

NATURAL AND ANTHROPOGENIC FACTORS AFFECTING ATMOSPHERIC
AIR POLLUTION IN TASHKENT

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ABSTRACT:

ARTICLE INFO:

Received: 06.10.2026

Revised: 07.10.2026

Accepted: 08.10.2026

KEY WORDS:

*geographical
location, atmospheric
air, geoecology,
anthropogenic factors,
natural factors, climate
change, dust particles,
environmental state, air
pollution.*

This article analyses the geoecological state of the atmospheric air of Tashkent and the natural and anthropogenic factors that shape it. The study focuses primarily on revealing the influence of local physical-geographical conditions on geoecological processes. From this perspective, the effects of the city's geographical location, relief features and meteorological factors such as wind regime, temperature inversion, relative humidity and precipitation on the dynamics of air quality (aerotechnogenic pollution) are assessed. Climate indicators for 1895–2024 – in particular the long-term variability of air temperature and the humidity regime – are analysed in relation to the dispersion (transformation) of dust and gaseous substances in the atmosphere. The findings provide a basis for developing science-based practical recommendations aimed at improving air quality and stabilising the environmental situation in Tashkent.

Introduction. The historical formation and development of Tashkent, one of the oldest centres of urbanisation in Central Asia, is a vivid example of the ecological adaptation of human society to natural landscape conditions. The favourable microclimatic features of the Tashkent oasis, an adequate water supply provided by the hydrological network of the Chirchik River basin, and the

presence of fertile oasis soils suitable for farming enabled sustainable agriculture and territorial expansion in the earliest settlements. However, over the course of historical evolution, the emergence of the region's largest urban agglomeration in place of small fortified settlements has led to a sharp increase in anthropogenic pressure on the natural environment. As a result, the self-purification and recovery (assimilation) capacity of natural landscapes has become limited, giving rise to systemic geoecological problems.

In the current context of global and regional climate change, air pollution in urbanised areas has become one of the most pressing problems, exerting a wide-ranging negative impact on public health, ecosystem stability and overall quality of life. In Uzbekistan, rapid demographic growth and urbanisation, increasing vehicle density, the expansion of industry and arid climatic conditions are contributing significantly to the degradation of air quality. Tashkent, one of the largest metropolitan areas in the region, is no exception to these adverse environmental transformations. The horizontal expansion of residential areas and the vertical densification of buildings and structures weaken the intra-urban wind regime and aerodynamic mobility (ventilation); together with the exponential growth in the number of cars and large-scale construction and industrial activity, this is causing a sharp deterioration in air quality and the formation of local environmental crisis hotspots.

At the same time, an analysis of data reported in the scientific literature, official statistics, observations of Uzhydromet, the views of environmental scientists and current state policy shows that urban air pollution is a multifactorial, complex and cyclical process in which natural factors and anthropogenic impacts act jointly and simultaneously. Accordingly, a comprehensive analysis of natural and anthropogenic factors is of considerable theoretical and practical importance.

Literature review. Atmospheric air is one of the Earth's most important natural components and is of decisive importance in sustaining living organisms. In recent decades, population growth, intensified urbanisation and the increasing number of industrial enterprises and motor vehicles have made air pollution one of the global environmental problems. For this reason, researchers worldwide and in Uzbekistan are conducting extensive studies of the composition of atmospheric air, its changes under the influence of natural and anthropogenic factors, and the environmental consequences of these changes.

Early scientific views on the influence of human activity on atmospheric composition are found in the works of the seventeenth-century Flemish scientist Jan Baptist van Helmont. He established that the combustion of fuels releases a number of gases into the air and introduced the term "gas" into scientific usage. His research laid the foundation for the scientific understanding that the composition of atmospheric air is not constant and may change as a result of human activity [6].



One of the scientists who provided a scientific basis for anthropogenic changes in atmospheric air was the English engineer Guy Stewart Callendar. In 1938 he showed that the large-scale combustion of coal and petroleum products following the Industrial Revolution was increasing the concentration of carbon dioxide in the atmosphere. By comparing temperature observations from different countries with data on atmospheric CO₂ concentrations, Callendar demonstrated that human activity was causing global warming [7]. Today his work is regarded as one of the cornerstones of the theory of anthropogenic climate change.

Among the scientists who achieved important results in atmospheric chemistry in the second half of the twentieth century is Paul Crutzen. He studied in depth the depletion of the stratospheric ozone layer, the distribution of nitrogen oxides and the impact of human activity on the atmosphere. According to the “Anthropocene” concept advanced by Crutzen and Stoermer, humanity’s influence on nature has become so strong that it has given rise to a new geological epoch in the Earth’s history [8]. This theory made it possible to assess the problem of air pollution on a global scale.

The work of Robert Angus Smith is of great significance for research into the environmental consequences of air pollution. Analysing air composition in the industrial cities of England, he found that sulphur oxides emitted into the atmosphere alter the chemical composition of precipitation. As a result, he was the first to introduce the term “acid rain” into the scientific literature [10]. This study is considered one of the earliest to show that industrial emissions affect other natural components via the atmosphere.

Research by Nikolai Alfredovich Fuchs occupies a special place in the study of the physical properties of aerosols and airborne suspended particles. He developed a fundamental theory of aerosol mechanics, examining the motion, dispersion and deposition of solid and liquid particles in the air [9]. His theories are widely used today in assessing PM_{2.5} and PM₁₀ particles in urban atmospheres.

In recent years, the research of John Seinfeld and Spyros Pandis has become particularly important for the assessment of air pollution. In their work on atmospheric chemistry and physics, they comprehensively described aerosols, photochemical smog and the atmospheric cycling of nitrogen and sulphur compounds [11].

The works of Academician Q.Z. Zokirov are important for the study of the formation and changes of atmospheric air in Central Asia. Studying the physical-geographical conditions, climate and atmospheric processes of Uzbekistan, he elucidated the role of climatic factors in the formation of regional environmental problems [1].

A number of studies on the assessment of air quality and its geoecological state in Uzbekistan have been carried out by O.J. Jalolov. He analysed the sources of air pollution in industrialised areas, their dispersion and their impact on public health. In his studies, the Almalyk Mining and



Metallurgical Combine, the Angren industrial complex and the industrial zones of Navoi were identified as the main anthropogenic sources of air pollution [2].

Several studies have also been conducted on the atmosphere of Tashkent. In particular, specialists of the Centre of Hydrometeorological Service of the Republic of Uzbekistan carry out regular monitoring of sulphur dioxide, nitrogen dioxide, carbon monoxide, formaldehyde and suspended particulate matter in the city's atmosphere. According to these studies, motor vehicles account for the major share of air pollution in Tashkent, while in some areas industrial enterprises and construction activities also have an adverse effect on air quality [5].

The works of N.M. Sharipov, A.A. Rafatov and other scientists are important for the study of atmospheric processes associated with the desiccation of the Aral Sea. They established that millions of tonnes of salt and dust particles are lifted into the atmosphere every year from the exposed seabed and dispersed over a large part of Central Asia. These aerosols adversely affect the optical properties of the atmosphere, public health and the condition of agricultural land [3, 4].

The above review shows that, alongside natural factors, human activity exerts a strong influence on the state of atmospheric air. Industrialisation, the development of the transport system, the expansion of the energy sector and population growth are among the main causes of air pollution. At the same time, natural factors such as dust storms in the Aral Sea region and climatic cycles also significantly affect the composition and quality of the atmosphere. The results of these studies may serve as an important theoretical basis for assessing the geoecological state of Tashkent's atmospheric air and for developing science-based measures to improve it.

Main part. There is a large body of research on the impact of anthropogenic factors on air pollution. In particular, extensive studies have addressed the health effects of fine particulate matter (PM_{2.5} and PM₁₀), the patterns of dispersion of vehicle exhaust gases in the urban environment, the monitoring of pollutants emitted by industrial enterprises, the effects of urbanisation on air quality, and the interrelationship between climate change and air pollution. Studies assessing the role of green spaces in purifying the air, their importance in shaping the urban microclimate, and their effectiveness in reducing air pollution also occupy an important place.

According to the Ministry of Ecology, a number of anthropogenic factors contribute to air pollution in the capital. These include the shrinking area of green spaces, the felling of trees and shrubs, large-scale construction work in the city and the growing number of motor vehicles. In addition, more frequent traffic congestion resulting from inefficient traffic management and the rising energy demand of economic sectors and households also have a negative impact on air quality. In this context, the increasing use of hydrocarbon fuels, including coal, as well as the use of fuel oil (mazut) as a supplementary fuel at heating plants to provide district heating during the



autumn–winter season, is increasing the volume of harmful substances emitted into the atmosphere.

At the same time, the natural geographical factors affecting urban air pollution deserve particular attention. Whereas the physical-geographical conditions of the area (relief, prevailing wind directions, temperature inversions and humidity) determine the self-purification capacity of the atmosphere, the city's geographical position – namely its location in the semi-enclosed valley of the Chirchik River, the high frequency of calm (windless) days, especially in winter and autumn, and the influx of natural dust from the nearby desert zone – contributes to air pollution.

The environmental state of Tashkent's atmospheric air is shaped not only by anthropogenic sources but also by climatic and meteorological factors. The dispersion, concentration and transformation of pollutants in the atmosphere are closely linked to air temperature, relative humidity and precipitation. From this perspective, we analysed long-term mean values for 1895–2024 in order to assess the influence of air temperature on the level of air pollution.

Table 1

Decade	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual mean
1895–1904	–2.03	2.82	7.96	13.52	20.14	24.38	26.79	24.59	19.13	12.05	6.64	2.77	13.24
1905–1914	0.28	1.67	6.85	14.22	19.59	24.38	26.45	24.12	18.93	11.94	7.59	2.23	13.19
1915–1924	1.12	2.06	7.90	14.58	19.93	24.22	26.75	25.45	19.46	13.10	6.40	1.05	13.51
1925–1934	–3.41	0.80	7.95	14.66	19.80	24.73	26.97	24.74	19.33	12.70	5.80	0.11	12.86
1935–1944	0.09	3.81	7.59	14.56	20.65	25.22	27.29	24.92	19.55	13.55	6.35	1.87	13.78
1945–1954	0.31	2.38	7.26	14.67	20.08	23.87	26.76	25.04	19.35	12.71	4.79	–0.01	13.10
1955–1964	0.97	3.97	8.32	14.39	19.86	25.04	27.05	25.05	19.92	12.71	6.48	1.58	13.78
1965–1974	–1.02	1.07	8.25	15.07	20.24	25.45	27.03	24.92	19.74	13.76	8.53	3.25	13.86
1975–1984	1.23	1.88	8.54	16.28	20.46	25.58	28.12	25.84	20.29	13.37	7.22	2.74	14.31
1985–1994	1.61	3.63	8.25	14.93	19.71	25.69	27.68	25.65	20.09	13.12	8.33	4.45	14.44
1995–2004	2.82	4.66	9.23	15.54	20.63	25.74	27.66	26.56	21.12	14.51	8.74	3.95	15.09
2005–2014	1.27	3.01	11.05	16.41	21.70	26.53	28.11	27.00	21.39	14.70	8.02	2.63	15.17
2015–2024	3.42	6.13	11.37	16.92	22.54	27.71	30.13	27.28	21.94	14.45	7.96	3.96	16.16

Source: Centre of Hydrometeorological Service of the Republic of Uzbekistan (Uzhydromet). Archival data of atmospheric air observations (1895–2024). Tashkent.

The long-term meteorological database presented above made it possible to trace the dynamics of climatic changes characteristic of the thermal regime of the Tashkent oasis and adjacent areas over a 130-year period (1895–2024). It reveals a steady and accelerating upward trend in mean annual temperature from the beginning of the twentieth century to the end of the first quarter of the twenty-first century. Whereas in 1895–1904 the mean annual temperature in Tashkent was +13.24 °C, in the decade 2015–2024 it rose to +16.16 °C; that is, over the observation period the

regional thermal regime has warmed by $+2.92^{\circ}\text{C}$ under the combined influence of anthropogenic and global factors. This is almost twice the global warming value reported by the World Meteorological Organization (WMO) and indicates the high sensitivity of Central Asia to global climate change owing to its inland continental location.

In the winter months (December, January and February), a reduction in anomalously cold periods and a “softening” of winters are clearly evident. In particular, whereas in the early twentieth century negative January values prevailed owing to intrusions of the strong Siberian anticyclone (e.g. -3.41°C in 1925–1934), in the last decade (2015–2024) the mean January temperature rose to $+3.42^{\circ}\text{C}$. The greatest warming is observed in February: for example, the mean February temperature increased from $0.80\text{--}1.67^{\circ}\text{C}$ in the first quarter of the twentieth century to $+6.13^{\circ}\text{C}$ in 2015–2024. This is an indicator of a shortening winter season and an earlier onset of the spring growing season.

A significant increase in air temperature is also observed in the spring months. In particular, whereas in the early twentieth century the March temperature was approximately $7\text{--}8^{\circ}\text{C}$, in recent years it has risen to 11.37°C . This indicates that spring warming now begins earlier than in previous periods. A steady rise in temperature is also observed in April and May.

In the summer months (June, July and August), air temperature has gradually increased over the years. The change is most pronounced in July: the mean July temperature was 26.79°C in 1895–1904, rising to 30.13°C in 2015–2024. Thus, the July temperature increased by almost 3.3°C over this period.

Temperatures in the autumn months are also rising, most noticeably in November. In the early twentieth century the mean November temperature was 6.64°C , while in 2015–2024 it reached 7.96°C . The increase of almost 1.3°C in November indicates a later onset of cold days in autumn, which in turn points to a gradual lengthening of the warm period of the year.

A chronological analysis of the data clearly shows rising temperatures and gradual changes in climatic conditions in the region in recent years, with the increase becoming even more pronounced after 1995. This is one of the key signs of intensifying hot and dry conditions in the area and of the increasingly evident process of climate aridisation. Higher temperatures may also intensify the urban heat island effect. Strong heating of the air in the urban area weakens air exchange and promotes the accumulation of harmful substances emitted by vehicles and industry in the atmosphere. From this perspective, it is important to study long-term temperature changes in conjunction with air pollution.

The long-term meteorological data also make it possible to assess the relative humidity of the air in Tashkent (Table 2).



Table 2

Relative humidity of the air, %													
Years	I	II	III	IV	V	VI	VII	VII I	IX	X	XI	XII	Annual
1915– 1925	73	68	61	60	53	40	39	42	45	57	66	73	56.0
2015– 2024	69	62.4	60.4	55.8	47.8	34.1	31.7	34.1	38	53.7	64.3	70	51.8

Source: Centre of Hydrometeorological Service of the Republic of Uzbekistan (Uzhydromet).
Archival data of atmospheric air observations (1915–1925 and 2015–2024).

According to these data, a comparison of 1915–1925 (early twentieth century) with 2015–2024 (first quarter of the twenty-first century) shows an overall decrease in relative humidity. In particular, the long-term mean relative humidity declined from 56.0% to 51.8%, i.e. by about 4.2 percentage points. This indicates that the humidity of Tashkent's air has been decreasing over the long term and that relatively dry climatic conditions are intensifying.

The analysis of precipitation is also important for assessing the state of atmospheric air (Table 3).

Table 3

Precipitation, mm													
Years	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual
1915–1924	52	68	65	59	38	12	3	1.5	4.5	22	46	55	426
2015–2025	50.83	61.79	77.57	47.41	32.86	10.36	1.29	3.75	2.56	31.33	49.12	50.96	419.85

Source: Centre of Hydrometeorological Service of the Republic of Uzbekistan (Uzhydromet).
Archival data of atmospheric air observations (2015–2025). Tashkent.

A comparison of 1915–1924 and 2015–2025 shows that annual precipitation decreased from 426 mm to 419.3 mm, i.e. by 6.7 mm or 1.6%. Thus, although the change in the total annual amount is relatively small, certain shifts have occurred in the distribution of precipitation across seasons and months.

Overall, the analysis shows that while annual precipitation in Tashkent has remained almost stable, its seasonal and monthly distribution is changing. In particular, the decrease in May, July–August and September may create conditions for more severe dry periods. When such hydrometeorological changes coincide with rising temperatures and declining humidity, they intensify the drying of the atmosphere and may become one of the factors favouring the dispersion and longer residence of dust particles in the air.

Conclusion. The results of the study show that the geoecological state of Tashkent's atmospheric air is complex and multifactorial. The main anthropogenic factors affecting air quality include the growing number of motor vehicles, the operation of industrial enterprises, the expansion of construction activities and the widespread use of hydrocarbon fuels in the energy sector. At the same time, natural factors – the city's geographical location, a limited wind regime, temperature inversions, dry climatic conditions in summer and reduced precipitation – create a favourable environment for the accumulation of pollutants in the atmosphere.

The analysis of meteorological data for 1895–2024 revealed trends of rising temperature, decreasing relative humidity and declining precipitation in the city. These trends promote the activation of photochemical reactions, the formation of smog and the prolonged suspension of PM2.5 and PM10 particles in the air.

The results obtained are important for assessing the role of physical-geographical factors in the formation of Tashkent's atmospheric air quality. Studying temperature not in isolation but together with wind, humidity, precipitation, atmospheric circulation and inversions will allow the factors of air pollution to be analysed more precisely.

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