Модель дозволяє дуже швидко розрахувати поле пилового забруднення. Наведено опис алгоритму розв'язання задачі по оцінці рівня забруднення повітряного середовища біля відвалу. Представлені результати обчислювального експерименту.
Ключові слова: відвал; забруднення повітряного середовища; поширення пилових забруднень; чисельне моделювання.

Biliaiev M. M., Kirichenko P. S., Klimenko I. V. CALCULATION OF AIR POLLUTION NEAR MINE PILE ON THE BASIS OF THE NUMERICAL MODEL

A 2D numerical model is proposed for estimating the level of air pollution near the mile piles. The developed numerical model is based on equation of pollutant transfer in atmosphere. To solve the modelling equation implicit difference scheme is used. The numerical model makes allows quickly to compute the field of dust pollution near mine piles. A description of the algorithm for solving the problem of assessing the level of air pollution near mine piles is considered. The results of the computational experiment are presented.
Keywords: heap; air pollution; spreading of dust pollution; numerical simulation.

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SIMULATION OF POLLUTION DISPERSION FROM ROAD TRAFFIC

Development of numerical model, which allows quick computation air pollution in streets from vehicles. The constructed model based on the equation for the velocity potential (the model of the irrotational flow) and the mass transfer equation. The equation for the velocity potential is used to calculate the velocity field of the air flow in the presence of cars on the road. To solve the equation for the velocity potential, an implicit difference scheme of "conditional approximation" is used. For numerical solution of the mass transfer problem, an implicit alternate-triangular difference scheme is used. The developed model allows to estimate the sizes, the form and intensity of a zone of pollution at a motorway.
Keywords: pollution of the atmosphere; emissions from vehicles; numerical simulation.

Introduction. Road traffic is an intensive source of air contamination in streets. Road traffic emitt different pollutants which include carbon monoxide, nitrogen oxides, particulate matter, etc. Changing in city infrastructure will influence the traffic intensity in streets and results in new level of contamination. This level must be predicted at the stage of project developing. Application of physical modeling, in this case, is very expensive [8]. More convenient is mathematical simulation. For quick prediction empirical models are used [1]. These models are convenient in practice, especially when we must run many “pilot” calculations. The lack of these models is that they do not take into account geometrical “features” in streets (presence of vehicles, etc).

Application of CFD models allow to obtain practically all necessary information about air contamination in streets [1,2,6, 8-10]. A lot of modern CFD models are based on Navier – Stokes equations coupled with turbulent models. Worthy of note, that application of Navier – Stokes equations needs application of very fine computational grid during the computational experiment to simulate in detail the process of vortexes formation and their dispersion and interaction in the region having comprehensive geometrical form. Using the model of viscous fluid (Navier – Stokes equations) we must use very fine grid inside in computational domain and in the boundary layers. This is a real problem if we have large dimensions of the buildings, obstacles in streets. So, in case of Navier – Stokes equations application it is necessary to use powerful PC and every computational experiment consumes much time. This is not convenient when we must run a lot of practical calculations considering different scenario of air pollution in streets and, especially, when we try to find the effective protection measures because in this case we must consider many alternative variants of protection. In this case it would be better to split the scientific study in two steps. At the first step we may find the "satisfying" variant using numerical model which does not consume much time and not take into account some physical features of the process. After that, at the second step, we may use more powerful model to compute in detail the variant of protection which has been chosen. So, for quick calculations at the first step it is important to have CFD models which consume not much computational time but they allow to take into account such important features as obstacles, emission rate, etc.

Goal of the work. The goal of the this work is development of quick computing numerical model to estimate air quality near roads.

Aerodynamic equation. To simulate the wind flow near the road we use model of potential flow. In this case the governing equation can be written as [5]:

$$\frac{\partial^2 P}{\partial x^2}+\frac{\partial^2 P}{\partial y^2}=0, \qquad (1)$$

where P is the potential of speed.

The wind velocity components are calculated as follows:

$$u=\frac{\partial P}{\partial x},\ v=\frac{\partial P}{\partial y}. \qquad (2)$$

Boundary conditions equation (1) are discussed in [5]. To perform numerical integration of this equation rectangular grid was used.

To solve equation of potential flow (1) we used the difference scheme of "conditional approximation".

Pollutant Transport Equation. To simulate the pollutant dispersion near road equation of convective – diffusive mass transfer is used [1, 3, 5, 7]:

$$\frac{\partial C}{\partial t}+\frac{\partial uC}{\partial x}+\frac{\partial vC}{\partial y}=div(\mu gradC)+ \\ +\sum_{i=1}^{N}Q_i(t)\delta(x-x_i)\delta(y-y_i), \qquad (3)$$

where C is mean concentration $C(x,y)=\frac{1}{W}\int_0^W C\ (x,y,z)dz$, W is width of the computational region; u, v are the wind velocity components; $\mu=(\mu_x,\mu_y)$ are the diffusion coefficients; Q_i is rate of emission; $\delta(x-x_i),\delta(y-y_i)$ – are Dirac delta function; t is time.

Initial and boundary conditions for Eq.3 are described in [1, 3, 5].

Before solving Eq. (3) we made it's physical splitting into the sequence of three equations. These are the following equations:

$$\frac{\partial C}{\partial t}+\frac{\partial uC}{\partial x}+\frac{\partial vC}{\partial x}=0,$$

$$\frac{\partial C}{\partial t}=\frac{\partial}{\partial x}\left(\mu_x\frac{\partial C}{\partial x}\right)+\frac{\partial}{\partial y}\left(\mu_y\frac{\partial C}{\partial y}\right), \qquad (4)$$

$$\frac{\partial C}{\partial t}=\sum Q_i(t)\delta(r-r_i),$$

where $\delta(r-r_i)$ is Dirac delta function; $r_i=(x_i,y_i)$ are the coordinates of the point source.

The first equation in (4) describes pollutant transfer along trajectories. The second equation in (4) describes the diffusive dispersion of pollutant. The third equation in (4) describes concentration change under the action of source Q.

To solve the first and the second equations in (4) the implicit change –triangle difference scheme was used [1, 5]. To solve the third equation from (4) Euler method was used [4].

Numerical integration of difference equations is performed using rectangular grid. Values of *P*, *C* are determined in the centers of computational cells, values of *u*, *v* are determined at the sides of the computational cells. For coding difference equations we used FORTRAN language.

Results. Numerical model was used to compute *CO* concentrations near road with curb where two vehicles are situated. "Body" of the vehicles are represented as rectangulars. Form of vehicles and form of the curb is represented in numerical model using "markers" (porosity technique). Outlet opening of the vehicle is a passive source of emission which has emission rate *Q*. Arrow indicates the wind direction in street. In Fig. 1 we see two vehicles which are situated in the road.

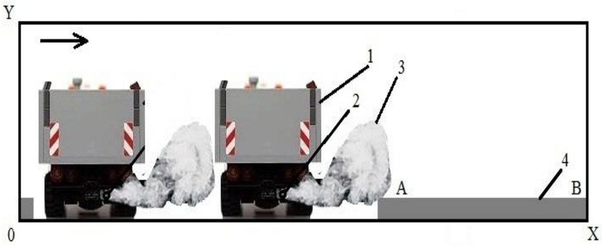

Fig. 1. Sketch of computational region:
1 – vehicle; 2 – source of emission (outlet opening);
3 – plume; 4 – curb

Results of numerical simulations are shown in Fig.2. This figure represents *CO* concentration field near the street road.

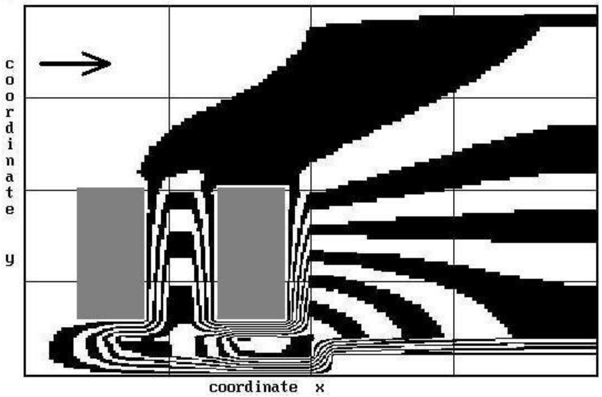

Fig. 2. Computed *CO* concentration near road

As one can see from Fig.2 the comprehensive concentration pattern is formed near the road. It is clear that this contaminated area can be separated in to two zones. The first zone is formed between vehicles. It means that drivers in vehicles are affected by the vehicles emission. The second zone is formed over the curb where pedestrians are situated.

In Tabl.1 we present computed *CO* concentration above the curb (height $h=1,6m$). For data in Tabl.1, position $x=0$ corresponds to point A (Fig.1).

Table 1 - Computed *CO* concentration at height =1,6m

Distance from point A	Concentration
0,6m	2,90 mg/m^3
1,0m	2,81 mg/m^3
1,4m	2,72 mg/m^3
1,8m	2,64 mg/m^3

As we can see from Tabl. 1 *CO* concentration slowly decrease along the curb. Worthy of note that computational time was about 2 sec to compute the wind pattern and pollutant distribution near the road.

Conclusions. Quick computing numerical model to simulate the level of atmospheric air pollution in case of traffic induced pollutant dispersion is proposed. This numerical model allows to take into account of geometrical form of vehicles, curb, intensity of emission rate, wind speed and turbulent diffusion. The solution of the aerodynamic problem is based on the numerical integration of equation for potential flow. This allows to compute quickly wind pattern near road using PC which are available now in Ukraine. To predict toxic gases concentrations near road convective – diffusive equation is used. Numerical integration of this equation is performed using implicit difference schemes. Further improvement of the model should be carried out in the direction of creating a 3D numerical model taking into account the vortex nature of wind flow.

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Беляев Н. Н., Славинская Е. С., Кириченко Р. В. МОДЕЛИРОВАНИЕ РАСПРОСТРАНЕНИЯ ЗАГРЯЗНЕНИЯ ОТ АВТОДОРОЖНОГО ТРАНСПОРТА
Разработка численной модели для быстрого расчета загрязнения воздушной среды возле автомагистрали. Построенная модель, основанная на уравнении для потенциала скорости (модель безвихревого течения) и уравнении массопереноса. Уравнение для потенциала скорости применяется для расчета поля скорости воздушного потока при наличии автомобилей на дороге. Для решения уравнения для потенциала скорости используется неявная разностная схема «условной аппроксимации». Для численного решения задачи массопереноса используется неявная попеременно - треугольная разностная схема. Разработанная модель позволяет оценить размеры, форму и интенсивность зоны загрязнения у автомагистрали.
Ключевые слова: загрязнения атмосферы; выброс от автотранспорта; численное моделирование.

Біляєв М. М., СлавінськаО. С., Кириченко Р. В. МОДЕЛЮВАННЯ ПОШИРЕННЯ ЗАБРУДНЕННЯ ВІД АВТОМОБІЛЬНОГО ТРАНСПОРТУ
Розробка чисельної моделі для швидкого розрахунку забруднення повітряного середовища біля автомагістралі. Побудована модель, заснована на рівнянні для потенціалу швидкості (модель безвихрової течії) і рівнянні масопереносу. Рівняння для потенціалу швидкості застосовується для розрахунку поля швидкості повітряного потоку при наявності автомобілів на дорозі. Для вирішення рівняння для потенціалу швидкості використовується неявна різницева схема «умовної апроксимації». Для чисельного рішення задачі масопереносу використовується неявна поперемінно - трикутна різницева схема. Розроблена модель дозволяє оцінити розміри, форму та інтенсивність зони забруднення у автомагістралі.
Ключові слова: забруднення атмосфери; викид від автотранспорту; чисельне моделювання.

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ЭКСПРЕС ОЦЕНКА ТЕРРИТОРИАЛЬНОГО РИСКА ПРИ ВЫБРОСЕ ХИМИЧЕСКОГО АГЕНТА В СЛУЧАЕ ТЕРАКТА

Предложен экспресс метод оценки территориального риска при выбросе химического агента при теракте в условиях городской застройки. Выброс происходит вблизи зданий. Ставиться задача разработки метода оценки территориального риска с учетом различных метеорологических ситуаций. Для оценки территориального риска используется разработанная численная модель. Приведено описание алгоритма решения задачи по оценке территориального риска при эмиссии химически опасного вещества при теракте. Представлены результаты вычислительного эксперимента.
Ключевые слова: территориальный риск; теракт; химическое загрязнение; численное моделирование, загрязнение воздушной среды.

Вступление. В круг крайне актуальных задач, связанных с решением проблемы защиты объектов и людей при терактах входит задача по оценке риска поражения людей при химической (биологической) атаке террористов в городе [1-3, 7-9]. В качестве химических агентов, при такой атаке, могут использоваться не только боевые отравляющие вещества, но и химические вещества, широко используемые в промышленности – хлор, аммиак и т.п. Поэтому, за рубежом, при изучении данной проблемы очень часто рассматривается