U.P.B. Sci. Bull., Series D, Vol. 74, Iss. 4, 2012 ISSN 1454-2358

SOME CONSIDERATIONS ON PARTICULATE GENERATED BY TRAFFIC

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În această lucrare, sunt prezentate tendințele emisiilor de particule pentru o regiune italiană punându-se accent pe sectorul de trafic. Au fost evaluate trei scenarii diferite, presupunând strategii diferite pentru evoluția flotei de vehicule. Rezultatele demonstrează că strategiile de modernizare a motorului (sustituind vehiculele vechi) ar trebui să fie o prioritate. În acest mod, avantajele ar fi legate de scăderea de precursori de particule secundare (în special datorită introducerii vehiculelor Euro 6).

In this paper, particulate emission trends are presented related to an Italian region and focused on the sector of traffic. Three different scenarios were assessed supposing different strategies for the vehicles fleet evolution. Results demonstrate that strategies for engine modernization (old vehicle substitution) should be a priority. To this concern, additional advantages would be related to the decrease of precursors of secondary particulate (in particular thanks to the introduction of Euro 6 vehicles).

Keywords: engine, PM_{10}, secondary particulate, traffic, vehicle.

1. Introduction

Air pollution generated by vehicles has negative effects not only on human health, but the emissions of harmful substances affect negatively and in a heavy manner climate changes, with the emission of greenhouse gases [1]. Air pollution generated by vehicles can also damage historical and artistic properties and the landscape. After the Kyoto protocol (2005) it is important to highlight some data that show the incidence of traffic emissions on global environmental aspects. The EU proposed that the emissions from the transport sector must be dropped by 50-70 per cent by 2050.

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In Italy, about 180 million of tons of greenhouse gas are related to the transportation system: road, air and rail [2]. About 27% of the energy generated in Italy is used for the transportation system and this percentage is doomed to increase in the next decade due to the increase of passengers and merchandises mobility demand. Less than 90% of energy consumption regarding the transportation sector is absorbed by road mobility network, about 6% by the aerial sector and about 3% by the railway sector. Significant data is related to the road transportation since 90s: in Italy 82% of people travels on road (in 1960 it was about 47%) and more than 85% of total amount of merchandises travels on road, including dangerous substances [3]. Most of the polluting substances generated by traffic are identified as greenhouse gas, as products responsible for air pollution and able to generate climate exchanges. Significant decreases of pollution by traffic could generate a reduction of greenhouse gas. Considering that the emission factors reach the maximum value in the metropolitan centres, it is important to underline that air pollutant concentration is mainly due to carbon monoxide, nitrogen dioxide, benzene and PM_{10} (dust). The concentrations of these pollutants increase in winter season due to the civil heating systems and unfavorable meteorological conditions, but in the warm months, 80% of these gases are generated by traffic [4, 5 and 6].

The PM particles are generally composed by a mixture of elements as: carbon (organic and inorganic), fibres, silica, metals (iron, copper, lead, nickel, cadmium etc.), nitrates, sulphates, organic compounds (hydrocarbons, organic acids, Aromatic Polycyclic Hydrocarbons), inert material (soil fragments, spores, pollen etc.) and liquid particles. These particles are divided in:

- large dimension particles: diameter higher than 10 µm;
- small dimension particles (PM_{10}): diameter between 2.5 µm and 10 µm;
- very small particles ($PM_{2.5}$): diameter lower than 2.5 µm.

In general, the large dimension particles are generated by natural sources (not controlled combustions, soil erosion, pollen, spores etc.); the small dimension particles are generated by human sources. The particles generated by human sources are mainly from vehicles traffic and domestic heating plants.

The European Regulations, the directive 98/70/CE and the directive 1999/39/EC established the measures to be adopted with the aim of a significant decrease of air pollution generated by motor vehicles (continuous reduction of the sulphur content in the fuels). The first consequence of the implementation of the directives has been the definition of new fuels specification, particularly regarding their chemical composition. In order to meet these new fuels specifications, the EU refineries have modified some production units with the aim to improve the desulphurization capacity and to obtain a significant reduction of the aromatic content in gasoline. In particular the purpose was to obtain:

- the sulphur content reduction (in weight) in diesel: down to 50 ppm by 2005, and 10 ppm by the 1st of January 2009, both achieved results;

- aromatic maximum content in gasoline: 35% (in volume) by 2005 - achieved result.

The effect of these prevention strategies can be seen in the data present in the Lombardy inventory [7]. In 2009, SO_2 emissions in Lombardy were assessed to be about 55,000 t/year. This emission resulted from the following sources: energy production and fuel transformation (56%), followed by industrial combustion (20%), road transportation (only 6%), non-industrial combustion (7%), production process (6%) and other mobile and machineries sources (4%).

Nowadays, gasoline and diesel are obtained by a mixture of different compounds, with the aim to guarantee a good level of quality in terms of octane number, density and volatility. These components have variable sulphur contents, between 0 ppm and 25,000 ppm. Only the components with a high sulphur content need a further desulphurization, in order to obtain, after the mixture with no sulphur components, a final product with 10 ppm of residual sulphur content.

As other air pollutants, the sulphur dioxide reacts producing particulate material, that successively moves itself or it is removed by rain or other transformation processes. Furthermore, sulphur dioxide is one of the gas sources for the formation of secondary air dust, in particular with fine dimensions as PM_{10} and $PM_{2.5}$.

Taking into account all these considerations, in this paper the particulate trend is presented related to the Italian Lombardy region. Three different scenarios were assessed supposing different strategies for the vehicles fleet evolution.

2. Materials and methods

Lombardy is the most important region in Italy under economic and demographic point of view, located in the northern part of the Country. In the recent Lombardy Report on environment state of Regional Environmental Protection Agency (ARPA), air pollutant yearly emissions are about 76,000 t_{SOx}, 220,000 t_{NOx}, 311,000 t_{COVNM}, 97,700 t_{NH3} and 21,500 t_{PM10}. Air pollutants can originate from human or nature sources, with variable contributions in function of the single pollutant.

Table 1 summarizes the contributions of each air pollutant in Lombardy, focusing the attention on the road transportation contribution [8] related to people cars (PCs). Table 2 presents the dynamics of the composition of the fleet of vehicles in the Lombardy region taking into account: cars, motorbikes, bus, vehicles for good transportation, special vehicles, tractors etc. [8].

The role of the diesel quality for not heating is very important, in order to obtain a decrease of air pollution in Lombardy. A better diesel fuel means a significant decrease of SOx, NOx and PM_{10}. It is important to highlight that actually 70% of cars are diesel, while in the year 1997 they were only the 10% of the total amount. If today the percentage of diesel cars should be 10%, less than 1,000 tons per year of PM_{10} could be generated.

Table 1

Characterization of the vehicle fleet for the study area, in terms of emission standards and fuel type (only PCs)

Fuel Type	Emission Standards						Total
	pre-EURO 1	EURO 1	EURO 2	EURO 3	EURO 4	EURO 5	
Gasoline	16,046	10,879	40,839	27,999	60,655	3,848	160,266
LPG	1,093	641	1,842	1,173	8,888	275	13,912
Methane	68	73	204	220	1,336	183	2,084
Gas Oil	2,523	1,657	16,441	42,249	57,368	5,287	125,499
Total	19,730	13,250	59,296	71,641	128,247	9,593	301,757

Table 2

Vehicular fleet in Lombardy

Year	Cars	Motorbikes	Bus	Goods transportation	Special vehicles	Tractors and others	Car per 1000 inh.
2004	5,470,480	722,125	10,824	625,546	189,416	21,486	583
2005	5,551,622	770,348	11,202	643,799	194,223	21,677	587
2006	5,620,891	813,926	11,178	656,781	198,681	21,951	589
2007	5,649,691	852,758	11,210	664,278	202,427	22,253	586
2008	5,708,432	886,421	11,403	674,539	207,369	23,058	586
2009	5,739,228	921,340	11,485	666,666	123,653	23,172	584

Referring to the vehicular fleet, three scenarios were taken into account:

- ***the first scenario,*** extremely optimistic: it was supposed that the vehicular fleet changes from the current classes to the two highest quality classes (50% Euro 5 and 50% Euro 6). The considered vehicles were cars, motorbikes, heavy and light freights. For the other vehicle typology an optimistic percentage referred to the highest classes was hypothesized.
- ***the second scenario,*** supposed to maintain the current classes, with the exception for Euro 0 and Euro 1 only for cars, considered extinct in the next future.
- ***the third scenario,*** referred to two different trends: it took into account the trend of vehicle number increase considering data registered in the years from 2004 to 2009 and upgrading the trend regarding the vehicle Euro classes until 2015.

For the development of the research regarding the emission of particulate, the COPERT 4 - *Computer Programme to calculate Emissions from Road Traffic* [9] was used for the classification of the vehicles in different classes of quality.

In Europe, the COPERT methodology is commonly used for evaluating traffic contribution to the national emission inventory, as suggested in the EMEP-Corinair project [10]. The methodology has been used both for high spatial resolution and multipurpose emission model [11] and for emission scenario estimates [12]. According to this methodology, traffic emissions are the sum of four terms:

$$E_{tot} = E_{hot} + E_{cold} + E_{evaporative} + E_{abrasion} \quad (1)$$

where E_{tot} = total emissions; E_{hot} =emissions during stabilized engine operation, E_{cold} = emissions during transient thermal engine operation (water temperature less than 70°C); $E_{evaporative}$ = emissions from fuel evaporation, relevant only for NMVOC species from gasoline powered vehicles; $E_{abrasion}$ = particulate emissions from abrasion of mechanical parts, like brakes, tyres and road pavement.

In Table 3, the Lombardy situation in 2009 is presented concerning the vehicle fleet.

Table 3

Vehicle fleet in Lombardy (2009) referred to the Copert classification

	Euro 0	Euro 1	Euro 2	Euro 3	Euro 4	Euro 5
Cars	484,554	243,480	1,069,255	1,341,131	2,449,633	218,190
	8 %	**4 %**	**18 %**	**23 %**	**43 %**	**4 %**
heavy freight	32,657	7,625	19,072	23,613	11,399	3,945
	33 %	**8 %**	**19 %**	**24 %**	**12 %**	**4%**
light freight	71,230	47,373	11,5956	194,821	176,093	12,375
	12 %	**7 %**	**19 %**	**32 %**	**28 %**	**2 %**
motorbikes	379,459	153,219	179,183	239,682	-	-
	40 %	**16 %**	**19 %**	**25 %**	-	-

3. Results and discussion

In Table 4, the situation taking into account the hypothesis for the three scenarios for the Lombardy case is presented.

Table 4

Vehicle fleet in Lombardy referred to scenario 1

		Euro0	Euro1	Euro2	Euro3	Euro4	Euro5	Euro6
Sc. 1	cars	-	-	-	-	-	30,47,100	3,047,100
		-	-	-	-	-	**50 %**	**50 %**
Sc. 2		-	-	1,279,782	1,584,492	2,925,216	365,652	-
		-	-	**21 %**	**26 %**	**47 %**	**6 %**	-
Sc. 3		-	-	780,120	1,251,250	3,301,650	414,860	346,320
		-	-	**13 %**	**21 %**	**54 %**	**7 %**	**5 %**
Sc. 1	heavy freight	-	-	157,362	26,228	36,718	26,228	-
		-	**-**	**15 %**	**25 %**	**35 %**	**25 %**	-
Sc. 2		34,620	8,393	19,932	25,178	12,589	4,196	-
		33 %	**8 %**	**19 %**	**24 %**	**12 %**	**4%**	-
Sc. 3		20,570	7,128	15,480	20,140	27,120	14,470	-
		20 %	**7 %**	**15 %**	**19 %**	**25 %**	**14 %**	-

Sc. 1	light freight	-	-	9,907	16,511	23,116	16,511	-
		-	-	**15 %**	**25 %**	**35%**	**25 %**	-
Sc. 2		7,925	4,623	12,548	29,474	18,493	1,321	-
		12 %	**7 %**	**19 %**	**32 %**	**28 %**	**2 %**	-
Sc. 3		52,650	30,350	80,180	93,040	33,1670	72,155	-
		8 %	**5 %**	**12 %**	**14 %**	**50 %**	**11 %**	-
Sc. 1	motor -bikes	-	-	607,822	607,822	-	-	-
		-	-	**50 %**	**50 %**	-	-	-
Sc. 2		486,258	194,503	230,972	303,911	-	-	-
		40 %	**16 %**	**19 %**	**25 %**	**-**	**-**	**-**
Sc. 3		342,690	130,120	179,310	563,525	-	-	-
		28 %	**11 %**	**15 %**	**46 %**	-	-	-

In Fig. 1, the total emission of particulate matter from the Lombardy vehicle fleet is presented for the three scenarios. The reported graphs have to be considered evaluating the cumulated effects connected to the four typology of vehicles. Obviously, the variation of vehicular fleet influences in a different way depending on the vehicular typology (cars, motorbikes heavy and light freights).

These results point out that the sector of traffic has a significant potential role in particulate reduction. That explains why in Italy environmental incentives for old vehicle substitution are present since years. Data in Fig. 1 refers to direct emission of PM_{10} but it must taken into account that the evolution of the engines gives favourable balances also for secondary particulate as the emission of precursors is reduced. To this concern, an important contribution is expected from Euro6 as they will allow a significant decrease of NO_x emissions.

4. Conclusions

The information available in regions like Lombardy allows detailed analyses of the role of specific pollutant sources. In the present paper, the analysis focused on the role of PM_{10} and traffic. The developed scenarios pointed out that the evolution of the engines (referred to their environmental performances) opens to significant decreases in the primary emissions of PM_{10} from vehicles. This result has important effects also on the generation of secondary particulate as the highest classes of engines guarantee, and a reduction in the emissions of particulate precursors. The considered operative scenarios regard different hypotheses on the vehicle fleet. Different scenarios have been hypothesized considering an optimistic prevision (best scenario) forecasting the best quality of vehicular fleet by year 2015.

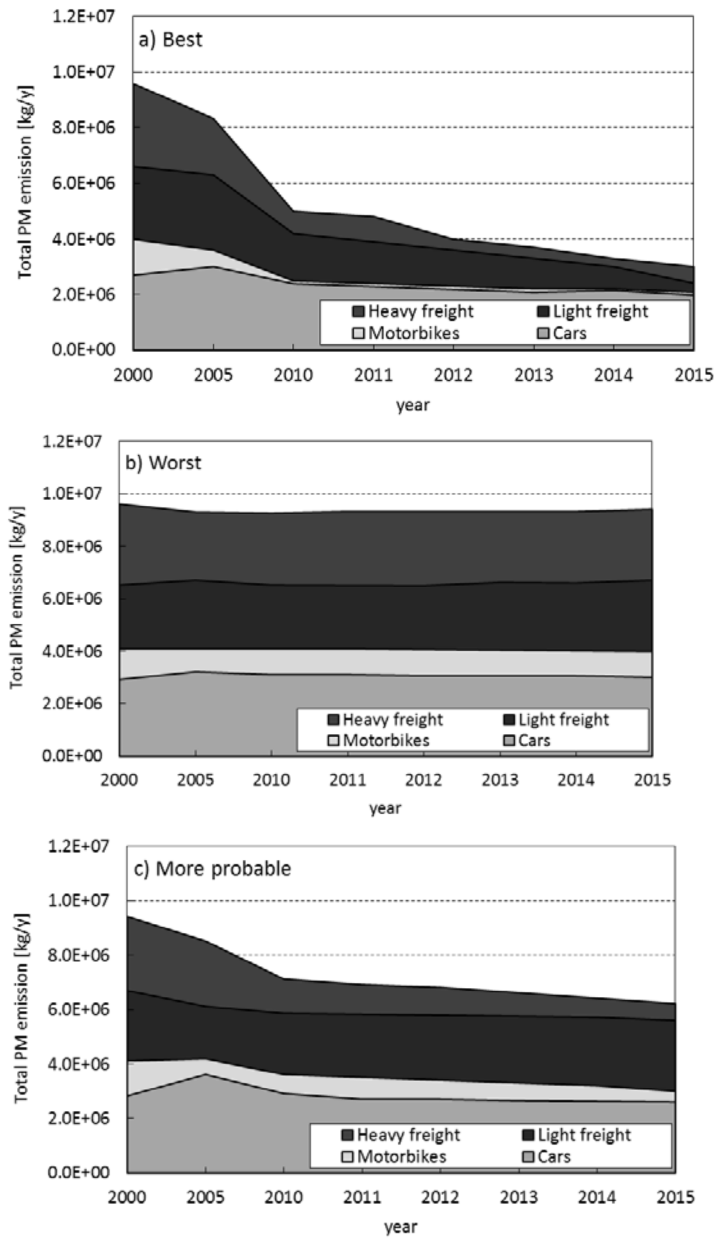

Fig. 1. Total emission of particulate matter from the Lombardy vehicles fleet assessed for the three scenarios.

The second scenario (worst scenario) is the pessimistic one, because it considers the maintenance of the current quality of the vehicular fleet with any improvement. The more probable considers the actual trend of improving of the quality of the vehicle fleet.

The work shows that road traffic emissions of PM_{10} are expected to decrease in the period 2010-2015, with a considerable reduction in the optimistic scenario with a fast vehicle turnover and a decrease in fuel usage. Increase in fuel consumption could substantially lower the emission reduction expected, off-setting a substantial part of the new technology benefits. The progressive introduction of DPF (Diesel Particulate Filter) vehicles will determine a reduction of PM_{10} exhaust, however this could potentially be stalled by the increase in diesel usage in the vehicle fleet.

The advantages of traffic pollutants reduction are related also to the height of the emission: typically vehicles emit at ground level causing a potentially high human exposure to pollutants.

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