Emission estimates for diffuse sources
Netherlands Emission Inventory

Road traffic engine oil leaks

Version dated June 2008

NETHERLANDS NATIONAL WATER BOARD - WATER UNIT
in cooperation with DELTARES and TNO

Road traffic engine oil leaks

1 Description of emission source

Motor vehicles consume a certain amount of engine oil in the course of operation. Part of this is the result of leakage, while some engine oil is also burned in the cylinders. Leakage of engine oil results in a diffuse emission of heavy metals and PAH to the environment.
This fact sheet describes the method for calculating these emissions resulting from leakage. This emission source is attributed to the governmental target sector "Transport".

2 Explanation of calculation method

The emissions are calculated by multiplying an activity rate (AR), in this case the traffic performance per type of vehicle in the Netherlands in millions of km, by an emission factor (EF) per type of vehicle, expressed in mg of engine oil leakage per km, and an emission profile for the specific substances per mg of oil leaked. This method of calculation is explained in detail in the publication *Handreiking Regionale aanpak diffuse bronnen* [1].

Emission = AR * EF * component

Where:
AR = Traffic performance (km)
EF = Engine oil leakage per kilometre (mg/km)
component = Content of substance in engine oil (mg/kg)

The emission calculated in this way is referred to as the total emission.

3 Activity rates

The activity rate (AR) is the total traffic performance of the different vehicle types. This traffic performance is recorded annually by the Task Force Traffic and Transport [2]. Table 1 gives the total traffic performance for the time period 1990-2006.

Table 1: Time frame, total traffic performance of road vehicles (in km x 1,000,000)

	1990	1995	2000	2005	2006
total km	96,819	102,197	118,870	129,101	130,577

4 Emission factors

A value of 10 mg engine oil/km is applied as average emission factor [3,4]. Based on this emission factor and the mileage in table 2, a total leakage of engine oil in the Netherlands is determined. The composition of engine oil is shown in table 2 [4].

Table 2: Contents of heavy metals and PAH emission profiles for engine oil (in mg/kg) [4]

	engine oil
cadmium	1.28
copper	33.8
chromium	7.7
nickel	3.25
zinc	825
arsenic	8.1
lead	148
naphthalene	6,000
anthracene	130
phenanthrene	1,000
fluoranthene	200
benzo(a)anthracene	175
chrysene	180
benzo(b)fluoranthene	100
benzo(k)fluoranthene	100
benzo(a)pyrene	180
indeno(1,2,3-cd)pyrene	65
benzo(ghi)perylene	220
Total Borneff 6 PAH	860
Total VROM 10 PAH	8,250

5 Effects of policy measures

No effects of measures are known.

6 Emissions calculated

The quantity of leaked engine oil calculated is shown in table 3.
The total quantities of PAH and heavy metals in engine oil are shown in table 4.

Table 3: Leaked quantities of engine oil (tonnes)

	1990	**1995**	**2000**	**2005**	**2006**
- urban roads	775	818	951	1,033	1,045
- rural roads	99	91	104	113	115
- highways	94	113	134	145	147
Total leakage	968	1,022	1,189	1,291	1,306

Table 4: Emissions as result of engine oil leakage (in kg)

	1990	1995	2000	2005	2006
cadmium	1	1	2	2	2
copper	33	35	40	44	44
chromium	7	8	9	10	10
nickel	3	3	4	4	4
zinc	799	843	981	1,065	1,077
arsenic	8	8	10	10	11
lead	143	151	176	191	193
naphthalene	5,808	6,132	7,134	7,746	7,836
anthracene	126	133	155	168	170
phenanthrene	968	1,022	1,189	1,291	1,306
fluoranthene	194	204	238	258	261
benzo(a)anthracene	169	179	208	226	229
chrysene	174	184	214	232	235
benzo(b)fluoranthene	97	102	119	129	131
benzo(k)fluoranthene	97	102	119	129	131
benzo(a)pyrene	174	184	214	232	235
indeno(1,2,3-cd)pyrene	63	66	77	84	85
benzo(ghi)perylene	213	225	262	284	287
Total Borneff 6 PAH	832	879	1,023	1,110	1,123
Total VROM 10 PAH	7,986	8,432	9,809	10,651	10,775

7 Release into environmental compartments

Emissions resulting from engine oil leaks enter the soil, surface water and the sewers. For the distribution of emissions across compartments, the engine oil leakage is assigned to the different vehicle types and the location (within or outside urban area, highways).
The assignment to the environmental compartments is directly related to the road types where the emissions take place. Table 5 shows the assignment of the emissions of engine oil for the various road types.

Table 5 - Distribution percentages of engine oil by compartment

	soil	sewers	water
urban roads	0	100	0
rural roads	80	0	20
highways	80	0	20

Source: methodology report, Traffic task group

For the distribution of the quantity of leaked engine oil across the different road types (within urban area, outside urban area and highways), it is assumed that 80% of oil leakage takes place within the urban area. The remaining quantity of leaked engine oil is distributed between the other two road types in proportion to traffic performance, using weighting factors by vehicle type that also depend on the age of the vehicle type. The calculation assumes that the distribution of the age of vehicle types is equal for the different road types. The way in which leakage loss is assigned based on these assumptions is explained in detail in Appendix 1, using the calculation for one year. Unlike emissions due to road surface wear and tyre wear, 100% of the emissions from engine oil leakage within the urban area are assumed to be emissions into the sewer system. While with road surface wear and tyre wear the assumption is that the emitted substance can be blown back into the atmosphere and travel further from the road, for emissions from engine oil leaks the assumption is that all engine oil ends up on the road surface and ultimately flows into the sewers. On highways, a portion of the emissions ends up in the ZOAB (very open asphalted concrete). The emissions on highways are corrected for the amount that ends up in the ZOAB (see table 7). For other emissions, 80% of the emission ends up in the soil and 20% in the surface water. Likewise, on rural roads outside of the urban area, 80% of the emissions go to the soil and 20% to the surface water (without correction for ZOAB). Tables 8-10 show the resulting distribution across the various compartments.

Table 7: Correction factor for ZOAB on highways [4].

	1990	1995	2000	2005	2006
ZOAB correction factor	0.94	0.81	0.68	0.59	0.57

Table 8: Leakage of engine oil, distribution across compartments (in tonnes)

	1990	1995	2000	2005	2006
soil	150	146	156	159	159
water, direct	37	36	39	40	40
sewers	775	818	951	1033	1045

Table 9: Emissions to soil as result of engine oil leakage (in kg)

	1990	1995	2000	2005	2006
cadmium	0.2	0.2	0.2	0.2	0.2
copper	5.1	4.9	5.3	5.4	5.4
chromium	1.2	1.1	1.2	1.2	1.2
nickel	0.5	0.5	0.5	0.5	0.5
zinc	124.1	120.7	128.9	131.3	131.1
arsenic	1.2	1.2	1.3	1.3	1.3
lead	22.3	21.7	23.1	23.6	23.5
naphthalene	902.3	878.2	937.1	955.0	953.5
anthracene	19.6	19.0	20.3	20.7	20.7
phenanthrene	150.4	146.4	156.2	159.2	158.9
fluoranthene	30.1	29.3	31.2	31.8	31.8
benzo(a)anthracene	26.3	25.6	27.3	27.9	27.8
chrysene	27.1	26.3	28.1	28.7	28.6
benzo(b)fluoranthene	15.0	14.6	15.6	15.9	15.9
benzo(k)fluoranthene	15.0	14.6	15.6	15.9	15.9
benzo(a)pyrene	27.1	26.3	28.1	28.7	28.6
indeno(1,2,3-cd)pyrene	9.8	9.5	10.2	10.3	10.3
benzo(ghi)perylene	33.1	32.2	34.4	35.0	35.0
Total Borneff 6 PAH	129.3	125.9	134.3	136.9	136.7
Total VROM 10 PAH	1,240.7	1,207.5	1,288.5	1,313.2	1,311.1

Table 10: Emissions to surface water as result of engine oil leakage (in kg)

	1990	1995	2000	2005	2006
cadmium	0.0	0.0	0.0	0.1	0.1
copper	1.3	1.2	1.3	1.3	1.3
chromium	0.3	0.3	0.3	0.3	0.3
nickel	0.1	0.1	0.1	0.1	0.1
zinc	30.7	30.0	32.1	32.7	32.7
arsenic	0.3	0.3	0.3	0.3	0.3
lead	5.5	5.4	5.8	5.9	5.9
naphthalene	223.3	218.2	233.3	237.9	237.6
anthracene	4.8	4.7	5.1	5.2	5.1
phenanthrene	37.2	36.4	38.9	39.7	39.6
fluoranthene	7.4	7.3	7.8	7.9	7.9
benzo(a)anthracene	6.5	6.4	6.8	6.9	6.9
chrysene	6.7	6.5	7.0	7.1	7.1
benzo(b)fluoranthene	3.7	3.6	3.9	4.0	4.0
benzo(k)fluoranthene	3.7	3.6	3.9	4.0	4.0
benzo(a)pyrene	6.7	6.5	7.0	7.1	7.1
indeno(1,2,3-cd)pyrene	2.4	2.4	2.5	2.6	2.6
benzo(ghi)perylene	8.2	8.0	8.6	8.7	8.7
Total Borneff 6 PAH	32.0	31.3	33.4	34.1	34.1
Total VROM 10 PAH	307.1	300.0	320.8	327.2	326.7

Table 11: Emissions to sewers as result of engine oil leakage (in kg)

	1990	1995	2000	2005	2006
cadmium	1.0	1.0	1.2	1.3	1.3
copper	26.2	27.6	32.1	34.9	35.3
chromium	6.0	6.3	7.3	8.0	8.0
nickel	2.5	2.7	3.1	3.4	3.4
zinc	639.1	674.5	784.5	852.1	861.8
arsenic	6.3	6.6	7.7	8.4	8.5
lead	114.7	121.0	140.7	152.9	154.6
naphthalene	4,648.0	4,905.5	5,705.8	6,196.8	6,267.7
anthracene	100.7	106.3	123.6	134.3	135.8
phenanthrene	774.7	817.6	951.0	1032.8	1044.6
fluoranthene	154.9	163.5	190.2	206.6	208.9
benzo(a)anthracene	135.6	143.1	166.4	180.7	182.8
chrysene	139.4	147.2	171.2	185.9	188.0
benzo(b)fluoranthene	77.5	81.8	95.1	103.3	104.5
benzo(k)fluoranthene	77.5	81.8	95.1	103.3	104.5
benzo(a)pyrene	139.4	147.2	171.2	185.9	188.0
indeno(1,2,3-cd)pyrene	50.4	53.1	61.8	67.1	67.9
benzo(ghi)perylene	170.4	179.9	209.2	227.2	229.8
Total Borneff 6 PAH	666.2	703.1	817.8	888.2	898.4
Total VROM 10 PAH	6,391.0	6,745.0	7,845.4	8,520.7	8,618.1

8 Description of emission pathways to water

The full amount of the emissions into the sewers is entirely via the system for rainwater drainage. The way in which these indirect emissions are carried to water is further described in the fact sheet "Effluents from waste water treatment plants and sewer systems" [5].
Additionally, a portion of the emissions flows directly into surface water.

9 Spatial allocation

The spatial allocation of emissions is assigned on the basis of a set of digital maps held by the Netherlands Environmental Assessment Agency (PBL) drawn up using emission records. These maps present the spatial distribution of all kinds of parameters throughout the Netherlands, such as population density, traffic intensity, area of agricultural crops, etc. For the purposes of emission registration these maps are used as 'locators' to determine the spatial distribution of emissions. The range of possible locators is limited (see [7] for a list of available locators), as not every conceivable parameter can be used as a locator. In practice the locator judged to be the best proxy of the activity rate of the emission in question is applied for the distribution of emissions. In some cases, one source is distributed via more than one locator. This is the case with engine oil leakage on rural roads, 80% of which is distributed via traffic intensity on highways and 20% via the number of residential dwelling units outside the urban area. This distribution is applied because small municipal roads are not included in the traffic intensity of rural roads. The traffic intensity on these roads is approximated by the number of residences outside of the urban area.
It is assumed that the distribution of emissions throughout the country is proportional to the national distribution of the locator.

The table below shows the locator used for the spatial allocation of the various emission sources.

Table 12: Summary of emission spatial allocation method

Element	Locators
Engine oil leakage, highways	Traffic intensity on highways
Engine oil leakage, rural roads (80%)	Traffic intensity on rural roads, 80%
Engine oil leakage, rural roads (20%)	Number of residential dwelling units outside urban area, 20%
Engine oil leakage, within urban area	Number of inhabitants per 500x500-metre grid cell

The method used to determine the locators is described in [7]:

Traffic intensity on highways and rural roads (see above)
Traffic intensity on highways is calculated in the light of information contained in the map of distribution among stretches of road on the basis of mileage. This map contains six categories:

- Highways (national trunk roads): passenger cars and vans
- Highways (national trunk roads): freight and other traffic
- Rural roads: passenger cars and vans
- Rural roads: freight and other traffic
- Urban area: passenger cars and vans
- Urban area: freight and other traffic

Data on the location and length of roads was taken from the database "Nationaal Wegenbestand" created by the "Adviesdienst verkeer en vervoer" (AVV). Intensities (average number of vehicles in a twenty-four hour period for the entire year in question x length of the stretch of road) were calculated for highways on the basis of traffic counts conducted by AVV and relate to 2005. The values for rural roads and roads in the urban area are modelled data based on a model called the "Nieuw Regionaal Model" (NRM) operated by the AVV and cover 2005. This model uses trafficcounts and socio-economic and demographic factors such as population and building density, employment opportunities and the types of businesses in the area. Values for traffic intensity within the urban area data from local authority traffic maps also were used. This data covers 2005. The traffic intensity results from the PBL/LOK environmental quality statistics, where they are used in calculating noise levels.

Number of residential dwelling units outside urban area and number of inhabitants per 500x500-metre grid cell
The number of inhabitants per grid cell measuring 500x500 metres is derived from the MNP's map of grid cell distribution based on the number of inhabitants, residential dwelling units and inhabitants per sewage area. This map is based on values produced by Statistics Netherlands (CBS) on numbers of inhabitants and numbers of residential dwelling units in each municipality (for 2005). The distribution of inhabitants among grid cells in a local municipality was calculated using the comprehensive database of address coordinates in the Netherlands (which contains addresses and types of dwelling unit) and the 2003 sewage area database.

10 Comments and changes in regard to previous version

The distribution of the emission across the road types was revised in 2008. In previous years, the amount of leaked engine oil was assigned across three road types in proportion to the number of kilometres driven. Because within the urban area the cars also stand still for a considerable portion of the time, this distribution has now been adjusted. The assumption is that 80% of engine oil leakage takes place within the urban area. The other 20% of the amount of leaked engine oil is assigned in proportion to the number of kilometres divided across the rural roads outside the urban area and the highways. The details of this calculation are presented in Appendix 1.

11 Accuracy and indicated subjects for improvement

The method used in Emission Inventory publications has been followed as far as possible in classifying the quality of information [8]. It is based on the CORINAIR (CORe emission INventories AIR) methodology, which applies the following quality classifications: CORINAIR uses the following quality classifications:

A: a value based on a large number of measurements from representative sources;
B: a value based on a number of measurements from some of the sources that are representative of the sector;
C: a value based on a limited number of measurements, together with estimates based on technical knowledge of the process;
D: a value based on a small number of measurements, together with estimates based on assumptions;

E: a value based on a technical calculation on the basis of a number of assumptions.

The emission factor calculation is contains significant uncertainties, and is classified as category E. The activity rate is fairly well known from the monitoring of traffic performance, but whether this is actually the best activity rate is not clear. Consequently, use of this activity rate does not lead to a precise emissions estimate, and so it is classified as category E. The distribution of the emissions across the compartments is classified as category D. The element 'emission pathways to water' is fairly clear, and is assigned classification B. Finally, the spatial allocation of the emissions is assigned reliability classification D. The assignment across the compartments and the spatial allocation are unreliable, because oil leakage is more time-dependent than kilometre-dependent, making the distribution of the number of kilometres driven not a very good indicator and leading to increased leakage on continuing roads as compared to places where cars are frequently parked. This leads to an increased emission to the sewers, and less direct emissions to surface waters and the soil.

Element of emission calculation	Reliability classification
Activity rates	C
Emission factors	E
Distribution among compartments	D
Emission pathways to water	B
Spatial allocation	D

The most significant areas for improvement are:
- Improvement of quantification of engine oil leakage. In particular, the general emission factor of 10 mg/km is uncertain, possibly outdated and appears to need revision

12 Request for reactions

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Appendix 1
Explanatory notes to the assignment of engine oil leaks to individual vehicle types and distribution across individual road types

For the distribution of the quantity of leaked engine oil across the different road types (within urban area, rural area and highways), it is assumed that 80% of oil leakage takes place within the urban area.

The remaining quantity of leaked engine oil is distributed between the other two road types in proportion to traffic performance. A certain relative emission as compared to the average emission of 10 mg/km is assumed for each vehicle type, taking into account factors such as age distribution of the vehicle type. For example, passenger cars younger than 5 years old are assumed to leak no oil, with oil leakage gradually increasing in cars between five and 10 years old, and cars older than 10 years reaching 100% of the assumed oil leak rate. Different assumptions are made for motorcycles, scooters, and vans.

Table B1: Leak losses of road vehicles by age (index: road traffic total = 100[1])

	Age (years)		where:				
	0-4	> 5	5	6	7	8	9
Passenger cars	0	-	60	70	80	90	100
Motorcycles	15	50[2]					
Scooters	0	30[2]					
Light commercial vehicles	0	100[2]					
Heavy commercial vehicles	50	500[2]					

[1] average leakage loss, total road traffic: 10 mg/km.
[2] no distinction by age.

Applying this table produces weighting factors per construction year, which are then combined with the traffic performance to compute the distribution of oil leakage across the various road types.
The weighting factors assumed in the calculation are shown in table B1.2. This weighting factor per construction year reflects the assumption that newer vehicles leak less engine oil than older vehicles.

Table B1.2: Weighting factors by construction year (relative fictive amounts) for 2006.

Construction year	**Passenger cars**			**Motor cycles**	**Scooters**	**Vans**			**Lorries**	**Trucks**	**Buses**	**Special vehicles**	
	Petrol	**Diesel**	**LPG**			**Petrol**	**Diesel**	**LPG**				**light**	**heavy**
< 1997	1	1	1	0.5	0.3	1	1	1	1	5	5	1	5
1998	0.9	0.9	0.9	0.5	0.3	1	1	1	1	5	5	1	5
1999	0.8	0.8	0.8	0.5	0.3	1	1	1	1	5	5	1	5
2000	0.7	0.7	0.7	0.5	0.3	1	1	1	1	5	5	1	5
2001	0.6	0.6	0.6	0.5	0.3	1	1	1	1	5	5	1	5
2002	0	0	0	0.1	0.15	0	0	0	0	0.5	0.5	0	0.5
2003	0	0	0	0.1	0.15	0	0	0	0	0.5	0.5	0	0.5
2004	0	0	0	0.1	0.15	0	0	0	0	0.5	0.5	0	0.5
2005	0	0	0	0.1	0.15	0	0	0	0	0.5	0.5	0	0.5
2006	0	0	0	0.1	0.15	0	0	0	0	0.5	0.5	0	0.5

The total number of kilometres driven in 2006, by construction year, is shown in table B1.3, below.

Table B1.3: Total number of kilometres driven, by construction year, in 2006 (x 1,000,000)

Const. year	Passenger cars			Motor cycles	Scooters	Vans			Lorries	Truck s	Buses	Special vehicles	
	Petrol	Diesel	LPG			Petrol	Diesel	LPG				light	heavy
< 1997	22,425	3,838	1,606	1,364	120	388	2,780	245	765	333	144	65	228
1998	4,020	1,646	450	94	54	21	1,203	20	146	167	19	6	25
1999	4,651	2,424	356	105	64	27	1,517	20	197	220	29	7	31
2000	4,635	2,587	385	105	79	23	1,720	23	241	311	45	7	35
2001	4,192	2,558	433	96	96	20	1,756	16	267	407	42	7	35
2002	4,497	2,691	347	92	114	19	1,998	17	252	386	43	7	33
2003	4,562	3,169	256	93	120	23	2,190	16	239	442	61	6	28
2004	4,872	3,867	227	102	132	22	2,766	13	244	558	72	5	25
2005	4,882	4,348	268	89	147	22	2,273	7	282	611	92	5	22
2006	3,258	2,706	219	43	73	10	1,274	3	203	519	34	3	16

First, an uncorrected engine oil leakage is calculated from the total number of kilometres, the number of kilometres driven by construction year, weighting factors by construction year, and emission factors. For each vehicle type, the corrected number of kilometres is calculated as:

Corrected number of kilometres driven = $\Sigma_{\text{age classes}}$ total km per age class * weighting factor

This results in table B.1.4, below, which shows the corrected number of vehicle kilometres. A portion of the engine oil in this result is allocated in proportion to the corrected number of vehicle kilometres. This is 20% of the total emissions of engine oil. The remaining 80% is assigned directly to the road type within the urban area. The total emissions are then easily calculated using the total number of kilometres driven, from table 1, and the emission factor of 10 mg/km.

Table B1.4: Number of Weighted kilometres by weighted oil leakage and distribution of oil leakage across vehicle types

Parameter	Passenger cars			Motor cycles	Scooters	Vans			Lorries	Truck s	Buses	Special vehicles	
	Petrol	Diesel	LPG			Petrol	Diesel	LPG				light	heavy
Corrected km (x 1,000,000)	36,290	10,853	2,82 5	912	125	479	9,012	324	8,386	7,59 5	1,477	92	1,803
% leakage = % corrected km	45.3	13.5	3.5	1.1	0.2	0.6	11.2	0.4	10.5	9.5	1.8	0.1	2.2
Oil leakage (tonnes)	574	172	45	15	3	8	143	5	143	141	26	1	30

Finally, in the last step, the distribution of traffic performance across the various road types (table B1.5) is used to further distribute the 20% of total leakage per vehicle type, as calculated in tabel B1.4, by road type.

This is divided in proportion to the number of kilometres driven on rural roads outside the urban area and on highways, in comparison to the total number of vehicle-kilometres on these two road types.

Table B1.5: Total traffic performance broken down by road type in 2006 (km x 1,000,000)

	Urban roads	Rural roads	Highways	Total
Passenger car - petrol	14,977	24,610	23,746	63,333
Passenger car - diesel	4,478	8,892	17,166	30,537
Passenger car - LPG	682	1,661	2,204	4,547
Motorcycle	753	753	753	2,258
Scooter	909	101	0	1,010
Van - petrol	230	173	173	575
Van - diesel	7,822	5,866	5,866	19,554
Van - LPG	152	114	114	381
Lorry - petrol	2	6	11	19
Lorry - diesel	365	904	1,675	2,944
Lorry - LPG	1	2	4	8
Hauler - petrol	0	0	1	1
Hauler - diesel	827	794	2,557	4,178
Hauler - LPG	0	0	0	1
Bus - petrol	0	0	0	1
Bus - diesel	235	154	227	615
Bus - LPG	3	2	3	8
Special vehicle (light) - petrol	7	3	2	12
Special vehicle (light) - diesel	58	24	15	97
Special vehicle (light) - LPG	6	2	1	10
Special vehicle (heavy) - petrol	6	2	1	9
Special vehicle (heavy) - diesel	284	118	71	474
Special vehicle (heavy) - LPG	3	1	1	5

The result of the distribution of the total calculated oil leakage across the road types is given in table B.1.6, below. The quantity of leaked engine oil within the urban area is 80% of the total quantity of leaked engine oil. The quantity of leaked engine oil outside of the urban area and on highways is calculated in proportion to the number of kilometres driven, as described above.

Table B1.6: Quantity of leaked engine oil in 2006 (tonnes)

Construction year	Passenger cars			Motor cycles	Scooters	Vans			Lorries	Truck s	Buses	Special vehicles	
	Petrol	Diesel	LPG			Petrol	Diesel	LPG				light	heavy
Corrected km (x 1,000,000)	36,290	10,853	2,825	912	125	479	9,012	324	8,386	7,59 5	1,477	92	1,803
% leakage	45.3	13.5	3.5	1.1	0.2	0.6	11.2	0.4	10.5	9.5	1.8	0.1	2.2
Within urban area	460	137	36	12	3	6	114	4	114	113	21	1	247
Outside urban area	58	12	4	2	1	1	14	1	10	7	2	0	4
Highways	56	23	5	2	0	1	14	1	19	22	3	0	2
Total	574	172	45	15	3	8	143	5	143	141	26	1	30