ATLANTIS PRESS
Advances in Engineering Research, volume 182
VIII All-Russian Science and Technology Conference "Contemporary Issues of Geology, Geophysics and Geoecology of the North Caucasus" (CIGGG 2018)

Problems of Airing Cities Located in Mountain Basin

Ilkhomzhon S. Shukurov
Moscow State University of Civil Engineering (MGSU)
Moscow, Russia
Shukurov2007@yandex.ru

Abstract—**This article reveals the problems of airing cities located in the mountain basin. The mountain-hollow space is characterized by considerable complexity due to the variety of orthography of the relief with the prevailing calm condition. The problem can be simplified by considering some thermally active surfaces and forms that are repeated throughout the territory of the mountain-basin space. The author describes the theoretical data defining the speed depending on the scheme of air along the slope of mountain-relief hollows. The article presents a calculated wind diagram of the structure of formula slopes and determines the velocity of the air flow along the slope, and the technique of field observations. Practical recommendations to enhance ventilation and normalization of the atmosphere in the city are given.**

Keywords—mountain basin; airing cities; atmosphere; wind regime; air exchange

I. Introduction

Historically, many cities in the world are located in river valleys or connected with mountains. It is possible to name the following cities and to allocate characteristic landscape positions for them:

- Valleys are typical of Paris, Baghdad, Cairo, Kiev, Moscow, Nizhny Novgorod, Yaroslavl, Mesopotamia, etc.
- Foothills are widespread in Istanbul, Shanghai, Tokyo, Mumbai, Rio de Janeiro, Havana, San Francisco, Vladivostok, Sochi, Sevastopol, and others.
- Submontane can be observed in Samarkand, Tashkent, Ashgabat, Alma-Ata, Vladikavkaz, Grozny, Milan, Munich, and others.
- Mountain Basin is present in Yerevan, Kabul, Tehran, Damascus, Geneva, Sanaa, Bishkek, Dushanbe, and others.

Here, we touch on the problems of airing cities located in the mountain basin. The location of cities at the depth of the mountain basins up to 150 m or more and the increase in the intensity of urban infrastructure and economy lead to stagnation of air and an increase in the level of gas contamination, dustiness of the building exceeding the maximum permissible values.

The negative factor in the location of these cities is the decrease in the intensity of natural air exchange, with the help of which the removal of pollutants outside urban areas is carried out. Consequently, at low wind speeds, it is vital to intensify the ventilation of cities. Therefore, the solution to the problem of increasing the efficiency of airing should be sought in the way of increasing natural air exchange in the very space of the city.

The microclimate of cities located in mountain-hollow conditions has distinctive features. In the absence or in a small amount of precipitation (particularly, rain) or adverse weather conditions there is an additional contamination of the atmosphere. Consequently, managing aerodynamic processes, ensuring ventilation and normalizing the atmosphere of cities by increasing the intensity of natural air exchange, are an important task, as well as the main condition in the life of citizens. Let us consider the city of Kabul, which is located in typical mountain-basin relief.

Afghanistan is a country in Central Asia, having no access to the sea. The country borders on six countries: Iran in the west, Uzbekistan, Tajikistan, Turkmenistan and the People's Republic of China to the north and Pakistan - to the east and south. Its capital is Kabul.

The city of Kabul is on the river Kabul. It is located at an altitude of 1800 meters above sea level. Here, the summer months are exceptionally hot, the winters are cool and rainy. Landscape conditions of the city are complicated by the seismic activity of the region. At the same time, it is located at the bottom of hollow part of the middle mountainous terrain.

Accounting for the wind regime of residential development in the conditions of the mountain-pithed relief, it is very actual for Kabul task. Against the backdrop of the positive political processes taking place recently in the Islamic Republic of Afghanistan, the issue is not only the restoration of houses destroyed during the war, but also the creation of a modern look of the country's capital - Kabul. However, Kabul is located in an area with hot climate combined with low air mobility, as the city is surrounded by mountains. The mountains occupy about three-quarters of its territory.

The maximum daytime temperature of outdoor air in the summer often reaches + 45-50 ° C. When measured near the earth's surface, heated by the sun, the temperature exceeds 80 °C. In high-altitude regions in the winter months, the air temperature drops to -30 °C and lower. The most favorable regions in terms of temperature conditions are mid-mountain regions, where the average air temperature in summer does not exceed + 25-26 °C.

The high altitude of 1200-1400 m above the sea level determines a noticeable change in the temperature-humidity and radiation regimes in comparison with the foothill areas.

The main components of the microclimate of the city include airspeed, temperature, solar radiation, and humidity. Speed, the air temperature in the city depend on the speed and temperature of the air on the surface, as well as on the thermal factor, which accelerates the heating or cooling of the airflow.

The maximum value of wind speed is observed in the daytime with convection, inversion – at night. Relative humidity of air in space can be less or more than on the surface. For the reliable protection of the atmosphere from pollution, it is necessary to carry out a set of preventive measures that take into account the climatic conditions on the basis of which the calculation of the city's ventilation. Thus, a change in these factors improves the natural airing of the city, and thereby reduces the concentration of harmful impurities, although possible, but on a very limited scale.

The composition of the atmosphere also affects the properties of air streams entering the atmosphere of the city.

Studies of the microclimate of Kabul were carried out with the help of statistical analysis of long-term observations in the measurement of wind speed, gradient observations at the "bottom-surface". With the help of an anemometer, the speed of air movement was measured, the direction of the wind at the highest point and near the Kabul River. The author established that the wind flow along the river has a predominantly western direction – 38%, the northern direction at the surface –33%, the northeast direction – 16-22%, with a wind speed of V≤2 m/s; the atmosphere of the city is polluted. Dust content reaches 1.5-50 mg/m^3.

II. Convective Air Exchange Scheme

The thermal regime of the city's atmosphere affects the intensity of contamination by harmful impurities. When heat is transferred by convection; unevenly heated volumes of gases move in space.

Convective air exchange on slopes arises if the vertical temperature gradient is positive and larger than the dry adiabatic temperature gradient. In this scheme, the air exchange on the slopes is carried out by air streams rising along with their slopes.

Due to the release of heat from the active surface, solar energy, convective heat exchange is created in the atmosphere. Solar energy is enhanced by the time of day, depending on the location of the building in space and its parameters. Heated air masses rise to the surface along the slopes of the mountain slopes, capturing harmful substances from the developed space. This creates a convective ventilation scheme (Figure 1).

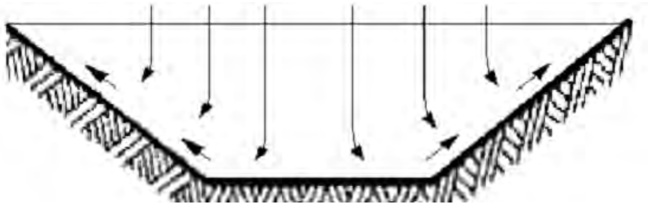

Fig. 1. Convective scheme for ventilating the slope in the floodplain of the river and the city

The reason for the formation of air currents is the difference in the heating of air on the slopes and at the same height in the free atmosphere. In this case, due to uneven heating of air, a horizontal pressure gradient arises, and in the free atmosphere of the slope, the pressure will be greater than on its slopes. Consequently, the warm layers of air adjacent to the heated slopes rise along with them, and the upper, less heated layers of air, like the heavier ones, descend downwards, which in turn warm up and, becoming less dense, also rise, and in their place cold layers of air return, etc.

The flow velocities in the convective scheme increase in the direction from the bottom upwards and on the northern side of the slope as more heated layers are obtained higher than on the southern slope. With a valley depth of up to 100 m-120 m, the flow velocity at the upper edge reaches 1.5 m / s (1).

$$u = 0.55K_1\sqrt{g(H_K - h)(\frac{t_K}{t_S} - 1)\sin\beta} \quad (1)$$

where K_1 is a coefficient that takes into account the slowing of the air flow due to the influence of the ledges (K_1 = 0.11 at a height of the steps of 10-12 m and slope angles of 20°–30°); g – acceleration of gravity, m / sec2; H_K – depth, m; h – depth of the location of the point from the surface in which the speed of the air flow is determined, m; t_K and t_S – respectively, the temperature of the air streams at a point located at a depth h and on the surface of the slope, °C; β – slope angle, degree.

The average wind speed of the mountain-valley circulation rises from 0 on the slope surface to a maximum at altitude:

$$V_{\max} = 0.322 \cdot \theta^1 \sqrt{\frac{g\beta\alpha^2}{\nu B}} , \quad (2)$$

where $\theta^1 = tk - tn -$ temperature perturbation; α – turbulent diffusivity coefficient; β – coefficient of temperature expansion; V – air flow velocity along the slope $B = \gamma_0\gamma$ – the difference between the adiabatic and the actual vertical gradient.

III. Inversion Scheme Of Air Exchange

As a result of uneven heating of the southern and northern slopes, an inversion-convective scheme for moving the air flow is created. At the same time, on one slope the air goes down, and on the other slope, it rises.

In this scheme, there can be two cases of air exchange, although they are based on the same physical phenomenon.

The first relates to air exchange on slopes located on the plain or in the valleys, which represent a closed contour (Fig.

2). In such places with inversions, the cooled air flows down to the deepest part of all the slopes, as a result of which layers of cool air polluted with dust or gases form on the bottom. In this case, the depth varies in large limits and even can be equal to the depth of the cavity. Velocity of streams of slope does not exceed 1-1.5 m/sec, and under the inversion level – 0.1 m/sec. Abbreviations and Acronyms

Define abbreviations and acronyms the first time they are used in the text, even after they have been defined in the abstract. Abbreviations such as IEEE, SI, MKS, CGS, sc, dc, and rms do not have to be defined. Do not use abbreviations in the title or heads unless they are unavoidable.

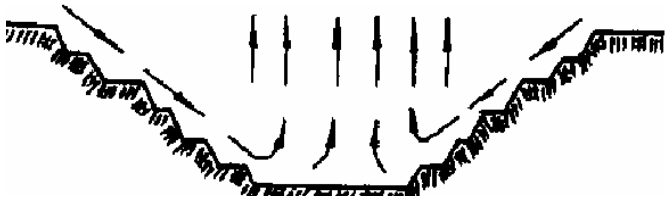

Fig. 2. Inversion scheme of air exchange in the valley of the river Barada

The flow velocities on the slopes of the slope above the inversion layer can roughly be determined by the formula (3).

$$u = K\sqrt{2gh\sin\beta\frac{T_S - T_K}{T_S}} \quad (3)$$

where K – an experimental coefficient that takes into account the decrease in the forces of gravity due to adiabatic heating of the air, the presence of steps and friction of the flowing airflow about layers of still air (K= 0.35 at slope angles of 25-30°); h – depth of the location of the point from the surface in which the speed of the air flow is determined, m; T_K, T_S – average absolute air temperature at the surface at a point located at a depth h, 0 K.

This case of the inversion scheme of air exchange is most unfavorable since in this case, dust and harmful impurities accumulate on the slopes and contamination of the general atmosphere and their removal begins only after filling the trap with cool air to the surface level.

The second case involves air exchange on the slopes located on the slopes of the reliefs (Fig. 3). With inversions, such slopes are ventilated by a descending cooled airflow that flows down to the valley adjacent to the slope, removing from it all harmful impurities.

At the same time, general air pollution or stagnant zones do not arise on slopes. Stream velocities on the slopes of the slope increase from top to bottom and at high values of the vertical gradient of air temperatures, steep angles of slopes and their large extent can reach 4-5 m / s and ensure intensive ventilation of the entire slope and individual locations.

Fig. 3. Inversion scheme of air exchange in sloping relief

In this case, the flow velocities on the slopes of the sides of the slope can also be roughly determined by the above formula.

IV. Straight-Through Scheme

Airing (Figure 4) is characterized by the coincidence of the air velocity vector at a high mark and in the city itself. A straight-through ventilation scheme arises at the slope angles of the leeward slope below 150.

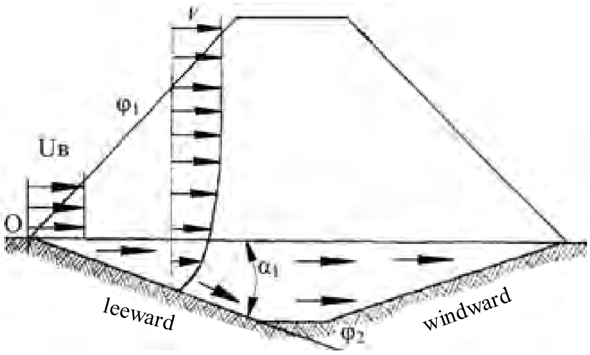

Fig. 4. Straight Flow Diagram

V. Recirculation Air Exchange Scheme

Recirculation scheme air exchange in the valley occurs at wind speeds of more than 0.8-1 m/sec and the slope angles of the leeward side $\beta > 15°$ or $\beta \leq 15°$, as a result, a considerable part of them (50% or more) creates conditions for the circulation of flows of the reverse direction. Here, the prevailing wind speed exceeds 0.8-1 m/sec and is characterized by the presence of a zone of reverse air currents (Fig. 5).

The air flow moving above the city is constantly expanding, reaching the opposite slope of the mountain, washing its ledges, moving upward, carrying with it harmful impurities near the river of the city, coming in the direction of the wind. In the deep parts of the city, a calm process of ventilation is observed for a very long time. With increasing wind speed and surface dimensions, the ventilation efficiency under this scheme increases.

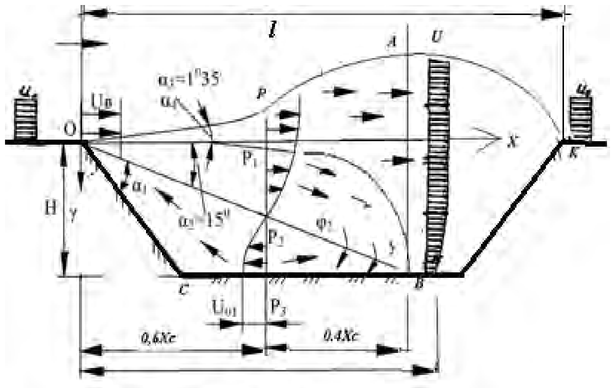

Fig. 5. Recirculation airing scheme

The airflow in the valleys acquires such structure when the outer boundary of the boundary layer reaches their windward slope, as well as in valleys with the ratio of geometric sizes:

$$\frac{l}{H} < 5 - 6. \tag{4}$$

VI. Inversion-Convective Air Exchange Scheme

If the air of one of the slopes is in the state of radiative cooling and the other is insulated, then conditions arise when the vertical gradient of air temperatures on one of the sides can have a negative value, and the other is positive and differs in magnitude from the dry adiabatic temperature gradient. In such cases, on the slopes along one side, the air flows down, while in others, it moves upward and the air exchange circuit in them is called the inversion-convective (Figure 6). Such conditions in valleys arise during periods of sunset or sunrise, and the duration of their action is insignificant. This scheme is inherent in all the shortcomings of the convective and inverting schemes of air exchange on the slopes.

Fig. 6. Inversion-convective air exchange scheme

The velocities of air currents on slopes of slopes do not exceed 1 -1.5 m/s and are minimal in its deep part.

With an inversion-convective scheme, the mass of fixed air at the bottom of the depression is not formed or its height will be negligible.

This scheme, after sunset, goes into the inversion mode, and after sunrise, into the convective air exchange scheme.

VII. A Mathematical Model Of Calculation Of Air Exchange In The City

To assess the effectiveness of the above methods of normalizing the atmosphere of the city, it is necessary to study the aerodynamic processes in these climatic conditions. Given the complexity of the task, the most appropriate method of investigation, in this case, should be considered modeling the distribution of airflow in the city. For cities with a rectangular or close to its layout form, the calculation method is simpler. For cities of complex configuration with poorly ventilated stagnant zones, more reliable data can be obtained by modeling. The data obtained can serve as a basis for calculating the necessary effect of a complex of measures and means for normalizing the airing of the city.

The following information is required for prediction by calculation or modeling:

1) Physical and mechanical properties of urban air.
2) Spatial planning organization of the city.
3) Characteristic profiles of the city.
4) Rose of Wind.
5) Wind direction and repeatability.
6) Humidity, air temperature, and an active surface, etc.

The application of the modeling method not only builds a model that takes into account the necessary features of the process of distribution of air masses in space but also imitates simulation. To do this, you must specify the initial and boundary conditions. The solution to this problem will allow calculating the number of stagnant zones and speed values for each city height.

To construct the model, we used the program ANSYS AIM. To improve the performance of natural ventilation, the slope of the river was subject to low-temperature heating. As a heat source, chrome wires. Electric heating was carried out with a voltage of 35-45V. Along the slope, the formation of a heat flux was considered, as a result of which the air exchange increased.

As a result of computer simulation, data have ben obtained that can serve as a basis for calculating the necessary effect of a complex of measures and means for normalizing the composition of air in a city. It will also be possible to determine the number of stagnant zones and the magnitude of the wind flow rates in each territory.

VIII. A Mathematical Model Of Calculation Of Air Exchange In The City

When processing the data obtained during field studies in Kabul, it was established that in the lower territories there would be a decrease in the wind speed, hence there is an increase in the volume of stagnant zones, which hinders the process of natural air exchange (Fig. 6).

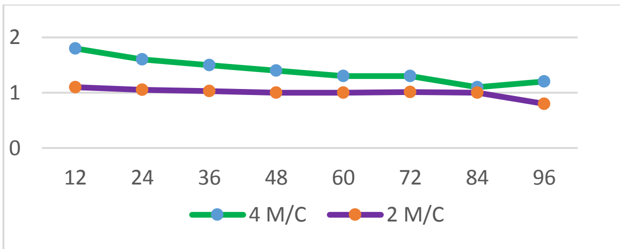

Fig. 7. The velocity of air flow at various depths of the city

IX. Conclusion

The above studies show that the speed of the airflow near the river and its space depends on the value of wind speed at a high point. Therefore, in assessing the intensity of natural ventilation, an analysis of the wind rose should be carried out, which reflects the frequency of repetition of wind currents of different directions. The efficiency of airing is connected with taking into account the prevailing winds in the city.

In 2016, in Kabul, there were field observations, measurements of airspeed at sites with different altitude marks and at different slope distances. Measurements were taken of air temperature on the surface of areas and in points, the speed of air flow and the relative humidity of the air.

It is known that in the immediate vicinity of the slope, the air flow around it is retarded, and strong vortices may appear in it. In hydro-aerodynamics, this layer is called the boundary layer. Experimental study of the boundary layer showed that on the very surface of the streamlined body, the flow does not move and, as it were, "sticks" to the surface.

In connection with the foregoing, it becomes necessary to determine the dependence of the angle of incidence and the profile of the slope, the velocity and the height of the propagation of a moving jet of air flow, so as to ensure the continuity of the flow from the initial slope to the river.

To solve this problem, we will consider the moving stream in the boundary layer to be laminar, since it is assumed that the slope and the territory near the river are completely washed with a stream of air (without detachment of the jet and formation of large eddies). Such flow is formed for small values of the Reynolds number ($Re < 4{,}5 \cdot 10^5$) (5), defined by the formula:

$$Re = \frac{\upsilon l}{\nu} \tag{5}$$

where υ – flow velocity for flow around a slope, m/sec; l – the height of the laminar flow in the projection on axis y; ν – kinematic viscosity of air, m^2/sec (under normal conditions $\nu = 1.45 \cdot 10^5$).

Flow with number Re occurs within the boundary layer, which within the height of the working zone (1.5-3 m above the ledges of the slope and the territory near the river).

Thus, the acquisition offers the opportunity to offer practical recommendations for enhancing air exchange and normalizing the atmosphere in the city.

References

[1] V.R. Krogius, Urban planning on the slopes. Moscow: Stroyizdat, 1988.

[2] E.V. Retter, “Modeling in the study of the microclimate of buildings and their complexes”, In: Climatic zoning for the design of dwellings. Moscow, 1969.

[3] I.S. Shukurov, “The problems of the heat and wind regime in Iraq's home”, In the book Construction - formation of the environment of life. Moscow, 2008.

[4] I.S. Shukurov, “Use of slopes, slopes and complex relief in landscape design "Akbulak"”, Problems of Architecture and Construction, № 3, Samarkand, 2017, pp.10-13.

[5] I.S. Shukurov, “Ahmed Elamin MA Influence of the Blue and White Nile on the ecological ecology of the coastal urbanized territories of Khartoum”, ASG, No. 3, 2016, pp. 15-19.

[6] I.S. Shukurov, Vertical planning of territories. Fundamentals of computer-aided design. Moscow: ASV, 2012, p. 223.

[7] I.S. Shukurov, “Heat-wind regime of residential development in conditions of hot-calm and dry climate”, Housing construction, № 2, 2005, pp. 20-21.

[8] I. S. Shukurov, A. El Amin, “Influence of the Blue and White Nile on the Gradoecology of the Coastal Urbanized Territories of Khartoum”, PGS, No. 3, 2016.

[9] I.S. Shukurov, “Investigation of the formation of convective airflows in multi-construction residential buildings”, Real Estate: Economics and Management, No. 4, pp. 27-33, 2015.