	70.59
Methyl Ethyl Ketone	1.00e-05	0.07
Naphthalene[c]	1.60e-04	1.18
Phenanthrene[c]	2.80e-05	0.21
Propionaldehyde	6.50e-05	0.48
Pyrene[c,e]	1.50e-06	0.01
Quinone	8.00e-05	0.59
Toluene	3.70e-04	2.72
Valeraldehyde	3.40e-05	0.25
Xylene	8.20e-05	0.60
Total for Oil-fired dryer	1.36e-02	100.27

[a]Factors kg/Mg 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.
[b]Tests included dryers that were processing reclaimed asphalt pavement (RAP). Because of limited data the effect of RAP processing on emissions could not be determined.
[c]Controlled by a fabric filter. Compound is classified as polycyclic organic matter (POM).
[d]Controlled by a wet scrubber.
[e]Emission Factor Rating: E

Table 6: Evaporative VOC emissions from cutback asphalts as a function of diluent content and cutback asphalt type[a]

Type of Cutback[b]	Percent, by Volume of Diluent in Cutback[c]		
	25%	**35%**	**45%**
Rapid cure	17	24	32
Medium cure	14	20	26
Slow cure	5	8	10

[a]These numbers represent the percent, by weight, of cutback asphalt evaporated. Factors are based on References 1 and 2.
[b]Typical densities assumed for diluents used in RC, MC, and SC cutbacks are 0.7, 0.8 and 0.9 kg/liter, respectively.
[c]Diluent contents typically range between 25-45%, by volume. Emissions may be linearly interpolated for any given type of cutback between these values.

9 SPECIES PROFILES

9.1 Hot Mix Plants

For hot mix asphalt plants, total organic emission factors are expressed as methane, and it is indicated that this may consist of low molecular weight VOCs and polycyclic compounds. Speciation of the TOC has been provided in Tables 4 and 5.

9.2 Liquefied Asphalt

If the detailed emission estimation method has been used for the liquefied asphalts, species profiles could be based on typical profiles for the diluent. Otherwise species profiles for these sectors have not been identified.

10 UNCERTAINTY ESTIMATES

The largest source of uncertainty in these estimates will be the level of detail available in terms of the relative breakdown of asphalt into asphalt cement, cutback asphalt and emulsified asphalt. As an example, in the U.S. in 1991, 86 percent of total asphalt sales was asphalt cement for hot mix use. If this was assumed to be RC cutback at an average of 45 percent, total emissions would be 6,448,174 tonnes VOC. In comparison, total organic emissions (expressed as methane) from hot mix plants would be 8815 Mg for an equivalent amount of asphalt cement, assuming that asphalt cement is 8 percent of hot mix. Therefore, the simpler estimation can greatly overestimate emissions of VOCs.

The state-of-the-art estimations will, however greatly improve the estimates as the detail of the base quantity estimates and characterizations improve.

11 WEAKEST ASPECTS/PRIORITY AREAS FOR IMPROVEMENT IN CURRENT METHODOLOGY

There is no available information on which to base a more realistic average emission factor for the simpler methodology. Therefore emission estimates may be grossly overestimated using this methodology.

12 SPATIAL DISAGGREGATION CRITERIA FOR AREA SOURCES

Since most of the emissions occur at the paving locations, emissions can be disaggregated based on percent of total paved road surfaces. If this information is not available the emissions can be disaggregated based on mobile source emission estimates or population.

13 TEMPORAL DISAGGREGATION CRITERIA

Available information indicates that VOC emissions occur within four months of paving, with the majority of this within one month (U.S.EPA 1985).

In climates where cold weather prevents paving for a portion of the year, paving emissions should be spread over this shorter season.

14 ADDITIONAL COMMENTS

15 SUPPLEMENTARY DOCUMENTS

16 VERIFICATION PROCEDURES

It may be possible to verify asphalt sales estimates through comparison with figures on road construction. Emissions estimates for hot mix plants may be verified by emission testing.

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18 BIBLIOGRAPHY

19 RELEASE VERSION, DATE AND SOURCE

Version: 1.3

Date: November 1995

Source: Marc Deslauriers
Environment Canada
Canada

Updated with particulate matter details by:
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20 POINT OF ENQUIRY

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