METHODOLOGY FOR ASSESSING THE LEVEL OF ATMOSPHERIC POLLUTION BY ROAD TRANSPORT IN THE PROJECTS OF MANAGEMENT OF ENVIRONMENTAL STATE OF A CITY

Olena Bakulich
candidate of technical sciences, Professor, National Transport University, Kyiv, Ukraine, bakulich.elena@gmail.com

Evgeny Samoilenko
Senior Lecturer, National Transport University, Kyiv, Ukraine, sirius27@ukr.net

Yuriy Peskovets
Department of Management
National Transport University, Kyiv, Ukraine, y5612585@gmail.com

KEYWORDS: Pollution assessment methodology; pollution level; project management; transport; ecological characteristics
JEL classification: O100, O110, O190 DOI: https://doi.org/10.52244/ep.2023.25.12

For citation: Bakulich O., Samoilenko E., Peskovets Yu., (2023) Methodology for assessing the level of atmospheric pollution by road transport in the projects of management of environmental state of a city**.** Economic Profile. Vol. 18, 1(25), p. 25–29. DOI: https://doi.org/10.52244/ep.2023.25.12

Abstract. *The level of environmental pollution is the main criterion that determines the quality of living conditions in cities. One of the most dangerous environmental problems of cities that affects the health of the population is atmospheric air pollution by road transport. In the city of Kyiv, the total volume of pollutant emissions from stationary sources in 2020 amounted to 25.5 thousand tons, from mobile sources almost 9 times more – 225.8 thousand tons. The comprehensive air pollution index (API) is used to characterize air quality in cities which allows you to determine how many times the total level of air pollution with several impurities exceeds the permissible value and to identify substances that contribute the most to atmospheric pollution. In most European countries, the USA, Canada and others, the air quality index (AQI) is used to control the level of atmospheric air pollution. When calculating the AQI, the concentration of pollutants is determined by field studies (monitoring) or mathematical modelling. In contrast to monitoring, which is a rather expensive study, mathematical modelling provides not only an operational assessment of the level of atmospheric pollution but also makes it possible to forecast the state of the air and to determine strategies for reducing pollutant emissions. In this regard, the creation of methods that allow making operational forecasts of the level of atmospheric pollution in cities and preventing critical situations in which the concentration of pollutants exceeds the maximum permissible values is an extremely urgent task.*

The purpose of the work is to create a methods for assessing the level of atmospheric air pollution by road transport in the projects of managing the ecological state of the city by modelling the concentration of the main pollutants in street canyons.

The main part.

The methodology for assessing the level of atmospheric air pollution by road transport in the projects of managing the ecological state of the

city includes the determination of the intensity of emissions of pollutants and the conditions of their dispersion. Pollution fields that are formed in the surface layer of the atmosphere have spatio-temporal heterogeneity, which is explained by dynamic and static factors: intensity, composition of traffic flow, meteorological conditions, geometric characteristics of the street-road network (SRN), topography of the area, presence of green spaces, regulated intersection, spatial orientation of the street, etc. The main approaches to determining the level of air pollution by road transport are methods based on Gaussian models: CALINE-4 (California Line Source Model), Roadway 2.0, Hiway-2; GFLSM (General Finite Line Source Model), etc. and urban canyon models. The most common among urban canyon models are: STREET (Johnson et al., USA, 1973); Canyon Plum Box Model (Yamartino et al., 1986); Operational Street Pollution Model (Berkowicz, 1996). The main disadvantages of most methods are that they do not take into account the microclimatic features of the city, the relief of the area, etc.

The algorithm of the methodology for assessing the level of atmospheric air pollution by road transport in the projects of managing the environmental condition of the city includes the following stages:

1) The street and road network of the city is approximated by a set of elementary homogeneous street canyons – areas with buildings between the nearest intersections, for which spatial and geometric characteristics are empirically determined: width, length, spatial orientation of the canyon, weighted average height, continuity and composition of buildings, etc.;

2) Division of the massif of street canyons according to spatial and geometric characteristics into homogeneous groups, in each of which a typical canyon is determined with further identification of real street canyons whose indicators are best matched with the indicators of a typical canyon. Empirical studies of the daily dynamics of traffic flow and meteorological indicators are carried out in the specified typical street canyons: wind speed, direction;

3) Running emissions of pollutants by vehicles of the corresponding category is determined on the basis of the concept of "efficient" traffic flow. "Efficient" traffic flow is a statistical aggregate of "efficient" vehicles of the respective categories and is defined as follows:

$$N_{ef} = N_{ef}(M_1) + N_{ef}(M_2) + N_{ef}(M_3) + \\ + N_{ef}(N_1) + N_{ef}(N_2) + N_{ef}(N_3) + N_{ef}(L) \quad (1)$$

where: N_{ef} – the number of "efficient" motor vehicles of all categories of which the city's fleet (flow) consists.

$N_{ef}(M_1) = N_{ef}\omega_1$ – the number of "efficient" motor vehicles of the category M_1;

$N_{ef}(M_2) = N_{ef}\omega_2$ – the number of "efficient" motor vehicles of the category M_2 and so on;

ω_i – normalized weighting factor that determines the share of motor vehicles of this category in the flow of the city

An "efficient" vehicle of the corresponding category is a virtual vehicle, the technical and operational characteristics of which correspond to the average weighted characteristics of vehicles of all makes, models, series of vehicles belonging to this category, taking into account their weighting factors. When building an "efficient" vehicle, technical and operational characteristics (engine capacity, power, type of fuel, fuel consumption, mass, dimensions, etc.) are applied which directly or indirectly affect the level of pollution;

4) Intensify emissions of pollutants is determined on the basis of data on daily dynamics of traffic characteristics, namely: intensity of traffic flow; traffic flow density; speed of traffic flow; the composition of the traffic flow; traffic delays; road loading level;

5) The concentration of pollutants is determined within the street canyon and is equal to the sum of the concentration of direct dispersion of pollutants, the

concentration caused by air recirculation in the street canyon and the urban background concentration. The concentration of direct dispersion of pollutants from the traffic flow is equal to:

$$C_d = \sqrt{\frac{2}{\pi}} \int \frac{Q dx}{U_s W \sigma_z(x)} \quad (2)$$

where Q – the intensity of emissions of polluting substances from the "effective" traffic flow, mg/m*s

U_s – wind speed at street level, m/c;

W – width of the street canyon, m;

$\sigma_z(x)$ – the vertical dispersion parameter at the distance x from the emission source;

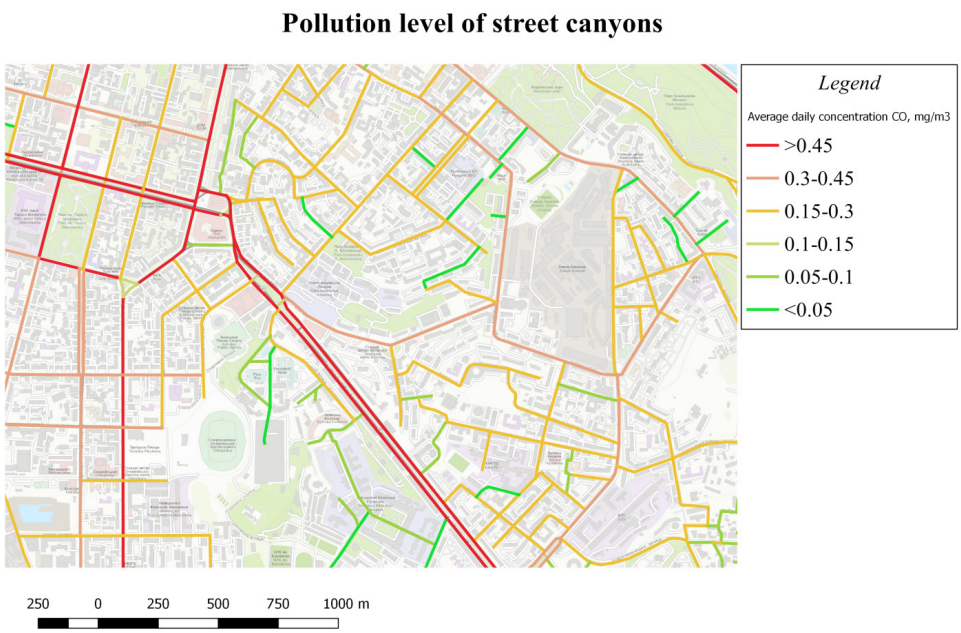
This model is based on the following assumptions: it is assumed that the traffic flow and emissions from it are evenly distributed over the canyon, the wind speed at the street level (U_s) is determined by assuming a logarithmic decrease in the wind speed from the average height of the roof of the buildings to the ground of the street.

6) The topography of the area can be taken into account by multiplying the total emissions by the emission intensity factor (ε). During movement on a horizontal section ε=1, during movement on an ascent ε=1.1–1.2, during movement on a descent ε=0.7-0.9. The emission intensity factor is selected empirically depending on the slope of the ascent (descent). With oncoming traffic, the total value ε will be close to 1.

7) Visualization of the level of atmospheric air pollution is carried out by drawing city street pollution maps using modern geographic information systems (GIS). GIS is a system of collection, storage, analysis and graphic visualization of spatial data and related information about the necessary objects. Street canyons can be represented on the map in the form of linear objects, with corresponding attribute information (name and type of street, length of the street canyon, road category, level of pollution by the corresponding harmful substance, etc.).

This methodology was used to assess the level of atmospheric air pollution in the city of Kyiv. The results of modelling the level of atmospheric pollution by road transport are presented in the form of a map of pollution of the street canyons of Pechersk district of Kyiv (Fig. 1). Drawing the map was carried out with the help of a geographic information system (GIS), which is a system of collection, storage, analysis and graphic visualization of spatial data and related information about the necessary objects.

Figure 1 – Map of the average daily level of carbon monoxide pollution of the street canyons of Kyiv at a wind speed of 5 m/c



Street canyons on the map are presented in the form of linear objects, with corresponding attribute information (name and type of street, length of the street canyon, road category, level of pollution by the corresponding harmful substance, etc.). The average daily concentration of carbon monoxide is displayed in different colours, depending on the pollution level of each of the street canyons.

Conclusions. Therefore, the proposed algorithm of the methodology for assessing the level of atmospheric air pollution in the projects of managing the ecological state of the city makes it possible to quickly determine and forecast the concentration of harmful substances. The research results will make it possible to warn of critical situations in which the concentration of pollutants exceeds the maximum permissible values, to determine emission reduction strategies and to introduce preventive measures.

References

1. Gutarevich Yu. F., Zerkalov D. V., Govorun A. G., Korpach A. A., Merzhyevska L.P. (2006) Ecology and road transport: Manual. – K.: Aristey, 292p. [in Ukrainian]

2. Abramovskij E.R., Karplyuk V.I., Peremetchik M.M. (2011) Atmosphere of big cities. Dn-sk.: Science and Education. – 350 p. [in Ukrainian]

3. R. Berkowicz, M. Ketzel, S. S. Jensen, M. Hvidberg, O. Raaschou-Nielsen (2008) Evaluation and application of OSPM for traffic pollution assessment for a large number of street locations. Environ. Model. Softw., 23, 296. doi:10.1016/J.ENVSOFT.2007.04.007 4. Berkowicz R. (2000) OSPM – a parameterized street pollution model // Kluwer Academ. Publishers. Netherlands. Environmental Monitoring and assessment. – Vol. 65. – P. 341-359.

5. Bakulich O.O., Oliynyk R.V., Samoylenko E.S. (2015) Potential environmental hazards of street canyons. Bulletin of the National Transport University. «Technical Sciences» series. Issue 1 (31). Pp. 18-26. URL: http://publications.ntu.edu.ua/visnyk/31_1_tech_2015/018-026.pdf [in Ukrainian]

6. Bakulich O.O., Samoylenko E.S. (2021) Dynamics of pollution level in urban areas. Bulletin of the National Transport University. «Technical Sciences» series. Scientific and technical collection. Issue 1 (48). Pp. 12-19. URL: http://publications.ntu.edu.ua/visnyk/48/012-019.pdf [in Ukrainian]

7. Bakulich O.O., Grebelnik M.M., Samoylenko E.S. (2022) Environmental security management of the megapolis. Bulletin of the National Transport University. «Technical Sciences» series. Scientific and technical collection. Issue 1 (51). Pp. 12-20. DOI: 10.33744/2308-6645-2022-1-51-020-027 URL:http://publications.ntu.edu.ua/visnyk/48/012-019.pdf [in Ukrainian]