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NEW APPROACH AND MICROSYSTEM TECHNOLOGY TO MODELLING DYNAMICS OF ATMOSPHERE VENTILATION OF INDUSTRIAL CITY AND ELEMENTS OF THE "GREEN-CITY" CONSTRUCTION TECHNOLOGY

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Abstract. We present a new generalized physical-mathematical approach to modelling a natural air ventilation of the industrial city, which is based on the Arakawa-Shubert model, modified to calculate the current involvement of the ensemble of clouds. New quantitative approach is based on an new theory of the atmospheric ventilation combined with hydrodynamic forecast model (with correct quantitative accounting for the turbulence in an atmosphere of the urban zone) and the Arakawa-Shubert method of calculating the cumuli convection and shifting cumulus cloud ensemble from surrounding regions. An advanced mathematical methods for modelling an unsteady turbulence in the urban area are developed. For the first time methods of a plane complex field theory applied to calculate the air circulation for the cloud layer arrays, penetrating into the territory of the city. We also consider the mechanisms of transformation of the cloud system advection over the territory of the urban area. As illustration of a new approach we present the results of series of the computer experiments on the calculation of the ventilation characteristics arising from the natural ventilation of the wind over the territory of the industrial city of Odessa. All above cited methods and models together with the standard monitoring, diagnosing and management measures can create a basis for a comprehensive "Green City" construction technology.

Keywords: atmospheric ventilation, new mathematical models, new microsystem technologies, "Green City" construction technology

НОВИЙ ПІДХІД І МІКРОСИСТЕМНА ТЕХНОЛОГІЯ МОДЕЛЮВАННЯ ДИНАМІКИ АТМОСФЕРНОЇ ВЕНТИЛЯЦІЇ ПРОМИСЛОВОГО МІСТА ТА ЕЛЕМЕНТИ ТЕХНОЛОГІЇ БУДІВНИЦТВА "GREEN-CITY"

О. Ю. Хецеліус, О. В. Глушков, Ю. Я. Бунякова, В. В. Буяджи, О. І. Бондарь, В. М. Ващенко, Н. Биковщенко

Анотація. Ми представляємо новий узагальнений фізико-математичний підхід до моделювання природної вентиляції промислового міста, який заснований на моделі Аракава-Шуберта, модифікованої для розрахунку поточної участі ансамблю хмар. Новий кількісний підхід включає вдосконалену теорію атмосферної вентиляції в поєднанні з моделлю гідродинамічного прогнозу (з правильним кількісним урахуванням турбулентності в атмосфері міської зони) і методом Аракава-Шуберта розрахунку кучкової конвекції і зміщення купчасті хмарність ансамблю від оточуючих регіони. Розроблено вдосконалені математичні моделі моделювання нестійкої турбулентності в міській зоні. Вперше для розрахунку циркуляції повітря для масивів хмарного шару, що проникають на територію міста, застосовані методи теорії плоского комплексного поля. Ми також розглядаємо механізми трансформації адвекції хмарної системи на територію міста. В якості ілюстрації нового підходу ми представляємо результати серії комп'ютерних експериментів з розрахунку характеристик вентиляції, що виникають в результаті природної вентиляції вітру над територією м. Одеси. Всі наведені вище методи і моделі разом зі стандартними заходами моніторингу, діагностики та управління можуть створити основу для комплексної технології будівництва «Green City».

Ключові слова: атмосферна вентиляція, нові математичні моделі, нові мікросистемні технології, технологія будівництва " Грин сити "

НОВЫЙ ПОДХОД И МИКРОСИСТЕМНАЯ ТЕХНОЛОГИЯ МОДЕЛИРОВАНИЯ ДИНАМИКИ АТМОСФЕРНОЙ ВЕНТИЛЯЦИИ ПРОМЫШЛЕННОГО ГОРОДА И ЭЛЕМЕНТЫ ТЕХНОЛОГИИ ПОСТРОЕНИЯ "GREEN-CITY"

О. Ю. Хецелиус, А. В. Глушков, Ю. Я. Бунякова, В. В. Буяджи, О. И. Бондарь, В. Н. Ващенко, Н. Быковщенко

Анотация. Мы представляем новый обобщенный физико-математический подход к моделированию естественной вентиляции промышленного города, который основан на модели Аракава-Шуберта, модифицированной для расчета текущего участия ансамбля облаков. Новый количественный подход включает усовершенствованную теорию атмосферной вентиляции в сочетании с моделью гидродинамического прогноза (с правильным количественным учетом турбулентности в атмосфере городской зоны) и методом Аракава-Шуберта расчета кучевой конвекции и смещения кучевого облачного ансамбля от окружающих регионы. Разработаны усовершенствованные математические модели моделирования неустойчивой турбулентности в городской местности. Впервые для расчета циркуляции воздуха для массивов облачного слоя, проникающих на территорию города, применены методы теории плоского комплексного поля. Мы также рассматриваем механизмы трансформации адвекции облачной системы на территории городской территории. В качестве иллюстрации нового подхода мы представляем результаты серии компьютерных экспериментов по расчету характеристик вентиляции, возникающих в результате естественной вентиляции ветра над территорией г. Одессы. Все приведенные выше методы и модели вместе со стандартными мерами мониторинга, диагностики и управления могут создать основу для комплексной технологии строительства «Green City».

Ключевые слова: атмосферная вентиляция, новые математические модели, новые микросистемные технологии, технология построения «Грин сити»

1. Introduction

The desire to ensure a steady pace of economic development, which has, the organizational forms of the globalization of the world economy and industrialization acquired in recent years, can not be realized except through an increase in the already excessive burden on the environment. One of the negative consequences of these processes, known as man-made, is, in particular, a catastrophic increase in atmospheric pollution. About 200 million tons of carbon dioxide, more than 150 million tons of sulfur oxide, more than 500 million tons of hydrocarbons, more than 250 million tons of fine aerosols (dust), and many other harmful substances [1-4] annually emit into the atmosphere as a result of such activities. Although the development of global transport and communication systems rule out the possibility of localization of human influence on the environment, the big industrial cities are in the most difficult situation as here there are focused a huge industrial and transport complex, which is the main source of the environmental pollution, and including the atmosphere. One of the difficult aspects of the problem is that the composition of the atmosphere of the city is influenced by many factors, which include the characteristics of pollution sources, their location on the terrain, climatic and meteorological parameters, especially the city's architecture, processes of energy and transport, dissipative and relaxation, self-cleaning and regeneration, etc. [1-15]. A link between the individual factors is difficult enough, processes are mostly random. It follows that the solution to the problem of the industrial cities air protection, in particular, and the environment as a whole requires a development of the principally new, comprehensive mathematical and ecological methods. It should be especially noted the importance and necessity of the development of modern methods of correct quantitative description of the dynamics of atmospheric venting in large industrial cities, where there are many companies with technological harmful emissions into the atmosphere.

At present time there are carried out a number of different models that allow to estimate the spatial structure of air pollution in the industrial cities, including scientific and methodical software package ISM (WMO), the American Environmental Protection Agency (AAER USA), Russian Geophysical Centre (Russia), Centre for Environment, Health and Welfare KIST (Korea) etc methods based on the laws of molecular diffusion, as well as a system of regression equations [1-5]. The most of these models have a number of fundamental flaws (model flare or molecular diffusion principle does not work if the atmosphere contains elements of convective instability) and at the application. The majority of the models are relatively simple and do not take into account the transience wind field, the mutual influence of the many sources of pollution and so on. Therefore, increasing the accuracy of prediction of air pollution and the underlying surface requires a development of principally new approach which takes into account all key physical and chemical factors etc. The peculiarity of the modern ecological situation is the technological level of use of laws of nature, associated with the transition from micro to macro level through molecular and atomic levels. It should be especially underlined that nowadays there are many attempts to develop so called “green city” construction technologies throughout the world, however majority of these research and actions are linked only with the preliminary monitoring and diagnosing measures (e.g. [9,10]), in particular, development fundamental technologies such as 1) monitoring urban/indoor air pollution and modeling, 2) diagnosing hazardous urban pollutants and control, and 3) managing urban environment conditions through integrated network technology [2,3].

The strategical aim of our research is develop new “Green City” construction technology that includes not only monitoring, diagnosing and management measures, and a group of the physical, chemical, ecological blocks which allow to create new clean cities of a future. As a first step, here we briefly present a new generalized physical-mathematical model of the natural ventilation of the industrial city, which is based on the Arakawa-Shubert model, modified to calculate the current involvement of the ensemble of clouds.

We present advanced mathematical methods for modelling an unsteady turbulence in the urban area. The balance relation’s calculations for the inside-urban zone turbulence have been carried out for turbulent regime kinetical energy equation. For the first time methods of a plane complex field theory applied to calculate the air circulation for the cloud layer arrays, penetrating into the territory of the city. We also consider the mechanisms of transformation of the cloud system advection over the territory of the urban area. We present a new effective scheme for calculation of the ventilation potential and stream’s function of winds in the urban area. As illustration of a new approach we present the data of series of the computer experiments on the calculation of the ventilation characteristics arising from the natural ventilation of the wind over the territory of the industrial city of Odessa. All calculations are performed with using “Geomath”, “Superatom” and “Quantum Chaos” computational codes [2,3,12-16].

2. Mathematical modelling an atmospheric ventilation of the industrial city

Let us start from the a new generalized model of the atmospheric ventilation of the industrial city, which is based on the Arakawa-Shubert model, modified to calculate the current involvement of the ensemble of clouds. Moreover we present a generalization of the Arakawa-Shubert method for calculation of the cloud work for situation of the city’s landscape. To calculate the involving streams (the real involving masses effect is created due to misbalance of vertical and down-running streams), reaching the territory of city, the Arakawa-Shubert equations system for humidity and warm flow equations are solved [3,5]. Scheme of ventilation of the urban zone by air flows in a presence of the cloud’s convection is presented in Figure 1 and explains the key physical processes in a system. The area of the horizontal section of dry thermion should be approximately equal to the area of the cloud base.

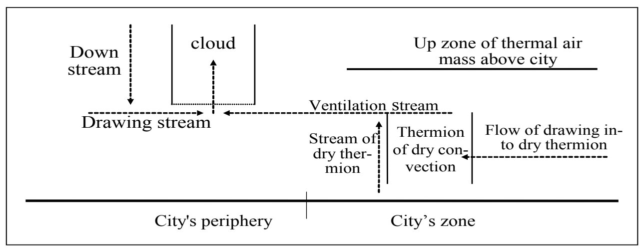


Figure 1. Scheme of air driving between the city and its periphery.

It is appropriate to note known effect of creation of meso-jets which are formed in the ventilation currents as the Couette flows. If square of aa cloud base is smaller than a square of cross-section of the dry thermion top, than the ventilation current can not be appeared due to a lack of power of a cloud in the formation of the involvement meso-jets. If a square of the cloud base is substantially larger than a square of cross-section of the dry thermion top, a ventilation current captures several dry thermions, or else compensate a mass-balance current by an involvement current from the periphery of the city. A signal of the destruction of the thermal air mass over the city is the appearance of convective cloudiness over the city territory. Basically convective clouds that move to the city territory, are formed by ridges on the secondary fronts or in the lines of convective instability arising in the synoptic processes, especially in the areas of the subtropics. Here it is extremely important to understand proportions on the dynamics of the processes occurring in the city with the processes in the atmosphere over the city periphery. On top of the thermal mass of the city there is no restriction in the air exchange in the absence of a closed circulation there, "bordering" heat "hat" of the city [1-3]. However, an extract of the lower layer of air from the air basin of the city should take place through a vertical convection current in a dry thermion, as it is indicated on the scheme in Figure 1.

Otherwise, the process may be in antiphase state and the involvement currents on the periphery of the city are on the contrary to strengthen an air circulation around the perimeter of the thermal ring. It is also possible when in a case of powerful extract the convection currents in dry thermals will not have time to make up for extract from a top of the thermal mass of the city. As a consequence, in this case it will only be observed thinning of the thermal mass of the city without concomitant ventilation of the air lower layers. It is well known that the city area has a fairly complex geometric relief, so the application of our method in its pure form is possible only to a flat surface. However, the city itself creates complex flow in the area of the streets inherent in him, parks and squares. Therefore, the flow of air streams in the city far from isotropic. The horizontal turbulent eddies within the city are involving circulation currents. Therefore, all hypothesizes on the city isotropic turbulence are really transformed here into a complex picture of the complex anisotropic flow vortex structure. It is clear that the turbulent eddies over the urban area must be in the interaction resonant contact with the turbulent eddies of cloud-based arrays in order to obtain a successful air ventilation. In fact the currents of the front convection must coincide with currents of thermal convection of the city in the phase setting. It is clear from the fact that the antiphase state of vertical currents of the urban convective centers with convective currents of the cloud convection would mean mutually compensating the two mechanisms. Therefore, the involvement currents caused by the city convection shall not extinguish the involvement currents caused by cloud arrays on the border of the city. Hence one can see a logically clear necessity for a resonance effect in the involvement currents of both mechanisms mentioned herein. In the antiphase case, the involving currents cancel each other and the city will be in a state of high-rise convective smog that often occurs and is manifested in the form of a thick haze over the city.

If A is a work of the convective cloud then it consists of the convection work and work of down falling streams in the neighbourhood of cloud:

$$\frac{dA}{dt} = 0 = \frac{dA}{dt}_{conv} + \frac{dA}{dt}_{downstr.}, \quad (1a)$$

$$\frac{dA}{dt}_{downstr.} = \int_0^{\lambda_{max}} m_B(\lambda') K(\lambda, \lambda') d\lambda',$$

Here $m_B(\lambda)$ is an air mass, drawn into a cloud with velocity of drawing λ; if

$$\frac{dA}{dt}_{downstr.} = F(\lambda), \quad \int_0^{\lambda_{max}} K(\lambda, \lambda') m_B(\lambda') d\lambda' + F(\lambda) = 0 \quad (1b)$$

is an mass balance equation in the convective thermik and $K(\lambda, \lambda')$ is a nucleus of integral equation (1), which determines the dynamical interaction between neighbour clouds:

$$\beta \int_0^{\lambda_{max}} K(\lambda, \lambda') m_B(\lambda') d\lambda' + F(\lambda) = m_B(\lambda) \quad (2)$$

The solution of this Arakawa-Shubert type eq. with accounting for air streams superposition of synoptic process is:

$$m_B(\lambda) = F(\lambda) + \beta \int_0^{\lambda_{max}} F(s) \Gamma(\lambda, s{:}\beta) ds, \quad (3a)$$

where $\Gamma(x, s{:}\beta)$ is an resolvent of the integral eq.(2):

$$\Gamma(\lambda, s{:}\beta) = \sum_{m=1}^{\infty} \beta^{m-1} K_m(\lambda, s) \quad (3b)$$

We determine the resolvent as expansion to the Loran set cycle in a complex plane ζ; its centre coincides with the centre of the urban heating island (spot) and internal cycle with its periphery. The external one can be moved beyond limits of the urban recreation zone. As result, one could obtain a representation for resolvent by the following Fourier expansion:

$$\Gamma = \sum_{n=\infty}^{\infty} c_n (\zeta - a)^n \quad (4)$$

$$c_n = \frac{1}{2\pi i} \oint_{|\zeta|=1} \frac{f(\zeta) d\zeta}{(\zeta - a)^{n+1}},$$

where a is centre of convergence ring of the Laurent series. Equations of atmosphere circulation above city's zone can be taken in an approximation of the "shallow water". Its solution is given by solution of the equations (1,2) and additionally can be bound by methods of the plane complex field theory. The cloud masses on the urban periphery can be defined in the wind field by the following formula (complex velocity potential):

$$v_x - iv_y = \frac{df}{d\xi} = \frac{\Gamma}{2\pi i}\left[\frac{1}{\zeta-\zeta_0} + \sum_{k=1}^{\infty}\left(\frac{1}{\zeta-\zeta_0-kl} + \frac{1}{\zeta-\zeta_0+kl}\right)\right] + \frac{d}{d\zeta}\left[\sum_{k=1}^{n}\Gamma_k \ln(\zeta - b_k)\right] \quad (5)$$

Here Γ_k –circulation on the vortex elements, created by clouds; b_k – co-ordinates of this forming; r – circulation's on standard vortexes for the Carman chain; l – distance between standard vortexes for the Carman chain; ζ - centre co-ordinate for line of convective perturbations or front divider; ζ - kl – co-ordinate of beginning for line of convective perturbation; ζ - kl – co-ordinate of the end for this line. Naturally, one could assume further that the possible convective perturbations in the periphery of the city come up to him in the form of convective ridges. The cited cloud ridges can be determined in a field of the vertical currents velocity and associated involvement currents. The method for calculation of the turbulence spectra inside the urban zone is based on the standard tensor equations of turbulent tensions (more detailed version will be presented in separated paper):

$$\frac{\partial \overline{u_i'u_j'}}{\partial t} + \frac{\partial}{\partial x_k}\left(\overline{u_k}\cdot\overline{u_i'u_j'} + \overline{u_k'u_i'u_j'}\right) + \frac{\partial \overline{p'u_i'}}{\partial x_j} + \frac{\partial \overline{p'u_j'}}{\partial x_i} = -\overline{u_i'u_k'}\frac{\partial \overline{u_j}}{\partial x} - \overline{u_j'u_k'}\frac{\partial \overline{u_i}}{\partial x} + \overline{p'\left(\frac{\partial u_i'}{\partial x} + \frac{\partial u_j'}{\partial x}\right)}; \quad (6)$$

Computing balance relationships for inside-urban zone is fulfilled on the basis of equation for kinetic energy of turbulent regime. The kinetical energy of fluctuations is defined as follows: $b^2 = \overline{u_k'u_k'}$. The corresponding equation for b is as follows:

$$\frac{\partial b}{\partial t} + \frac{\partial u_k b^2}{\partial x_k} + \frac{\partial}{\partial x_k}\left(\overline{u_k'u_i'u_j'} + 2\overline{u_k'p'}\right) = -2\overline{u_k'u_i'}\frac{\partial u_i}{\partial x_k} - 2\frac{g}{\theta_0}\overline{w'\theta'} \quad (7)$$

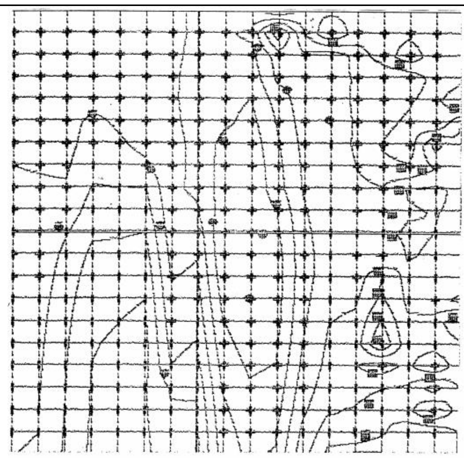
Advection	Turbulent diffusion	Effect of forces of the tension	Interaction: Reynolds tension-averaged motion	Accounting for swimming forces

Here g is the magnitude of the acceleration vector due to the planet's gravity, θ_0 is the equilibrium potential temperature, θ', p' are departures from equilibrium values.

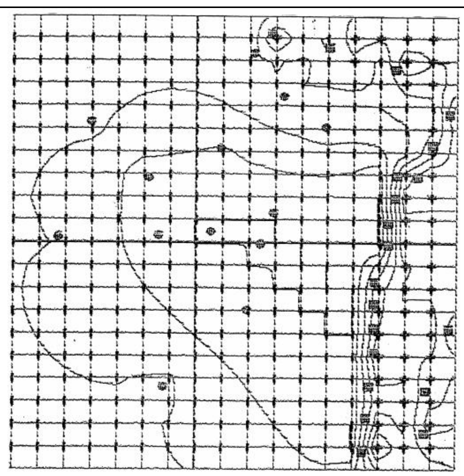
Equating the velocity components determined in the shallow water model and model (5), one could find the spectral matching between the wave numbers that define the functional elements in the Fourier-Bessel series with the source element of a plane field theory. At last, let us remind that any vector field u can be separated into rotational and divergent parts, i.e., $u = \Delta\psi + u_\chi$. If the vector field is a horizontal wind, one can define a current function ψ, to express the rotational part, and a velocity potential χ, to express the divergent part. Namely these parameters are of a great interest in applied analysis of an air ventilation in the urban zone.

3. The numerical results for air ventilation in Odessa and conclusions

As application of a new approach we carried out the PC simulation results on modelling the air ventilation for a number of the industrial cities: Odessa (Ukraine), Trieste (Italy), Aleppo (Syria). Below we are limited by data for Odessa. The experiments are fulfilled with using natural and model data on a cloudiness and convection intensities. All input data parameters are taken from [2,3]. Naturally the corresponding model situations on cloudiness are real and can be by a basis for the possible recreation measures within "Green city" construction technology. Basically, it was assumed that the cloud masses coming to the city by the lines of convective instability. The distance between the convective clouds was assumed to be 300 to 700 meters. The results of computing are presented in Figure 2. In Figure 2a we present the calculated field of a ventilation potential, which is equivalent to a field of potential in the complex velocity potential function. Note that the clouds are designed as black squares. The figure is oriented so that the sea is in the right part, the borders of a figure are corresponding to the borders of Odessa city. Approximately one can assume that the contours of the complex potential reflects the variation in time of the velocity field, namely 0.5 m/s for an hour. Density of current lines is adequate to the venting flows speed, about 1 m/s to 0.5 cm of gradient in Figure. Analysis of the potential function gives the following: if $v_x > 0$, the velocity rate increases in the direction of positive foci (and similarly on y). This means that the potential function draws flow in positive foci. In figure a field of positive foci are marked with sign "+" and negative one – by sign"-". Thickening a current function isolines means increasing a velocity. The direction of flow is obtained from the definition of the current function, i.e ., $v_x > 0$, if $\partial\varphi/\partial y > 0$. It means an availability of positive foci of the current function from a flow direction. The isolines in the figure are not signed, because modular values depend on many factors, notably than intensity of convection, which determines the involvement currents power and a density of the cloud arrays.



a



b

Figure 2. Potential of ventilation χ (a) and current function ψ (b) for atmospheric situation, presented in Figure 2a (Odessa city).

Figure 2a shows the results of computer simulation of the synoptic situation in Odessa, when the clouds run from the sea by two lines of convective disturbances and penetrate deep into the Gulf of Odessa and the city respectively. Besides, there are presented the dry thermions (marked by black circles in the figure) located in the city area. These dry thermions, on the one hand, create their involvement currents, but on the other hand, increase the intensity of the annular heat circulation. In this case (figure 2a) one can see the picture of penetration of an air ventilation for most of the city. However, in the current function field (Figure 2b), the penetration of ventilation is expressed more weakly. We considered only one synoptic situation example for Odessa city, which illustrates quite effective possibilities of our mathematical models to treat an atmospheric ventilation in the city (in principle, in any of the synoptic conditions). The knowledge of more or less realistic picture of the city's atmospheric ventilation allows further to carry out appropriate recreational activity to improve air quality and so on.

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NEW APPROACH AND MICROSYSTEM TECHNOLOGY TO MODELLING DYNAMICS OF ATMOSPHERE VENTILATION OF INDUSTRIAL CITY AND ELEMENTS OF THE "GREEN-CITY" CONSTRUCTION TECHNOLOGY

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Summary

The aim of the work is to develop and present a new approach and correspondingly a new microsystem technology for advanced analysis, modelling and forecasting the temporal and spatial dynamics of atmospheric ventilation and apply it to quantitative studying a air ventilation for the concrete large industrial cities.

We present a new generalized physical-mathematical approach to modelling a natural air ventilation of the industrial city, which is based on the Arakawa-Shubert model, modified to calculate the current involvement of the ensemble of clouds. New quantitative approach is based on an new theory of the atmospheric ventilation combined with hydrodynamic forecast model (with correct quantitative accounting for the turbulence in an atmosphere of the urban zone) and the Arakawa-Shubert method of calculating the cumuli convection and shifting cumulus cloud ensemble from surrounding regions. An advanced mathematical methods for modelling an unsteady turbulence in the urban area are developed. For the first time methods of a plane complex field theory applied to calculate the air circulation for the cloud layer arrays, penetrating into the territory of the city. We also consider the mechanisms of transformation of the cloud system advection over the territory of the urban area.

As illustration of a new approach we present the results of series of the computer experiments on determination of the ventilation characteristics (velocity potential etc) arising from the natural ventilation of the wind over the territory of the industrial city of Odessa. For example, the results of computer simulation of the synoptic situation in Odessa, when the clouds run from the sea by two lines of convective disturbances and penetrate deep into the Gulf of Odessa and the city respectively. The dry thermions, on the one hand, create their involvement currents, but on the other hand, increase the intensity of the annular heat circulation.

The approach (all above cited methods and models) together with the corresponding standard monitoring, diagnosing, ecological, economical, logistic and management blocks provides a basis for a comprehensive "Green City" (or Smart-City) construction technology.

Keywords: atmospheric ventilation, new mathematical models, new microsystem technologies, "green city" construction technology

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НОВИЙ ПІДХІД І МІКРОСИСТЕМНА ТЕХНОЛОГІЯ МОДЕЛЮВАННЯ ДИНАМІКИ АТМОСФЕРНОЇ ВЕНТИЛЯЦІЇ ПРОМИСЛОВОГО МІСТА ТА ЕЛЕМЕНТИ ТЕХНОЛОГІЇ БУДІВНИЦТВА "GREEN-CITY"

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Реферат

Метою роботи є розробка та представлення нового підходу та, відповідно, нової мікросистемної технології для поглибленого аналізу, моделювання та прогнозування часової та просторової динаміки атмосферної вентиляції та її застосування для кількісного вивчення вентиляції повітря для прикладі конкретних великих промислових міст.

Ми представляємо новий узагальнений фізико-математичний підхід до моделювання природної вентиляції промислового міста, який заснований на моделі Аракава-Шуберта, модифікованої для розрахунку поточної участі ансамблю хмар. Новий кількісний підхід включає вдосконалену теорію атмосферної вентиляції в поєднанні з моделлю гідродинамічного прогнозу (з правильним кількісним урахуванням турбулентності в атмосфері міської зони) і методом Аракава-Шуберта розрахунку кучкової конвекції і зміщення купчасті хмарність ансамблю від оточуючих регіони. Розроблено вдосконалені математичні моделі моделювання нестійкої турбулентності в міській зоні. Вперше для розрахунку циркуляції повітря для масивів хмарного шару, що проникають на територію міста, застосовані методи теорії плоского комплексного поля. Ми також розглядаємо механізми трансформації адвекції хмарної системи на територію міста.

В якості ілюстрації нового підходу ми представляємо результати серії комп'ютерних експериментів з розрахунку характеристик вентиляції, що виникають в результаті природної вентиляції вітру над територією м. Одеси. Наприклад, докладно проаналізовані дані комп'ютерного моделювання синоптичної ситуації в Одесі, коли хмари протікають з моря двома лініями конвективних порушень і проникають глибоко в Одеський затоку та місто відповідно. Сухі терміки, з одного боку, створюють їх потоки залучення, але, з іншого боку, збільшують інтенсивність кільцевої теплової циркуляції міста.

Новий підхід (всі наведені вище методи та моделі) разом із відповідним стандартним моніторингом, діагностикою, екологічним, економічним, логістичним та управлінським блоками є основою для нової технології будівництва "Зеленого міста" (або "Смарт-Сіті").

Ключові слова: атмосферна вентиляція, нові математичні моделі, нові мікросистемні технології, технологія будівництва «зеленого міста»