Dustiness and Aerodynamics of Air in Central Asian Cities

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Abstract. One of the adverse meteorological factors for the cities of Central Asia are dust storms and haze. The average annual number of days with haze in the cities of Central Asia reaches from 10 to 20 days. Among them, the “Afghan” wind stands out. (garmessel - fiery, hot, dry wind), suddenly begins dusty storm in the deserts Afghanistan. It causes significant damage to the health of the population and the economies of Central Asian countries. The article describes the characteristics of the origin of dust and the process of dust transfer of wind. Research has shown that the process of transporting natural dust begins with the movement of particles with a diameter of 100–500 microns. The main types of occurrence and distribution of dust in cities are identified. The main results of field observations on measuring the content of fine dust were carried out in the atmospheric air of the urban environment. The paper also applied computer simulation technologies that can significantly simplify the analysis of dust and wind conditions. The analysis of urban greening is presented. The practical implementation of the proposed methods creates a real opportunity to improve the quality indicators of the atmospheric air of cities with a complex landscape location in the summer, which will directly affect the improvement of people's health.

1. Dustiness and aerodynamics of air in Central Asian cities

One of the adverse meteorological factors is dust storms and haze. The average number of days with haze in the cities of Central Asia reaches from 10 to 20 days.

In the cities of the region, the “Afghan” wind is often observed (garmessel - a fiery, hot, dry wind), a sudden dust storm in the deserts of Afghanistan. It is a whirlwind of hot air saturated with dust and sand. This is accompanied by abrupt changes in atmospheric pressure (Fig. 1).
Sudden dust storms pose a serious danger to the public. However, bad weather is dangerous not only for human health, which was especially observed in the summer of 2018 in all cities of Central Asia.

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A higher temperature of the air on hot days and its low humidity contributes to an increase in the mortality of the urban population. Polluted air hanging over the city by a dome-heated and holding back the flow of ultraviolet rays contributes to the development of lung cancer, bronchitis, and emphysema, as well as many infectious diseases.

Carmel is also causing significant damage to the economies of Central Asian countries.

Dust worsens the appearance of territories, and its impact on urban planning has been little studied, and monitoring of the content of fine dust particles in the air of cities is still missing.

One of the main tasks of operational organizations is to remove pollution that accumulates on the surface of territories, roadways, and areas that are a source of dust in the air of urban buildings.

The issue of wind transport of dust from natural sources and, as a result, the dustiness of the urban environment is relevant for many cities of Central Asia but is not well understood. Even in areas with active dust-light activity due to natural and climatic conditions, the dustiness factor is not sufficiently taken into account when making town-planning decisions.

Dust - particles of solids suspended in the air. By origin, dust can be classified into terrestrial and cosmic, natural and artificial, industrial and domestic, mineral and organic, plant and animal, etc.

The physical and chemical properties of dust particles are determined by the size, weight, density, shape, hygroscopicity, solubility, PH, electrical charge, chemical composition, radioactivity.

In the hygienic assessment of dust, the size of its particles and dispersity are of great importance. Particles with a diameter of 1-10 microns easily penetrate into the lungs. Larger dust is trapped in the upper respiratory tract (nose, trachea) and ciliated epithelium bronchi. On average, about 50% of the inhaled dust precipitates in the nasal cavity of a person.

Prolonged inhalation of highly dusty air irritates the nasal mucosa. In the pulmonary alveoli, special cells (phagocytes) trap dust particles and dissolve them or transfer them to the bronchi or lymphatic pathways, thus removing them from the lungs. A significant part of the delayed dust is released when sneezing and coughing.
For human health, dust particles as small as 5 microns are the most dangerous. They easily penetrate into the lungs and settle there, causing bronchitis, asthma and the growth of connective tissue, which is not able to transfer oxygen from the inhaled air to the hemoglobin of the blood and release carbon dioxide.

Normalizes dust depending on its nature and the mechanism of action on the human body. For example, crystalline silicon dioxide with content in the dust from 10 to 70% has a predominantly fibrogenic effect and is normalized: MPC maximum-one-time -6 mg / m³, MPC is medium-change-2 mg / m³.

Tearing a particle from the surface, the wind flow can transport it in both vertical and horizontal directions, while the quantitative indicators in both cases depend on the size of the particles.

Dust particles, under conditions of surface dust formation, are able to move in three ways: a) by saltation, b) by rolling and c) in suspension. Particles with a size of 100 μm and less move in suspension, particles with a size of 100-500 μm are moved by the method of salvation (the largest number of particles are moved by saltation ), the size of more than 500 μm is by rolling. At a wind speed of 1 m / s, dust with a diameter of 10 μm (particle size (fraction) is described by the unit of measure “micrometer” (μm), which corresponds to 10 ~ 3 mm.) Is transferred to 100 m, 1 μm in diameter to 900 m, and at speed winds of 4 m / s - respectively at 400 and 3600 m [2].

The urban environment has changed the individual properties of air, lowering its humidity in the first place. The air temperature in urban areas and streets on a summer sunny day is 2.0-2.5 °C higher than in a green suburb, relative humidity is 10-35% lower.

At different levels of streets and roofs, large areas of solid, dense, dry, waterproof surfaces are formed. Brick and asphalt, like giant batteries, accumulate heat during the day and give it away at night. The overheating source of urban air is also heated due to combustion in furnaces and internal combustion engines. and gas.

The effect of the dust content of the air in the upper atmosphere on the accumulation of heat is clearly traced. A dome of dust over the city contributes to the so-called hot island effect. The degree of manifestation of this effect depends on the population density and size of the city, as well as on the days of the week.

With the effect of hot islands associated local increase in the intensity of circulation of the convection air currents, both significantly (30 to 50% compared to the suburb) horizontal movement of the air mass (Figure 2) decreases.

Figure 2. Scheme of pollution and air flow in cities: 1 is the most intense part; 2- less intensive part.
Direct solar radiation in large cities in the summer is reduced by 20%, in the winter to 50%. Dustiness of air can reduce visibility in the horizontal direction by 80-90%.

To set in motion one or another dust particle, a certain value of wind speed from 1 to 20 m/s is needed, which is called the threshold or critical speed for dust particles, upon reaching which the dust transfer process begins. The critical wind speed of the separation of particles from the surface of the earth depends on the size of the particles, the density of dust, and the cohesive forces of the soil, determined by its humidity [1].

The deposition rate of dust depends on the size of its particles and the density of dust. Large particles settle faster. Air heat flows and Brownian motion affect particles of 0.1–1 µm in size; they are in suspension for much longer. When particles move in the air, their collision is possible, as a result of which individual particles of fine dust combine (coagulate) into larger ones [2, 3].

Research has shown that the process of transporting natural dust begins with the movement of particles with a diameter of 100–500 microns. Since the pressure inside the air flow decreases with height, due to the difference in aerodynamic pressure, the particle almost vertically flips up and enters the turbulent air flows [2,4,5]. Particle separation occurs at the moment when the aerodynamic force acting on the particle exceeds its mass. Under the action of gravity and air pressure, the particle returns to the soil surface at an angle of 6-12° or bounces again, or it spends its energy on knocking new particles out of the surface. A fallen particle may remain on the surface or continue moving. A large particle moving further, hitting the soil surface, lifts smaller particles (100 microns or less) into the air, which are then picked up by the wind and carried in the form of dust over long distances [7].

To study the dustiness associated with the aerodynamics of the air of Central Asian cities, we carried out field observations.

The purpose of field observations is to determine the type of occurrence of dust and its aerodynamic characteristics depending on the speed and direction, and wind in a housing estate.

The analysis of the granulometric composition of the road estimate was carried out, the content of dust and clay particles in it was determined from 15 to 30% (depending on cities), able to rise into the air under the influence of wind flows and stay there from several hours to several days.

In field observations, measurements of the content of fine dust were carried out in the atmospheric air of the urban environment with the help of electroporator PU-ZE /12. To calculate the coefficients of the regression equation, the module "Nonlinear Estimation" of the statistical analysis software package BTAISISA 6.0 was used. The significance of the coefficients was checked by comparing the tabulated values of the Student's criterion with the calculated values at a confidence level of p = 95%. Checking the adequacy of the equations was carried out according to the Fisher criterion.

The study of dust transfer of the environment allowed us to distinguish three main types of dust generation and distribution: a – advective or macro; b - intracity or Mezo and in-place or micro.

2. The advective or macro pulper transfer occurs as a result of the intensive movement of air masses. In this case, the dust of very small fractions at high altitude is transported over long distances and during steady calm weather settles [4]. Protective measures for advective dust transfer are recommended to be carried out in large areas. Intracity or mesophiles transfer occurs both when an external dusty wind flows into the city, as well foras a result of dust rising into the city itself. Dust contains fractions larger than advective dust transfer.

Natural dust mesophiles are generated in the suburban area in areas with disturbed soil and vegetation cover (inadequate roads, industrial areas, etc.). Protection against local dust transfer should be organized in the suburban area [2].
The local or micro-dust transfer occurs under the influence of local winds and occurs mainly in the surface layer of the atmosphere. Dust can be transported by local dust storms, dusty dry winds, and dusty drifts and settle when the speed drops below the threshold.

Protection against micro dust transfer should be provided in the residential area of the city.

Observations have shown that the composition of dust samples taken from urban air consists mostly of soil primary particles. This fact led to the conclusion that even for large areas of covered artificial surfaces of modern cities, it is possible to regulate intracity dust transfer in the mode of surface dust formation by determining its threshold speed. For this, it is necessary to have data on the threshold velocities of dust transfer of the most typical local soils [9].

The work has also been applied technology and computer modeling that will allow the greatly simplify the analysis of dust and wind conditions, which reduce the time spent on research.

One of the goals of the current research was to compare the results of field observations of micropipe transfer using SolidWorks 2015, with the addition of Flow Simulation.

Tests of models in this program allowed us to establish a qualitative and quantitative picture of the flow of models around the airflow depending on:
- the shape of the model;
- parameters of the cross-section of the model, including the relative height of the building.

For the first series of experimental studies, two development models with different lengths were adopted. (L = 6 h, L = 10 h).

General settings specified before conducting research in the program SolidWorks: Task type - external; Fluid medium - Air (gases); The type of flow is only turbulent; Turbulence intensity - 2%; The scale of turbulence is 0.0001; Humidity is absent;

Airflow velocity measurements were made at a height of H = 10 m from the ground (or 10 mm on the model), which corresponds to the height of the weather vane location. All measurements were made on a scale of 1:4000. In all cases, the size of the simulated construction area is 740 × 740 m, those. 51.84 hectares, the number of calculated points - 20.

At the start of the study, diagrams of airflow distribution were obtained, taking into account the specified conditions. Flow rates at different sites are indicated by a characteristic color. Further, using plots, the transformation ratio values for each point were calculated using the formula \( \tau = \frac{U_i}{U} \), where \( U \) is the unperturbed flow velocity specified in the input data, \( U_i \) is the velocity on the model at the selected point.

The results were decorated in a graphical way. On the basis of the data obtained, diagrams and graphs were constructed, combining the results of the initial and conducted studies.

The transformation ratios of incoming airflow at each of the points were processed with the help of lines of the same speed, which were carried out every 0.2 coefficient values, that is, the points were connected with indicators of 0.6; 0.8; 1.0, etc. (Fig. 3).

Results for study with L = 6h, h / a = 1 5/12:
Figure 3. Plot the dependence of the values of the transformation ratio of \( x \) for \( L = 6 \) h.

Figure 4. 1-compiled from the results of a model study in Solidworks 2015 Simulations; 2- compiled from the results of the study of the model in a wind tunnel.

Section B - the source (2) and the resulting (1) graphs repeat each other, the deviation of the experimental dependence at the point \( x = 7h \) is 14.2%

Plot B - graphs (1) and (2) have the same contour, but the graph (1) is omitted relative to the graph (2): the speed in the resulting relation (1) increases more slowly. The maximum deviation at the point \( x = 19h \) is 21.4%

In the presence of high-rise and extended houses on the territory of the city, these cases may arise directly and in the very building of the city.

In many cities of Central Asia area's landscaping of common areas falls from 1.8 to 5.5 m\(^2\) per person, that is, from 21 to 45% of the standard indicator for SP 42.13330.

Landscaping system of the city is a prerequisite for the formation of a full-fledged environment of the city.

To reduce the harmful effects of road transport requires the creation of special sanitary-protective zones of green spaces and open spaces.
In the newly created parks and squares, as well as in the reconstruction of existing plantings, an assortment of trees and shrubs adapted to local conditions should be introduced. About whom again

Parks, gardens, squares and boulevards should be equipped with plumbing, watering, sewage, lighting, as well as utility rooms, as the greenery in the city improves the microclimate of the urban area, creating good conditions for outdoor recreation, protects the soil from excessive overheating of the territories, walls of buildings and sidewalks.

For successful work on gardening you need:

- use the local range of trees and shrubs;

- To take into account the architectural-planning and landscape organization of the territory of parks, squares;

- Conduct regular maintenance.

Above the parks and squares descending air, flows occur because the surface of the leaves is much cooler than asphalt and iron. Dust entrained by the downward currents of air settles on the leaves; 1 hectare of coniferous trees hold up to 40 tons of dust per year, and hardwood - about 100 tons.

Parks and squares, attached during construction to the relief, can be active conductors of clean air to the central areas of the city. The quality of air masses is significantly improved if they pass over parks and squares. At the same time, the amount of suspended impurities decreases by 10 ... 40%. The practice has shown that this is quite an effective means of combating harmful emissions from motor vehicles, whose effectiveness can vary within fairly wide limits - 7 ... 35% [12].

Thus, the practical implementation of the proposed methods creates a real opportunity to improve the quality indicators of the atmospheric air of cities with a complex landscape location in the summer, which will directly affect the improvement of people's health.

3. Findings

1. The dustiness of residential development is determined primarily by intracity dust transfer, caused by the penetration of external dusty wind flows into the city or by raising dust into the air, which is located on the territory of the building itself.

2. The obtained regularities of the velocity change near the streamlined residential building allow us to proceed to the study of pressure and determine the aerodynamic coefficients of dust transfer.

3. The methodology for predicting the concentration of dust can be recommended for the formation or improvement of monitoring in assessing the compliance of the ecological status of urban areas with current standards.

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