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A study of air pollution with formaldehyde along the highways in Kyiv city.

Olena Voloshkina [1*] ORCID: 0000-0002-3671-4449,
Rostyslav Sipakov [2] ORCID: 0000-0002-0862-5043,
Olena Zhykova [3] ORCID: 0000-0003-0662-9996,
Julia Bereznitska [4] ORCID: 0000-0001-7953-3974

[1,2,3,4] Kyiv National University of Construction and Architecture,

*Corresponding author: e.voloshki@gmail.com, Povitroflotsky Avenue, 31, Kyiv, Ukraine, 03037,

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ABSTRACT

The problem of air pollution in the cities of Ukraine was described. The methodology of calculation of hydrocarbon emission on automobile overpasses and crossroads of Kyiv was suggested. By the number of bands, the number of cars was determined. The calculation has shown that at the same time near 300 cars can be on the overpass during peak hours. The average concentration of formaldehyde according to the calculations and observation data in 2016 was presented.

1. Introduction

Recently the problem of air pollution in the cities of Ukraine has become very sharp. [1,3,7,11 etc.]

As main sources of formaldehyde which gets into the air the following groups are divided (which, in turn, are divided into primary and secondary): enterprises that use

formaldehyde in their activities; sanitary burning of fuel and waste; movable sources; materials that contain formaldehyde (its evaporation occurs); city fires; land fields of domestic waste; natural sources.

For the city of Kyiv, the formaldehyde formation from movable sources of hydrocarbon emission (secondary pollution) has a very powerful impact on atmospheric air pollution index. [4.11 and others].

It is the growth of number of vehicles that work on natural gas in big cities of Ukraine is connected with formaldehyde concentration increasing in recent years.

The existing models and methods of calculation of formaldehyde concentration in big cities are connected, in particular, with the creation of mathematic models of air pollution basing on experimental data about pollution and on geoinformation system (GIS) data. The separate type of models concerns the realization of solving methods of spatial non-stationary, adequately diffusive kinetic equations for dissemination and turbulent dispersal of chemically reacting pollutants in the surface layer of atmosphere in urbanized areas. The nowadays existing methods of modelling both as the spatial dissemination of pollutants, analysis of regressive mapping dependencies and as the atmospheric diffusion models [7,8,9,14 and others] cannot be unified as there are a lot of differences of large cities which have been considered; so, many processes and atmospheric physic-chemical phenomena need to be included into the model.

2. Presentation of the main material of the study

Basing on long-term monitoring data the current survey includes the analysis of average monthly dependencies and the maximum concentration of formaldehyde from air temperature, and the methodology of calculation of hydrocarbon emission on automobile overpasses and crossroads of Kyiv was suggested.

Basing on the given methodology the load on transport node between Sapero-Slobids'ka street and Naddniprians'ke highway was found out by the authors.

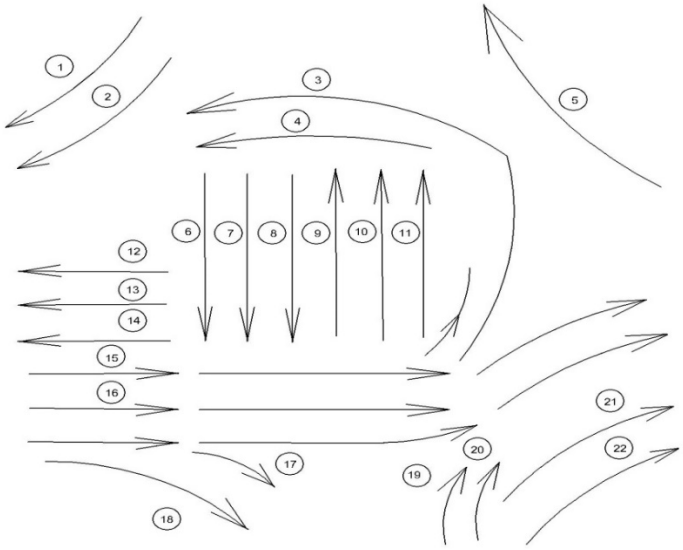
The suggested mathematic model of calculation of formaldehyde concentration consists of two parts. The first considers the amount of heat which comes from the surface area of the transport node. The equation of amount of moving contaminated air will allow to define the parameters of the polluted air jet and to calculate the heat amount that comes out from the heat

source into the environment, it also will help us to define the character and parameters of convective air jet over the warm surface.

For that we should find the surface of the transport node - S (m2) on the map; the amount of heat on the surface consists of the amount of direct and diffused radiation as well as from the vehicles heat on the transport node.

By the number of bands, we can determine the number of cars. According to the scheme of the traffic flows on the junction (pic.1) we calculate 22 traffic flows for the given overpass.

The calculation has shown that at the same time near 300 cars can be on the overpass in peak hours. For 1 car the fuel consumption is 8 liters per 100 km, or 0,00008 l/m.



Pic.1. The scheme of transport flows on the transport node between Saperno-Slobids'ka street and Naddniprians'ke highway.

The period of maximum heat release occurs at 11^{00}-$12^{00}$and 12^{00}-13^{00}. The average speed of warm air which rises upward over the surface we can obtain through the formula [4]:

$$V_y = 0{,}56 \cdot \left(\frac{Q_K}{y - y_0}\right)^{0{,}33} \quad (1)$$

We consider that the narrowest section of the convective jet is located on the distance 2D from the land surface, i.e. 600m for the considered transport node.

Consumption Q_K can be found by the formula:

$$Q_k = R_p + R_c + R_a (\text{MJ/m}^2\text{per month}) \quad (2)$$

When R_p, R_c, R_a - accordingly, is the sum of direct and diffused radiation for Kyiv city and the heat from car emissions on the transport node.

The average temperature in the passage section of convective jet:

$$\Delta t_{cep} = \frac{41 \cdot (Q_K)^{\frac{2}{3}}}{(y - y_0)^{\frac{5}{3}}} = \frac{41 \cdot 1000^{\frac{2}{3}}}{600^{\frac{5}{3}}} = 0{,}45^{o}\text{C}$$

The typical composition of exhaust gases from the engine of one car are presented in the survey [6].

Table 1

Typical composition of exhaust gases (Hydrocarbons $CH_{1,85}$)

Engine type		
Stepper motors	*Intermediate*	*7,5 g/kWh*
Diesel engine	*Capacity*	*0,5 5 g/kWh*

300 cars with the speed~60 km/h with average capacity 100 kW make the emission:

$$300\ cars \cdot 100\ kW \cdot 7\frac{g}{kWh} \cdot \frac{1}{3600s} = 70\frac{g}{s}$$

Consumption in the upper jet is:

$$\frac{\pi \cdot D^2}{4} \cdot V_y = 0{,}785 \cdot 300^2 \cdot 1\frac{m^3}{s} = 70000\frac{m^3}{s}$$

Concentration of the cars emission in the heat jet:

$$C_{CH} = \frac{70000\frac{mg}{s}}{70000\frac{m^3}{s}} = 1\frac{mg}{m^3}$$

Having found ethen concentration in the vertical convicting jet on the height of 600s above the surface of the overpass we can find the part of its transformation into formaldehyde on particular weather conditions. Formaldehyde concentration (secondary pollution) in general:

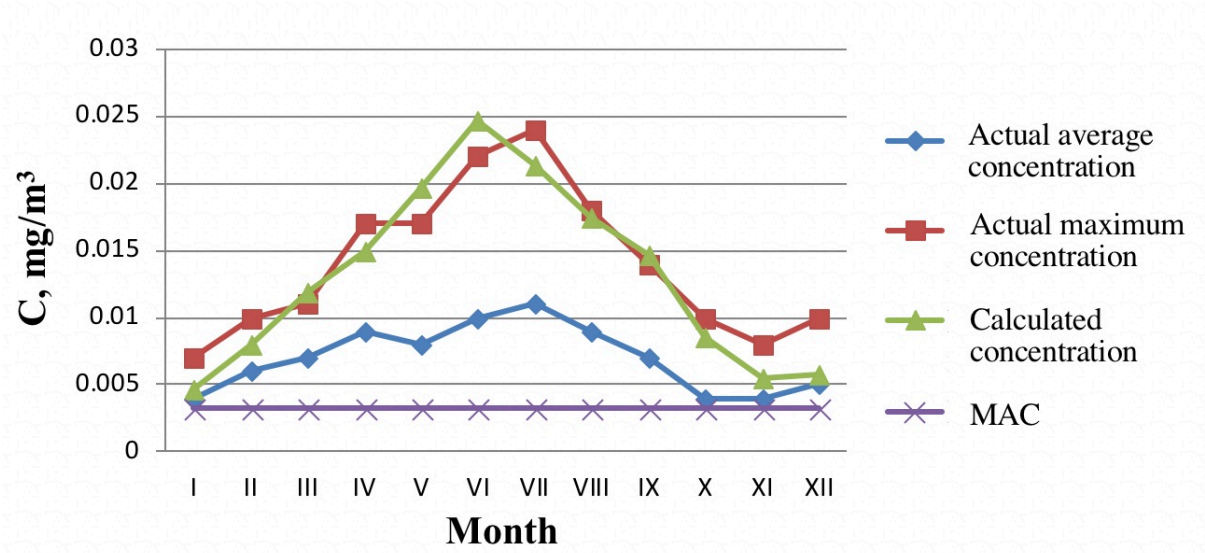
$$C_{CHOH} = k \cdot C_{CH}$$

when k - coefficient, which depends on air temperature, time, intensity of sunlight, etc.

Transformation speed coefficient was considered in details in the work [4] and, basing on the experimental data it was proved that this parameter can be found by the formula:

$$\ln k = -\frac{3784}{t} + 8{,}959$$

Having made the estimation for different monthly average temperatures we should consider the distribution of monthly average concentration of formaldehyde on the given transport overpass. At pic. 2. The curve of average annual concentration is presented according to the calculations and actual data.



Pic. 2. The chart of curves of average concentration of formaldehyde according to the calculations and observation data in 2016.

From the given diagram it is possible to draw the conclusion that concentration data which have been calculated by using the suggested method and the data from monitoring

observations are well matched for the maximum values of formaldehyde concentration in atmospheric air on the given territory. As for comparison of average monthly data, the inflated data of the calculated concentrations can be explained by the fact of photochemical transformation and formation, as a consequence, of formaldehyde at a distance of more than 200 m from the ground surface, when the monitoring data were taken from the surface layer of atmosphere. The formula for determination of Δt (the average temperature in the cross-section of convicting jet) demonstrates clearly the rising of temperature at a distance of 600 m from the ground surface.

Basing on the conducted researches we can draw a conclusion about expediency of application of convicting jet theory when estimating and predicting formaldehyde concentration above transport overpass.

The suggested methodology gives good comparisons with the measured formaldehyde concentrations in atmospheric air above other overpasses in Kyiv and can be used in different cities of Ukraine where there is considerable pollution of atmospheric air from vehicles.

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