DISPERSION AND ASSESSMENT OF FORMALDEHYDE EMISSIONS BY AUTOMOBILES AND THEIR INFLUENCE ON THE AIR QUALITY

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Abstract: *The paper deals with dispersion of formaldehyde, which is emitted by cars. According to our study of statistical data for Chernivtsi city, formaldehyde is the most dangerous component of the exhaust fumes.The intensity of the traffic as well as formaldehyde emission in city's streets net according to a mathematical model of the chosen part of the Chernivtsi has been studied. Such modeling enables us to define the level of air contamination in any part of the chosen area. In the result of our research we defined the contour maps of concentration of formaldehyde.The objective of the study is to improve mathematical model, calculate 2D concentration profile of formaldehyde in surface air of the area under study with availability of wind, and conduct virtual experiment with different boundary conditions in the contours of the buildings and streets. The obtained results of the modeling are more accurate and more suitable for description of dispersion processes over crossroads. Under windy weather conditions, in particular during strong winds, we can observe considerable shift of concentration profiles of formaldehyde, and the highest pollution levels from motor vehicles that is observed and proven by the model in Holovna, Chervonoarmiyska, Prospekt Nezalezhnosti, Storozhynetska, Vynnychenka, Chapayeva, Stasiuka Streets. Realistic concentration profile is reached not only above the road but also over surrounding area and within the residential area.*
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Keywords: *environmental pollution, fumes exhaust, convection-diffusive equation, mathematical model.*

Introduction

Global ecological security is very important problem nowadays. This is global question and not problem of one country or region. Preservation of atmosphere is actual task. Because, everyday we listen about ozone hole, greenhouse effect, smog etc.

This is actual problem for Ukraine too. In some region are considerable difference variable quality environment from standard including atmospheric air. According to modern research, cars are one of the biggest agents of air pollution especially in big cities. Basic pollution substances are carbon oxide, carbon dioxide, nitrogen oxides, compounds of sulfur, formaldehyde, volatile organic compounds.

In city is necessary to take into consideration building (housing system). Because the building may be such so street ventilation process are absent or very small. In such situation to take place increased (higher) concentration of pollution.

In EU widely use a number of models for environmental impact begins the built has been started. Such modelling permits to foresee and prevent ecological problem area and helps safe dispersion of pollutants [1– 3].

Chernivtsi city is comparatively clean and ecologically favorable region centre of Ukraine. Motor transports are the biggest source of air pollution there. The motor transport emission made in mean value 29 thousands ton per year from 1999 till 2006.

There are 85,6% from total quantity of emission.

Tendency of increase of quantity of emission has been starting from 2007. Seeing the quantity of motor transport was increased. Introduction in exploitation new roundabout way for region centre can helped the quality of atmospheric air of Chernivtsi to do something better.

According to statistics of Environmental Protection Authority in Chernivtsi region on 2008 was been excelling of maximum permissible concentration of formaldehyde and nitrogen dioxide. Environmental pollution by formaldehyde cause by increasing quantity furniture manufactures big building shop, warehouse with materials of timber industry, and quantity of automobiles

Table 1

Greatest mean and maximum concentration of pollution substances in city's air in 2007 [5]

Pollution substances	Maximum permissible concentration		Average concentration*	Maximum of 20–30 minutes concentration*
	Daily average, mg/m^3	20–30 minutes concentration, mg/m^3		
Suspended particles	0.15	0.5	0.3	0.4
Sulfur dioxide	0.05	0.5	0.04	0.2
Carbon oxide	3.0	5.0	0.5	1.4
Nitrogen dioxide	0.04	0.085	0.7	2.8
Nitrogen oxide	0.06	0.4	0.2	0.3
Phenol	0.03	0.01	0.7	2.5
Fluoric hydrogen	0.005	0.02	1.3	1.7
Chlorine hydrogen	0.2	0.2	0.9	4.9
Formaldehyde	0.003	0.035	1.7	1.5

* - in deal of maximum permissible concentration

Nitrogen dioxide is present in fumes exhaust. According to our study of statistical data for Chernivtsi city, formaldehyde is the most dangerous component of the exhaust fumes [4]. Therefore formaldehyde emissions were taken by us for study of its dispersion and influence on environment.

International agency for studying cancer, which is a part of World Health Huard Organization, admitted that are many facts about oncological properties of formaldehyde. In last time formaldehyde called carcinogen in mass media but World Health Huard Organization in official documents tells only about some carcinogenic effect on experimental animals [6].

Practical application convection-diffusive model of dispersion of admixture

Scientific researches in sphere assessment of fumes exhaust by motor transport in city's atmospheric air basin are actual problem nowadays. Especially dangerous situations are when come into being traffic jam and slowly traffic in hot hours.

The quantity of emission create less if are high speed traffic, new cars, high-quality fuel. But in hot hours we locked many traffic jams, where motor transport went very slowly. On pedestrian transit, traffic lights, crossroads the motor transport must slow down. In downtown city's parts streets are narrow with bad level of ventilation of air but with high traffic intensity, because, above such streets we observe high concentration of pollutant [7, 8].

Nowadays literature has materials with attempt of monitoring air pollution by motor transport in Chernivtsi. But this papers pertain pollution only over roadway and cannot answer the question about level of contamination on dwelling area or near the streets.

Experimental and methods

The work purpose – to carry out an observation the intensity of the street traffic in some streets of Chernivtsi, to calculate 2D profile of concentration of formaldehyde in a near ground layer of atmosphere in the presence of air exchange processes, to make virtual experiment with different boundary conditions for geometry of streets and buildings.

The task of study is to make mathematical model of a dispersion of formaldehyde in atmospheric air of a part of a city Chernivtsi for possibility of an assessment of a dispersion of emissions of motor transport including with presence of a network of streets and building.

For attainment aim had chosen part of city which are shown on figure 1, in electronic version are represent on figure 2, with housing system a) and without b). Quantity of points which used in calculation were about 40 000. Scheme of streets and building is necessary for correct boundary conditions description for the convective-diffusion equation solving. Value of concentration had received from own observing and data of Research Institute of Medico Ecological Problems.

On boundary street - housing system constraints 3rd kind proceeding from Schukarev's law have been used:

$$-D\frac{\partial C}{\partial x} = \beta \cdot (C_0 - C).$$

On boundary building's geometry constraints 2nd kind by Neyman was used:

$$\frac{\partial C}{\partial x} = 0.$$

We used mathematical modeling on convective-diffusion equation base because the OND-86 and ISCLT2 methods have limitation for calculating dispersion of pollutant for objects with complicated geometry.

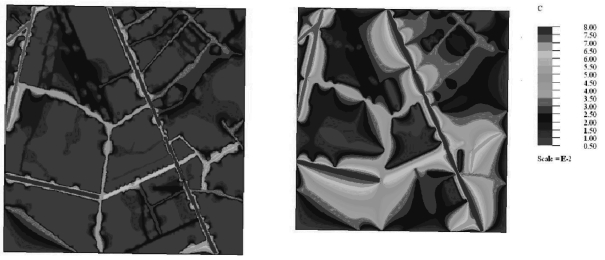
Figure 1. Chosen part of Chernivtsi

a) b)

Figure 2. Electronic version of selected part:
a) with housing system; b) without housing system

Results of study

As results of modeling calculation for two variants: with housing system and without housing system on chosen part, we have calculated contour maps of concentration of formaldehyde, which are shown on figure 3.

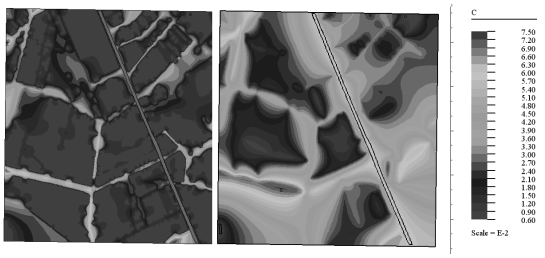


a) b)

Figure 3. Result of calculation:
a) with housing system; b) without housing system

We can see on fig.3, contour maps are very different. In the presence of housing system takes place higher pollution over roadways and in near laying territories, including over pavements. Such situation is dangerous for apartments which have ventilation processes near the roadway.
As contour maps of concentration are so different next research will implement with housing system for trustworse results.
If we can see on figure 3, on the streets crossroads, especially if across streets with high difference intensity traffic, are high difference concentration of formaldehyde. It cannot be in really. This situation was cause peculiarity of geometry record and boundary conditions of modeling. It had incited for next model upgrade, especially working about constrains for crossroads' regions. We had attempted to write group of streets as one continuous polygon. But such experiment hadn't has positive result. In next studies this problem had been decided by writing 3rd boundary conditions constrains for streets' geometry. In result we have obtained the next contour maps, which are shown on figure 4a.
We can see that such results are more correct and describe dispersion process in crossroads' region more precise. Beside that in given work has been writing more correctly conditions of dispersion for boundaries of selected area, that is concentration in outside wasn't as background impurity concentration, this is not absolutely right and had been described by 2nd boundary conditions later.
In preceding models dispersion pollutant with housing system (picture 3, 4a), it had been use assumption that concentration on building-air boundary is constant and makes 10% from maximum level of pollution. But air permeates into the building, opening and chink, that is process of replacement of air to takes place. It had been written and 2nd kind's boundary conditions for building geometry was writing. After this it has been calculating. We have obtained results, which are shown on picture 4b.
If it is seen on picture 4b, when we used 2nd kind boundary conditions pollution permeate deep inside dwelling area. This really describes real dispersion process and mixing pollutant with air. If it is compared results, which are shown on figures 4a and 4b, we can see that average concentration of formaldehyde into the housing system makes $0.9 \cdot 10^{-2}$ and $2.4 \cdot 10^{-2}$ accordingly. It makes difference is approximately 2,5 - 3

times. According to statistics of Environmental Protection Authority in Chernivtsi region during 2009 for most of months the excelling of maximum concentration limit of formaldehyde level was been.

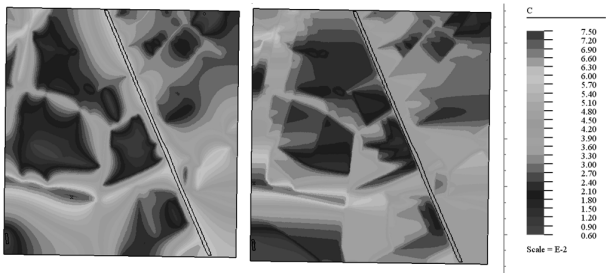


a) b)

Figure 4. Results modeling dispersion of formaldehyde: a) the 1st kind's boundary conditions have writing for building geometry (concentration of formaldehyde is constant on building-air boundary). b) the 2nd kind's boundary conditions have writing for building geometry (concentration of formaldehyde inside buildings is equal as concentration on building-air boundary)

All results gained above are made for windless cases. The given model allows making calculations of a dispersion of formaldehyde in the presence of a wind of the set force and direction. For example if to set the western wind force of 3 m/s then it is possible to obtain following results which are presented on the figure 5.

That is, apparently from results of modeling in cases windy weather, especially at strong winds considerable displacement contour maps of formaldehyde concentration is observed. Building presence changes symmetry of diffusive profile of substance dispersion. If to consider in the given model force and a direction of winds which most typical for Chernivtsi throughout all year or for some season then it is possible to obtain results – contour maps of formaldehyde concentration and dispersion, that will be characteristic and are most probable at hot hour a current of year.



a) b)

Figure 5. Dispersion calculation in cases of calm and the western wind.a) windless conditions; b) wind along an axis of abscissa of 3 m/s.

So, apparently from results of study the greatest levels of pollution by formaldehyde from motor transport emissions are observed and prove to be true model oversuch streets: Golovna, Chervonoarmiiska, Prospect Nezalezhnosti Storozhenetcka, high enough level of formaldehyde also are over streets Vynnechenka, Chapaeva, Stasyuka, Chkalova, Gertcena and Karmelyuka. The realistic profile of concentration is observed not only over road, but also over the adjoining territories and in the heart of an inhabited area.

Conclusions

The designed mathematical model adequately describes substance dispersion in a near ground layer of atmosphere.

It was obtained results of dispersion of formaldehyde. It follows that in majority of housing system's areas concentration of formaldehyde at level $2,5\text{-}4,5\cdot10^{-2}$ was observed, that does not exceed of 1,2 maximum permissible concentration. However near the streets with high intensity of traffic concentration at level $5\text{-}5,5\cdot10^{-2}$ was observed or near 1,5 maximum permissible concentration.

When calculation performs for cases of presence of a wind it is observed more penetration into building area of a wind direction.

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