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JOURNAL	World Science
p-ISSN	2413-1032
e-ISSN	2414-6404
PUBLISHER	RS Global Sp. z O.O., Poland

ARTICLE TITLE	ENVIRONMENTAL POLLUTION AND IMPACT OF HIGHWAYS DURING OPERATION
AUTHOR(S)	Nataliia Kharytonova
ARTICLE INFO	Nataliia Kharytonova. (2023) Environmental Pollution and Impact of Highways During Operation. *World Science*. 3(81). doi: 10.31435/rsglobal_ws/30092023/8045
DOI	https://doi.org/10.31435/rsglobal_ws/30092023/8045
RECEIVED	23 August 2023
ACCEPTED	29 September 2023
PUBLISHED	30 September 2023
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ENVIRONMENTAL POLLUTION AND IMPACT OF HIGHWAYS DURING OPERATION

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DOI: https://doi.org/10.31435/rsglobal_ws/30092023/8045

ARTICLE INFO

Received: 23 August 2023
Accepted: 29 September 2023
Published: 30 September 2023

KEYWORDS

Environmental Pollution, Exhaust Gases, Highways, Microparticles, Micropollutants, Oil Products, Roadside Area

ABSTRACT

The current state and rapid development of road construction and transport infrastructure are the reasons for the increase in environmental pollution, especially in the immediate vicinity of highways. Roadside areas accumulate a large amount of pollutants which leads to changes in soil properties and comprehensive degradation of landscapes. Together with the road runoff, pollutants enter the lakes and the rivers and cause significant damage to aquatic flora and fauna. During the operation of highways, a large amount of exhaust gases, oil products, heavy metals, and dust enters the natural environment. Currently, in Ukraine, most studies are aimed at reducing the negative impact of exhaust gases on the atmosphere, oil pollution of soils and the aquatic environment. Unlike in the European countries, the research on the formation of microparticles which, together with dust and surface runoff contaminate soils, surface and groundwater of roadside areas has not been conducted at all. This paper analyzes the European research experience on the negative impact of microparticles on the environment. The components of microparticles - micropollutants formed as a result of the interaction of vehicles with the road surface (tire wear products, road dust, road markings, etc.) are presented. The paper also presents the sources of formation, qualitative and quantitative characteristics of the main micropollutants and their pathways in the roadside area. This will allow further developing the effective measures to reduce the formation and spread of micro-pollutants which minimizes their negative impact in the roadside areas.

Citation: Nataliia Kharytonova. (2023) Environmental Pollution and Impact of Highways During Operation. *World Science*. 3(81). doi: 10.31435/rsglobal_ws/30092023/8045

Introduction.

Human impact on the environment is increasing as civilization develops and technological progress accelerates. At present, the negative impact on the ecological situation has approached a critical mark, after which irreversible consequences associated with destructive anthropogenic activities can begin.

Motor road and road transport is a source of environmental pollution by petroleum products, heavy metals, suspended matters, dust, which is formed by wear of tires or pavement, de-icing materials, etc. [1].

One of the sources of environmental pollution is surface (rain and melt) runoff water flowing from the roadway. Surface runoff from highways can be a source of pollution of natural waters.

In the current Ukrainian regulatory document [2] the content of suspended solids in the surface runoff from roads is defined as follows: up to 1 300 mg / l – in rainfall runoff and up to 2 700 mg / l – in meltwater runoff, oil products – up to 24 mg / l and 26 mg / l respectively.

To prevent the negative impact on the environment in the design and construction of roads, it is necessary to include engineering measures, such as the collection and treatment of surface runoff from roads.

Considering that oil products as a pollutant of road surface runoff is already known [3], then the nature of suspended solids and their impact on the environment has began to be studied recently. Problems of pollution of water bodies by microsurfactants are widely covered in the scientific works of foreign [4–6] and domestic scientists [7, 8]. It is determined that some micropollutants, such as metals, have a toxic, mutagenic and carcinogenic effect on living organisms. They also have the ability to accumulate in bottom sediments and living tissues [9]. In [10], a classification of micropollutants in surface runoff is given.

However, the issue of contamination of surface road runoff by micropollutants has not been studied sufficiently. In this article I will try to analyze the qualitative composition of such microparticles to identify the main sources of pollution and make predictions on the distribution of microparticles in the roadside zone.

General regulations.

The main sources for micropollutants in road dust are the wear surface of car tyres (i.e. the tread), road pavement where polymer modified bitumen are used in the wear layer and road marking paints. See Figure 2.1. In addition to these, general micropollutants littering along roads could be an important secondary B source to micropollutants in road dust. In urban centers, road dust may also contain plastics derived from a range of other sources, among them construction and building materials (e.g. paintings, foils, foams, cement composites etc.), air deposition and artificial turfs (rubber granules and artificial grass fibres.

Tyre tread.

The tread is composed of a complex mixture of compounds in which different types of rubbers typically make up from 40% to 60%, and the remaining compounds are added to give the tread necessary hardness, wear resistance, durability, elasticity and stickiness. The rubber mix of tyres for passenger cars is typically a mix of styrene-butadiene rubber (SBR) and polybutadiene rubber (PBR), while natural rubber (NR) is the dominating rubber in tyre treads of heavy vehicles. Non-studded winter tyres of passenger cars need a softer rubber mix for proper grip, hence they typically have a somewhat higher PBR ratio than summer tyres.

Polymer modified bitumen.

Bitumen is the "glue" in the wear and binder layers of asphalt pavement to keep the gravel together. Polymer modified bitumen (PMB) is also used to increase the strength, stability and adhesive properties of the pavement also under cold winter conditions The most commonly used polymer is the thermoplastic elastomer Styrene Butadiene Styrene (SBS), because it retains most of its properties at low temperatures. Since 2008 there has been a marked increase in the use of PMB on the national roads with heavy traffic, resulting in less rutting because of improved resistance against deformation and wear and tear from studded tyres. The typical SBS content in bitumen is approximately 5%.

Road paint markings.

Both thermoplastic markings and water-based polymer paints are used. While the plastic polymer content of thermoplastic markings is as low as 1–5% due to high filler levels, the acrylic polymer content of the polymer paints is much higher (e.g. 15–40% according to Lassen et al. 2015). The most commonly used polymers in road markings are styrene-isoprene-styrene (SIS), ethylene vinyl acetate (EVA), polyamide (PA) and polyacrylate.

In Figure 1summariseddifferent types of particles appear. For particles derived from tyre treads we distinguish between pure tread particles (TP) that typically are carved out or shredded from car tyres and tread wear particles (TWP) that are generated while driving with passenger cars (TWPP) and heavy vehicles (TWPH). There are two particles derived from the road, those coming from road pavement where PMB has been used in the wear layer (RWPPMB) and those coming from road markings (RWPRM). When we refer to all the above mentioned wear particles, we will use the abbreviation RAMP for Road dust-Associated Microplastic Particles. Road dust particles in general, which include also other sources such as break wear and exhaust emissions, are denoted with RP, while larger fragments or shreds from the PMB-pavement or road markings are denoted RPPMB and RPRM, respectively.

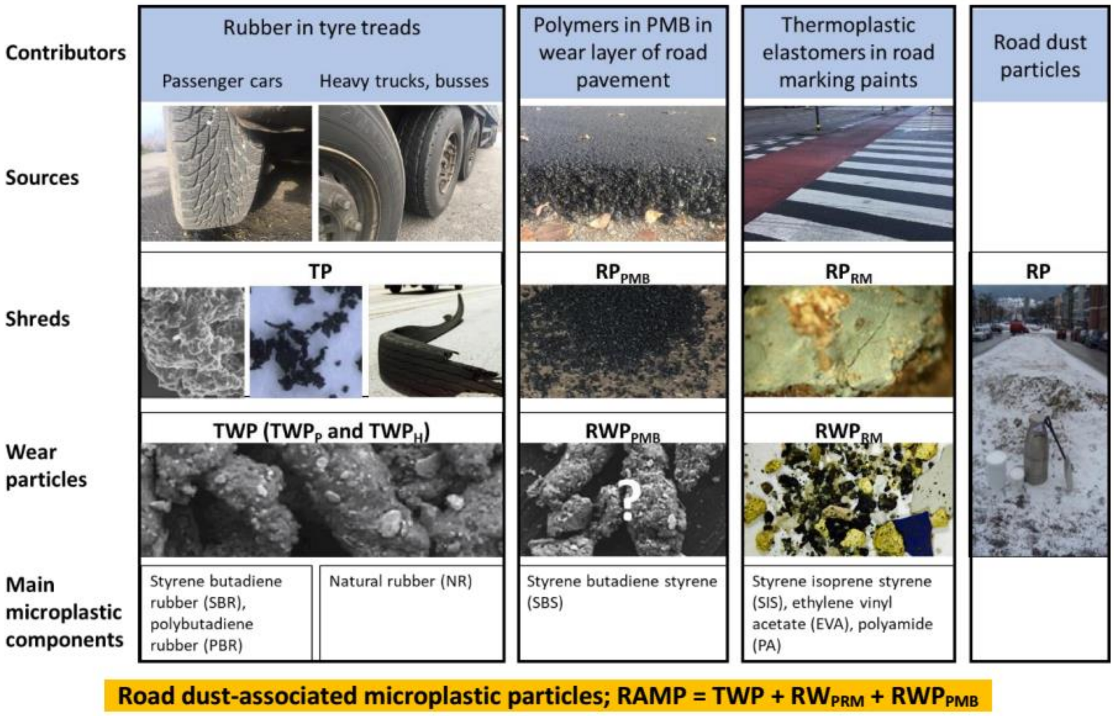

Figure 1. Main suspects of microplastics in road dust, their sources and notation used to distinguish between larger shreds and wear particles from the different sources.

The ways of spreading of micropollutants in the roadside zone.

Though wear particles are constantly generated by passing traffic, they are not accumulating on the road at the same rate. Passing vehicles and wind impact suspension and resuspension of settled particles on the road under dry conditions, which will bring (more of) the wear particles to the road verge. Since smaller particles tend to accumulate more easily within microstructures of the pavement, they are usually not resuspended as much as larger particles.

Wind may contribute to long distance transport of airborne particles directly to both terrestrial and aquatic environments. The transported distance is dependent on both particle size, wind speed and local topographic features (including vegetation and buildings). Though tread wear particles up to 30 µm have been shown to be airborne, particles >10 µm are not likely to stay airborne for long. The behavior of particles in the 1–10 µm range strongly depends on particle characteristics and local conditions. These particles can stay in the air for minutes to hours and typically travel distances varying from hundred meters to as much as 50 km (Kole et al., 2015). As only around 7% of the tyre wear particles are assumed to be <30 µm in size, the long-distance transport loss of tyre wear particles due to wind is probably relatively small if not in a particularly windy location.

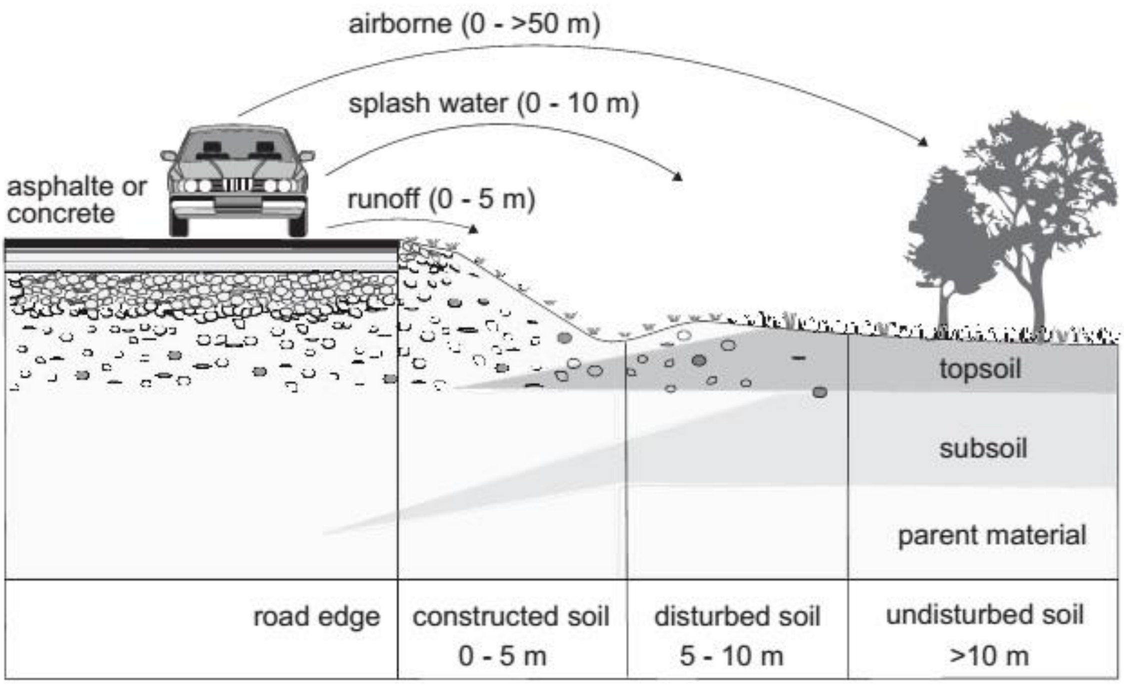

Figure 2. Schematic representation of the roadside zone and ways of micropollutants spreading.

Precipitation (as rain or snow) will drastically increase the deposition of airborne particles on the road or road verge. Since snowflakes are falling slower and have larger surface areas than rain droplets, they will collect more pollution from the air. Furthermore, due to the use of studded tyres (among other things), the airborne particle levels (PM 10) are usually also much higher during the winter season.

However, the deposited particles will not necessarily stay on the road. There were found that particles started to accumulate on the road after approximately 2 hours of drizzling rain (0.5–2 mm/h). When the precipitation intensity exceeded a certain threshold, defined by the Rainfall Detachment Index (RDI), particles deposited on the road began to be transported off the road with the road runoff. RDI is dependent on the road micro and macro structures and incline, hence how well it is to retain both water and particles. The transported amount increased linearly with the precipitation intensity up to a maximum 32 where it levelled off for rainfall events up to five hours duration. For long rainfall events, there was no clear relationship between precipitation intensity and amounts of particles transported away from the road.

In countries, where almost all highways have been constructed with a very porous asphalt, 95% of all tyre wear particles deposited on the road are claimed to be permanently embedded in the small cavities in the road, or approximately 40% of all TWP.

Road runoff waters are able to convey a number of organic and inorganic pollutants originated by different non-point sources and by the road surface itself. Such pollutants can enter aquatic systems, thus contributing to water and soil contamination.

In receiving waters the principal pollutants are suspended solids, heavy metals, hydrocarbons and de-icing salts. Their runoff is considered a major source of the pollution in the environment.

Scientists are engaged in various types of simulation and forecasting of the processes of the spread of pollutants. Considerable attention is paid to the phenomenon of atmospheric turbulence and the conditions that causes it. Also, the impact of the relief, the type of terrain and the location of the road according to road-climatic zoning on the processes of dissipation of pollution in the atmosphere was studied in detail. Atmospheric turbulence serves as a mechanism for mixing and reducing the concentration of gas and dust pollutants during the transport with medium wind strength. Ukrainian scientists study patterns of the spread of pollutants from sources of pollution. This method is based on the study of the theory of atmospheric diffusion and allows investigating the micropollutants pathways at various environmental characteristics and empirical and statistical analysis of the distribution of pollutants in the atmosphere.

Also, considerable attention is paid to the mechanism of the spread of pollutants (especially metals) at a depth from the source of pollution.

The accumulation of micropollutants in the roadside zone depends on: the intensity of traffic flow and its composition, the type of pavement, the adjacent road landscape, natural and climatic conditions (amount of precipitation, wind direction and speed) and geophysical conditions (relief, vegetation, soil type, engineering-geological and hydrological conditions, which, in turn, are characterized by runoff conditions, water evaporation, the thickness of the snow cover and the intensity of spring snow melting, the depth of groundwater and features of their regime, which directly or indirectly affect the number and distribution of micropollutants in the roadside environment.

Conclusions.

Based on the foregoing, we can identify the main sources of micropollutants, directly derived from the road transport traffic, the components of each micropollutant and its approximate number.

We analyzed the mechanisms of spread of micropollutants in the roadside zone and gave an indicative scheme indicating the distances of accumulation.

Unfortunately, in Ukraine and in European countries, environmental issues are different. While Europeans countries pay attention even to microplastics, exceeding allowable pollutants concentrations levels are observed on our roads. In order to solve these issues, it is necessary to study in detail the spread of pollutants in the roadside area and improve the existing systems of disinfection of runoff of roadside area in general. The development of road construction and infrastructure contributes to increasing environmental contamination, especially in close proximity to highways and related objects such as petrol stations, car washes and car parking lots.

And therefore, it is very important to develop and further study the formation of micropollutants, the study of measures to reduce their spread and accumulation in the roadside areas, thereby minimizing the negative impact of the road on the environment.

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