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# Improving management of environmental risk from urbanized areas highways' air pollution (on an example of Kyiv city)

***V. Trysnyuk** *(Institute of Telecommunications and Global Information Space, NASU)*, **R. Sipacov** *(Institute of Telecommunications and Global Information Space, NASU)*, **O. Lebid** *(Institute of Telecommunications and Global Information Space, NASU)*, **T. Trysnyuk** *(Institute of Telecommunications and Global Information Space, NASU)*, **V. Prystupa** *(Institute of Telecommunications and Global Information Space, NASU)*, **L. Horoshkova** *(National university of "Kyiv-Mohyla academy", Zaporizhzhia National University)*

## SUMMARY

In the work according to the proposed scenario, the concentrations of secondary formaldehyde pollution from road transport near the main overpasses were calculated at the maximum monthly concentrations and the environmental risks to public health for the conditions of Kyiv were calculated. The results of calculations for the most polluted interchanges in Kyiv are visually presented.

An online system (web portal) of environmental analysis, created on the basis and using ArcGIS solutions (Environmental Analysis) for assessing and understanding the potential ecological risk impact on the environment and public health, taking into account the predicted indicators of formaldehyde concentrations from vehicles at the time of designing the development of city infrastructure (automobile highway), allows you to optimize the environmental impact assessment and reduce the time that needed for required to review the project by government agencies and environmental organizations.

The model creates a real-time forecast (synchronization of data on the calculation of formaldehyde concentrations) for each point (highways) of the earth, which allows you to predict future risk trends, allowing you to move from response strategy to warning strategy and make more informed decisions.

## Introduction

Atmospheric air pollution in urban areas due to the increase in mobile motor vehicle pollution sources running on gasoline and diesel fuel has become significant in recent years.
Recently, in large industrial cities of the world and, in particular, Ukraine, as a result of air pollution, such a negative phenomenon as the formation of photochemical smog has become more frequent. The main factors and mechanism of smog formation, including over the city of Kiev, studied to date insufficiently. And although the mechanism of smog formation, which was considered in many foreign authors' works, is identical to the air of large cities, the indicator of urban photochemical pollution is chosen in each case. It depends on many factors, especially weather conditions, type of pollutants, and more (*Varavin, 2018*).
For Kyiv, such an indicator can be the concentration of formaldehyde as a product of oxidation of hydrocarbons from the emission of exhaust gases from various automobile engines and natural factors (hydrocarbons of plant origin). Given the annual growth of road transport on the roads of major cities of Ukraine, including Kyiv, the correlation of photochemical smog over road overpasses (especially at two or more levels) and at busy intersections and the number of vehicles, extremely relevant and timely scientific and practical task of assessing and forecasting the concentration of secondary air pollution by formaldehyde in cities transport.

## Method

These existing solutions' capabilities allow obtaining relative estimates of the "contribution" of mobile sources (including vehicles) in total emissions into the atmosphere. Also, with the help of direct measurements to solve the problem of identifying emissions from road overpasses and large intersections, where vehicles move at low speeds and stand in the so-called "traffic jams" and "traffic jams" is impossible (*Trofymchuk and Myrontsov , 2021*).
It is important to make a preliminary forecast of air pollution in these local areas of the city to help management decisions and evaluate traffic flows in city highways' design and rehabilitation, taking into account forecast forecasts. In practical situations, with an existing fixed network of monitoring observations, there is usually a need for operational information for management decision-makers to assess and forecast the formation of smog situations over road junctions and overpasses. The paper substantiates the need to develop a mathematical model to determine the concentration of hydrocarbon emissions from engines running on gasoline and diesel fuel and secondary air pollution due to photochemical transformations, formaldehyde, which is an indicator of photochemical smog over city highways (*Azimov and Kuraeva, 2019*)
The dissertation research addresses environmental risk management in urban areas with secondary pollution of atmospheric air by formaldehyde from vehicles. This study's proposed calculation scenario is where the level of risk is determined depending on the concentration of formaldehyde molecules formed in the air resulting from photochemical transformations under stable weather conditions.
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To determine secondary pollution concentration by formaldehyde was developed mathematical model consists of two interconnected blocks: dynamic and kinetic. The first block of the model developed based on a convective jet theory from a warm surface, thus allowing to obtain the parameters of a polluted air dome formed over a motor transport highway. Depending on the road junction area and the site's meteorological conditions, the system of the model's dynamic block's obtained equations makes it possible to get the total amount of hydrocarbon emissions, depending on the number of vehicles on the highway at the same time (*Trofymchuk and Kaliukh, 2015*)

The kinetic block of the model makes it possible to determine the concentration of secondary pollution with formaldehyde in atmospheric air due to photochemical transformations of hydrocarbons included in the emissions of internal combustion engines. The reaction rate of conversion for chemical elements was performed based on Van-Hoff-Arrhenius differential equation.
Based on the calculations, the error between the calculated and measured values of formaldehyde concentrations, which does not exceed 7.2%. Similarly, calculations were made on 7 overpasses in the city of Minsk (Belarus), the resulting error does not exceed 8% (*Trofimchuk, 2002*).
In the environment of Microsoft Excel (Tabl. 1) the convenient calculator of calculation of concentrations of pollution from motor transport is programmed. Also created templates (scriptinglanguage) for scientific and analytical programs Python, MATLABwhich allow you to automate the calculation of predicted concentrations of formaldehyde for many coordinates while deriving the necessary analytical graphs (*Okhariev and Trysnyuk, 2020*).

***Table 1*** *Calculator (.xlsx) for estimating the dependence of hydrocarbon emissions*

| | Indicator, Unit | Description | Formula | Value |
|---|---|---|---|---|
| *1* | $t, °C$ | outdoor air temperature | n/a | -10.0 |
| *2* | $L, m$ | distance between vehicle | n/a | 20 |
| *3* | $l, m$ | vehicle length | n/a | 5 |
| *4* | $L', m$ | length of one lane | n/a | 300 |
| *5* | $n, entire$ | number of road lanes | n/a | 22 |
| *6* | $N, entire$ | number of vehicles | $\frac{n * L'}{l + L}$ | 264 |
| *7* | $D, entire$ | size of transport hub | n/a | 300 |
| *8* | $q_a, l/m$ | fuel per 1m/vehicle | n/a | 0.00008 |
| *9* | $R_s, MJ/m\text{^}2/h$ | scatter radiation | n/a | 42 |
| *10* | $R_d, MJ/m\text{^}2/h$ | direction radiation | n/a | 85 |
| *11* | $R_a, MJ/m\text{^}2/h$ | heat from all vehicles | $\frac{q_a * N * 40000}{100000}$ | 0.000845 |

The error in comparing the experimental and calculated values of the rate constant of the conversion of hydrocarbon emissions from vehicles into formaldehyde can be explained by the fact that the main process of smog formation occurs at an altitude of 200 (two hundred) m and more. -1/T when calculating (Darnytsia area PSZ №9) values of lnK (CHCOH/CCH), while monitoring measurements of CHCOH occur in the surface layer of atmospheric air at a height of about 2 (two) m from the surface (Fig. 1).
This positive error is variable, tends to increase in the summer months and is also characteristic of a number of Ukrainian cities. The mathematical model developed using a system of regular monitoring observations of atmospheric air pollution in Kyiv. Using the developed model, the Microsoft Excel calculator and the program codes (scripting languages for scientific-analytical programs such as Python, MATLAB) allow calculating hydrocarbons' emission into the atmosphere from road transport as well as formaldehyde concentration. It can reduce environmental risk to the health of the population located on motor transport highways and residential areas on the verge of a motor transport junction (*Trofymchuk and Kaliukh, 2018*).

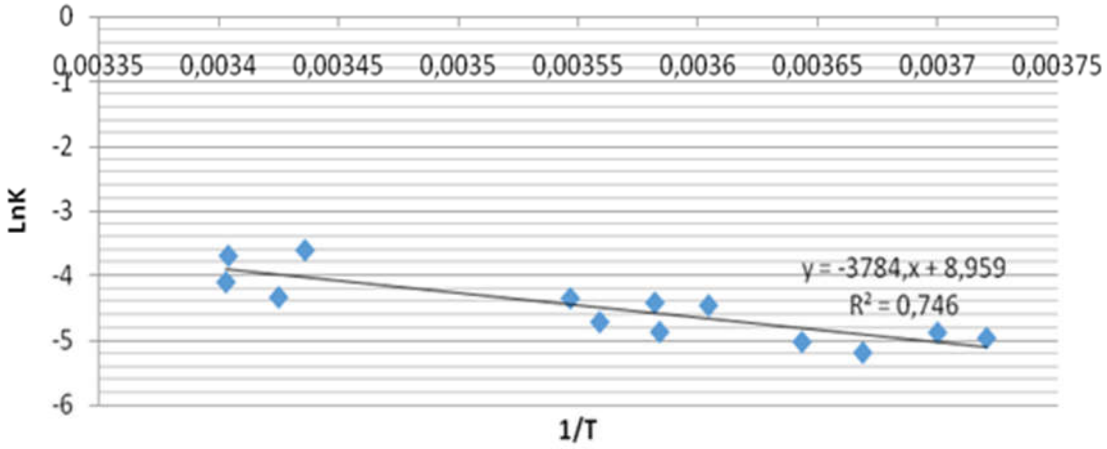


***Figure 1*** *Linear approximation of dependence* $lnK = f(1/T)$.

The calculation of carcinogenic and non-carcinogenic risks to public health from air pollution according to the standard method at the main intersections and overpasses of Kyiv showed that the average carcinogenic risk is in the range of IELCR (min: 5,12E-05, max:1,54E-04) and HQ (min:1,72, max:5,17), which according to the existing classification of risk levels is defined as average, which requires dynamic control and in-depth study of the possible consequences of adverse effects on the population. The maximum values of both non-carcinogenic and carcinogenic risk are observed in the summer months near the Central Bus Station, metro stations "Shulyavka", "Lybidska", "Dorogozhychi", at the intersection of Danyla Sherbakivskoho and Stetsenko streets, near Poshtova (Fig.2) Square.

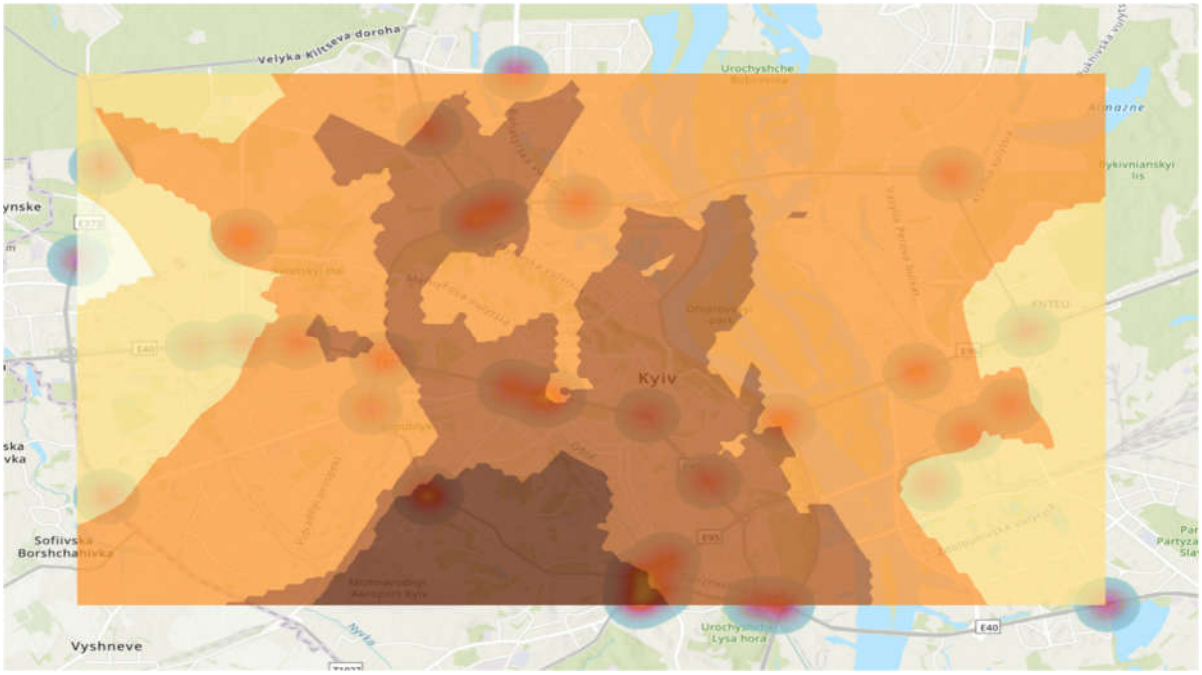


***Figure 2*** *Significance of environmental risks to public health from the concentration of formaldehyde on some overpasses in Kyiv.*

**Conclusion**

For required to review the project by government agencies and environmental organizationsIn the work according to the proposed scenario, the concentrations of secondary formaldehyde pollution from road transport near the main overpasses were calculated at the maximum monthly concentrations and the environmental risks to public health for the conditions of Kyiv were calculated. The results of calculations for the most polluted interchanges in Kyiv are visually presented.
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