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Emissions of mopeds and motorcycles in Belgium

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Abstract

In this paper we report our estimates for the total emission of CO, NO_x, VOC and CO_2 of mopeds and motorcycles in Belgium and indicate confidence intervals.
Data on the fleet of motorcycles are readily available from registration records, but the number of mopeds had to be estimated. Different sources were evaluated to obtain a best estimate for the yearly mileage and a distribution over rural, urban and highway roads. Most emission factors used were provided by MEET. Emission factors for CO and VOC are much higher than the factors of modern petrol cars.
When compared to the total Flemish road transport emission (1999) it turns out that mopeds and motorcycles can no longer be neglected. They are responsible for 11% (58ktonne; 7-15%) of the CO emission and 25% (22ktonne; 15-35%) of the VOC emission. These shares have doubled over the last decade. This can be explained by their success, but also by the introduction of environmentally friendly cars since the beginning of the nineties and the fact that more stringent emission regulations for mopeds and motorcycles came into force in 1997.
When compared to the total emission of Flanders in 1999, the mopeds and motorcycles are responsible for 6.6% of the total emission of CO and 6.9% of the total emission of NMVOC, or, weighted to the capacity to produce ozone, of 3.7% in the total emission of ozone precursors.
An attempt to quantify the noise emission by mopeds and motorcycles failed due to a lack of data.

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1 Introduction

Despite their recent success, mopeds (scooters included) and motorcycles are often excluded from environmental and mobility studies in Belgium, because so little is known about them. Today this lack of knowledge is seriously hampering a range of environmental and mobility studies.
The last survey of the emissions of these vehicles in Belgium dates from 1995 [1]. It showed that in 1990 mopeds and motorcycles accounted for 5.5% of the total emission of CO by road transport and 11% of the total emission of VOC. In 1993, these shares had increased to 7.0% and 13% respectively.
In the meanwhile, powered two-wheelers gained popularity; the number of motorcycles has more than doubled from 1990 to 2000 and sales figures of new scooters rose from 5,000 in 1990 to 27,000 in 1999. An update of their impact on the environment is hence needed.
In this paper, the emissions of mopeds and motorcycles are calculated for the year 2000 and compared to the national emission inventory. Attention is also paid to noise pollution caused by these vehicles.

2 Methodology

The general formula for calculating emissions is:

$$\text{emission [tonne/year]} = \text{number of vehicles} \times \text{activity} \times \text{emission factor}$$

This formula is applied for four types of emissions:
- tail-pipe emissions,
- extra emissions at start,
- hot soak emissions,
- diurnal breathing emissions.

In the case of tail-pipe emissions, the activity refers to the average mileage [km/year] of the vehicles. For calculating the extra emissions at start and hot soak emissions, the number of starts are taken. Diurnal breathing emissions are evaluated per day.
Tail-pipe emission factors [g/km] were found in literature for CO, CO_2, NH_3, N_2O, NO_x, PM and VOC and extra start emission factors [g/start] for CO, NO_x and VOC. Hot soak emissions [g/stop] and diurnal breathing emissions [g/day] are only calculated for VOC.
Out of the CO_2 emissions, the fuel consumption and emissions of lead and SO_2 are derived based on fuel characteristics. The VOC emissions are split up into emissions of CH_4, NMVOC, benzene, toluene and xylene with constant fractions.
The accuracy is assessed for each of the factors in the general formula, allowing the determination of a confidence interval for the calculated emitted quantities.

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3 Available data

3.1 Number of mopeds and motorcycles in Belgium

Motorcycles with a cylinder content exceeding 50cc are registered and their exact number - 277,838 in 2000, compared to 139,170 in 1990 - is hence known [2].
For the sake of accuracy, this fleet has to be split up in different segments according to the type of engine (two-stroke or four-stroke), cylinder capacity (less than 250cc, 250-750cc, higher than 750cc) and according to the emission legislation they comply with.
Little information is available about the size of each segment. A share of 4% for two-stroke motorcycles is assumed, based on advice from representatives of manufactures and suppliers. Following MEET [3], 65% of the fleet is believed to be conventional, whilst the rest complies with the European directive 97/24/EC. The classification according to cylinder content – 14% < 250cc, 51% between 250 and 750cc and 35% > 750cc – is derived from sales figures.
Mopeds are not longer registered since 1986, so their present number has to be estimated. Based on sales statistics and an estimated lifetime, a number of 400,000 ± 15% for 2000 is derived, which is about one fourth more than in 1990. The proportion of conventional mopeds (69%) and moped complying with 97/24/EC Stage 1 (17%) and Stage 2 (14%) is taken from MEET [3].

3.2 The activity of mopeds and motorcycles in Belgium

An assessment revealed that the mean yearly mileage for Belgian motorcycles is 6,400 km/year (± 15%) and for mopeds 4,600 km/year (± 15%) [4]. The mileage for motorcycles is corrected for cylinder capacity, based on the results of a Swiss survey [5]. Light motorcycles (<250cc) are believed to have a mileage which is 30% lower than average (4,500 km/year), heavy motorcycles to have a mileage which is 25% higher than average (8,000 km/year).
The mileage travelled with powered two-wheelers is distributed over highways, rural and urban roads. For each of these conditions, a fraction of peak traffic is assumed and a mean speed is allocated [4], see table 1.

Table 1: distribution of the mileage over different traffic conditions with the corresponding mean speed

Location	Traffic condition	Moped		Motorcycle	
		fraction	speed	fraction	speed
Highway	normal	0%	-	16%	110 km/h
	peak	0%	-	4%	25 km/h
Rural	normal	45%	36 km/h	45%	51 km/h
	peak	5%	25 km/h	5%	25 km/h
Urban	normal	35%	31 km/h	21%	25 km/h
	peak	15%	25 km/h	9%	15 km/h

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A mobility survey carried out in Flanders, Belgium, revealed that the average length of a trip with a motorcycle is 12km and with a moped 4.6km [6]. This allows us to calculate the number of starts and stops.

3.3 Emission factors for mopeds and motorcycles

The tail-pipe emission factors for CO, CO_2, NO_x and VOC were taken from MEET [3].
Figure 1, showing the emission factors for mopeds, indicates that the combustion of fuel is more complete for Stage 2 mopeds compared to Stage 1 mopeds. This is in turn more complete than the combustion for conventional mopeds, as the latter ones emit relatively more VOC and CO and less CO_2 than the former ones.

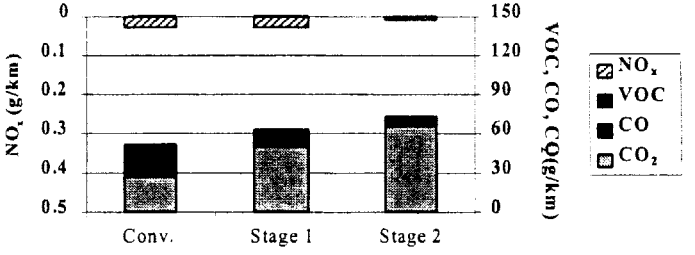

Figure 1: Emission factors for NO_x (left axis), CO, CO_2 and VOC (right axis) for different categories of mopeds

This applies also to motorcycles. The conversion of the fuel to CO_2 is more complete for motorcycles, complying with 97/24/EC compared to conventional ones, regardless whether they are driven by a two-stroke of a four-stroke engine, see Figure 2.

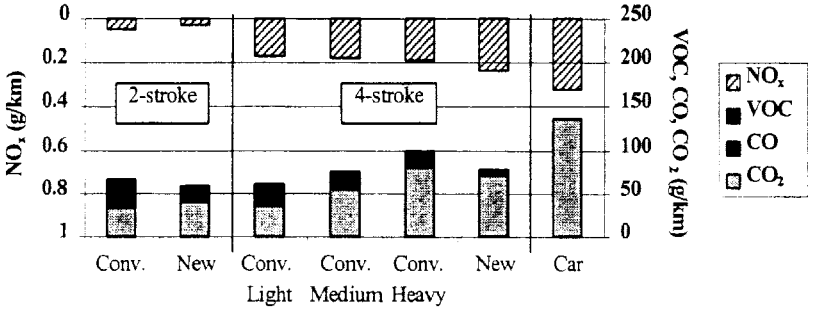

Figure 2: Emission factors for NO_x (left axis), CO, CO_2 and VOC (right axis) for different categories of motorcycles (New: complying with 97/24/EC – Light: <250cc, Medium: 250-750cc, Heavy: >750cc) and an Euro1 small petrol car at a speed of 51 km/h

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Figure 2 clearly demonstrates that motorcycles emit substantial amounts of CO and VOC, compared to an average small Euro1 petrol car.
The NO_x emissions of a four-stroke motorcycle are lower than those of a petrol car and in turn higher than those of a two-stroke motorcycle. This phenomenon is due to the high amount of residual burnt gas in the cylinders, acting as an internal exhaust gas recirculation.
An uncertainty interval for tail-pipe emission factors of 40% was assumed for mopeds and 15% for motorcycles.
Emissions factors for hot soak and diurnal breathing evaporative emissions are also given by MEET [3]. The emissions factors for extra emissions at a start were taken from EPA [7], as no factors could be found in a European source.
For particulate matter, N_2O and NH_3 are only indicative emission factors available [8, 9].

4 Results

Table 2 shows the calculated emissions of various pollutants and the fuel consumption of mopeds and motorcycles in Belgium in 2000.
The confidence intervals are a result of a combination of the confidence intervals of the number of vehicles, their activities and of the emission factors. No confidence interval was calculated on the emitted quantities of N_2O, NH_3 and PM_{10}, as only rough, indicative emission factors could be found.

Table 2: emissions and fuel consumption of mopeds and motorcycles in Belgium in 2000

		Mopeds	Motorcycle	Sum
Benzene	tonne	680 ± 50%	340 ± 50%	1,000 ± 50%
CH_4	tonne	1,000 ± 50%	520 ± 50%	1,500 ± 50%
CO	tonne	25,000 ± 35%	33,000 ± 40%	58,000 ± 38%
CO_2	ktonne	60 ± 40%	144 ± 40%	200 ± 40%
N_2O	tonne	9.2	8.9	18
NH_3	tonne	3.7	3.6	7.2
NMVOC	tonne	14,000 ± 50%	7,000 ± 50%	21,000 ± 50%
NO_x	tonne	53 ± 40%	360 ± 40%	420 ± 40%
Pb	kg	96 ± 50%	230 ± 50%	330 ± 50%
PM_{10}	tonne	74	210	290
SO_2	tonne	5.5 ± 50%	13 ± 50%	19 ± 50%
Toluene	tonne	1,800 ± 50%	900 ± 50%	2,700 ± 50%
VOC	tonne	15,000 ± 40%	7,500 ± 40%	22,000 ± 40%
Xylene	tonne	1,600 ± 50%	820 ± 50%	2,500 ± 50%
Fuel	TJ	860 ± 50%	860 ± 50%	2,900 ± 50%

The confidence intervals are very broad; for mopeds is this mainly due to the low accuracy of their number and of the emission factors, for motorcycles is this

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mainly a consequence of assumptions on the geographical distribution of the mileage and the composition of the fleet.

The figures in table 2 concern the emissions of the four types considered in this study. Figure 3 splits the VOC emissions of motorcycles up according to the type.

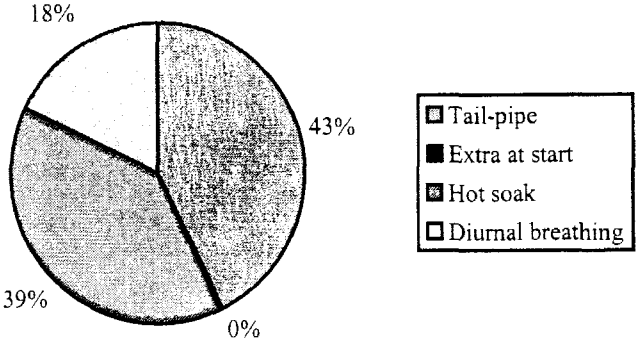

Figure 3: Contribution of every type of emission to the overall VOC emission by motorcycles in Belgium

The extra emissions at start can be neglected compared to the tail-pipe emissions. This is not the case for the hot soak and diurnal breathing emissions; according to the calculation results, they may account for more than half of the total VOC emissions.

However it is quite likely that the evaporative emissions are overestimated, as every stop was assumed to lead to a complete cooling of the motorcycle and as no seasonal influences were included into the calculation. Nevertheless figure 3 reminds us that evaporative emissions of powered two-wheelers should not be neglected.

The figures in table 2 were compared with national emission levels and fuel consumption. However, due to a lack of a national inventory of the emissions for the year 2000, these figures were compared, after correction for the number of mopeds and motorcycles, with the emitted quantities in Flanders for 1999 [10], see table 3.

Within the road transport sector, powered two-wheelers seem to be an important source of pollution, especially for CH_4, CO and NMVOC.

Even when compared to the total emissions of these pollutants in Flanders, table 3 reveals that mopeds and motorcycles account for about 7% of the CO (4-9%) and the NMVOC (3-10%) emissions. Hence, powered two-wheelers cannot longer be neglected as a source of these pollutants in Flanders or Belgium.

When the emissions of CH_4, CO, NMVOC and NO_x are weighted for their capacity to form ozone, the contribution of mopeds and motorcycles to the emission of ozone precursors by the road transport is 8.8% (4.8-13%) and by all sources in Flanders 3.7% (2.0-5.6%). The contribution to photochemical smog by mopeds and especially motorcycles might exceed the contribution to the

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emission of ozone precursors, as their activity in summertime is higher than in wintertime.

Table 3: Contribution of mopeds and motorcycles (M&M) to the emission and fuel consumption by road transport and to the total emission and fuel consumption in Flanders, Belgium in 1999

		M&M	Total road transport		Total Flanders	
		Emission	Emission	Contrib. M&M	Contrib. road trsp.	Contrib. M&M
CH_4	tonne	880	2,838	31%	1%	0.2%
CO	tonne	33,000	288,939	11%	58%	6.6%
CO_2	ktonne	120	14,633	0,8%	22%	0.2%
NMVOC	tonne	12,000	49,518	24%	28%	6.9%
NO_x	tonne	230	82,382	0.3%	53%	0.1%
SO_2	tonne	11	3,977	0.3%	3%	<0.1%
VOC	tonne	13,000	52,356	25%	10%	2.5%
Fuel	PJ	1.7	198.6	0.9%	22%	0.2%

The results from this study can be compared with those of the previous survey in Belgium [1], see table 4.

Table 4: Share of mopeds and motorcycles in the Belgian fleet of road transport vehicles and their contribution to the emission of CO and VOC by road transport in Belgium in 1999

	Number of vehicles	CO emission	VOC emission
1990	9.3%	5.5%	11%
1993	9.1%	7.0%	13%
1999	11%	11%	25%

The CO and VOC emission of mopeds and motorcycles have increased with 60%, resp. 70%, in absolute figures from 1990 to 1999. The contribution of these vehicles to the road transport emissions however has doubled and has risen more than their share in the national fleet of road transport vehicles. This is not because powered two-wheelers nowadays are more polluting than ten years ago, but because cars and trucks became much cleaner under pressure of various European directives, which came into force at the beginning of the nineties.
Mopeds and motorcycles did however not escape the European Commission's notice completely, but the emission standards they have to meet only came into force at the end of the nineties. One might hence expect that, unless the number of powered two-wheelers continues to grow, the contribution of these vehicles to the pollution of road transport would drop in future.

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5 Noise pollution

Motorcycles and especially mopeds are a known source of noise pollution. A Dutch survey revealed that mopeds are the most predominant source of annoyance and disturbed sleep. Motorcycles occupy the third place with regard to annoyance and the eighth with regard to sleep disturbance [11]. Similar results might be expected for Belgium.
However, a literature research failed in providing noise emission factors. Only rough noise emission levels for motorcycles could be traced, indicating that an average motorcycle is almost twice as loud as an average car and almost as loud as an average lorry [12]. As a consequence, the noise impact of mopeds and motorcycles could not be assessed. Further research is hence needed to fill the gap.

6 Conclusion

In this paper we have presented estimates of the emissions of mopeds and motorcycles in Belgium.
A lot of information regarding these vehicles is missing and if some data can be found, it often lacks accuracy. Most striking among the gaps in knowledge is the unknown number of mopeds in Belgium. Also the lack of detail regarding the composition of the fleet of mopeds and motorcycles was hampering this study.
Further research is needed to provide emission factors with a higher degree of accuracy than present. Attention should first be addressed to evaporative emissions.
Despite these shortcomings, this study revealed that mopeds and motorcycles should no longer be neglected as an important source of CO and NMVOC pollution, as they contribute about 7% to the overall emission levels in Flanders, Belgium. When the emissions are weighted to their capacity to form ozone, mopeds and motorcycles contribute about 3.7% to the overall emission level.
According to the calculation results, more than half of the VOC emitted originates from evaporative emissions, both of hot soak emissions and of diurnal breathing emissions. This might be an overestimation, but highlights that this type of emission should not be overlooked.
Mopeds and motorcycles emitted about 60 to 70% more CO and NMVOC in 1999 than in 1990, but their contribution to the emission by road transport has doubled. This is a result of the emission reduction strategy implemented on passenger cars and trucks since the beginning of the previous decade. European directives, aiming at reducing emissions of powered two-wheelers, only came into force at the end of the nineties.
This study also attempted to quantify the noise impacts of mopeds and motorcycles, but failed due to a lack of data. This is striking as, in other countries, mopeds - and motorcycles to a lesser extent - are recognized as the most predominant source of annoyance and sleep disturbance. Further research is hence needed.

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