TYRES WEAR, HARMFUL EFFECT ON HUMAN AND MEASUREMENTS FOR IT REDUCTION: A REVIEW

Nadica Stojanović[1], Ivan Grujić[1], Milan Ivković[1], Danijela Miloradović[1], Suzana Petrović Savić[2]

[1]University of Kragujevac, Faculty of Engineering, Department for Motor Vehicles and Motors, Sestre Janjić 6, Kragujevac, Serbia, nadica.stojanovic@kg.ac.rs, ivan.grujic@kg.ac.rs, milan.ivkovic@kg.ac.rs, neja@kg.ac.rs,
[2]University of Kragujevac, Faculty of Engineering, Department for Production Engineering, Sestre Janjić 6, Kragujevac, Serbia, petrovic.savic@kg.ac.rs

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Corresponding Author: Nadica Stojanović, University of Kragujevac, Faculty of Engineering, Department for Motor Vehicles and Motors, Sestre Janjić 6, Kragujevac, Serbia, nadica.stojanovic@kg.ac.rs

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ABSTRACT

The tires are the acting organs of the vehicle by which it achieves its movement. During the vehicle movement/drive it comes to the friction between the tires and road, which causes the tires wear. The particles formed due to the tires wear, are harmful for human and its environment. In the paper is conducted the review of existing literature, where firstly are presented factors which contribute to the tires wear. After, it is given the representation, how these particles enter into human organism, and how this further influence on human health. Further are presented measurements for wear reduction. On the basis of the comprehensive analysis of the observed papers from the subject field, have come to the very useful conclusions as well as propositions to what should give attention during the future researches, as well as during the development of new tires, in order to reduce their wear.

Keywords: particles, tires wear, environment, human health.

INTRODUSTION

Tire wear particles are particles with a diameter of ≤5 mm. During the rolling of tires on the road surface, tire wear occurs due to the action of shear forces [1]. According to available data, air pollution ranked as the second leading risk factor in terms of the total number of deaths in 2023 [2], whereas in 2019 it was ranked fourth [3]. Considering only airborne particles, according to the

World Health Organization (WHO), they were responsible for 239,000 premature deaths in the EU during 2022 [4]. Tire abrasion is the main source of microplastics in the environment [5]. Airborne particles are a mixture of solid and liquid particles that differ in size (Figure 1), chemical composition, shape, solubility, surface properties, and origin [6]. Airborne particles can be classified according to their size as follows [7], [8]:

- Coarse particles – which are less than10 μm and are classified as PM_{10},
- Fine particles – which are less than 2,5 μm and are classified as $PM_{2,5}$, and
- Ultrafine particles – particles which are less than 0,1 μm and are classified as $PM_{0,1}$.

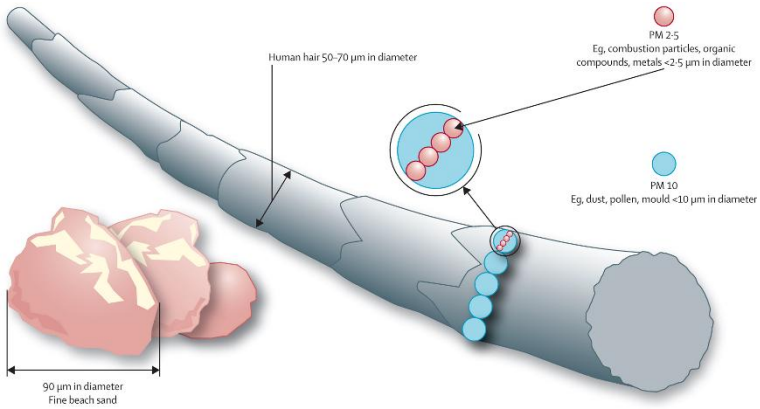


Figure 1. *The illustrative comparison of the particles size in respect to the human hair* [9]

Figure 2 presents statistical data on the amount of PM10 originating from several different sources. Since it is expected that electric vehicles will account for a larger share of road traffic by 2035, particles originating from combustion processes will decrease, while the emission of particles originating from tires will increase. The reason for this increase is the greater mass of electric vehicles due to their batteries. Until recently, the maximum permissible emissions originating from tires were not defined by standards. However, this has now been regulated under the Euro 7 standard [10].



Figure 2. Amount of PM10 in EU27 for years 2015., 2025. и 2035. Which originate from road, vehicle exhaust gasses, brakes and tires and total tires wear [4]

The impact of particles on humans is a highly relevant topic. Particles generated as a result of tire wear attract significant attention from researchers around the world. The main questions raised, which this research aims to answer, are:

- How are tire wear particles generated?
- Which factors contribute to tire wear?
- How do tire wear particles affect human health?
- What measures can be taken to reduce tire wear?

The introductory section explains the process of tire wear formation, thereby providing an answer to the first question. Section three addresses the factors contributing to tire wear, which corresponds to the second question. An overview of how particles generated by tire wear affect human health is presented in the fourth section. This is followed by a section discussing measures for reducing tire wear, thereby answering the fourth question. Finally, the conclusions derived from this research are presented.

RESEARCH METHODOLOGY

The research methodology was carried out through several phases. The study is based on a review of available research conducted by authors in the relevant field, as well as available statistical data. The research phases implemented in this paper are as follows:

1. Familiarization with the process of tire wear generation, possible particle sizes, and available statistical data;
2. Identification of factors which contribute to the tire wear generation;
3. Analysis of their effects on humans;
4. Proposed measures for reduction; and
5. General conclusions derived from the conducted research.

FACTORS WHICH CONTRIBUTE TO THE TIRES WEAR

Factors which contribute to the tires wear are next [11]:

- Tire characteristics:
  - The silica content in the tread compound affects the increased emission of fine particles, while the amount of coarse particles is lower [12];
  - Studded winter tires emit a larger quantity of particles [13];
  - If the tire pressure is higher than recommended, the pressure exerted on the road surface increases, contributing to increased tire wear [14], [15]. In cases where tire pressure is lower than specified by the manufacturer, greater and uneven tire wear will occur [16];
  - With an increase in tire tread temperature, the size of tire wear particles increases, whereas at lower temperatures, the particle size is smaller [17];
  - When the road surface is wet, friction is reduced and tire wear is lower [17], and
  - TWR (Treadwear Rating) affects the degree of wear. Two tires from the same manufacturer with different ratings showed that the tire with the lower rating experienced greater tread mass loss [18];

- Road surface characteristics:
  - Greater road surface irregularities lead to a larger quantity of coarse tire wear particles [17];
  - The greater the roughness of the road surface, similar to sandpaper, the greater the tire wear [19];
  - The presence of sand on the road contributes to increased tire wear, and
  - Road pavement texture also affects tire wear [20];

- Vehicle operation:
  - Increasing speed limits on roads has led to increased tire wear [21], [22], [23];
  - Longer traveling time at high speeds lead to abnormal tire wear [24];
  - Vehicle movement from a stationary position accompanied by wheel slip leads to higher emissions of tire wear particles [25];
  - Long-term braking [26], [27];
  - Sudden braking in accident or emergency situations [28], and
  - Vehicle movement while cornering [26];

- Vehicle characteristics
  - Increasing vehicle mass results in greater emissions of tire wear products [29], [30];
  - Improper wheel dynamic performance, under the influence of stiff suspension systems and axles, contributes to increased tire wear [31];
  - Increasing the toe angle by 1° to 1.5° can cause tire wear to increase by 3 to 10 times [32], and
  - The amount of tire wear is also influenced by the vehicle category [33].

HARMFUL EFFECT ON HUMAN

Tire wear particles can enter the human body in three ways: through food intake, consumption of contaminated water, or inhalation [34], [35], [36]. The most common way in which tire particles enter the human body is through the consumption of contaminated food or water, after which they enter the bloodstream and negatively affect human health [37]. When particles enter the body together with food, they also adversely affect the digestive organs, particularly intestinal digestion and absorption [38]. Research on how tire particles affect human health when inhaled is still limited. The only effects observed by researchers are DNA damage and inflammatory effects [39]. This prompted some researchers to conduct studies on mice. When mice inhaled air contaminated with tire particles, it was observed that it caused respiratory dysfunction and pulmonary fibrosis [40]. In addition, disorders of lipid metabolism were also reported [41]. Since research on the effects of inhaled tire particles on human health is still limited, comprehensive conclusions cannot yet be drawn. However, based on a study reviewing 400 scientific papers, it was determined that tire particles cause oxidative stress and inflammation [42].

MEASURES FOR THE REDUCTION

There are several different measures and recommendations for reducing tire wear, including:

- Installation of tire pressure sensors that promptly inform the driver when tire inflation is required [43];
- Tire pressure should be checked every 14 days or before longer journeys in order to minimize tire wear [44], [45];
- The use of tunnels [46] positioned near the wheel and intended for capturing particles (Figure 3);
- The application of tires which contain ISAF N234 [47];
- Adding nanoprene to a tread mix containing silica [48] in the tread compound to improve wear resistance, as well as the addition of nano-silica and carbon black [49] [50];
- Selection of road construction materials, specifically the use of low-noise pavements [51], [21];
- Replacing signalized intersections with roundabouts [52];
- The application of self-driving cars [34], and
- Wheel alignment adjustment [53].

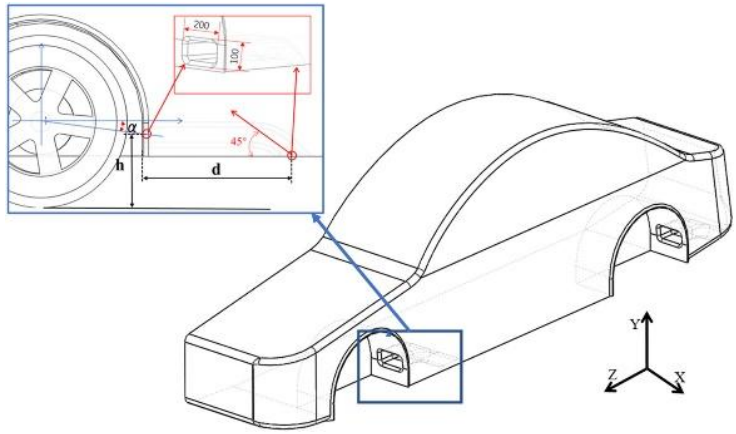


Figure 3 Tunnel on a vehicle for capturing particles generated by tire wear [46]

CONCLUSION

The emission of harmful substances originating from vehicles is currently attracting significant public attention. During vehicle operation, emissions are generated not only from the combustion process occurring in the internal combustion engine, but also from tire and brake wear. The focus of this paper is placed on tire wear because it contains microplastics and other harmful components that may adversely affect human health. Based on the literature review, the following conclusions were drawn:

- The main source of microplastics in the environment is tire wear.
- The degree of tire wear depends on tire characteristics, road surface characteristics, vehicle characteristics, and vehicle operating conditions.
- Tire wear products most commonly enter the human body through the consumption of contaminated food.
- Research on how tire particles affect human health when inhaled is still limited.
- Tire wear reduction can be achieved through regular tire pressure checks and maintaining pressure within prescribed limits, the application of tire pressure sensors, reconstruction of road infrastructure, and similar measures

The presented conclusions provide highly important information for ensuring key elements related to ecology, impacts on humans and the environment, and aspects that should receive particular attention in future research.

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DECLARATIONS OF INTEREST STATEMENT

The authors affirm that there are no conflicts of interest to declare in relation to the research presented in this paper.

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