SNAP CODE: **070600**

SOURCE ACTIVITY TITLE: **GASOLINE EVAPORATION FROM VEHICLES**

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1 ACTIVITIES INCLUDED

This chapter provides the methodology, emission factors and relevant activity data to calculate evaporative NMVOC emissions from gasoline vehicles (SNAP code 0706). The term “evaporative emissions” refers to the sum of all NMVOC emissions not deriving from fuel combustion.

2 CONTRIBUTIONS TO TOTAL EMISSIONS

The contribution of evaporative losses to the total road transport related VOC emissions has been decreased considerably since the introduction of carbon canisters. The percentage contribution for various European countries in 2006 is shown in Table 2-1, based on the methodology presented in this chapter and the activity data and exhaust emissions calculated with TREMOVE v2.5.

Table 2-1: 2006 Total Evaporative Emissions as Percentage of the National Total VOC of Road Transport

Country	%	Country	%
AT	2.9	HU	4.4
BE	6.8	IE	12.7
CH	11.2	IT	8.5
CZ	5.0	LU	6.6
DE	11.5	NL	4.9
DK	6.1	NO	16.7
ES	9.0	PL	9.4
FI	5.1	PT	3.5
FR	10.5	SE	10.2
GR	8.8	SI	3.6
		UK	15.2

3 GENERAL

3.1 Description

Breathing losses through the tank vent and fuel permeation are in general the most important sources of evaporative emissions in a vehicle. Breathing losses are due to evaporation of gasoline in the tank during driving and parking, as a result of normal diurnal temperature variation. In current vehicles vapour emissions are controlled by means of an activated carbon canister connected to the fuel tank. Various studies, (e.g. CRC, 2004; Reuter et al., 1994), indicate that liquid fuel seepage and permeation through plastic and rubber components of the fuel and vapour control system contribute significantly to the total evaporative emissions. There are three main mechanisms causing evaporative emissions from gasoline powered vehicles, that is diurnal emissions, running losses and hot soak emissions.

3.1.1 Diurnal emissions

The evaporative emissions associated with the daily (diurnal) variation in ambient temperature result from the vapour expansion inside the gasoline that occurs as the ambient temperature rises during the daylight hours. Without an emission control system, some of the increasing volume of fuel vapour is vented to the atmosphere.

3.1.2 Running losses

Running losses are the result of vapour generated in gasoline tanks during vehicle operation. For older vehicles equipped with carburettor and/or fuel return systems, engine operation results in a significant temperature increase in the fuel tank and/or the carburettor (Morgan et al., 1993). For such vehicles, the combined effect of high ambient temperature and exhaust system heat can generate a significant amount of vapour in the gasoline tank. For gasoline vehicles with fuel injection and returnless fuel systems, the fuel temperature in the tank is not affected by engine operation and thus no fuel vapour is generated in the tank. The running losses of these vehicles are therefore very low and may be attributed to fuel permeation and/or leakage.

3.1.3 Hot soak emissions

Hot soak evaporative emissions are the emissions caused when a hot engine is turned off. Heat from the engine and exhaust system increases the temperature of the fuel in the system that is no longer flowing. Carburettor float bowls are a particularly significant source of hot soak emissions. For vehicles with fuel injection and returnless fuel systems, no fuel vapour is generated in the tank when a hot engine is turned off and thus hot soak emissions are mainly due to fuel permeation and/or leakage.

All three types of evaporative emissions are significantly affected by the volatility of the gasoline being used, the absolute ambient temperature and temperature changes, and vehicle design characteristics. For hot soak emissions and running losses the driving pattern is also of importance.

Fuel vapour loss also takes place during vehicle refuelling. However, this is not included in this chapter as it is considered part of loss during fuel delivery at the petrol stations.

3.2 Emissions

Evaporative VOC emissions from gasoline fuelled vehicles add to total NMVOC emissions. For evaporating emissions tank breathing is reported as $CH_{2.1}$. These are the units used to report test protocols.

3.3 Controls

Until 1993 evaporative losses of gasoline passenger cars were not controlled in Europe, with the exception of Austria, Denmark, Finland, Sweden and Switzerland which adopted the US EPA SHED test procedure. In the EU, a limit value of 2.0 g of HC per test was first introduced by Directive 91/441/EEC (Euro 1 and Euro 2 vehicles). In order to meet this emission limit, the installation of small on-board carbon canisters was necessary. Directive 91/441/EC was superseded by Directive 98/69/EC, applicable to Euro 3 and Euro 4 vehicles. According to this, the limit value for evaporative emissions remained at the same level, however the evaporative emissions testing procedure has been increased in severity. The introduction of larger carbon canisters is necessary to comply with these more stringent requirements.

4 SIMPLER METHODOLOGY

The main equation for estimating the evaporative emissions is:

$$E_{eva,voc,j} = 365 \times N_j \times (HS_j + e_{d,j} + RL_j) \qquad (1)$$

where:

$E_{eva,voc,j}$: annual VOC emissions due to evaporative losses of vehicles in category j (g)

N_j: number of gasoline vehicles of category j

HS_j: average daily hot and warm soak emissions of vehicle category j (g/day)

$e_{d,j}$: average diurnal losses of vehicle category j (g/day)

RL_j: average daily hot and warm running losses of vehicle category j (g/day)

and

$$HS_j = x\ \{c\ [p\ \ e_{s,hot,c} + (1 - p)\ e_{s,warm,c}] + (1 - c)\ e_{s,hot,fi}\} \qquad (2)$$

$$RL_j = x\ \{c\ [p\ e_{r,hot,c} + (1 - p)\ e_{r,warm,c}] + (1 - c)\ e_{r,hot,fi}\} \qquad (3)$$

where:

x: mean number of trips per vehicle per day, average over the year (trips/day)

c: fraction of gasoline powered vehicles equipped with carburettor and/or fuel return systems

p: fraction of trips finished with hot engine, i.e. an engine that has reached its normal operating temperature and the catalyst its light-off temperature (dependent on the average monthly ambient temperature)

$e_{s,hot,c}$: mean hot soak emission factor of gasoline powered vehicles with carburettor and/or fuel return systems (dependent on fuel volatility and average monthly ambient temperature) (g/procedure)

$e_{s,warm,c}$: mean cold and warm soak emission factor of gasoline powered vehicles with carburettor and/or fuel return systems (dependent on fuel volatility and average monthly ambient temperature) (g/procedure)

$e_{s,hot,fi}$: mean hot soak emission factor of gasoline powered vehicles with fuel injection and returnless fuel systems (dependent on fuel volatility and average monthly ambient temperature) (g/procedure)

$e_{r,hot,c}$: mean emission factor for hot running losses of gasoline powered vehicles with carburettor and/or fuel return systems (dependent on fuel volatility and average monthly ambient temperature) (g/trip)

$e_{r,warm,c}$: mean emission factor for cold and warm running losses of gasoline powered vehicles with carburettor and/or fuel return systems (dependent on fuel volatility and average monthly ambient temperature) (g/trip)

$e_{r,hot,fi}$: mean emission factor for hot running losses of gasoline powered vehicles with fuel injection and returnless fuel systems (dependent on fuel volatility and average monthly ambient temperature) (g/trip)

The number of trips per day, if not known from statistical data, can be estimated by the expression:

$$x = \frac{M_j}{365 \times l_{trip}} \tag{4}$$

where M_j is the total annual mileage of gasoline vehicles of category j.

The fraction of trips finished with cold and warm engine, (1-p), is linked to the parameter β, also used in the calculation of cold start emissions: both depend, inter alia, on ambient temperature. In the absence of better data, the assumed relation between (1-p) and β is $(1-p) \approx \beta$. Parameter β also depends on the average trip length l_{trip}. This indicates that, for the calculation of the cold start emissions and soak emissions, the average trip length is of great importance.

In order to apply equation (1), Table 4-1 provides emission factors for gasoline passenger cars in three different size classes and Table 4-2 for two wheelers. Emission factors are given for typical temperature ranges in winter and summer and typical fuel vapour pressures. For canister-equipped passenger cars, three different carbon canister sizes (small, medium, large) were considered, depending on vehicle engine size and technology as indicated in Table 6-4. Hence, the calculation of total evaporative emissions with this methodology is straightforward.

Table 4-1: Summary of simplified emission factors for estimating evaporative emissions of passenger cars for typical summer and winter conditions

	summer		winter		summer		winter		summer		winter	
T. variation (°C)	20−35	10−25	0−15	-5−10	20−35	10−25	0−15	-5−10	20−35	10−25	0−15	-5−10
Fuel DVPE (kPa)	60	70	90	90	60	70	90	90	60	70	90	90
	Gasoline passenger cars <1.4 l - uncontrolled				Gasoline passenger cars 1.4 - 2.0 l - uncontrolled				Gasoline passenger cars >2.0 l - uncontrolled			
e_d (g/day)	3.90	2.35	1.74	1.24	4.58	2.76	2.04	1.45	5.59	3.36	2.49	1.77
$e_{s,hot,fi}$ (g/proced.)	0.10	0.07	0.04	0.04	0.10	0.07	0.04	0.04	0.10	0.07	0.04	0.04
$e_{s,warm,c}$ (g/proced.)	8.48	5.09	3.75	2.63	10.01	6.01	4.42	3.10	12.29	7.38	5.43	3.80
$e_{s,hot,c}$ (g/proced.)	11.93	7.16	5.27	3.69	14.08	8.45	6.22	4.36	17.31	10.39	7.65	5.35
$e_{r,hot,fi}$ (g/trip)	0.13	0.08	0.06	0.04	0.13	0.08	0.06	0.04	0.13	0.08	0.06	0.04
$e_{r,warm,c}$ (g/trip)	1.84	1.11	0.81	0.53	2.15	1.30	0.95	0.67	2.62	1.58	1.15	0.81
$e_{r,hot,c}$ (g/trip)	10.05	6.03	4.44	3.11	11.85	7.12	5.24	3.67	14.56	8.74	6.43	4.50
	Gasoline passenger cars <1.4 l - small canister				Gasoline passenger cars 1.4 - 2.0 l - small canister				Gasoline passenger cars >2.0 l - small canister			
e_d (g/day)	0.61	0.15	0.11	0.10	0.95	0.17	0.11	0.10	1.57	0.21	0.11	0.10
$e_{s,hot,fi}$ (g/proced.)	0.10	0.07	0.04	0.04	0.10	0.07	0.04	0.04	0.10	0.07	0.04	0.04
$e_{s,warm,c}$ (g/proced.)	0.63	0.13	0.06	0.04	0.96	0.15	0.06	0.04	1.82	0.20	0.06	0.04
$e_{s,hot,c}$ (g/proced.)	1.74	0.20	0.06	0.04	2.87	0.26	0.07	0.05	4.92	0.43	0.09	0.05
$e_{r,hot,fi}$ (g/trip)	0.13	0.08	0.06	0.04	0.13	0.08	0.06	0.04	0.13	0.08	0.06	0.04
$e_{r,warm,c}$ (g/trip)	0.13	0.08	0.06	0.04	0.13	0.08	0.06	0.04	0.13	0.08	0.06	0.04
$e_{r,hot,c}$ (g/trip)	0.13	0.08	0.06	0.04	0.13	0.08	0.06	0.04	0.13	0.08	0.06	0.04
	Gasoline passenger cars <1.4 l - medium canister				Gasoline passenger cars 1.4 - 2.0 l - medium canister				Gasoline passenger cars >2.0 l - medium canister			
e_d (g/day)	0.24	0.13	0.10	0.10	0.26	0.13	0.10	0.10	0.32	0.14	0.10	0.10
$e_{s,hot,fi}$ (g/proced.)	0.10	0.07	0.04	0.04	0.10	0.07	0.04	0.04	0.10	0.07	0.04	0.04
$e_{s,warm,c}$ (g/proced.)	0.22	0.09	0.05	0.04	0.26	0.09	0.05	0.04	0.35	0.10	0.05	0.04
$e_{s,hot,c}$ (g/proced.)	0.35	0.10	0.05	0.04	0.45	0.11	0.05	0.04	0.70	0.13	0.06	0.04
$e_{r,hot,fi}$ (g/trip)	0.13	0.08	0.06	0.04	0.13	0.08	0.06	0.04	0.13	0.08	0.06	0.04
$e_{r,warm,c}$ (g/trip)	0.13	0.08	0.06	0.04	0.13	0.08	0.06	0.04	0.13	0.08	0.06	0.04
$e_{r,hot,c}$ (g/trip)	0.13	0.08	0.06	0.04	0.13	0.08	0.06	0.04	0.13	0.08	0.06	0.04
	Gasoline passenger cars <1.4 l - large canister				Gasoline passenger cars 1.4 - 2.0 l - large canister				Gasoline passenger cars >2.0 l - large canister			
e_d (g/day)	0.20	0.13	0.10	0.10	0.20	0.13	0.10	0.10	0.21	0.13	0.10	0.10
$e_{s,hot,fi}$ (g/proced.)	0.10	0.07	0.04	0.04	0.10	0.07	0.04	0.04	0.10	0.07	0.04	0.04
$e_{s,warm,c}$ (g/proced.)	0.15	0.07	0.05	0.04	0.16	0.08	0.05	0.04	0.17	0.08	0.05	0.04
$e_{s,hot,c}$ (g/proced.)	0.18	0.08	0.05	0.04	0.20	0.08	0.05	0.04	0.23	0.09	0.05	0.04
$e_{r,hot,fi}$ (g/trip)	0.13	0.08	0.06	0.04	0.13	0.08	0.06	0.04	0.13	0.08	0.06	0.04
$e_{r,warm,c}$ (g/trip)	0.13	0.08	0.06	0.04	0.13	0.08	0.06	0.04	0.13	0.08	0.06	0.04
$e_{r,hot,c}$ (g/trip)	0.13	0.08	0.06	0.04	0.13	0.08	0.06	0.04	0.13	0.08	0.06	0.04

Table 4-2: Summary of simplified emission factors for estimating evaporative emissions of two wheelers for typical summer and winter conditions

	summer		winter		summer		winter		summer		winter	
Temp variation (°C)	20−35	10−25	0−15	-5−10	20−35	10−25	0−15	-5−10	20−35	10−25	0−15	-5−10
Fuel DVPE (kPa)	60	70	90	90	60	70	90	90	60	70	90	90
	Mopeds <50 cm^3				Motorcycles 2-stroke >50 cm^3				Motorcycles 4-stroke <250 cm^3			
e_d (g/day)	0.59	0.37	0.28	0.22	0.79	0.49	0.37	0.28	0.93	0.57	0.43	0.33
$e_{s,hot,fi}$ (g/proced.)	0.27	0.16	0.12	0.08	0.41	0.25	0.18	0.13	0.50	0.30	0.22	0.15
$e_{s,hot,c}$ (g/proced.)	0.69	0.41	0.30	0.21	1.03	0.62	0.45	0.32	1.26	0.75	0.55	0.39
$e_{r,hot,fi}$ (g/trip)	0.19	0.11	0.08	0.06	0.28	0.17	0.12	0.09	0.34	0.21	0.15	0.11
$e_{r,hot,c}$ (g/trip)	0.49	0.30	0.22	0.15	0.74	0.44	0.33	0.23	0.90	0.54	0.40	0.28
	Motorcycles 4-stroke 250 – 750 cm^3				Motorcycles 4-stroke > 750 cm^3 – uncontrolled				Motorcycles 4-stroke > 750 cm^3 – small canister			
e_d (g/day)	1.47	0.89	0.67	0.49	1.60	0.97	0.73	0.53	0.22	0.13	0.10	0.10
$e_{s,hot,fi}$ (g/proced.)	0.86	0.52	0.38	0.27	0.95	0.57	0.42	0.29	0.02	0.00	0.00	0.00
$e_{s,hot,c}$ (g/proced.)	2.17	1.30	0.96	0.67	2.40	1.44	1.06	0.74	0.05	0.01	0.00	0.00
$e_{r,hot,fi}$ (g/trip)	0.59	0.35	0.26	0.18	0.65	0.39	0.29	0.20	0.01	0.00	0.00	0.00
$e_{r,hot,c}$ (g/trip)	1.56	0.94	0.69	0.48	1.73	1.03	0.76	0.53	0.03	0.01	0.00	0.00

5 DETAILED METHODOLOGY

Equation (1) can be also used to estimate evaporation emissions with the detailed methodology. In this case, detailed emission factors can be used depending on the temperature profile and the driving and parking pattern over the day.

5.1 Diurnal temperature variation

Diurnal losses take place during vehicle parking as the ambient temperature varies during the day. In order to calculate diurnal losses both the temperature variation and the parking distribution during the day need to be known.

The diurnal temperature variation may be simulated by a probability density function of a normal distribution between the minimum and the maximum ambient temperatures given by the following equation:

$$T = T_{min} + T_{rise}\, e^{-0.0247\,(t-14)^2} \tag{5}$$

where

t: hour of the day (h)

T_{min}: minimum daily temperature (°C)

T_{max}: maximum daily temperature (°C)

T_{rise}: rise in the daily temperature, calculated as $T_{max} - T_{min}$ (°C)

The minimum and maximum temperatures need to be calculated over a complete parking period. A parking period can be defined from the end-time of the parking period and the parking duration t_{park}. In order to estimate diurnal losses in detail, the parking duration can be distributed into 24 time classes ranging from <0.5 to >11.5 h. Each combination of parking duration and parking end-time has a probability factor f_k as shown in Table 5-1. The sum of f_k values in Table 5-1 equals 1.

Table 5-1: Parking time distribution as a function of parking end-time

Parking end-time t_2 (hh:mm)	Parking duration t_{park} (h)				
	< 0.5	1	1.5	…	>11.5
0:00	f_1	f_2	f_3	…	f_{24}
1:00	f_{25}	f_{26}	f_{27}	…	f_{48}
2:00	f_{49}	f_{50}	f_{51}	…	f_{72}
…	…	…	…	…	…
23:00	f_{553}	f_{554}	f_{555}	…	f_{576}

The start time of parking may be calculated as $t_1 = t_2 - t_{park}$.

5.2 Fuel tank vapour generation

The vapour generation in the fuel tank (g) may be calculated as a function of fuel volatility, temperature variation, fuel tank size and fill level by the following equation (Reddy, 1989):

$$m_{tank}(T_{1,k}, T_{2,k}) = (1 - h/100)\, v_{tank}\left(0.025\, e^{0.0205\, vp}\left(e^{0.0716\, T_{2,k}} - e^{0.0716\, T_{1,k}}\right)\right) \quad (6)$$

where:

h: fuel tank fill level (%)

v_{tank}: fuel tank, fuel system and vapour control system volume (lt)

vp: fuel vapour pressure (DVPE) (kPa)

$T_{1,k}$: minimum tank temperature during parking period k (°C)

$T_{2,k}$: maximum tank temperature during parking period k (°C)

The above equation is valid only for the fraction of the parking period for which temperature increases. In the occasion of a continuous temperature decrease (e.g. after daily maximum value) there is no vapour generated in the fuel tank (m_{tank}=0).

5.3 Canister breakthrough emissions

Based on experimental work on carbon canisters (Mellios and Samaras, 2007) it was found that the canister weight gain during loading with fuel vapour is best described by the following equation:

$$m_{ads} = m_{load} - e^{(a + b \times s \times m_{load})} \quad (7)$$

and

$$a = -3.27861 - 0.01052\, vp + 0.0229\, T \quad (8)$$

$$b = 0.03247 + 0.00054\ vp + 0.00056\ T \tag{9}$$

where:

m_{ads}: cumulative fuel vapour adsorbed on the carbon canister during loading (g)

m_{load}: cumulative fuel vapour loaded to the carbon canister (g)

s: canister size (s=2 for small, s=1 for medium and s=0.5 for large canister)

The initial canister weight is determined from the cumulative mileage of the vehicle as:

$$m_{ads,1} = 1/s\ [8.13\ \ln(M_{cum,j}) - 22.92] \tag{10}$$

where $M_{cum,j}$ is the cumulative mileage of the vehicle category j.

An initial amount of vapour loaded to the canister $m_{load,1}$ is calculated by equations (7)-(9) for the vapour pressure and the initial temperature of the fuel in the tank. This vapour load corresponds to the amount of vapour needed to increase the canister weight from dry to its initial weight at the beginning of the parking period. The amount of fuel vapour generated over the parking period is calculated by equation (6), and it is then added to $m_{load,1}$ to give the final vapour load $m_{load,2}$. The canister breakthrough emissions (g) are then calculated as:

$$m_{break}(T_{1,k}, T_{2,k}) = e^{(a+b\times s\times m_{load,2})} - e^{(a+b\times s\times m_{load,1})} \tag{11}$$

Permeation and leakage emissions

The mean emission factor (g/h) is given by the following equation:

$$m_{perm}(T) = e^{0.004\cdot vp} \times (6.1656\times10^{-6}\ T^{2.5} + 0.0206) \tag{12}$$

The permeation emissions (g) over a parking period k are thus calculated as:

$$m_{perm}(T_{1,k}, T_{2,k}) = \sum_{T_{1,k}}^{T_{2,k}} e^{0.004\cdot vp}(6.1656\times10^{-6} T^{2.5} + 0.0206) \tag{13}$$

6 RELEVANT ACTIVITY STATISTICS

Further to the emission factors, the proposed methodology requires a number of statistical data which are most likely not available in many countries, e.g. the parameters p, c, x, t_{park}, t_{trip} and l_{trip}. These data can be found in detailed national statistics or various experimental studies (e.g. André et al., 1994). Examples for some countries are shown in Tables 4 and 5 below. Tables 6 and 7 suggest input data for the parking time distribution and vehicle design characteristics respectively.

Table 6-1: Average daily uses of vehicles

	Number of trips/day	Driving duration (min)	Daily distances (km)
Germany	5.8	75	66.0
France	4.8	60	36.8
UK	4.7	58	41.0
Average	5.1	64	46.4

Table 6-2: Average trip characteristics

	Average length (km)	Average duration (min)	Average speed (km/h)
Germany	10.6	12.3	51.4
France	7.6	12.4	36.8
UK	8.4	12.1	41.5
Average	8.9	12.3	43.4

Table 6-3: Parking time distribution

	Parking duration t_{park} (h)																							
Parking end-time t_2 (hh:mm)	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	
0:00	0.94%	0.31%	0.04%	0.11%	0.13%	0.04%	0.07%	0.03%	0.03%	0.02%	0.02%	0.01%	0.02%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.30%	**2.2%**
1:00	0.51%	0.17%	0.02%	0.06%	0.07%	0.02%	0.04%	0.02%	0.02%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.17%	**1.2%**
2:00	0.30%	0.10%	0.01%	0.04%	0.04%	0.01%	0.02%	0.01%	0.01%	0.01%	0.01%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.10%	**0.7%**
3:00	0.17%	0.06%	0.01%	0.02%	0.02%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.06%	**0.4%**
4:00	0.30%	0.10%	0.01%	0.04%	0.04%	0.01%	0.02%	0.01%	0.01%	0.01%	0.01%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.10%	**0.7%**
5:00	0.94%	0.31%	0.04%	0.11%	0.13%	0.04%	0.07%	0.03%	0.03%	0.02%	0.02%	0.01%	0.02%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.30%	**2.2%**
6:00	1.97%	0.64%	0.09%	0.23%	0.28%	0.09%	0.14%	0.07%	0.07%	0.05%	0.05%	0.02%	0.05%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.63%	**4.6%**
7:00	2.40%	0.78%	0.11%	0.28%	0.34%	0.11%	0.17%	0.08%	0.08%	0.06%	0.06%	0.03%	0.06%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.77%	**5.6%**
8:00	2.23%	0.72%	0.10%	0.26%	0.31%	0.10%	0.16%	0.08%	0.08%	0.05%	0.05%	0.03%	0.05%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.72%	**5.2%**
9:00	2.23%	0.72%	0.10%	0.26%	0.31%	0.10%	0.16%	0.08%	0.08%	0.05%	0.05%	0.03%	0.05%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.72%	**5.2%**
10:00	2.27%	0.74%	0.11%	0.27%	0.32%	0.11%	0.16%	0.08%	0.08%	0.05%	0.05%	0.03%	0.05%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.73%	**5.3%**
11:00	2.35%	0.76%	0.11%	0.28%	0.33%	0.11%	0.17%	0.08%	0.08%	0.06%	0.06%	0.03%	0.06%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.76%	**5.5%**
12:00	1.97%	0.64%	0.09%	0.23%	0.28%	0.09%	0.14%	0.07%	0.07%	0.05%	0.05%	0.02%	0.05%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.63%	**4.6%**
13:00	2.23%	0.72%	0.10%	0.26%	0.31%	0.10%	0.16%	0.08%	0.08%	0.05%	0.05%	0.03%	0.05%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.72%	**5.2%**
14:00	2.40%	0.78%	0.11%	0.28%	0.34%	0.11%	0.17%	0.08%	0.08%	0.06%	0.06%	0.03%	0.06%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.77%	**5.6%**
15:00	2.48%	0.81%	0.12%	0.29%	0.35%	0.12%	0.17%	0.09%	0.09%	0.06%	0.06%	0.03%	0.06%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.80%	**5.8%**
16:00	2.78%	0.90%	0.13%	0.33%	0.39%	0.13%	0.20%	0.10%	0.10%	0.07%	0.07%	0.03%	0.07%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.90%	**6.5%**
17:00	2.78%	0.90%	0.13%	0.33%	0.39%	0.13%	0.20%	0.10%	0.10%	0.07%	0.07%	0.03%	0.07%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.90%	**6.5%**
18:00	2.70%	0.88%	0.13%	0.32%	0.38%	0.13%	0.19%	0.09%	0.09%	0.06%	0.06%	0.03%	0.06%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.87%	**6.3%**
19:00	2.18%	0.71%	0.10%	0.26%	0.31%	0.10%	0.15%	0.08%	0.08%	0.05%	0.05%	0.03%	0.05%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.70%	**5.1%**
20:00	1.88%	0.61%	0.09%	0.22%	0.26%	0.09%	0.13%	0.07%	0.07%	0.04%	0.04%	0.02%	0.04%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.61%	**4.4%**
21:00	1.80%	0.58%	0.08%	0.21%	0.25%	0.08%	0.13%	0.06%	0.06%	0.04%	0.04%	0.02%	0.04%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.58%	**4.2%**
22:00	1.67%	0.54%	0.08%	0.20%	0.23%	0.08%	0.12%	0.06%	0.06%	0.04%	0.04%	0.02%	0.04%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.54%	**3.9%**
23:00	1.33%	0.43%	0.06%	0.16%	0.19%	0.06%	0.09%	0.05%	0.05%	0.03%	0.03%	0.02%	0.03%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.43%	**3.1%**
	43%	**14%**	**2.0%**	**5.0%**	**6.0%**	**2.0%**	**3.0%**	**1.5%**	**1.5%**	**1.0%**	**1.0%**	**0.5%**	**1.0%**	**0.5%**	**0.5%**	**0.5%**	**0.5%**	**0.5%**	**0.5%**	**0.5%**	**0.5%**	**0.5%**	**0.5%**	**14%**	**100%**

Table 6-4: Suggested fuel tank volumes and carbon canister sizes for the various COPERT categories

Sector	Subsector	Technology	Tank (lt)	Canister*
Passenger Cars	Gasoline <1,4 l	PRE ECE	50	NO
Passenger Cars	Gasoline <1,4 l	ECE 15/00-01	50	NO
Passenger Cars	Gasoline <1,4 l	ECE 15/02	50	NO
Passenger Cars	Gasoline <1,4 l	ECE 15/03	50	NO
Passenger Cars	Gasoline <1,4 l	ECE 15/04	50	NO
Passenger Cars	Gasoline <1,4 l	Improved Conventional	50	NO
Passenger Cars	Gasoline <1,4 l	Open Loop	50	NO
Passenger Cars	Gasoline <1,4 l	PC Euro 1 - 91/441/EEC	50	SC
Passenger Cars	Gasoline <1,4 l	PC Euro 2 - 94/12/EEC	50	SC
Passenger Cars	Gasoline <1,4 l	PC Euro 3 - 98/69/EC Stage2000	50	MC
Passenger Cars	Gasoline <1,4 l	PC Euro 4 - 98/69/EC Stage2005	50	MC
Passenger Cars	Gasoline <1,4 l	PC Euro 5 (post 2005)	50	MC
Passenger Cars	Gasoline 1,4 - 2,0 l	PRE ECE	60	NO
Passenger Cars	Gasoline 1,4 - 2,0 l	ECE 15/00-01	60	NO
Passenger Cars	Gasoline 1,4 - 2,0 l	ECE 15/02	60	NO
Passenger Cars	Gasoline 1,4 - 2,0 l	ECE 15/03	60	NO
Passenger Cars	Gasoline 1,4 - 2,0 l	ECE 15/04	60	NO
Passenger Cars	Gasoline 1,4 - 2,0 l	Improved Conventional	60	NO
Passenger Cars	Gasoline 1,4 - 2,0 l	Open Loop	60	NO
Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 1 - 91/441/EEC	60	SC
Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 2 - 94/12/EEC	60	SC
Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 3 - 98/69/EC Stage2000	60	MC
Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 4 - 98/69/EC Stage2005	60	MC
Passenger Cars	Gasoline 1,4 - 2,0 l	PC Euro 5 (post 2005)	60	MC
Passenger Cars	Gasoline >2,0 l	PRE ECE	75	NO
Passenger Cars	Gasoline >2,0 l	ECE 15/00-01	75	NO
Passenger Cars	Gasoline >2,0 l	ECE 15/02	75	NO
Passenger Cars	Gasoline >2,0 l	ECE 15/03	75	NO
Passenger Cars	Gasoline >2,0 l	ECE 15/04	75	NO
Passenger Cars	Gasoline >2,0 l	PC Euro 1 - 91/441/EEC	75	MC
Passenger Cars	Gasoline >2,0 l	PC Euro 2 - 94/12/EEC	75	MC
Passenger Cars	Gasoline >2,0 l	PC Euro 3 - 98/69/EC Stage2000	75	LC
Passenger Cars	Gasoline >2,0 l	PC Euro 4 - 98/69/EC Stage2005	75	LC
Passenger Cars	Gasoline >2,0 l	PC Euro 5 (post 2005)	75	LC
Passenger Cars	Hybrid Gasoline <1,4 l	PC Euro 4 - 98/69/EC Stage2005	50	MC
Passenger Cars	Hybrid Gasoline 1,4 - 2,0 l	PC Euro 4 - 98/69/EC Stage2005	60	MC
Passenger Cars	Hybrid Gasoline >2,0 l	PC Euro 4 - 98/69/EC Stage2005	75	LC
Light Duty Vehicles	Gasoline <3,5t	Conventional	60	NO
Light Duty Vehicles	Gasoline <3,5t	LD Euro 1 - 93/59/EEC	60	SC
Light Duty Vehicles	Gasoline <3,5t	LD Euro 2 - 96/69/EEC	60	SC
Light Duty Vehicles	Gasoline <3,5t	LD Euro 3 - 98/69/EC Stage2000	60	MC
Light Duty Vehicles	Gasoline <3,5t	LD Euro 4 - 98/69/EC Stage2005	60	MC
Light Duty Vehicles	Gasoline <3,5t	LD Euro 5 - 2008 Standards	60	MC
Mopeds	<50 cm^3	Conventional	5	NO
Mopeds	<50 cm^3	Mop - Euro 1	5	NO
Mopeds	<50 cm^3	Mop - Euro 2	5	NO
Mopeds	<50 cm^3	Mop - Euro 3	5	NO
Motorcycles	2-stroke >50 cm^3	Conventional	8	NO
Motorcycles	2-stroke >50 cm^3	Mot - Euro 1	8	NO
Motorcycles	2-stroke >50 cm^3	Mot - Euro 2	8	NO
Motorcycles	2-stroke >50 cm^3	Mot - Euro 3	8	NO
Motorcycles	4-stroke <250 cm^3	Conventional	10	NO
Motorcycles	4-stroke <250 cm^3	Mot - Euro 1	10	NO
Motorcycles	4-stroke <250 cm^3	Mot - Euro 2	10	NO
Motorcycles	4-stroke <250 cm^3	Mot - Euro 3	10	NO
Motorcycles	4-stroke 250 - 750 cm^3	Conventional	18	NO
Motorcycles	4-stroke 250 - 750 cm^3	Mot - Euro 1	18	NO
Motorcycles	4-stroke 250 - 750 cm^3	Mot - Euro 2	18	NO
Motorcycles	4-stroke 250 - 750 cm^3	Mot - Euro 3	18	NO
Motorcycles	4-stroke >750 cm^3	Conventional	20	SC
Motorcycles	4-stroke >750 cm^3	Mot - Euro 1	20	SC
Motorcycles	4-stroke >750 cm^3	Mot - Euro 2	20	SC
Motorcycles	4-stroke >750 cm^3	Mot - Euro 3	20	SC

* NO = no canister, SC = small canister, MC = medium canister, LC = large canister

7 POINT SOURCE CRITERIA

There are no relevant point sources which fall under the source activities dealt with in this chapter.

8 EMISSION FACTORS, QUALITY CODES AND REFERENCES

8.1 Gasoline Passenger Cars

8.1.1 Diurnal emissions

For any parking period k the vapour generated in the tank and the associated breakthrough emissions are calculated using equations (6)-(11) as described above. The permeation emissions are calculated by equation (13). The diurnal emissions for each parking period k (in g/parking) are thus calculated as:

$$m_{break}(T_{1,k}, T_{2,k}) + e_{perm}(T_{1,k}, T_{2,k}) \tag{14}$$

Taking into account all parking periods, the average diurnal emissions (in g/day) are calculated as:

$$e_d = \sum_k f_k \cdot \left(m_{break}(T_{1,k}, T_{2,k}) + m_{perm}(T_{1,k}, T_{2,k})\right) \tag{15}$$

For gasoline vehicles without carbon canister all vapour generated in the fuel tank is released in the atmosphere. Thus the mean emission factor for uncontrolled vehicles (in g/day) is given by the following equation:

$$e_d = \sum_k f_k \cdot \left(m_{tank}(T_{1,k}, T_{2,k}) + m_{perm}(T_{1,k}, T_{2,k})\right) \tag{16}$$

Hot soak emissions

For gasoline vehicles with fuel injection and returnless fuel systems, the fuel temperature in the tank is not affected by engine operation and thus no fuel vapour is generated in the tank when a hot engine is turned off. Hot soak emissions are mainly due to fuel permeation and/or leakage. Taking into account the increased temperature of the fuel circulating in the fuel system (from fuel tank to injectors), the mean hot soak emission factor for gasoline vehicles (both canister-equipped and uncontrolled) with fuel injection and returnless fuel systems (in g/procedure) is given by the following equation:

$$e_{s,hot,fi} = \sum_k f_k \cdot m_{perm}(T_{1,k} + 11) \tag{17}$$

For vehicles equipped with carburettor and/or fuel return systems, engine operation results in significant temperature increase in the fuel tank and/or the carburettor (Morgan et al., 1993). The additional fuel vapour that is generated loads the carbon canister causing breakthrough emissions which are calculated using equations (6)-(11) as described above. For the warm soak emissions a 4.5°C increase in the fuel temperature in the tank is used, while a 6°C increase is used for hot soak emissions. The mean warm and hot soak emission factors for canister-equipped gasoline vehicles with carburettor and/or fuel return systems (in g/procedure) are thus given by the following equations:

$$\begin{aligned} e_{s,hot,c} &= \sum_k f_k \cdot m_{break}(T_{1,k}, T_{1,k} + 6) + e_{s,hot,fi} \\ e_{s,warm,c} &= \sum_k f_k \cdot m_{break}(T_{1,k}, T_{1,k} + 4.5) + e_{s,hot,fi} \end{aligned} \tag{18}$$

For uncontrolled vehicles the above equations are rewritten as follows:

$$\begin{aligned} e_{s,hot,c} &= \sum_k f_k \cdot m_{tank}(T_{1,k}, T_{1,k} + 6) + e_{s,hot,fi} \\ e_{s,warm,c} &= \sum_k f_k \cdot m_{tank}(T_{1,k}, T_{1,k} + 4.5) + e_{s,hot,fi} \end{aligned} \tag{19}$$

8.1.2 Running losses

As mentioned above, for vehicles with fuel injection and returnless fuel systems the fuel temperature in the tank is not affected by engine operation and thus the running losses are attributed to fuel permeation and/or leakage. The mean running losses emission factor for gasoline vehicles (both canister-equipped and uncontrolled) with returnless fuel systems (in g/trip) is calculated as:

$$e_{r,hot,fi} = t_{trip} \cdot \sum_k f_k \cdot m_{perm}(T_{2,k} + 15) \tag{20}$$

where t_{trip} is the mean driving duration per trip, average over the year (h/trip).

For vehicles equipped with carburettor and/or fuel return systems, the additional fuel vapour that is generated in the fuel tank loads the carbon canister. However, the canister is being purged with air at certain time intervals and thus no significant breakthrough emissions are observed (except for long periods of idling when the purge valve, controlling the amount of air that is used for purging, remains shut). For canister-equipped vehicles with carburettor and/or fuel return systems, equation (20) can be used for calculating hot and warm running losses, i.e.:

$$e_{r,hot,c} = e_{r,warm,c} = e_{r,hot,fi} \tag{21}$$

For uncontrolled vehicles the fuel vapour generated in the tank due to temperature increase also contributes to the running losses. For the warm running losses a 1°C increase in the fuel temperature in the tank is used, while a 5°C increase is used for hot running losses. The mean warm and hot running losses factors for uncontrolled gasoline vehicles with fuel return systems (in g/trip) are thus given by the following equation:

$$\begin{aligned} e_{r,hot,c} &= \sum_k f_k \cdot m_{tank}(T_{2,k}, T_{2,k} + 5) + e_{r,hot,fi} \\ e_{r,warm,c} &= \sum_k f_k \cdot m_{tank}(T_{2,k}, T_{2,k} + 1) + e_{r,hot,fi} \end{aligned} \tag{22}$$

8.2 Light Duty Vehicles

The same emission factors as for passenger cars may be applied.

8.3 Two wheelers

Diurnal emissions for canister-equipped and uncontrolled two wheelers are calculated by equations (15) and (16) respectively.

The mean warm and hot soak emission factors for controlled motorcycles equipped with fuel injection and those equipped with carburettor (in g/procedure) are given by the following equations:

$$\begin{aligned} e_{s,hot,fi} &= \sum_k f_k \cdot m_{break}(T_{1,k}, T_{1,k} + 1.5) \\ e_{s,hot,c} &= \sum_k f_k \cdot m_{break}(T_{1,k}, T_{1,k} + 3.5) \end{aligned} \tag{23}$$

For uncontrolled mopeds and motorcycles equipped with fuel injection and those equipped with carburettor (in g/procedure) the mean warm and hot soak emission factors are:

$$\begin{aligned} e_{s,hot,fi} &= \sum_k f_k \cdot m_{tank}(T_{1,k}, T_{1,k} + 1.5) \\ e_{s,hot,c} &= \sum_k f_k \cdot m_{tank}(T_{1,k}, T_{1,k} + 3.5) \end{aligned} \tag{24}$$

The mean warm and hot running losses factors for controlled motorcycles equipped with fuel injection and those equipped with carburettor (in g/trip) are given by the following equations:

$$\begin{aligned} e_{r,hot,fi} &= \sum_k f_k \cdot m_{break}(T_{2,k}, T_{2,k} + 1) \\ e_{r,hot,c} &= \sum_k f_k \cdot m_{break}(T_{2,k}, T_{2,k} + 2.5) \end{aligned} \tag{25}$$

For uncontrolled mopeds and motorcycles equipped with fuel injection and those equipped with carburettor the mean warm and hot running losses factors (in g/trip) are:

$$\begin{aligned} e_{r,hot,fi} &= \sum_k f_k \cdot m_{tank}(T_{2,k}, T_{2,k} + 1) \\ e_{r,hot,c} &= \sum_k f_k \cdot m_{tank}(T_{2,k}, T_{2,k} + 2.5) \end{aligned} \tag{26}$$

8.4 Summary

The basic emission factors, which are necessary to apply the methodology, are listed in Table 8-1 for uncontrolled and controlled vehicles.

Table 8-1: Summary of emission factors for estimating evaporative emissions of passenger cars, light duty vehicles and two wheelers

Emission factor	Uncontrolled vehicle	Canister-equipped vehicle
Passenger cars and light duty vehicles		
e_d (g/day)	$\sum_k f_k \left(m_{tank}(T_{1,k}, T_{2,k}) + m_{perm}(T_{1,k}, T_{2,k})\right)$	$\sum_k f_k \left(m_{break}(T_{1,k}, T_{2,k}) + m_{perm}(T_{1,k}, T_{2,k})\right)$
$e_{s,hot,fi}$ (g/proced.)	$\sum_k f_k \cdot m_{perm}(T_{1,k} + 11)$	$\sum_k f_k \cdot m_{perm}(T_{1,k} + 11)$
$e_{s,warm,c}$ (g/proced.)	$\sum_k f_k m_{tank}(T_{1,k}, T_{1,k} + 4.5) + e_{s,hot,fi}$	$\sum_k f_k m_{break}(T_{1,k}, T_{1,k} + 4.5) + e_{s,hot,fi}$
$e_{s,hot,c}$ (g/proced.)	$\sum_k f_k \cdot m_{tank}(T_{1,k}, T_{1,k} + 6) + e_{s,hot,fi}$	$\sum_k f_k \cdot m_{break}(T_{1,k}, T_{1,k} + 6) + e_{s,hot,fi}$
$e_{r,hot,fi}$ (g/trip)	$t_{trip} \cdot \sum_k f_k \cdot m_{perm}(T_{2,k} + 15)$	$t_{trip} \cdot \sum_k f_k \cdot m_{perm}(T_{2,k} + 15)$
$e_{r,warm,c}$ (g/trip)	$\sum_k f_k \cdot m_{tank}(T_{2,k}, T_{2,k} + 1) + e_{r,hot,fi}$	$e_{r,hot,fi}$
$e_{r,hot,c}$ (g/trip)	$\sum_k f_k \cdot m_{tank}(T_{2,k}, T_{2,k} + 5) + e_{r,hot,fi}$	$e_{r,hot,fi}$
Two wheelers		
e_d (g/day)	$\sum_k f_k \cdot \left(m_{tank}(T_{1,k}, T_{2,k}) + m_{perm}(T_{1,k}, T_{2,k})\right)$	$\sum_k f_k \cdot \left(m_{break}(T_{1,k}, T_{2,k}) + m_{perm}(T_{1,k}, T_{2,k})\right)$
$e_{s,hot,fi}$ (g/procedure)	$\sum_k f_k \cdot m_{tank}(T_{1,k}, T_{1,k} + 1.5)$	$\sum_k f_k \cdot m_{break}(T_{1,k}, T_{1,k} + 1.5)$
$e_{s,hot,c}$ (g/procedure)	$\sum_k f_k \cdot m_{tank}(T_{1,k}, T_{1,k} + 3.5)$	$\sum_k f_k \cdot m_{break}(T_{1,k}, T_{1,k} + 3.5)$
$e_{r,hot,fi}$ (g/trip)	$\sum_k f_k \cdot m_{tank}(T_{2,k}, T_{2,k} + 1)$	$\sum_k f_k \cdot m_{break}(T_{2,k}, T_{2,k} + 1)$
$e_{r,hot,c}$ (g/trip)	$\sum_k f_k \cdot m_{tank}(T_{2,k}, T_{2,k} + 2.5)$	$\sum_k f_k \cdot m_{break}(T_{2,k}, T_{2,k} + 2.5)$

9 SPECIES PROFILES

The content of non-methane VOCs in different species is given in Table 9-1. The proposed fractions have been obtained by results from a European test programme on evaporative emissions from canister-equipped gasoline passenger cars (JRC, 2007). It should be noted that the speciation of evaporative emissions depends on the fuel composition. Light fuel components are easier to evaporate than heavy ones. Hence, the profile of species evaporating may be shifted to lighter components.

Table 9-1: Composition of NMVOC in evaporative emissions

Group	Species	NMVOC fraction (% wt)
Alkanes	ethane	0.30
	propane	5.15
	i-butane	4.38
	n-butane	5.86
	i-pentane	10.69
	n-pentane	7.72
	2-methylpentane	14.02
	3-methylpentane	25.14
	n-hexane	2.02
	n-heptane	1.65
Alkenes	ethene	0.05
	propene	0.28
	1-butene	0.72
	trans-2-butene	1.19
	isobutene	0.12
	cis-2-butene	1.05
	1,3 butadiene	0.00
	trans-2-pentene	1.60
	cis-2-pentene	0.75
	isoprene	0.00
Alkines	propyne	0.07
	acetylene	0.01
Aromatics	benzene	0.97
	toluene	3.94
	ethylbenzene	3.52
	m-xylene	5.79
	o-xylene	2.52
	1,2,4-trimethylbenzene	0.50
	1,3,5-trimethylbenzene	0.00
Totals (all NMVOC species)		100

10 UNCERTAINTY ESTIMATES

Using the indicators introduced in Chapter B710, Table 10-1 provides qualitative estimates of the precision which can be allocated to the calculation of evaporative losses.

Table 10-1: Summary of precision indicators of the evaporative emission estimates

Vehicle category	NMVOC
Passenger cars conventional	B
Passenger cars canister-equipped	A
Light duty vehicles conventional	D
Light duty vehicles canister-equipped	D
Two wheelers conventional	B
Two wheelers canister-equipped	B

11 WEAKEST ASPECTS/PRIORITY AREAS FOR IMPROVEMENT IN CURRENT METHODOLOGY

The proposed methodology has been based on results from a range of canister-equipped gasoline vehicles representative of current Euro 3-4 technology and typical summer and winter fuels and temperatures. Although a large number of hot soak and diurnal tests has been carried out, running losses were not measured and therefore the proposed emission factors need further improvement. Other areas requiring additional consideration include:

i) evaporative emission factors for light duty vehicles, and

ii) evaporative emission factors for fuels containing bio components (e.g. ethanol).

12 SPATIAL DISAGGREGATION CRITERIA FOR AREA SOURCES

Evidently the principles of the approaches outlined for exhaust emission spatial allocation apply equally to evaporative losses. In particular as regards the top down approach, the following hints may be useful:

- Diurnal losses: As diurnal losses occur at any time, their spatial allocation to urban/rural/highway conditions depends on the time spent by the vehicles on the different road classes. Therefore for those vehicles that are used by city inhabitants one can assume that 11/12 of their diurnal emissions occur in urban areas, the rest being split between rural and highway driving proportionally to the ratio of (rural mileage . highway speed) / (highway mileage . rural speed)
- Soak losses: The majority of these emissions occur in the area of residence of the car owner, as they are associated with short trips.
- Running losses: Running losses are proportional to the mileage driven by the vehicles. Therefore their allocation to urban areas - rural areas - highways has to follow the mileage split assumed for the calculation of the exhaust emissions.

13 TEMPORAL DISAGGREGATION CRITERIA

14 ADDITIONAL COMMENTS

The evaporation losses calculation scheme presented above, is fully integrated into COPERT 4 (Computer Programme to Calculate Emissions from Road Traffic), which substantially facilitates the practical application of the methodology (see Ntziachristos et al. 2000).

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16 VERIFICATION PROCEDURES

See the discussion in Chapter 16 of Chapter B710 on road transport.

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18 BIBLIOGRAPHY

List of abbreviations

DVPE: Dry Vapour Pressure Equivalent at a temperature of 37.8°C

NMVOC: Non-Methane Volatile Organic Compounds

VOC: Volatile Organic Compounds

List of symbols

c: fraction of gasoline powered vehicles equipped with carburettor and/or fuel return systems

e_d: average diurnal losses of vehicle category j (g/day)

$e_{r,hot,c}$: mean emission factor for hot running losses of gasoline powered vehicles with carburettor and/or fuel return systems (g/trip)

$e_{r,hot,fi}$: mean emission factor for hot running losses of gasoline powered vehicles with fuel injection and returnless fuel systems (g/trip)

$e_{r,warm,c}$: mean emission factor for cold and warm running losses of gasoline powered vehicles with carburettor and/or fuel return systems (g/trip)

$e_{s,hot,c}$: mean hot soak emission factor of gasoline powered vehicles with carburettor and/or fuel return systems (g/procedure)

$e_{s,hot,fi}$: mean hot soak emission factor of gasoline powered vehicles with fuel injection and returnless fuel systems (g/procedure)

$e_{s,warm,c}$: mean cold and warm soak emission factor of gasoline powered vehicles with carburettor and/or fuel return systems (g/procedure)

$E_{eva,voc,j}$: VOC emissions due to evaporative losses caused by vehicle category j (g)

f_k: probability factor for combination of parking duration and ending hour of parking

h: fuel tank fill level (%)

HS_j: average daily hot and warm soak emissions of vehicle category j (g/day)

l_{trip}: average trip length (km)

m_{ads}: cumulative fuel vapour adsorbed on the carbon canister during loading (g)

m_{load}: cumulative fuel vapour loaded to the carbon canister (g)

m_{tank}: fuel vapour generation (g)

m_{break}: canister breakthrough emissions (g)

m_{perm}: emissions due to fuel permeation and/or leakage (g)

M_j: total annual mileage of gasoline vehicles of category j

$M_{cum,j}$: total cumulative mileage of gasoline vehicles of category j

N_j: number of gasoline vehicles of category j

p: fraction of trips finished with hot engine, i.e. an engine that has reached its normal operating temperature and the catalyst its light-off temperature

RL_j: average daily hot and warm running losses of vehicle category j (g/day)

s: canister size (s=2 for small, s=1 for medium and s=0.5 for large canister)

t: hour of the day (h)

t_1: hour of the day at the beginning of a parking period (h)

t_2: hour of the day at the end of a parking period (h)

t_{park}: mean parking duration (h)

t_{trip}: mean driving duration per trip, average over the year (h/trip)

T: ambient temperature (°C)

$T_{1,k}$: minimum tank temperature during parking period k (°C)

$T_{2,k}$: maximum tank temperature during parking period k (°C)

T_{min}: minimum daily temperature (°C)

T_{max}: maximum daily temperature (°C)

T_{rise}: rise in the daily temperature, calculated as $T_{max} – T_{min}$ (°C)

v_{tank}: fuel tank, fuel system and vapour control system volume (lt)

vp: fuel vapour pressure (DVPE) (kPa)

x: mean number of trips per vehicle per day, average over the year (trips/day)

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20 POINT OF ENQUIRY

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