Vehicle emission of greenhouse gases in municipality solid waste collecting and handling

Mishko Djidrov [1, a], Dejan Mirakovski [1, b], Simeon Simeonov [1, c]

[1] *Faculty of Mechanical engineering, Goce Delcev University, Stip, Macedonia*

misko.dzidrov@ugd.edu.mk [a], dejan.mirakovski@ugd.edu.mk [b], simeon.simeonov@ugd.edu.mk [c]

Abstract: Motor vehicles pollution has become an issue because of the steady increase from both, the number of vehicles in use and the distance travelled by each vehicle every year. Throughout the last 50 years, mobile sources of fossil fuel combustion have become the major threat to air quality around the world. The main polluting emissions coming from vehicles are: carbon monoxide (CO), NO_x, hydrocarbons (HC) and particles. In this research we will discuss and present a way of calculating the vehicle emissions of greenhouse gasses (GHG) in municipality solid waste (MSW) collecting and handling processes.

Keywords: Vehicles emission, pollution, calculation, heavy duty vehicles

Introduction

Motor vehicles pollution has become an issue because of the steady increase in both the number of vehicles that are in use and the travelled distance by each vehicle each year. Looking at the data we can see that since 1960s, the total number of motor vehicles in the world has been growing faster than the total world population. For example in 1950 there were 50 million cars and 3.5 billion people, but now there are more than 650 m cars and more than 6 billion people in the world. The global production is more than 45 million cars per year and it is estimated that by year 2020 there will be a billion cars. The rate of net growth for all motor vehicles is now around 5%, where the population growth rate is only 1 to 2%.

In Macedonia there is a constant increase in the number of motor vehicles as shown in **Figure 1**. As a consequence to this, the use of motor vehicles now generates more air pollution than any other single human activity, not just in Macedonia, but all around the world. Motor vehicles pollution represent the fastest-growing source of CO_2, and in the urban areas it accounts for the bulk of emissions of CO, HC and NO_x. The

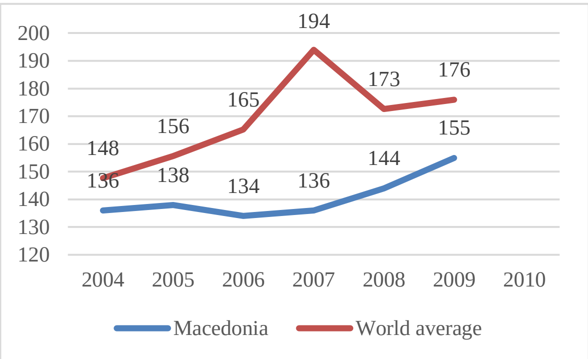

Figure 1 Motor vehicles (per 1,000 people) in the World and Macedonia
Source: World Bank

concentration of both people and vehicles is greater in the urban areas, where also the emission densities per unit area are the highest and the dispersion conditions is the worst.

Motor vehicle emissions

In the 50 years, the mobile sources have taken the position of a major threat to air quality around the world, where the static combustion of fossil fuel has become less of a threat to the air quality. There are four main polluting emissions from motor vehicles: carbon monoxide (CO), NO_x, hydrocarbons (HC) and particles.

There are a number of factors that affect the rate at which any vehicle emits air pollutants. Some of the most important are:

- Vehicle type (passenger cars, light-duty trucks, heavy-duty trucks, urban and school buses, motorcycles);
- Vehicle age and accumulated driven distance;
- Fuel used (gasoline, diesel, others);
- Ambient weather conditions (temperature, precipitation, wind);
- Maintenance condition of the vehicle;
- Type of driving (e.g., long driving at highway speeds, stop-and-go urban driving, urban mixed driving)

Both petrol and diesel engines, and both complete and incomplete combustion of the fuel generates a complex mixture of gases and particulate pollutants, where many of them are harmful to human health. Emission concentrations generated by non-catalysed petrol engine and a diesel engine are indicated in Table 1. From the table we can see that the concentrations are very sensitive to how the engine operates.

Fuel and pollutant	Emissions (ppm by volume in the exhaust)			
	Idling	Accelerating	Cruising	Decelerating
Petrol				
CO	69 000	29 000	27 000	39 000
HC	5 300	1 600	1 000	10 000
NOx	30	1 020	650	20
Diesel				
CO	trace	1 000	trace	trace
HC	400	200	100	300
NOx	60	350	240	30

Table 1 Emission concentrations sensitivity to the engine operation

Calculating

There are many practical issues that have to be considered when calculating potential emissions for a given length of road and a given vehicle. The total rate of emission for sure will vary, not only in the obvious factors such as traffic density (flow rate in vehicles per hour), vehicle speed, driving mode (shown in Table 1: accelerating, decelerating, cruising or idling), and engine types (petrol or diesel or other), but also the less obvious factors such as engine maintenance, air temperature and humidity and engine operating temperature can vary as well.

In order to calculate the magnitude of quantities of vehicle emissions and to get a general idea of how significant they are compared to other factors, we can say that combustion of 1L of fuel generates 100g CO, 20g VOC, 30g NOx and 2.5kg CO_2, plus smaller quantities of sulphur oxides, lead and fine particles. If we use this estimation on a single vehicle with 16 000 km driven per year with fuel consumption of 16 km l1, hence using 1000 l of fuel. This single vehicle will generate the emissions as shown in Table 2, where we assume that there are no emission controls. Although this is not precise calculation and it ignores the factors such as different vehicle types and different driving patterns, it does show how serious vehicle emissions are on a global scale.

Pollutant	Per litre of fuel/g	Single car / kg per year	Global fleet / Mt per year
CO	100	100	60
VOC	20	20	12
NOx	30	30	18
CO2	2 500	2 500	1 500

Table 2 Generation of emissions per litre, per single car and global

Talking about the heavy duty vehicles (HDVs) we can say that they are almost entirely diesel-fuelled. Far fewer emission data is available for them and what is available is mostly from engine test beds where the engine alone, rather than the complete vehicle, is studied. The MEET Report (Methodology for Calculating Transport Emissions and Energy Consumption by European Commission) recommended that emissions from HDVs can be described by this general function:

$$E = K + aV + bV^2 + cV^3 + \frac{d}{V} + \frac{e}{V^2} + \frac{f}{V^3}$$

Where E is the emission rate in g km^{-1}, K is a constant, a–f are coefficients, V is the mean speed of the vehicle in km h^{-1}.

Deferent researchers and even some countries[1] have used the discussed relationship to analyse the HDVs emissions and from their results we can see that as the speed increases, emissions per km generally decrease. The decrease in emissions of PM_{10} (particles on the order of ~10 micrometres or less) and VOC (Volatile organic compounds) is very clear. Oppositely there is a sharp increase in these emissions when traffic slows down. For example, a vehicle might emit 10 times the weight of CO and 7 times the weight of VOC when dragging in the

[1] NAEI - UK National Atmospheric Emissions Inventory database of emission factor

traffic with 1 km at 10 km h^{-1} compared with the same distance covered with speed of 60 km h^{-1}. If the vehicle speeds increases above 60–80 km h^{-1}, emissions again start to rise.

Table 3 presents emission rates for petrol and diesel fueled HDVs from another research[2] where the overall average emission factors presented for each category are weighted to account for the distribution of vehicles across the different weight classes. Here THC stands for Total hydrocarbons including methane, $PM_{2.5}$ for particulate matter under 2.5 microns diameter, sometimes referred to "fine particulate".

Pollutant	HDV petrol	HDV diesel
VOC	1.586	0.447
THC	1.635	0.453
CO	13.130	2.311
NOx	2.914	8.613
$PM_{2.5}$	0.044	0.202
PM_{10}	0.051	0.219

Table 3 Average In-Use Emission Rates for Heavy-Duty Vehicles (in grams per mile)

Conclusion

It is clear from the above discussion that accurate prediction of the emissions from a fleet of vehicles in an urban area, especially HDVs, requires a very high level of detailed information. As we said there is a lack of data for HDVs emissions and we cannot neglect this kind of pollution since it is the one that is affecting the human health at the most. We must know not only the flow rate and mix of vehicles (the engine type and size, and years of legislation in which they were manufactured), but also their engine operating temperatures, speeds and acceleration modes. If these parameters are not known for a particular situation, then we can use default values from researchers and national average statistics to determine the overall emission.

Reference list

[1] Average In-Use Emissions from Heavy-Duty Trucks, 2008, U.S. Environmental Protection Agency (EPA);

[2] Jeremy Colls, 2002, Air Pollution, Measurement, modelling and mitigation, Third edition, Mobile sources;

[3] World bank, (worldbank.org), Information on Motor vehicles (per 1,000 people) [accessed 10.08.2013]

[2] EPA - U.S. Environmental Protection Agency