https://doi.org/10.33271/nvngu/2025-5/103

O. Ye. Kofanov[1],
orcid.org/0000-0003-2181-9288,
O. V. Kofanova[1],
orcid.org/0000-0002-9851-6392,
A. V. Pavlychenko[2],
orcid.org/0000-0003-4652-9180,
O. Ya. Tverda[*1],
orcid.org/0000-0003-3163-0972,
S. I. Protsenko[3],
orcid.org/0009-0007-7015-6632

1 – National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", Kyiv, Ukraine
2 – Dnipro University of Technology, Dnipro, Ukraine
3 – State University "Kyiv Aviation Institute", Kyiv, Ukraine
* Corresponding author e-mail: tverda.o-iee@lll.kpi.ua

MINIMIZING THE IMPACT OF MOTOR VEHICLES ON THE ENVIRONMENT AND THE HEALTH OF THE POPULATION OF AGGLOMERATIONS

Purpose. To reduce the ecotoxicological impact of particulate matter (PM) on human health at public transport stops and, in the territories, adjacent to them.

Methodology. To assess the state of the surface layer of the air environment polluted by PM, spatial mathematical models of toxicant dispersion fields were developed in MathCad using the solution of a semi-empirical equation of turbulent diffusion.

Findings. It was proposed to add a biocomponent (biodiesel) to diesel fuel. To substantiate the effectiveness of the proposed solution, we have carried out dispersion fields modeling for the studied areas using mixed diesel fuel (with 30 % by volume of biofuel) and biodiesel for vehicles. In the case of a hypothetical replacement of the traditional diesel fuel with a bio-based fuel, the excess of the maximum permissible single concentration (MPC) for PM will decrease by 1.63 times (by 38.8 %), and when using diesel fuel with a bio-based fuel content of up to 30 % by volume – by 1.14 times (by 12.2 %). It was determined that it is more expedient to use diesel fuel with a 30 % by volume bio component, which will reduce the excess of the MPC for particulate matter and will not increase the content of nitrogen oxides in diesel engine emissions. Along with the use of a bio-component in diesel fuel, it is proposed to use biopolymer solutions based on starch or lignin and micro-green barriers in the form of moss panels. This will simultaneously solve the problem of exceeding the MPC for particulate matter in urban air and create an additional environmental effect using

Originality. Based on predictive models of local pollution of the surface air layer with PM, it has been determined for the first time that the use of diesel fuel with 30 % biofuel content reduces the level of PM pollution and prevents the MPC from being exceeded, even at public transport stops and the adjacent territories.

Practical value. Predictive mathematical models of PM_{10} dispersion can be used to determine safe distances from roads, assess environmental risks to human health, and make management decisions. The use of 30 % biofuel in diesel fuel, together with the application of biopolymer solutions and micro-green barriers will reduce PM emissions and prevent an increase in nitrogen oxide content in engine exhausts, which is typical when running vehicles on 100 % biodiesel.

Keywords: *pollution, environment, dispersion, particulate matter, diesel, biodiesel, green barriers, circularity*

Introduction. According to the World Health Organization, air pollution with fine particulate matter, soot, other components of explosive gases, and motor vehicle emissions not only causes respiratory diseases, but also diseases of the cardiovascular and endocrine systems [1, 2], and cognitive impairment, especially in children. Air pollution increases the risk of Alzheimer's disease and other forms of dementia in the elderly; carcinogenic components of emissions and explosions cause the formation and growth of tumors, including malignant ones. Even in peacetime, emissions from motor vehicle engines, especially diesel engines (carbon and nitrogen oxides, particulate matter (PM), sulfur compounds, hydrocarbons, aldehydes, etc.), are one of the main sources of toxic effects on human health in highly urbanized areas. There are studies that prove a decrease in morbidity and mortality rates among populations in various countries around the world in cases where harmful emissions into the atmosphere have been significantly reduced [3, 4].

At the same time, the principles of circular "green" economy and sustainable development are becoming increasingly relevant given the need for eco-centric and energy-efficient restoration of urban infrastructure and the introduction of innovative green business solutions [5].

The penetrating ability of finely dispersed solid aerosol particles is significantly influenced not only by their size, but also by their chemical composition. Depending on the ability of PM to penetrate the human body, these solid particles are divided into certain classes, namely those that enter the human body through breathing (inhalable particles) and are unable to penetrate further than the bronchi; thoracic particles, which are capable of reaching the terminal bronchioles and accumulating in the airways of the lungs and gas exchange areas; respirable particles, which enter the bloodstream from the alveoli. Thus, suspended particles can be deposited in

various organs and tissues of the human body, causing complex negative consequences for human health [6, 7]. Children suffering from bronchial asthma, chronic bronchitis, pneumonia, etc., and elderly people are particularly vulnerable to the harmful effects of atmospheric pollution caused by motor vehicle emissions. This is because most of the harmful components of emissions and explosions are concentrated near the earth's surface due to their significant relative density compared to air

$$D_{air} = M_{pollutant} / M_{air},$$

where $M_{pollutant}$ is molar mass of the pollutant; M_{air} is molar mass of air, equal to 29 g/mol.

In the air of large cities, especially near roads and industrial facilities, the content of certain harmful impurities can exceed their maximum permissible concentrations (MPC) by tens of times [7, 8]. The environmental situation in cities and suburbs is significantly deteriorating even in peacetime due to the huge flows of transit vehicles moving through the city, as these flows mostly consist of a significant proportion of diesel trucks and buses.

When released into the air, components of engine exhaust gases, as well as toxic explosive gases and dust, on the one hand, mix with each other and, depending on meteorological and climatic conditions, can disperse in the atmosphere and/or be adsorbed on the surface of solid soot particles and absorbed in rivers and reservoirs [9–11]. On the other hand, complex and multi-stage physical and chemical transformations are potentially possible between individual components of emissions, which can lead to the formation of new compounds that are often even more toxic to human health.

The national environmental monitoring system in Ukraine includes a network of monitoring stations operated by the Boris Sresnevsky Central Geophysical Observatory and mobile stations for rapid monitoring of atmospheric pollution. Sometimes, special mobile observation posts are used to monitor phenomena such as smoke, explosive gas emissions, and other aerosol emissions. However, these monitoring stations are generally unable to cover the entire city, especially roadside areas, sidewalks next to busy highways, public transport stops, etc., where fine aerosol particles are concentrated. It is important to note that due to the developed surface of these particles and their enormous capacity to adsorb harmful substances such as polyaromatic hydrocarbons, including benz(a)pyrene, aldehydes, heavy metals, etc., these aerosols are extremely toxic to human health [10, 12].

Primary air pollution causes specific geochemical anomalies with high concentrations of suspended particles, both up to 10μ (PM_{10}) and up to 2.5μ ($PM_{2.5}$) in size, and due to possible secondary pollution under the influence of strong wind currents and mechanical transport, there is a real threat to the respiratory system and other organs and tissues of people who spend a long time at public transport stops or walk along sidewalks along roads. The hazardous impact of finely dispersed solid impurities on human health is evident even in rooms on lower floors, when traveling by motor vehicle, especially during warm weather and in calm conditions. Thus, it is relevant and important to reduce the ecotoxicological impact of fine particulate matter on human health in places where people spend a lot of time (sidewalks, public transport stops, especially near educational institutions, children's recreation areas, etc.) through measures developed based on the results of environmental hazard assessments.

In this context, research aimed at minimizing the impact of fine particulate matter on human health at public transport stops and adjacent areas is of particular importance. That is why it is advisable to analyze scientific approaches and practical solutions related to assessing and reducing the risks of PM.

Literature review. There are many different models for predicting the environmental situation in areas adjacent to busy roads, enabling scientists and practitioners to develop and make informed and sound decisions in the field of urban air pollution monitoring [13, 14]. In this context, it is worth noting the studies by domestic researchers N. V. Vnukova and G. M. Zhelnovach, L. D. Plyatsuk and V. S. Bakharev, S. I. Snizhko and V. M. Shmandii, as well as some of the models developed by foreign developers – Gaussian models AERMOD, CALINE4, and Airviro Gauss; Euler models CALGRID, FARM, and PANACHE; Lagrangian models GRAL and FLEXPART; improved dispersion models UK-ADMS5 and CALPUF [15, 16].

The orography of the terrain has a huge impact on the dispersion and local concentration (creation of geochemical anomalies) of virtually all toxicants. Papers [6, 17] emphasize that specific turbulence fields arise in the surface layer of air due to the topographical features of the terrain, which lead to changes in both horizontal and vertical flows, as well as contribute to a specific distribution of temperature and humidity. Accordingly, these changes have a decisive influence on the diffusion of toxicants in the near-surface layer of the air (not considering secondary chemical transformations), contributing to their mixing, dispersion, and/or concentration. Therefore, the state of the lower layer of the atmosphere depends on many factors, which, in turn, are also determined by several parameters. This, in turn, leads to a certain/significant degree of uncertainty regarding the accurate assessment of the mutual influence of various factors on the territory or object under study. The situation with forecasting is somewhat worsened due to local concentration processes, the formation of geochemical anomalies of individual toxicants, which is caused by both the physical and chemical properties of impurities, as well as the orography of the terrain and the mutual influence of other important factors.

From a mathematical point of view, complex processes and phenomena occurring in the air environment of cities and areas adjacent to highways are dynamic, with parameters that constantly change, both in time and space. Therefore, it is extremely important to map the dispersion fields of toxicants emitted by motor vehicle engines, in particular dust and soot aerosols, to assess and reduce their potential ecotoxicological impact on human health in public transport stops.

Thus, in [18], the impact of London's Low Emission Zones (LEZ) was analyzed using two regression models and the openair tool in R, changes in nitrogen dioxide NO_2 and PM2.5 concentrations were assessed, and conclusions were drawn regarding the long-term consequences for public health. Based on the results obtained, the effectiveness of the Manchester Clean Air Plan was

assessed, and it was established that without LEZ, its impact on air quality and human health is insufficient.

In article [19], the authors used data on air pollution in Madrid for 2015–2018 (the period before the introduction of the LEZ) to simulate a "baseline" scenario without a low-emission zone using three machine learning algorithms. The forecasts obtained were compared with actual data for 2022 (after the introduction of LEZ). The results showed a significant reduction in NO_2 concentrations (29–35 %), but no clear improvement was recorded for PM_{10} and $PM_{2.5}$.

The authors of [20] investigated the effectiveness of a "tredge" – a living green fence made of trees trimmed to head height, installed along a road next to a school in Manchester. The authors collected PM_{10} and $PM_{2.5}$ samples on filters and fence leaves, analyzed their magnetic properties, and found a significant reduction in particulate matter concentration behind the fence: up to 78 % for PM_{10} and 82 % for $PM_{2.5}$. The study showed that green barriers can significantly reduce the impact of road emissions and are an effective and relatively inexpensive strategy for protecting human health.

The authors [21] assessed how effectively green barriers of different heights (0.5, 1.0, and 1.5 m) help reduce the impact of $PM_{2.5}$ particles on passengers at bus stops. The authors found that barriers 1.0–1.5 m high are the most effective, as they reduce the risk to passenger health by approximately 62 %. The study also suggests additional strategies, such as changing passenger seating arrangements and optimizing entry/exit at stops.

The authors of the study [22] examined the effectiveness of various road barriers (fences, solid walls, green spaces, etc.) in reducing air pollution from motor vehicle traffic in Atlanta, the USA. The authors measured the concentration of black carbon and fine particles and found that green barriers are the most effective means of reducing black carbon content by 37 % in areas located behind them. This confirms that green spaces can be, where possible and appropriate, an effective tool for improving air quality near motorways.

In [23], researchers measured levels of $PM_{2.5}$ and black carbon pollution at bus stops and modeled the impact of their design on pollutant distribution. They found that the highest concentrations of particles were observed in the bus departure area, especially during the evening hours. The results also showed that closed or semi-closed front barriers at bus stops can significantly reduce pollution levels.

The authors of [24] carried out research and monitoring of fine particulate matter ($PM_{2.5}$ and PM_{10}) emissions at a bus station in Žilina, Slovakia. The results showed that pollution levels significantly exceed acceptable limits, especially during morning rush hour, and that these particles accumulate under bus stop shelters. The study highlights a direct link between diesel bus traffic and high levels of pollution, which poses a threat to the health of passengers and staff.

Paper [25] is a review of studies devoted to the design of bus stops as sustainable urban infrastructure. The authors analyze how bus stop design can help solve problems related to air pollution. Research in Nanjing, China, showed that green hedges 1.5 meters high effectively filter solid particles. Research in Seoul (South Korea) showed that a special bus stop design with a curved barrier and airflow system can reduce fine dust exposure by 88 %. The authors emphasize that, although innovative solutions exist, such as integrated cooling and filtration systems at public transport stops, their effectiveness may be limited in certain ways. They also emphasize the lack of empirical data and the need for further research focused on how the design of bus stops will affect air quality in real-world conditions.

The purpose. The aim of the study is to reduce the ecotoxicological impact of fine particulate matter (PM) on human health at public transport stops and adjacent areas.

Materials and methods. The study determined the ecotoxicological impact on human health at public transport stops caused by air pollution with fine solid aerosol particles emitted by vehicle engines. The construction of PM_{10} dispersion fields was implemented in the MathCAD software environment using a plume approximation model and solving a semi-empirical equation of turbulent diffusion. The result of the modeling is the dependence of the multiple exceeding of the maximum permissible single concentration of PM on the distance from the center of the road (dispersion field).

The specifics of using the software and determining the diffusion coefficients of impurities are described in detail in [7, 11]. The initial data for constructing dispersion fields at certain public transport stops were obtained from our own field observations and analysis of literary sources. In particular, the following factors were taken into account: the power of the emission source (the mass of substance emitted by the pollution source per unit of time), the height of the emission source above the ground, the atmospheric stability parameter, wind direction and speed, as well as the physical characteristics of the impurity through its diffusion coefficient in the atmospheric air. The change in PM_{10} load on roadside areas when using fuel modified with bio-component (30 % vol.) or pure biofuel was adjusted using a computational experiment, considering that the share of diesel vehicles operating in the city is approximately 35–40 % [26].

To model the dispersion fields of ecotoxicants from motor vehicle emissions, spatial and temporal field surveys were carried out to determine the intensity and composition of motor vehicle traffic on busy roads in the capital. Road conditions, location and waiting times of people at public transport stops and adjacent areas located near educational institutions, recreational areas, etc. were studied. The surveys were carried out on working days between 8:00 a.m. and 9:00 a.m. and between 6:00 p.m. and 7:00 p.m. at different times of the year during 2024–2025 on days when there were no traffic jams or heavy precipitation.

The choice of areas for study was determined by the fact that these roads, firstly, are quite busy, with high traffic density, and, secondly, there are several educational institutions (schools, universities, etc.) located nearby, as well as places where children play and spend time. It should be noted that there are no traffic light-controlled intersections on the road sections under study, so in the absence of traffic jams, most of the traffic flow moves continuously and at a relatively constant speed.

To construct dispersion fields for PM_{10} impurities, the location of the road section and the public trans-

port stops under study were also determined; its length L with the streets that intersect or border it; the width of the road b and sidewalks b_{tr}; the number of lanes in each direction; the distance from the stop to the edge of the road; the average speed of traffic flow v_{TF}; the roughness of the underlying surface and meteorological conditions.

The intensity of traffic flows N_{TF} was determined by the number of vehicles passing through the intersection of the studied section in 20 minutes. At the same time, it was considered that the value of N_{TF} was not constant but varied both in time and space on the studied road sections. The density of TF ρ_{TF} was calculated based on the number of vehicles on the section of the road where public transport stops are located at a given moment in time. Based on this indicator, the road congestion index was further calculated [6, 7]. The composition of the traffic flow was characterized by the ratio of different types of vehicles (gasoline and diesel passenger cars, buses, minibuses, trucks, etc.); it was also important for the study to determine the share of diesel vehicles in the city.

Results and discussion. It is known that highways and traffic flows can be considered and modeled as linear sources of harmful emissions, the diffusion patterns of which are determined primarily by the height of the emission source above ground level, stratification, average wind direction and speed, traffic conditions and characteristics of motor vehicle traffic, the orography of the underlying surface, the nature of urban development, etc. Vegetation, and especially the presence of park areas and water bodies along roads, will also significantly affect wind flow characteristics and the diffusion of pollutants in the air. Air pollution from motor vehicle traffic is also determined by the characteristics of the street and road network and is geometrically linked to roads, intersections, buildings, public transport stops, etc.

It is known that the surface layer of atmospheric air is characterized by a certain stability. At the same time, unlike an unstable atmosphere, where intense mixing of air masses occurs, in a stable atmosphere, the dispersion of toxicants is significantly more difficult. The dispersion parameters of impurities, namely their dispersion coefficients σ_x, σ_y, and σ_z, are directly related to the atmospheric stability index (designated by Pasqual-Giford as *A*, *B*, *C*, *D*, *E*, *F*, if atmospheric stability increases from *A* to *F*). Thus, the parameters of impurity dispersion in the surface layer of air (i.e., their dispersion σ_y and σ_z) are expressed using the corresponding diffusion coefficients D_y and D_z

$$\sigma_y^2 = 2 \cdot D_y \cdot x;$$

$$\sigma_z^2 = 2 \cdot D_z \cdot x.$$

These parameters of toxicant dispersion in atmospheric air (σ_y and σ_z) are determined either using nomograms or empirically using equations, and they depend on the intensity of turbulence, as well as on the stability (resistance) of the atmosphere

$$\sigma_y = \alpha_y \cdot x / S_1(x);$$

$$\sigma_z = \alpha_z \cdot x / S_2(x),$$

where $S_1 = (1 + \beta_1 \cdot x)^{1/2}$; $S_2 = (1 + \beta_2 \cdot x)^{1/2}$; α_y, α_z and β_2 are parameters of dispersion of impurities in the air environment (Table); coefficient $\beta_1 = 1.0 \cdot 10^{-4}$.

It is known that wind currents play a decisive role in the dispersion of toxic pollutants in the surface layer of air at approximately 2–3 m from the ground. For example, frequent calm periods with wind speeds of less than 5–6 m/s usually led to local pollution of areas near highways and the formation of specific geochemical anomalies of toxicants.

To assess the state of the surface layer of the air environment contaminated with PM_{10}, spatial mathematical models of the dispersion fields of the studied toxicant were constructed in MathCad using the solution of a semi-empirical equation of turbulent diffusion. Figs. 1 and 2 show spatial models of PM_{10} dispersion fields at public transport stops along the studied transport arteries of Kyiv (No. 1 – Beresteiskyi Avenue and No. 2 – Borshchahivska, Liubomyra Huzara, and Lesia Kurbasa Streets) during the warm season at the most unfavorable average wind speeds and directions for human health. As can be seen in the figures, the excess of the maximum permissible single concentration of suspended substances in the center of the road is approximately 2.5–2.7 times for transport artery No. 2, which carries slightly less dust load compared to transport artery No. 1, where the maximum permissible single concentration of PM_{10} is exceeded by 3.7–4.9 times.

Since the main emitters of fine particulate matter are diesel engines, especially those in heavy trucks and buses, special attention was paid to the diesel component when calculating the volume of toxic emissions in the studied road sections – public transport stops. These vehicles must be equipped with modern exhaust gas cleaning systems and comply with environmental classes higher than Euro 3. Observations also showed an increase in the proportion of freight vehicles, mainly diesel vehicles with a carrying capacity of up to 3.5 tons, in the morning hours and after 5 p.m., which is most likely due to the start and end of the working day at construction sites, industrial enterprises, large stores, etc. At the studied stops of transport artery No. 1 and adjacent territories, in addition to local route taxis and public transport, several suburban bus routes are actively operating, including buses with a passenger capacity of more than 42 people, equipped with diesel engines. This is particularly noticeable in the area near Zhytomyrska metro station (Kyiv, Ukraine), which is part of or the starting point for many urban and suburban routes and where there is a high concentration of

Table

Values of dispersion parameters for impurities in the air environment α_y; α_z and β_2

Atmospheric stability class	α_y	α_z	β_2
A	0.22	0.2	0
B	0.16	0.12	0
C	0.11	0.08	$1.5 \cdot 10^{-4}$
D	0.008	0.06	$2.0 \cdot 10^{-4}$
E	0.06	0.03	$3.0 \cdot 10^{-4}$
F	0.04	0.02	$3.0 \cdot 10^{-4}$

people waiting for transport. Figs. 1 and 2 show that under conditions of primary atmospheric dispersion, the maximum concentration of pollutants is observed in the middle of the opposing lanes of the roadway, gradually decreasing toward the roadside. In this case, the exceedance of the maximum permissible single concentration of PM should cease at an environmentally acceptable distance (3.0–4.5) m from the center of the road. However, due to significant secondary dispersion of pollutants caused by the high speed of motor vehicles on the studied arteries and wind speeds of 15 m/s (Figs. 3, 4), additional dust dispersion occurs, with most of it being emitted onto sidewalks and public transport stops. Therefore, under such conditions of total primary and secondary atmospheric pollution with fine dust, the area exceeding its maximum permissible single concentration significantly expands, posing a danger to the health of people who spend long periods of time near the road.

Considering the results of a literature review on reducing the ecotoxicological impact of fine particulate matter on human health, the authors propose adding a bio-additive (biodiesel) to diesel fuel. To substantiate the effectiveness of the proposed solution, PM_{10} dispersion fields were modeled for the studied road sections, assuming that motor vehicles were powered by mixed fuel (30 % biofuel by volume) and biodiesel.

Figs. 3, 5, and 6 show that the maximum permissible single concentration of toxicants in the middle of the road when using pure biodiesel will decrease by 1.63 times (by 38.8 %). At the same time, when using blended diesel fuel containing a bio-additive (30 % by volume), this figure will be reduced by a factor of 1.14, i.e. by 12.2 %. The data indicate significant potential for the use of biofuels both in peacetime and during martial law and post-war reconstruction of the country.

Depending on the city's objectives, a specific option can be selected. In particular, the use of diesel fuel with a bio-additive (30 % by volume) will reduce the excess of the maximum permissible single concentration of fine dust and at the same time prevent an increase in the content of nitrogen oxides. The concentration of nitrogen oxides in engine emissions may increase due to an increase in temperature in the combustion chamber and intensification of the interaction between oxygen and nitrogen in the air. This situation is observed when 100 % biodiesel is used. Therefore, considering the Concept of Environmental Policy of Kyiv until 2035, as well as the level of atmospheric pollution in the city, it is advisable to use diesel fuel with a bio-additive (30 % by volume). In addition to preventing the maximum permissible single concentration from being exceeded in public transport stops, the proposed solution will stimulate the development of a circular "green" economy in the food industry and agricultural sector, as well as the creation of new jobs and diversification of the energy market.

In addition to adding bio-components to diesel fuel, the authors suggest using starch- or lignin-based biopolymer solutions and micro-green barriers in the form of moss panels.

It is proposed that biopolymer solutions be produced from renewable raw materials, from agro-industrial waste (corn starch, cellulose residues, wood biomass, etc.). Such solutions can be sprayed using special tank trucks or fine-spray irrigation systems on the dustiest sections of roads. When dry, they form a thin film that binds fine dust particles, preventing them from being lifted back into the air by wind and traffic. A significant advantage is their complete biodegradability and lack of toxic impact on soil, water, and vegetation.

Micro-green barriers are proposed to be implemented in the form of mobile panels with moss, fixed along highways on noise barriers or dividing barriers in large cities. Moss is a unique plant capable of actively absorbing dust and heavy metals, retaining them in its biomass.

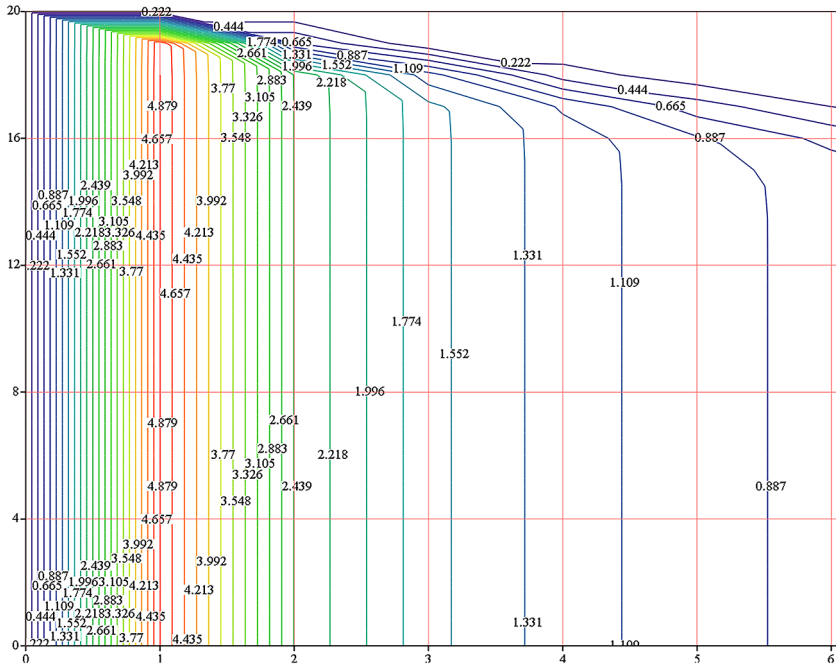

Fig. 1. PM_{10} dispersion fields in the air at a public transport stop near the Zhytomyrska metro station (Kyiv, Ukraine) along transport artery No. 1 under the following conditions: wind direction – northeast; average wind speed 4 m/s

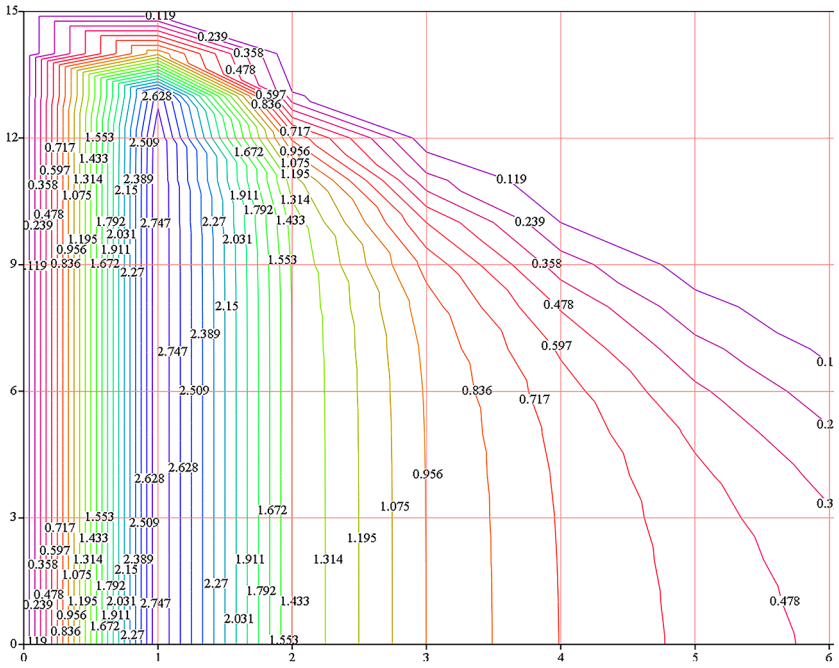

Fig. 2. PM_{10} dispersion fields in the air at a public transport stop on Liubomyra Huzara Street (Kyiv, Ukraine) along transport artery No. 2 under the following conditions: wind direction — north-west; average wind speed 4 m/s

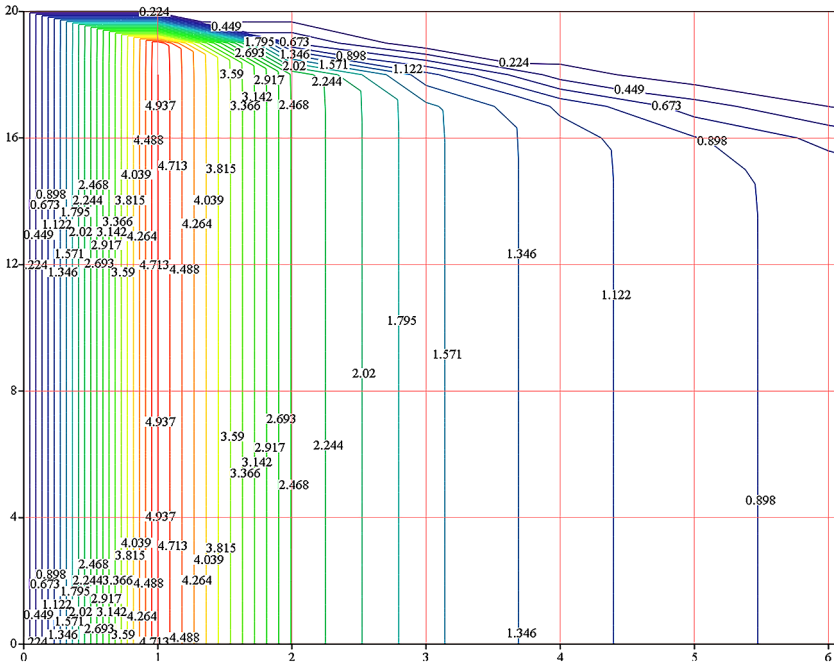

Fig. 3. Fields of secondary dispersion of PM_{10} in the air at a public transport stop near the Zhytomyrska metro station (Kyiv, Ukraine) along transport artery No. 1 under the following conditions: wind direction — northeast; average wind speed 15 m/s

To maintain its viability, drip or mist irrigation systems are to be used, which can be filled with rainwater. These panels will serve a dual purpose: firstly, reducing air pollution and, secondly, improving the microclimate of the urban environment.

These solutions will simultaneously address the problem of exceeding the maximum permissible single concentration of fine particulate matter in the air and create an additional environmental benefit using renewable resources and green technologies. The effectiveness of such innovative solutions is the subject of further research, including modeling their impact on air quality and assessing the economic feasibility of their implementation.

Conclusions. PM_{10} air pollution from motor vehicle engines, especially diesel engines, tends to spread across roadways and near sidewalks, public transport stops, etc., at approximately (5–7) m. This significantly increases the toxicity of the impurity due to its elevation to human breathing height, adsorption of other toxicants, and secondary transport over considerable distances by wind and transport flows.

To assess the state of the surface layer of the air environment contaminated with PM_{10}, spatial mathematical

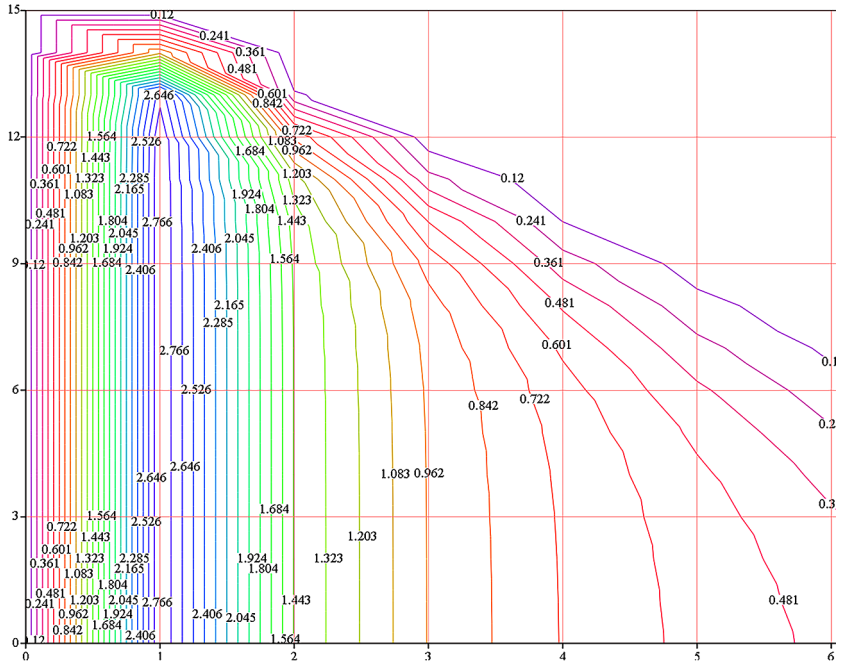

Fig. 4. Fields of secondary dispersion of PM_{10} in the air at a public transport stop on Liubomyra Huzara Street (Kyiv, Ukraine) along transport artery No. 2 under the following conditions: wind direction – north-west; average wind speed 15 m/s

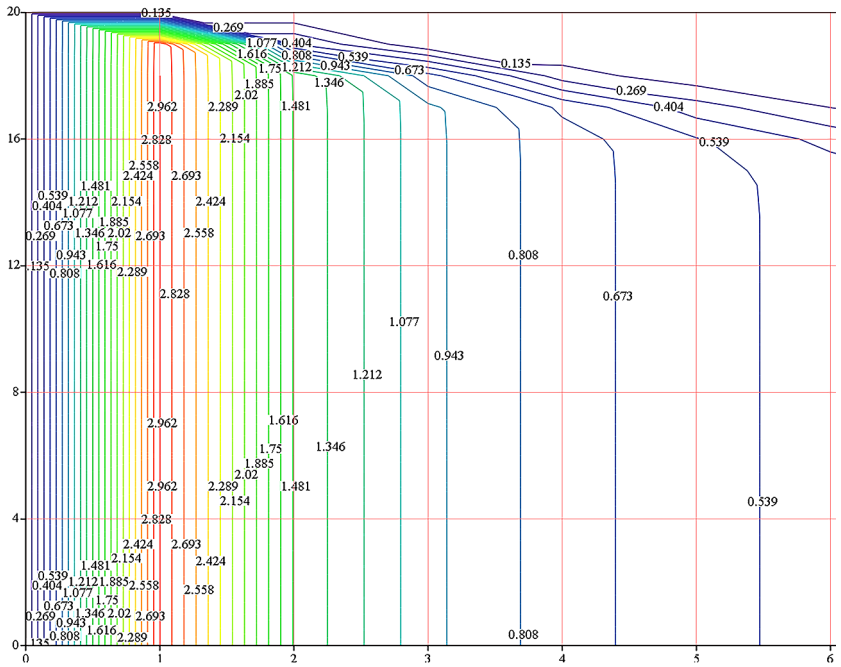

Fig. 5. Fields of secondary dispersion of PM_{10} in the air at a public transport stop near the Zhytomyrska metro station (Kyiv, Ukraine) along transport artery No. 1 under the following conditions: wind direction – northeast; average wind speed 15 m/s and replacement of diesel fuel with biodiesel

models of toxicant dispersion fields were constructed in MathCad using the solution of a semi-empirical equation of turbulent diffusion.

It is proposed to add a bio-component (biodiesel) to diesel fuel. To justify the effectiveness of the proposed solution, PM_{10} dispersion fields were modeled for the studied road sections, assuming that vehicles were powered by a fuel mixture (30 % by volume bio-additive) and biodiesel.

Exceeding the maximum permissible single concentration of toxicants in the middle of the road when motor vehicles are powered by pure biodiesel will decrease by 1.63 times (by 38.8 %). When using a fuel mixture with a biofuel content of 30 % by volume, this indicator will be reduced by 1.14 times, or 12.2 %.

Along with the use of bio-components in diesel fuel, it is proposed to use biopolymer solutions based on starch or lignin and micro-green barriers in the form of

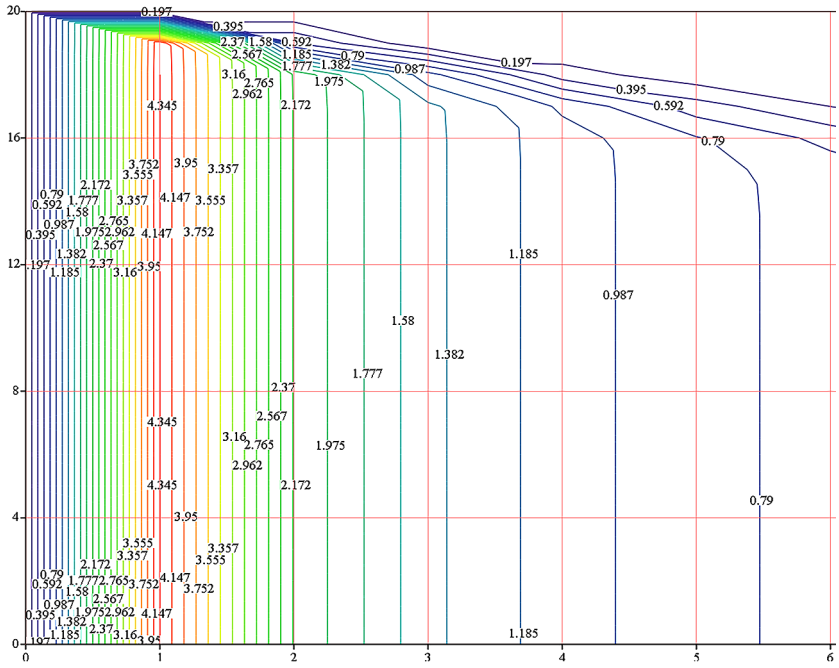

Fig. 6. Fields of secondary dispersion of PM_{10} in the air at a public transport stop near the Zhytomyrska metro station (Kyiv, Ukraine) along transport artery No. 1 under the following conditions: wind direction – northeast; average wind speed 15 m/s and partial (30 % by volume) replacement of diesel fuel with biodiesel

moss panels. This will simultaneously solve the problem of exceeding the maximum permissible single concentration of fine particulate matter in the air and create an additional environmental effect using renewable resources and green technologies.

References.

1. Gold, D. R., & Mittleman, M. A. (2013). New insights into pollution and the cardiovascular system: 2010 to 2012. *Circulation*, *127*(18), 1903-1913. https://doi.org/10.1161/CIRCULATIONAHA.111.064337

2. Pota, P., Suwannasom, P., Chattipakorn, S. C., & Chattipakorn, N. (2025). From smog to scarred hearts: Unmasking the detrimental impact of air pollution on myocardial ischemia-reperfusion injury. *Cellular and Molecular Life Sciences*, *82*(1). https://doi.org/10.1007/s00018-025-05585-0

3. Dockery, D. W., Rich, D. Q., Goodman, P. G., Clancy, L., Ohman-Strickland, P., George, P., & Kotlov, T. (2013). *Effect of air pollution control on mortality and hospital admissions in Ireland* (Research Report 176). Health Effects Institute, 3-109. Retrieved from https://www.healtheffects.org/system/files/Dockery-176.pdf

4. Johnston, F. H., Hanigan, I. C., Henderson, S. B., & Morgan, G. G. (2013). Evaluation of interventions to reduce air pollution from biomass smoke on mortality in Launceston, Australia: retrospective analysis of daily mortality, 1994–2007. *BMJ*, *346*. https://doi.org/10.1136/bmj.e8446

5. Kofanov, O., Kofanova, O., Tkachuk, K., Tverda, O., & Shostak, I. (2024). Enhancement of the market attractiveness and success of startups on the circular economy and sustainability principles. *Agricultural and Resource Economics: International Scientific E-Journal*, *10*(2), 167-189. https://doi.org/10.51599/are.2024.10.02.07

6. Kofanov, O., Vasylkevych, O., Kofanova, O., Zozul'ov, O., Kholkovsky, Yu., Khrutba, V., Borysov, O., & Bobryshov, O. (2020). Mitigation of the environmental risks resulting from diesel vehicle operation at the mining industry enterprises. *Mining of Mineral Deposits*, *14*(2), 110-118. https://doi.org/10.33271/mining14.02.110

7. Kofanov, O., Kofanova, O., Chepel, A., Kriuchkov, A., Rabosh, I., & Zhukova, N. (2022). Modeling of the car traffic air pollution on the territories neighboring multi-level interchanges. *Journal of Environmental Research, Engineering and Management*, *78*(4), 17-38. https://doi.org/10.5755/j01.erem.78.4.31583

8. Gao, Z., Mei, E. J., He, X., Ebelt, S., Rich, D. Q., & Russell, A. G. (2025). Accountability assessment of source-specific impacts of regulations on emissions and air quality using positive matrix factorization. *Environmental Science & Technology*, *59*(17), 8651-8661. https://doi.org/10.1021/acs.est.4c12511

9. He, S., Lin, Y., Wei, Z., Wan, M., & Min, Y. (2025). Sustainable emission control in heavy-duty diesel trucks: fuzzy-logic-based multi-source diagnostic approach. *Sustainability*, *17*(8), 3605. https://doi.org/10.3390/su17083605

10. Li, C., He, H., & Peng, Z. (2025). Spatiotemporal distribution of particulate matter in urban near-road communities using UAV. *Tongji Daxue Xuebao/Journal of Tongji University*, *53*(6), 934-943. https://doi.org/10.11908/j.issn.0253-374x.23364

11. Kofanov, O., Kofanova, O., Tverda, O., Tkachuk, K., Huzan, A., & Borysov, O. (2024). Strategic planning and ecological safety evaluation of university campuses on green marketing principles. *Journal of Environmental Research, Engineering and Management*, *80*(1), 101-114. https://doi.org/10.5755/j01.erem.80.1.34678

12. Meena, S., & Singh, S. K. (2025). Real-world emission assessment of diesel passenger cars in urban traffic: a comparative analysis of compliance with bharat stage VI standards. *Advance Sustainable Science Engineering and Technology*, *7*(1), 02501018. https://doi.org/10.26877/asset.v7i1.1294

13. Patiño, W. R., Vlček, O., Bauerová, P., Belda, M., Bureš, M., Eben, K., ..., & Resler, J. (2024). On the suitability of dispersion models of varying degree of complexity for air quality assessment and urban planning. *Building and Environment*, *264*, 111892. https://doi.org/10.1016/j.buildenv.2024.111892

14. Kilbo, E. K., Kisiel, M. A., Asker, C., Segersson, D., Bennet, C., Spanne, M., ..., & Molnár, P. (2024). High-resolution dispersion modelling of $PM_{2.5}$, PM_{10}, NO_x and NO_2 exposure in metropolitan areas in Sweden 2000–2018 – large health gains due to decreased population exposure. *Air Quality, Atmosphere & Health*. https://doi.org/10.1007/s11869-024-01535-0

15. Khan, S., & Hassan, Q. (2021). Review of developments in air quality modelling and air quality dispersion models. *Journal of Environmental Engineering and Science*, *16*(1), 1-10. https://doi.org/10.1680/jenes.20.00004

16. Haeger-Eugensson, M., Achberger, C., Nygren, H., Bäck, E., Bjurbäck, A., Garcia, M. R., & Forssén, J. (2021). Air quality modeling in dense urban areas at ground level – CFD, OSM or Gauss? In C. Mensink, & V. Matthias (Eds.). *Springer Proceedings in Complexity. Air Pollution Modeling and its Application XXVII*, (pp. 265-270). Springer. https://doi.org/10.1007/978-3-662-63760-9_37

17. Zgurovsky, M. Z., Mel'nik, V. S., & Kasyanov, P. O. (2011). *Evolution Inclusions and Variation Inequalities for Earth Data Processing I: Operator Inclusions and Variation Inequalities for Earth Data Processing*. Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-13837-9

18. Broster, S., & Terzano, K. (2025). A systematic review of the pollution and health impacts of low emission zones. *Case*

Studies on Transport Policy, *19*, 101340. https://doi.org/10.1016/j.cstp.2024.101340
19. Doval-Miñarro, M., Bueso, M. C., & Guillén-Alcaraz, P. A. (2025). Assessing the impact of a low-emission zone on air quality using machine learning algorithms in a business-as-usual scenario. *Sustainability*, *17*(8), 3582. https://doi.org/10.3390/su17083582
20. Sheikh, H. A., Maher, B. A., Woods, A. W., Tung, P. Y., & Harrison, R. J. (2023). Efficacy of green infrastructure in reducing exposure to local, traffic-related sources of airborne particulate matter (PM). *Science of The Total Environment, 903*, 166598. https://doi.org/10.1016/j.scitotenv.2023.166598
21. Wang, J., Li, Z., Kumar, P., & Ren, C. (2024). Mitigating particulate matter exposure at bus stations using green infrastructure. *Sustainable Cities and Society, 113*, 105703. https://doi.org/10.1016/j.scs.2024.105703
22. Greenwald, R., Sarnat, J. A., & Fuller, C. H. (2024). The impact of vegetative and solid roadway barriers on particulate matter concentration in urban settings. *Plos One, 19*(1), e0296885. https://doi.org/10.1371/journal.pone.0296885
23. Liu, K., Lin, X., Xu, J., Ma, F., Yang, W., Cao, R., ..., & Wang, Z. (2024). Investigating the influence of platform design on the distribution of traffic particulate matter at the bus stop. *Building and Environment, 255*, 111395. https://doi.org/10.1016/j.buildenv.2024.111395
24. Šarkan, B., Loman, M., Stopka, O., Caban, J., & Małek, A. (2025). Quantifying the Volume of Particulate Matter at Bus Stations. *Promet – Traffic & Transportation, 37*(1), 19-35. https://doi.org/10.7307/ptt.v37i1.675
25. Briant, S., Cushing, D., Washington, T., & Swart, M. (2025). Small but Significant: A Review of Research on the Potential of Bus Shelters as Resilient Infrastructure. *Applied Sciences, 15*(12), 6724. https://doi.org/10.3390/app15126724
26. Eauto (2023). Ukrainians prefer gasoline cars, but the share of diesel cars has increased. Results 2022. *Automotive Market Research Institute*. Retrieved from https://eauto.org.ua/en/news/252-ukrainians-prefer-gasoline-cars-but-the-share-of-diesel-cars-has-increased-results-2022

Мінімізація впливу автотранспорту на навколишнє середовище й здоров'я населення агломерацій

О. Є. Кофанов[1], *О. В. Кофанова*[1], *А. В. Павличенко*[2], *О. Я. Тверда*[*1], *С. І. Проценко*[3]

1 – Національний технічний університет України «Київський політехнічний інститут імені Ігоря Сікорського», м. Київ, Україна
2 – Національний технічний університет «Дніпровська політехніка», м. Дніпро, Україна
3 – Державний університет «Київський авіаційний інститут», м. Київ, Україна
[*] Автор-кореспондент e-mail: tverda.o-iee@lll.kpi.ua

Мета. Зниження екотоксикологічного впливу дрібнодисперсних твердих частинок (PM) на здоров'я людей на зупинках громадського транспорту та прилеглих до них територіях.

Методика. Для оцінки стану приземного шару повітряного середовища, забрудненого PM, у MathCad із використанням розв'язку напівемпіричного рівняння турбулентної дифузії побудовані просторові математичні моделі полів дисперсії токсиканту.

Результати. Запропоновано додавати до дизельного палива біоскладову (біодизель). Для обґрунтування ефективності запропонованого рішення проведене моделювання полів дисперсії PM для досліджуваних ділянок за умови живлення автотранспортних засобів сумішевим паливом (30 % об. біоскладової) і біодизелем. У разі заміни нафтового палива на біоскладову перевищення $ГДК_{м.р.}$ PM зменшиться у 1,63 рази (на 38,8 %), а при застосуванні дизельного палива із вмістом біоскладової 30 % об. – у 1,14 рази (на 12,2 %). Встановлено, що доцільніше застосовувати дизельне паливо з біоскладовою (30 % об.), що забезпечить зменшення перевищення $ГДК_{м.р.}$ дрібнодиспесного пилу й не дозволить збільшити вміст оксидів Нітрогену у викидах дизельних двигунів. Разом із застосуванням біоскладової до дизельного палива пропонується використовувати біополімерні розчини на основі крохмалю чи лігніну та мікро-зелені бар'єри у вигляді мохових панелей. Це дозволить одночасно вирішувати проблему перевищення $ГДК_{м.р.}$ дрібнодисперсних твердих частинок у повітрі міст і створювати додатковий екологічний ефект завдяки використанню відновлюваних ресурсів і «зелених» технологій.

Наукова новизна. На основі прогнозних моделей локального забруднення приземного шару повітря дрібнодисперсним пилом уперше встановлено, що застосування дизельного палива з 30 % об. біоскладовою автотранспортними засобами знижує рівень пилового забруднення й запобігає перевищенню $ГДК_{м.р.}$ навіть у зонах зупинок громадського транспорту та на прилеглих до них територіях.

Практична значимість. Прогнозні математичні моделі дисперсії PM_{10} можуть слугувати для визначення безпечної відстані від дороги, оцінювання екологічного ризику для здоров'я людей та ухвалення управлінських рішень. Використання 30 % об. біоскладової у дизельному паливі разом із застосуванням біополімерних розчинів і мікрозелених бар'єрів дозволить зменшити викиди дрібнодисперсного пилу й запобігти зростанню вмісту оксидів Нітрогену у викидах двигунів, що є характерним при живленні автотранспортних засобів 100%-м біодизелем.

Ключові слова: *забруднення, довкілля, дисперсія, пил, дизель, біодизель, біобар'єри, циркулярність*

The manuscript was submitted 04.06.25.