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# ROAD VEHICLE AS A SOURCE OF NON-EXHAUST PARTICULATE MATTER

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**Abstract:** A vehicle represents a set of different parts and systems that can adversely affect the environment by its wear. The wear effects are reflected in the formation of suspended particles with different diameters. Suspended particles can significantly affect human health, knowing that people can inhale them. The aim of this paper is to identify, based on available literature and own research, the most influential systems and elements on the vehicle that are the source of particles (Particulate matter), but which are not generated by combustion in the engine, so-called non-exhaust particles. This overview of the most influential elements in the creation of non-exhaust particles is of importance for further investigation of the influence of particular systems on the vehicle as sources of non-exhaust particles and further development of certain parts of the vehicle for the smallest environmental pollution.
**Keywords:** Non-exhaust, particulate, matter, vehicle

## INTRODUCTION

The formation of particles is one of the negative phenomena that can be created by different sources, but it can certainly affect human health equally. Suspended particles are particles of very small dimensions that can be of different compositions, but mainly fractions of various harmful substances and heavy metals.

Particle sources can be different, but can generally be divided into two basic categories, namely stationary sources and non-stationary sources. Bearing in mind the topic of work in this case, only the vehicle is seen as an unsteady source of suspended particles, and particles that do not result from combustion in the engine, or those resulting from the wearing of different parts of the vehicle.

On the basis of the available literature in this paper, the analysis of the formation of particles that do not result from combustion in the engine, as well as the fractions that occur in this way, and certainly the extent to which the particles can affect human health are analyzed. The particles that can be formed are particles produced by the wearing of system elements such as the braking system, coupling, tire, re-suspending the particles from the road.

## INFLUENCE OF PARTICLES METTER ON HUMANS HEALTH AND VEHICLES AS A SOURCE OF PARTICULATE METTER

Particles generated by the vehicle represent highly harmful substances that have a significant effect on human health. Of course, it is important to note that the effect of particles on human health is above all its diameter.

The particles that are formed are generally those smaller than 10 μm ($PM_{10}$) or smaller particles with a diameter of 2.5 μm or less ($PM_{2.5}$). Particles less than 10 μm in diameter are the biggest problems, because they can penetrate deep into your lungs, and some can even enter the human bloodstream. Exposure to such particles can affect both the lungs and the cardiovascular system [1].

In long-term exposure to fine particles, studies conducted in the United States have shown that an increase in $PM_{2.5}$ concentration of 10 μg/m$^3$ results in a 6% increase in all types of health risks, 9% of cardiopulmonary risks and 14% increase in lung tumor risk.

Scientists in Canada and the United States have found that long-term exposure to $PM_{2.5}$ significantly increases not only chances for cardiopulmonary problems, but also mortality from lung cancer. Moreover, the 7-year study (2000 to 2007) in the United States showed that the average life expectancy was extended by 0.35 years for every 10 μg/m$^3$ of $PM_{2.5}$ reduction [2].

After research by 29 European countries, it was found that mortality from respiratory damage increased by 0.58% for every 10 μg/m$^3$ increase in $PM_{10}$. It has recently been reported that the incidence of respiratory illnesses increased by 2.07%, while the hospitalization rate accordingly increased by 8%, when the daily $PM_{2.5}$ was increased by 10 μg/m$^3$. This study also found that elevated particulate air pollutants are directly related to more severe symptoms of respiratory tract disease, impaired lung function, and increased morbidity and mortality from cardiopulmonary diseases. In addition, this correlation was more evident in older people, pregnant women, adolescents, babies, patients with a history of cardiopulmonary problems and other sensitive populations [3].

Vehicle or traffic is certainly one of the particulate sources as one complex system can create particles in two basic ways by combustion in the engine or on the other by wearing some elements of the system on a motor vehicle. Figure 1 shows an overview of the total emission of harmful substances that have an impact on the environment, where exactly the system or element emits different types of harmful substances.

It is noticeable that the suspended particles are emitted by the road (dust, etc.), by combustion in the engine, by wearing various parts of the vehicle such as pneumatic,

brake or coupling [4]. In the continuation of this paper, only particles not generated by combustion in the engine, or only non-exhaust particles, as well as comparison with those resulting from combustion in the engine will be emphasized.

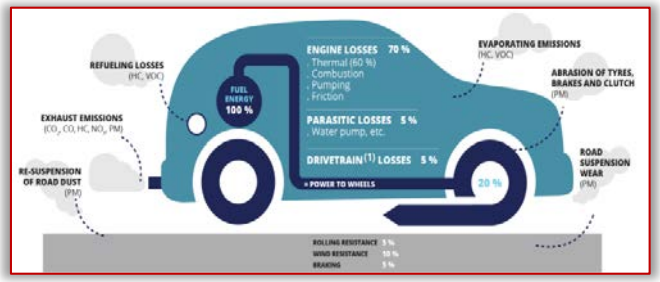


Figure 1. Sources of particulate matter on vehicle [4]

## SOURCES OF NON-EXHAUST PARTICULATE METTER ON THE VEHICLE

Non-exhaust particles belong to particles that do not occur in combustion in the engine, but by wearing different elements on the vehicle. Most often, as the emitter of these particles, and when it comes to vehicles, they represent a braking system, a coupling, a tire, etc.

In addition, there may also be some elements on a motor such as nails that represent the connection between the different systems on the engine. Since there are various sources on the vehicle, they produce different particle sizes, and each of the systems can produce different particle sizes depending on the driving mode, driving mode depending on the road, etc. On the other side, the road can be one of the sources of non-exhaust particles that also re-suspend dust from the road. According to source [5], the largest emitter of these particles is a braking system or better sad wearing braking systems, tire wear and eventually the road. The largest number of particles produced in this way is in the range between 1 and 10 μm, as shown in Figure 2.

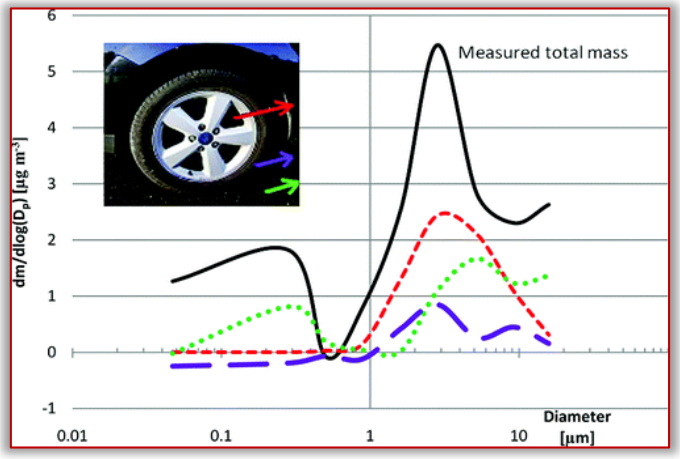


Figure 2. Size distribution of the particles measured, where are: The red line shows brake wear, the purple line shows tire wear, and the green line shows resuspension [5]

One study according to [6] showed that the difference between the electric motor and internal combustion engines does not have significant differences in $PM_{10}$ emissions. A study by a team from the University of Edinburgh and independent engineering company INNAS BV found that, when taking into account additional weight factors for electric vehicles and suspended non-combustion sources, the total emissions of $PM_{10}$ from electric vehicles (EV) are the same modern internal combustion engine. The sources of the formation of these suspended particles in this case include wearing tires, wearing brakes, wearing road surfaces and dust that is on the road and re-raising it. For the emission of suspended particles PM2.5, electric vehicles are a source that only generates a negligible reduction in emissions of this type of particles. Compared to the average IC engine that burns petrol EV (electric vehicles), they emit 3% less $PM_{2.5}$. Compared to the average IC engine used as propellant fuel, EV emits 1% less $PM_{2.5}$. Thus, according to this source, the use of electric vehicles would not result in a significant reduction in PM2.5 particulate emissions compared to internal combustion engines. According to these sources, with the increase in the mass of the vehicle, the number of these particles increases.

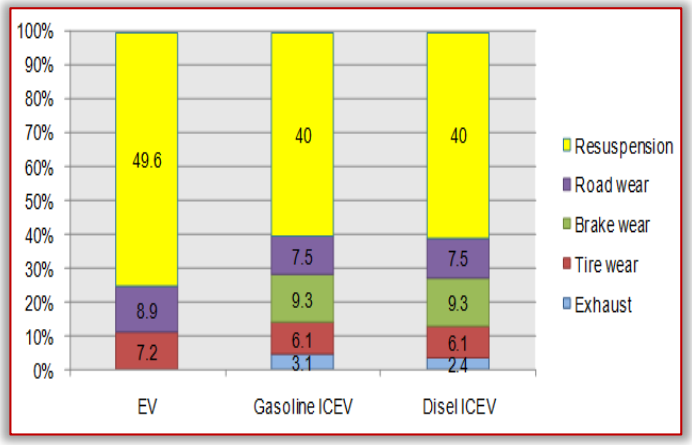


Figure 3. Comparative analysis of the formation of particles $PM_{10}$ depending on the drive of the vehicle and their mass [6]

According to the research [7] carried out in Portugal, the main sources of $PM_{10}$ have been identified, where different categories of vehicles were compared to the way these particles were formed, and the sources of suspended particles on vehicles were analyzed. In this study, four types of vehicles were analyzed: light commercial vehicles (diesel fuel and gasoline), heavy duty diesel vehicles, buses and motorcycles.

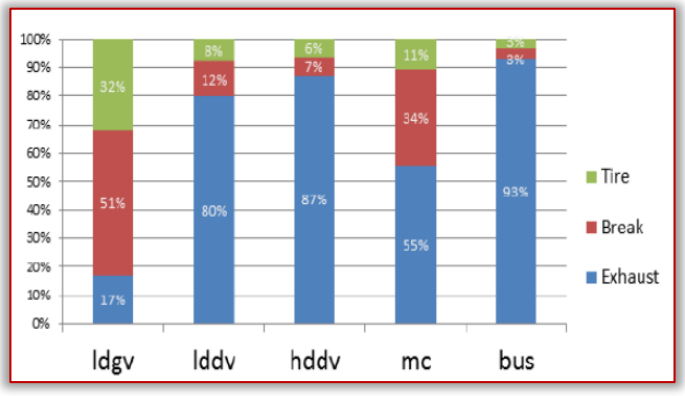


Figure 4. Exhaust and non-exhaust traffic contribution to $PM_{10}$ concentration (%) [7]

The measurement included more than 10,000 vehicles of different categories. According to this study, three types of particles are analyzed, those generated by the engine, brakes, but also by tire wear along the road. Based on the studies in Figure 4, a diagram is given showing the differences in the formation of different $PM_{10}$ particles depending on the vehicle category.

According to the source [8], particle analysis of $PM_{10}$ particles and when all the sources on the vehicle that can emit suspended particles are obtained, the results are shown in Figure 5. According to this study, the $PM_{10}$ most suspended $PM_{10}$ particulate matter is diesel engines, while in the case of particles which do not result from combustion, the biggest source of emissions is the way in which tire wear on the road surface can also be considered.

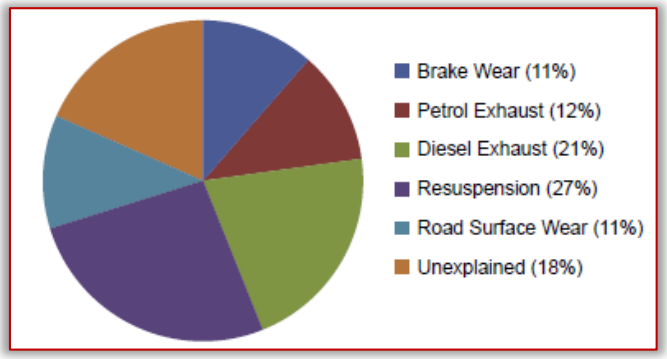


Figure 5. Percentage distribution of particle formation $PM_{10}$ depending on the mode of production by vehicles [8]

Based on the source [9], the tracking and investigation of the formation of particles by the vehicle resulted in the data shown in Figure 6. In this study, which was conducted in 24 countries of Europe, and in order to determine the influence of the particles $PM_{10}$ and $PM_{2.5}$ by the system for braking and pneumatics, but also the wear and tear of the road, which are caused by the abrasion of the road surface.

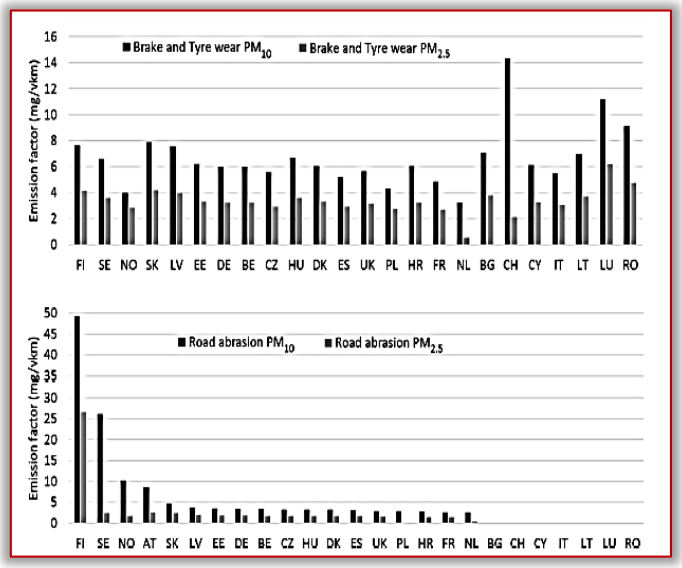


Figure 6. Calculated implied emission factors for $PM_{10}$ and $PM_{2.5}$ for brake and tire wear (top) and for road abrasion (bottom) for European countries [9]

The problem is that some of the countries have not submitted a report on the amount of particles caused by road wear, but there are definitely data related to the formation of particles by wearing brakes and tires. Some of these countries may have included road abrasion emissions under brake and tire wear. Figure 6 shows the obtained results of the measurement of the emission of the resulting particles. It is noticeable that the biggest $PM_{10}$ particulate emissions are due to brake wear and tire measurement in Switzerland, while the highest emissions of $PM_{10}$ particles produced by brake wear and pneumatic measurement in Luxembourg.

## CONCLUSION

Traffic or vehicle as part of traffic is one of the sources that certainly have an impact on the formation of particles, of different sizes that have a different impact on human health. Based on the literature analyzed regarding the formation of non-exhaust particles by vehicles, it can be concluded that the basic sources of the vehicle are tires and a braking system. It is also not possible to omit the formation of particles that result from the resumption of particles in the atmosphere by passing the vehicle. Compared to particles produced by combustion in the engine, it can be concluded that the results depend on the vehicle category and the fuel used. In the case of modern electric vehicles. The brake system and the tires are the largest non-exhaust particulate source so they have a higher amount of gritted particles compared to modern IC engines.

**Note:**

This paper is based on the paper presented at DEMI 2019 – The 14th International Conference on Accomplishments in Mechanical and Industrial Engineering, organized by Faculty of Mechanical Engineering, University of Banja Luka, BOSNIA & HERZEGOVINA, co–organized by Faculty of Mechanical Engineering, University of Niš, SERBIA, Faculty of Mechanical Engineering Podgorica, University of Montenegro, MONTENEGRO and Faculty of Engineering Hunedoara, Unversity Politehnica Timisoara, ROMANIA, in Banja Luka, BOSNIA & HERZEGOVINA, 24–25 May 2019.

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ISSN: 2067-3809