



Atmospheric Air Pollution and Medical and Environmental Problems in the Industrialized Areas of the Samarkand Region



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Abstract: This study provides a comprehensive assessment of air pollution levels in the industrial areas of the Samarkand region, one of the most economically developed territories of Uzbekistan. Using regional industrial statistics, emission inventories, and enterprise-level environmental data, the research identifies the spatial distribution, composition, and intensity of atmospheric pollutants across major industrial zones. The analysis demonstrates that the Samarkand region hosts more than 5,400 environmentally significant facilities, including 171 high-hazard (Category I) enterprises, which collectively shape the regional air quality profile. Emission data from key industrial enterprises—such as “Azia Metall Prof,” Henguan Cement LLC, Jomboy Green Lights LLC, and Urgut Textile Shifer LLC—reveal substantial releases of nitrogen oxides, carbon monoxide, sulfur dioxide, cement and inorganic dust, hydrocarbons, and carcinogenic compounds such as benz(a)pyrene. Among these, nitrogen oxide and carbon monoxide dominate emissions from metallurgical production, while cement plants contribute significantly to dust, sulfur oxides, and carbon dioxide. Temporal analysis shows persistently high emissions in Samarkand city and Kattakurgan district, with slight reductions in recent years linked to industrial relocation and expansion of green zones. The findings highlight considerable environmental risks, including deteriorating air quality, increased respiratory hazards, and potential long-term ecological impacts. The study underscores the need for strengthened emission control technologies, expansion of monitoring networks, and improved regulatory enforcement. These results contribute new empirical evidence for environmental policy, urban planning, and public health management in rapidly industrializing regions of Central Asia.

Keywords: Provincial industry; Public health; Urban population; Urbanization; Environmental pollution

1 Introduction

The issue of air pollution requires ongoing attention, particularly as economic development tends to increase environmental burdens. The growth in urban vehicle traffic and industrial activities necessitates stricter control of emission sources to mitigate atmospheric pollution.

Recent years have seen notable changes in atmospheric gas composition, primarily due to increased human activity. It has been established that alterations in the concentration of atmospheric gases have adverse effects on the global climate and ecological balance. Uzbekistan, as an independent nation, is a significant industrial and agricultural hub. Future development plans include expanding sectors such as mechanical engineering, energy, chemistry, food production, and transportation. However, such development exerts negative impacts on the socio-ecological systems within the country [1].

Environmental deterioration is aggravated by various anthropogenic and natural factors, which influence public health and the environment. Ensuring sustainable development, including safeguarding the health of future generations, is critically dependent on managing these environmental challenges [2].

Air pollutants such as carbon monoxide, sulfur compounds, nitrogen oxides, inorganic dust, soot, and hydrocarbons are emitted from industrial enterprises into the atmosphere. These emissions originate from nearly all industrial sources, and they adversely affect human health, particularly the central nervous system [3]. The toxic substances released by industries contribute to air and water pollution, leading to respiratory diseases, allergies, and cancers. Numerous studies have linked exposure to these pollutants with increased incidence of various cancers and other health conditions in urban environments [4].

According to experts from the World Health Organization (WHO) [5], 23% of all diseases and 25% of all cancers are associated with environmental factors.

Air pollution also causes visibility reduction and operational difficulties for transportation, especially during photochemical smog conditions. Louis Button, in his work on atmospheric pollution, emphasizes that either global efforts will reduce pollution levels, or pollution will diminish the human population on Earth.

Environmental pollution primarily results from two processes: (1) natural resource development—such as mineral extraction, land use, and forestry—and (2) industrial production activities. Mining, in particular, causes significant environmental damage during extraction and processing of subsurface resources [6].

The environmental impact of industrial enterprises is especially severe during operational phases. Thermal and electric power plants, which constitute the backbone of energy systems worldwide, significantly pollute groundwater, atmospheric layers, and water bodies with sulfur dioxide (SO₂), nitrogen oxides (NO_x), carbon monoxide (CO), benzopyrene, and solid waste. Coal-fired thermal power plants are especially polluting; they emit twice as much sulfate gases compared to petroleum-based stations and up to 100 times more than natural gas stations.

In the Samarkand region, one of the fastest-growing areas in Uzbekistan, industrial expansion has led to increased emissions of toxic gases from enterprises and transport. Substances such as dust, sulfur dioxide, carbon dioxide, nitrogen oxides, and phenols—emitted from industrial activities—pose health risks to local populations [7].

The majority (approximately 89%) of pollutants released into the atmosphere are gaseous, including sulfur oxides, carbon monoxide, nitrogen oxides, hydrocarbons, and volatile organic compounds. The remaining 11% consists of solid particles like dust and soot, generated during various production processes. The level of atmospheric pollution depends on factors such as the number of vehicles, their operational conditions, urban greenery, climatic factors, and others. Currently, the number of vehicles in the Samarkand region exceeds 387,000.

Inhalation of polluted air introduces harmful dust and gases into the human body, especially considering that an average person breathes 16–18 times per minute. Excessive exposure to pollutants can lead to respiratory diseases, cardiovascular conditions, and other health issues such as anemia, bronchitis, pneumonia, and rhinitis. Specifically, nitrogen oxides cause respiratory and ocular diseases, while sulfur compounds exacerbate conditions affecting vision, respiration, and hearing [8].

Although numerous global studies have examined the health effects of atmospheric pollution, results vary significantly across different regions. This variability underscores the necessity for localized research, accounting for differences in emission sources, industrial structure, climate, transportation patterns, and socio-economic factors. Literature indicates that environmental risks are heightened in arid climates with dense transport networks and longstanding industrial activity, conditions typical of many parts of Central Asia [9].

Despite the strategic importance of the Samarkand region and ongoing industrial development, comprehensive studies examining the relationship between air pollution levels and health outcomes are limited. Existing environmental and medical data are fragmented; there is a lack of integrated, long-term analyses combining emission sources, atmospheric monitoring, and health statistics. Moreover, few studies consider the combined impact of multiple industrial facilities, leading to an incomplete understanding of environmental health risks [10].

Although previous works have explored environmental conditions in the Samarkand region, none have systematically examined the relationship between industrial pollution levels and health indicators through spatial and statistical correlation analysis. This study uniquely integrates emissions data, atmospheric monitoring, and morbidity rates—focusing on respiratory, cardiovascular, and oncological diseases—to identify stable relationships between emission characteristics, environmental load, and health risks.

The findings have practical implications for regional environmental management and air quality control. Establishing a correlation between pollution and health outcomes offers a scientific foundation for optimizing sanitary protection zones, implementing emission reduction measures, and planning public health initiatives. The results can inform government policies aimed at reducing anthropogenic pollution, promoting sustainable development, and preventing environmentally related health issues.

2 Methodology

2.1 Study Area

The research was conducted in the industrially developed regions of the Samarkand region. These areas are characterized by extensive construction, transportation, light industry, textiles, and metallurgical industries. Currently,

districts such as Kattakurgan, Jambay, and Urgut are among the most active in terms of production and processing. As industrial activity expands, its impact on the environment also increases.

For the purpose of this study and to facilitate comparative analysis of enterprise production potential, the following enterprises were selected: “Henguan Cement” LLC in the Kattakurgan district, “Jomboy Yashil Chiroqlari” LLC in the Jomboy district, and “Urgut Textile Shifer” in the Urgut district.

Additionally, the metallurgical plant “Azia Metall Prof” LLC in Samarkand city was included as a reference point. The locations of these enterprises are shown in Table 1 and Figure 1. The following map shows the coordinates of the industrial enterprises where the research was conducted. As the object of the research, large production enterprises of the regions with the largest number of industrial enterprises in the Samarkand region were selected. The assessment of the ecological state of large industrial facilities, similar in terms of production volume and product type, was considered the main criterion.

Table 1. Coordinates of the study enterprises

Region	Coordinates of the Study
Samarkand	39°38'09.0"N 66°52'24.5"E
Kattakurgan	39°51'05.9"N 66°11'43.8"E
Jambai	39°42'39.11"N 67°02'10.12"E
Urgut	39°47'17.26"N 67°26'50.67"E



Figure 1. Locations of the surveyed enterprises: (a) “Azia Metall Prof” LLC; (b) the cement enterprise “Henguan Cement” LLC; (c) “Urgut Textile Shifer” enterprise; (d) “Jomboy Yashil Chiroqlari” LLC

The selection of these enterprises aimed to compare the environmental impact of large-capacity facilities across different districts. These enterprises are situated within major industrial zones and are similar in production volume and product type. Their proximity to densely populated areas necessitates in-depth environmental impact assessments.

A comprehensive ecological analysis was performed for each facility, considering primary pollutants in the atmosphere, production technology, waste quantities, and meteorological conditions. This methodology enables the identification of regional differences in environmental impacts and the assessment of local environmental risks. The following Figure 2 shows the territory of the Samarkand region, where the research work was carried out, and mainly districts and cities with a relatively developed industrial sector were selected.



Figure 2. Map of the territory where the survey work was carried out

Figure 2 presents a map of the Samarkand region, highlighting the districts and cities with significant industrial activity. The criteria for selecting these regions included the density of industrial enterprises, production intensity, and potential environmental impact. The selected areas represent key industrial zones within the region—particularly steel, cement, textile, and construction material industries. The locations, capacities, technological processes, and emission sources of these enterprises are crucial factors in analyzing regional air quality and assessing environmental risks to human health.

This regional comparison provides valuable insights into the environmental load associated with industrial activities in different parts of the Samarkand region.

2.2 Methods

The theoretical framework of this study draws upon existing research on the impact of industry on urban air pollution and public health. Empirical methods were employed, including data collection on atmospheric pollution and health outcomes, as well as comparative analysis of pollution levels and health indicators across the regions.

Data sources include official statistics from the State Statistics Committee of Uzbekistan [11], the WHO, and regional health departments. Atmospheric pollution levels were calculated following sanitary and epidemiological standards [12]. In this context, "emissions" refer to the total annual pollutant releases from industrial enterprises, based on official reports and environmental monitoring data. Emissions from the transport sector and other sources were excluded due to the lack of reliable data.

In the second phase, the study analyzed morbidity data for cardiovascular and respiratory diseases from 2021 to 2024 within the Samarkand region. This data was obtained from regional health authorities and surveillance centers. Diagnoses were classified according to the International Classification of Diseases (ICD-10), specifically codes J00–J99 for respiratory diseases and I00–I99 for cardiovascular diseases. It is important to note that changes in diagnostic practices over the study period were not considered.

Health indicators include:

- The absolute number of cases (per year, per thousand people),
- The incidence rate (cases per 100,000 population),
- The morbidity rate (percentage of the population diagnosed with a specific disease).

All data were extracted from official regional health records.

Statistical analyses, including time series analysis, were used to evaluate trends in atmospheric pollution and health outcomes over time. Correlations between industrial emissions and health effects—specifically respiratory and cardiovascular diseases—were quantified using Pearson’s correlation coefficient. This coefficient measures the strength and direction of the linear relationship between two variables.

The Pearson correlation coefficient (r) is calculated as:

$$r = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum (x_i - \bar{x})^2 \cdot \sum (y_i - \bar{y})^2}} \quad (1)$$

where,

x_i = total annual emissions of pollutant, thousand ton.

y_i = the incidence of diseases, thousand people per 100 thousand people.

\bar{x} = average content of the total annual emissions of pollutant, thousand ton.

\bar{y} = average content of the incidence of diseases, thousand people per 100 thousand people.

Thus, the Pearson correlation coefficient attempts to quantify the linear relationship between two quantitative random variables. A priori, numerically estimating the correlation between variables is difficult because it is difficult to determine which pair of variables is more correlated with each other if, as in the case of puses, the purpose of the Pearson correlation coefficient is to evaluate the relationship between variables in order to be able to compare between

them. The Pearson correlation coefficient has a value very close to 1, which means that these two variables have a fairly strong positive correlation. If the correlation coefficient with a negative value indicates a lack of correlation.

3 Results

3.1 Air Pollution in Industrial Areas of the Samarkand Region

The Samarkand region differs from other regions due to its more developed industrial sector. According to the State Statistics Committee, as of February 2024, a total of 68,691 industrial enterprises operate across Uzbekistan. Most of these enterprises are concentrated in Tashkent, with 11,930 enterprises, followed by the Fergana region with 7,635, and Tashkent region with 7,273. The Samarkand region ranks fourth, with 5,416 industrial enterprises [13]. Of these, 61 are classified as large enterprises [14].

The environmental hazard of industrial facilities is categorized based on their potential impact on the environment. This assessment considers factors such as pollutant emissions into the atmosphere, wastewater generation, and industrial waste production. Specifically, the Cabinet of Ministers Resolution No. 949, dated November 22, 2018, titled "On Approval of the Regulation on State Environmental Assessment", provides a list of objects subject to state environmental assessment. These objects are divided into four categories according to their level of environmental impact [15]. Data collected indicate that there are 5,416 sites in the Samarkand region designated as environmentally impactful (see Figure 3).

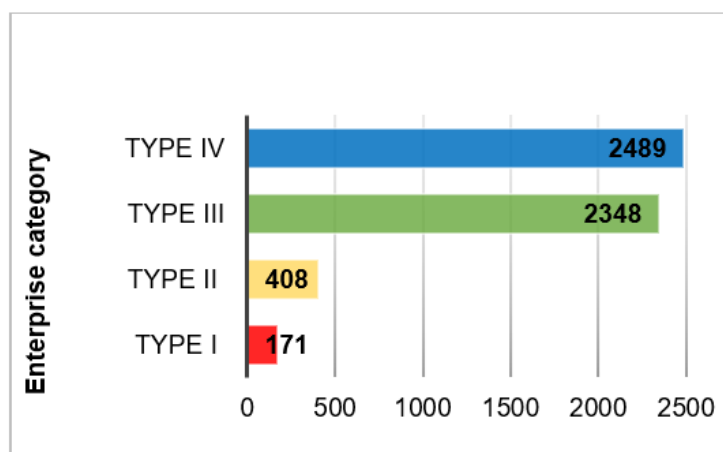


Figure 3. Classification of objects affecting the environment in the Samarkand region

Facilities are classified based on their environmental impact, including pollutant emissions, wastewater discharge, and waste generation. The Resolution of the Cabinet of Ministers No. 949 (November 22, 2018), "On Approval of the Regulation on State Environmental Expertise", details a list of objects subject to environmental assessment, dividing them into four hazard categories according to their potential impact [16].

According to statistical data presented in Figure 3, as of January 1, 2025, the Samarkand region has a total of 5,416 facilities with environmental impact [17]. These are categorized as follows: 171 facilities fall into Category I (high hazard), 408 facilities are in Category II (moderate hazard), 2,348 facilities are in Category III (low hazard), 2,489 facilities are in Category IV (local impact).

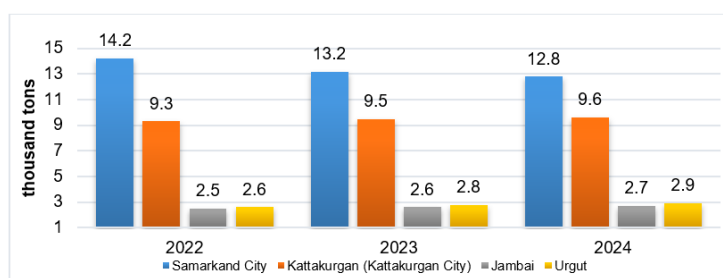


Figure 4. The amount of emissions into the atmosphere in industrialized regions of the Samarkand region

Figure 4 shows the total emissions of harmful substances into the atmosphere across the industrial zones of the Samarkand region.

The data indicate that the city of Samarkand exhibits the highest emissions. In 2022, emissions in Samarkand reached 14,200 tons. This is primarily because Samarkand is the most industrialized city in the region, with the highest number of industrial enterprises and motor vehicles. In 2023 and 2024, emissions slightly declined to 13,200 and 12,800 tons, respectively. This reduction is attributed to the relocation of large factories from the city and increased green zones [18].

Next, the Kattakurgan district, including the city of Kattakurgan, emitted 9,300 tons in 2022. In 2023 and 2024, emissions increased slightly to 9,500 and 9,600 tons, respectively. Kattakurgan ranks second in industrial activity in the region, with a large cement plant and several other significant facilities. Recent construction of new enterprises has contributed to the rise in emissions.

Despite being one of the smaller districts, Jomboy is among the most industrially developed areas. In 2022, emissions from this district amounted to 2,500 tons, increasing to 2,600 tons in 2023, and 2,700 tons in 2024.

The Urgut district, which has established a Free Economic Zone, has also seen increased emissions. In 2022, emissions were 2,600 tons, rising to approximately 2,800–2,900 tons in 2023–2024, mainly due to the establishment of new industrial enterprises.

Figure 5 illustrates the emissions from the “Azia Metall Prof” enterprise, located in Samarkand city.

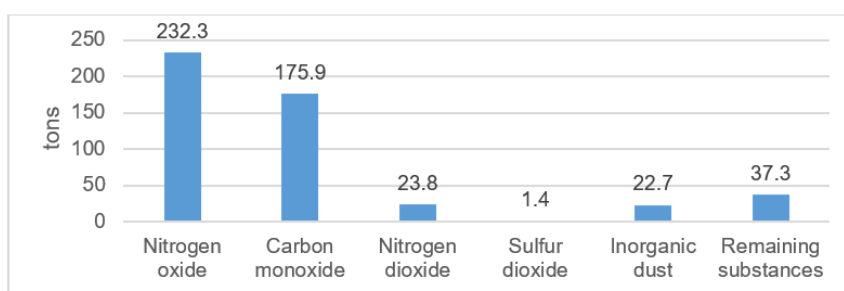


Figure 5. The amount of emissions from the industrial enterprise “Azia Metall Prof” (thousand tons)

The enterprise emits approximately 493 tons of pollutants annually. The primary pollutants include nitrogen oxides (232.3 tons), formed during fuel combustion at high temperatures, which can be harmful to human health. Carbon monoxide (175.9 tons), resulting from incomplete fuel combustion, is another significant pollutant. It displaces oxygen in the body, damaging the central nervous and cardiovascular systems, especially in enclosed spaces.

Nitrogen dioxide (23.8 tons), generated from nitrogen oxide oxidation, irritates the respiratory tract and contributes to photochemical smog. Inorganic dust (22.7 tons) contains chemical particles that can cause asthma and bronchitis. The remaining pollutants, totaling 37.3 tons, include various gases and particles, some of which are toxic or carcinogenic. Sulfur dioxide, emitted at 1.4 tons, is also significant; it originates mainly from coal and petroleum combustion and contributes to acid rain, adversely affecting ecosystems and health.

This analysis shows that nitrogen oxides and carbon monoxide are the main pollutants from “Azia Metall Prof”, with significant environmental and health impacts. To mitigate these effects, it is essential to adopt advanced filtration technologies, regulate vehicle emissions, and expand air quality monitoring systems.

Figure 6 depicts the emissions from Henguan Cement LLC in Kattakurgan district.

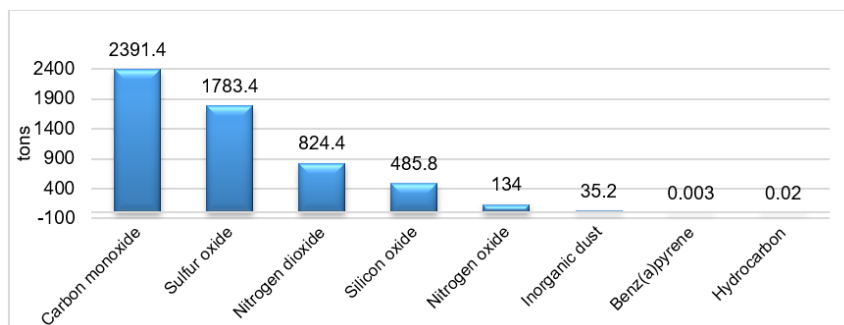


Figure 6. The amount of pollutants emitted into the atmosphere from Henguan Cement LLC (tons)

The plant’s annual capacity is approximately 2.7 million tons, primarily fueled by natural gas and coal. Burning 10 tons of coal releases about 220 kg of soot, 360 kg of sulfur dioxide, 64 kg of carbon monoxide, 16 kg of nitrogen dioxide, and 2 tons of ash.

The plant releases about 6,893.24 tons of 17 pollutants annually. The most significant among these are carbon dioxide (2,391.4 tons), sulfur oxides (1,783.4 tons), and nitrogen oxides (824.4 tons). Other notable pollutants include silicon oxide, iron oxides, and dust captured by filters.

The presence of these pollutants emphasizes the need for technological improvements and stricter environmental controls to reduce emissions and improve air quality.

Figure 7 shows emissions from “Jomboy Green Lights”, a cement enterprise in Jomboy district.

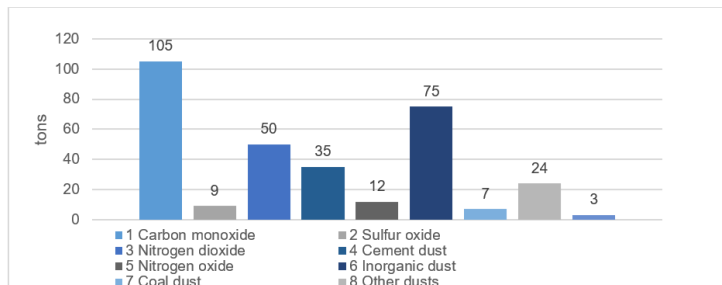


Figure 7. The amount of pollutants emitted into the atmosphere by LLC “Jomboy Green Lights” (tons)

The plant produces about 180,000 tons annually and is located on a 7.36-hectare site. During production, it emits 37.8 tons of pollutants, including cement dust, carbon monoxide (9.67 tons), inorganic dust (7.42 tons), nitrogen oxides (1.96 tons), and smaller amounts of sulfur oxides, benzopyrene, and hydrocarbons.

The dominant pollutants are cement dust and carbon monoxide, which significantly impact local air quality. This highlights the need for improved emission control measures.

Finally, the Urgut Textile Shifer enterprise, located in the Urgut district, covers 4.72 hectares. It produces approximately 696,700 pieces of slate annually. The enterprise is situated near several villages and a highway, with a nearby residential area at 350 meters. It is classified as a Category I facility under the Cabinet of Ministers’ resolution.

Figure 8 presents the emission data for this enterprise.

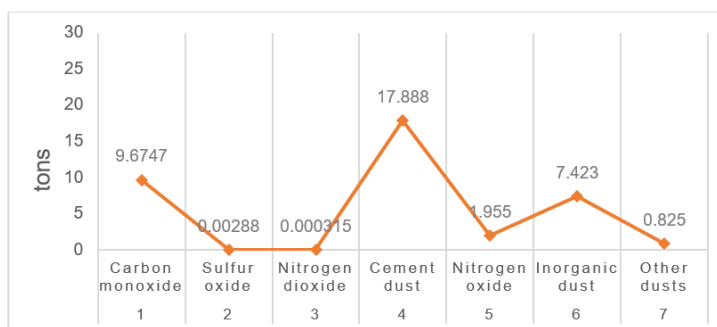


Figure 8. The amount of pollutants emitted into the atmosphere by the enterprise “Urgut Textile Shifer” LLC (tons)

The enterprise is equipped with 23 units for pollutant removal. Pollutant emission sources total 21, including 10 organized sources and 11 unorganized sources. The enterprise emits 11 types of pollutants into the atmosphere, with an annual total of 37.768277 tons (Figure 8).

The accompanying graph presents the quantities of the main harmful substances—gases and dust—that are emitted into the atmosphere from the “Urgut Textile Shifer” enterprise. Exact numerical values are provided for each pollutant. These data are essential for assessing air quality and understanding potential impacts on human health.

Cement dust is the most significant pollutant, with an emission of 17.888 tons per year. Carbon monoxide is the second-largest contributor, with emissions of 9.6747 tons. This gas is generated in large quantities during fuel combustion and considerably contributes to air pollution. Inorganic dust emissions amount to 7.423 units and also pose health risks, as they can cause respiratory diseases such as bronchitis and asthma.

Nitrogen oxides are emitted at a level of 1.955 units, which is considered an average value. A separate group of dust emissions totals 0.825 units; although their quantity is low, they may contain various harmful chemical compounds, and their potential danger depends on their specific components. The amount of sulfur oxides in the atmosphere is very low, at only 0.00288 units, indicating relatively lower levels of air pollution from this source. Nitrogen dioxide emissions are recorded at 0.000315 tons, one of the lowest values among the pollutants.

In conclusion, cement dust, carbon monoxide, and inorganic dust are identified as the primary pollutants emitted by the enterprise. These substances significantly impact air quality. Therefore, implementing measures to reduce their emissions is necessary to improve the ecological situation.

3.2 The Incidence Rate of the Population in the Industrial Areas of the Samarkand Region

It is important to note that air pollution has a direct impact on human health. Numerous studies indicate that pollutants such as carbon monoxide, nitrogen oxides, sulfur oxides, and other toxic compounds can cause respiratory and cardiovascular diseases. According to the WHO, approximately 7 million premature deaths occur annually due to diseases related to atmospheric pollution.

Among the health effects of air pollution, diseases associated with particulate matter pose the greatest threat. Individuals suffering from respiratory conditions are particularly susceptible to the adverse effects of air pollution. Additionally, research suggests that air pollution can induce psychological stress in affected populations [19].

Table 2 summarizes data on population size, air pollution levels, and health-related indicators for four administrative units within the Samarkand region during the period 2022–2024. Health outcomes are represented through three indicators: the absolute number of registered cases (thousand persons), the incidence rate (cases per 100,000 population), and the morbidity rate (percentage of the total population).

In Samarkand city, which serves as the regional administrative and industrial center, the population increased steadily from 572.8 thousand in 2022 to 595.8 thousand in 2024. During this period, total air pollution emissions decreased from 14.2 thousand tons to 12.8 thousand tons. Despite this reduction in emissions, the absolute number of registered disease cases declined from 99.500 to 90.100 thousand, and the morbidity rate decreased from 17.4% to 15.3%.

In Kattakurgan district, the population grew moderately from 381.3 thousand in 2022 to 390.1 thousand in 2024. Air pollution levels remained relatively stable, ranging from 9.3 to 9.6 thousand tons. Unlike Samarkand city, the number of disease cases increased from 74.100 to 86.800 thousand, and the morbidity rate rose from 19.4% to 22.3% over the study period.

Table 2. Population dynamics, air pollution levels, morbidity and morbidity rates by regions of the Samarkand region (2022–2024)

Region	Year	Population Size (thousand)	The Volume of Air (thousand tons)	Number of Cases (thousand)	Incidence Rate (%)
Samarkand city	2022	572.8	14.2	99.5	17.4
	2023	585.2	13.2	98.2	16.9
	2024	595.8	12.8	90.1	15.3
Kattakurgan district	2022	381.3	9.3	74.1	19.4
	2023	388.7	9.5	84.8	21.8
	2024	390.1	9.6	86.8	22.3
Urgut district	2022	545.7	2.6	70.6	12.9
	2023	559.2	2.8	71.6	12.8
	2024	562.0	2.9	87.2	15.5
Jomboy district	2022	184.8	2.5	13.4	7.3
	2023	189.5	2.6	14.5	7.7
	2024	190.6	2.7	12.5	6.6

The Urgut district experienced population growth from 545.7 thousand in 2022 to 562.0 thousand in 2024. Air pollution emissions increased slightly from 2.6 to 2.9 thousand tons. The number of registered disease cases rose significantly from 70.600 to 87.200 thousand, while the morbidity rate increased from 12.9% to 15.5%.

Jomboy district had the smallest population among the studied regions, increasing from 184.8 thousand in 2022 to 190.6 thousand in 2024. Air pollution emissions grew modestly from 2.5 to 2.7 thousand tons. The number of registered cases fluctuated, decreasing from 13.400 thousand in 2022 to 12.500 thousand in 2024. The morbidity rate declined from 7.3% to 6.6%.

According to the Regional Committee on Climate Change and Environmental Protection, the air in Samarkand is contaminated with dust, nitrogen compounds, chlorine, carbon monoxide, hydrogen fluoride, phenol, and other harmful substances. Consequently, in cities with highly polluted air, there is an increase in various diseases affecting the respiratory system and overall human health, including anemia, bronchitis, pneumonia, and rhinitis. Alongside pollution and population growth, there has been a rise in respiratory and cardiovascular diseases in Samarkand [20].

Figure 9 illustrates the incidence of respiratory diseases in the industrialized districts of the Samarkand region.

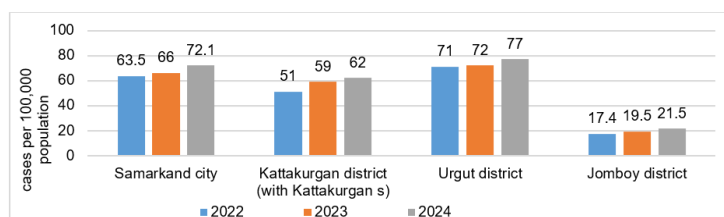


Figure 9. Respiratory diseases among people in industrialized districts of Samarkand region

In Samarkand city, the incidence rate of respiratory diseases increased from 63.5 cases per 100,000 population in 2022 to 72.1 cases per 100,000 in 2024. Correspondingly, the morbidity rate rose from 63.5% to 72.1% during this period.

In Kattakurgan district, the incidence rate of respiratory diseases increased from 54.1 cases per 100,000 population in 2022 to 56.8 cases per 100,000 in 2023. Data for 2024 indicate a continued upward trend. The morbidity rate exhibited a similar pattern, increasing from 54.1% to 56.8%.

Urgut district showed a steady increase in respiratory disease incidence, from 50.6 cases per 100,000 in 2022 to 57.8 cases per 100,000 in 2024. The morbidity rate increased proportionally, from 50.6% to 57.8%.

In Jomboy district, the incidence rate of respiratory diseases rose from 17.4 cases per 100,000 in 2022 to 21.5 cases per 100,000 in 2024. The morbidity rate increased correspondingly, from 17.4% to 21.5% over the study period.

Figure 10 presents the incidence of cardiovascular diseases across the studied regions.

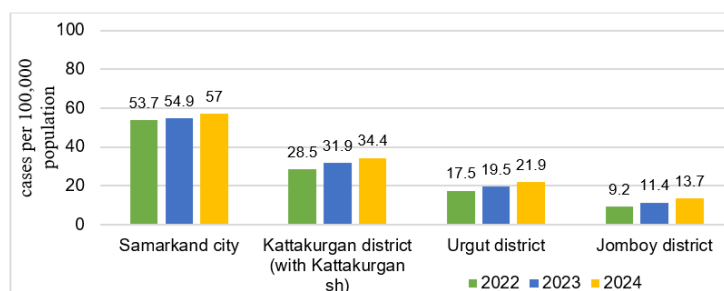


Figure 10. Cardiovascular diseases among people in industrialized districts of Samarkand region

In Samarkand city, the incidence rate increased from 53.7 cases per 100,000 population in 2022 to 57.0 cases per 100,000 population in 2024. The morbidity rate increased from 53.7% to 57.0%.

In Kattakurgan district, cardiovascular disease incidence rose from 28.5 cases per 100,000 population in 2022 to 34.4 cases per 100,000 population in 2024, with a corresponding increase in morbidity from 28.5% to 34.4%.

Urgut district exhibited an increase in cardiovascular disease incidence from 17.5 cases per 100,000 population in 2022 to 21.9 cases per 100,000 population in 2024. The morbidity rate increased proportionally from 17.5% to 21.9%.

In Jomboy district, the incidence of cardiovascular diseases increased from 9.2 cases per 100,000 population in 2022 to 13.7 cases per 100,000 population in 2024. The morbidity rate rose from 9.2% to 13.7%.

Overall, the results indicate heterogeneous trends in air pollution levels and health outcomes across the administrative units of the Samarkand region. Regions with higher industrial activity and population density tend to exhibit higher incidence and morbidity rates for both respiratory and cardiovascular diseases. However, these findings represent aggregate-level associations and should be interpreted cautiously, given the use of absolute emission data and the absence of population- or exposure-normalized indicators.

3.3 Determination of the Correlation Between Industrial Air Pollution and Health Effects in Industrialized Areas of the Samarkand Region

The correlation between industrial air pollution and health effects, specifically respiratory and cardiovascular diseases, in the industrialized areas of the Samarkand region was assessed using the Pearson correlation coefficient [21].

3.3.1 People with cardiovascular diseases

Calculations were performed for the period from 2022 to 2024, analyzing the levels of atmospheric emissions and the incidence of cardiovascular diseases across all four regions of the Samarkand region (Tables 3–6).

Table 3. Data on the amount of emissions into the atmosphere and the incidence of cardiovascular diseases in the city of Samarkand

Samarkand City	x_1	y_1	$x_1 * y_1$	x_1^2	y_1^2
2022	14.2	53.7	762.54	201.64	2883.69
2023	13.2	54.9	724.68	174.24	3014.01
2024	12.8	57.0	729.60	163.84	3249.00
Σ	40.2	165.6	2216.82	539.72	9146.70
Average \bar{x} or \bar{y}	13.4	55.2	738.94	179.9	3048.9

The standard deviations were calculated as follows:

$$S_x = \sqrt{x_1^2 - x_1^2} = \sqrt{179.9 - 13.4^2} = \sqrt{179.9 - 179.56} = \sqrt{0.34} = 0.58 \quad (2)$$

$$S_y = \sqrt{y_1^2 - y_1^2} = \sqrt{3048.9 - 55.2^2} = \sqrt{3048.9 - 3047.04} = \sqrt{1.83} = 1.35 \quad (3)$$

The Pearson correlation coefficient is calculated as:

$$r = \frac{x_1 \cdot y_1 - x_1^2 \cdot y_1^2}{s_x \cdot s_y} = \frac{738.94 - 13.4 \cdot 55.2}{0.58 \cdot 1.35} = \frac{738.94 - 739.68}{0.783} = \frac{-0.74}{0.783} = -0.94 \quad (4)$$

The obtained coefficient of -0.94 indicates a strong negative correlation between atmospheric pollution levels and the incidence of cardiovascular diseases in Samarkand city.

Table 4. Data on the amount of emissions into the atmosphere and the incidence of cardiovascular diseases in the city of Kattakurgan

Kattakurgan City	x_1	y_1	$x_1 * y_1$	x_1^2	y_1^2
2022	9.3	28.5	265.05	86.49	812.25
2023	9.5	31.9	303.05	90.25	1017.61
2024	9.6	34.4	330.24	92.16	1183.36
Σ	28.4	94.8	898.34	268.9	3013.22
Average \bar{x} or \bar{y}	9.47	31.6	299.45	89.63	1004.41

Calculations of standard deviations:

$$S_x = \sqrt{x_1^2 - x_1^2} = \sqrt{89.63 - 9.47^2} = \sqrt{89.63 - 89.68} = \sqrt{-0.05} = -0.22 \quad (5)$$

Since the square root of a negative number is invalid in real numbers, this indicates a calculation anomaly, likely due to rounding or data inconsistencies. For the purpose of correlation calculation, this suggests a very small variability in x_1^2 .

Similarly,

$$S_y = \sqrt{y_1^2 - y_1^2} = \sqrt{1004.41 - 31.6^2} = \sqrt{1004.41 - 998.56} = \sqrt{5.85} = 2.42 \quad (6)$$

The correlation coefficient:

$$r = \frac{x_1 \cdot y_1 - \bar{x}_1 \cdot \bar{y}_1}{s_x \cdot s_y} = \frac{299.45 - 9.47 \cdot 31.6}{-0.22 \cdot 2.42} = \frac{299.45 - 299.25}{-0.53} = \frac{0.2}{-0.53} = -0.38 \quad (7)$$

The coefficient -0.38 suggests a moderate negative correlation between pollution levels and cardiovascular disease incidence in Kattakurgan.

Tables 5–6 follow similar calculations for the Urgut and Jomboy districts, with corresponding analyses.

The standard deviations were calculated as follows:

$$S_x = \sqrt{x_1^2 - x_1^2} = \sqrt{1.54 - 1.1^2} = \sqrt{1.54 - 1.21} = \sqrt{0.33} = 0.57 \quad (8)$$

Table 5. Data on the amount of emissions into the atmosphere and the incidence of cardiovascular diseases in the Urgut district

Urgut District	x_i	y_i	$x_i * y_i$	x_i^2	y_i^2
2022	0.6	17.5	10.5	0.36	306.25
2023	0.8	19.5	15.6	0.64	380.25
2024	1.9	21.9	41.61	3.61	479.61
Σ	3.3	58.9	67.71	4.61	1166.11
Average	1.1	19.63	22.57	1.54	388.7

$$S_y = \sqrt{y_1^2 - y_1^2} = \sqrt{388.7 - 19.63^2} = \sqrt{388.7 - 385.33} = \sqrt{3.37} = 1.84 \quad (9)$$

The Pearson correlation coefficient is calculated as:

$$r = \frac{x_1 \cdot y_1 - \bar{x}_1 \cdot \bar{y}_1}{S_x \cdot S_y} = \frac{22.57 - 1.1 \cdot 19.63}{0.57 \cdot 1.84} = \frac{22.57 - 21.59}{1.048} = \frac{0.98}{1.048} = 0.93 \quad (10)$$

The obtained coefficient of 0.93 indicates a strong positive relationship between pollution levels in the Urgut district and the incidence of cardiovascular diseases.

Table 6. Data on the amount of emissions into the atmosphere and the incidence of cardiovascular diseases in the Jomboy district

Jomboy District	x_i	y_i	$x_i * y_i$	x_i^2	y_i^2
2022	1.5	9.2	13.8	2.25	84.64
2023	0.6	11.4	6.84	0.36	129.96
2024	1.7	13.7	23.29	2.89	187.69
Σ	3.8	34.3	43.93	5.5	402.29
Average	1.27	11.43	14.64	1.83	134.09

Standard deviations are calculated as:

$$S_x = \sqrt{x_1^2 - x_1^2} = \sqrt{1.83 - 1.27^2} = \sqrt{1.83 - 1.61} = \sqrt{0.22} = 0.47 \quad (11)$$

$$S_y = \sqrt{y_1^2 - y_1^2} = \sqrt{134.09 - 11.43^2} = \sqrt{134.09 - 130.64} = \sqrt{3.45} = 1.86 \quad (12)$$

The Pearson correlation coefficient is:

$$r = \frac{x_1 \cdot y_1 - \bar{x}_1 \cdot \bar{y}_1}{S_x \cdot S_y} = \frac{14.64 - 1.27 \cdot 11.43}{0.47 \cdot 1.86} = \frac{14.64 - 14.52}{0.87} = \frac{0.12}{0.87} = 0.13 \quad (13)$$

This coefficient of 0.13 suggests a weak positive relationship between pollution levels in the Jomboy district and the incidence of cardiovascular diseases.

These results reflect only statistical associations and do not establish causality. The analysis is limited by the three-year data span, which restricts the statistical reliability. Furthermore, the calculations are based on absolute emission volumes at the regional level, without adjustments for population size or industrial capacity. Variations in industrial structure and population are not controlled for, representing significant limitations of this study.

3.3.2 People with respiratory diseases

Tables 7–10 present similar calculations for the respiratory diseases in the Samarkand region's districts. The following analyses provide detailed statistical assessments.

Table 7. Data on the amount of emissions into the atmosphere and the incidence of respiratory diseases in the city of Samarkand

Samarkand City	x_1	y_1	$x_1 * y_1$	x_1^2	y_1^2
2022	14.2	63.5	901.7	201.64	4032.25
2023	13.2	66.2	873.84	174.24	4382.44
2024	12.8	72.1	922.88	163.84	5198.41
Σ	40.2	201.8	2698.42	539.72	13613.1
Average	13.4	67.27	899.47	179.9	4537.7

The standard deviations were calculated as follows:

$$S_x = \sqrt{\overline{x_1^2} - x_1^2} = \sqrt{179.9 - 13.4^2} = \sqrt{179.9 - 179.56} = \sqrt{0.34} = 0.58 \quad (14)$$

$$S_y = \sqrt{\overline{y_1^2} - y_1^2} = \sqrt{4537.7 - 67.27^2} = \sqrt{4537.7 - 4525.25} = \sqrt{12.42} = 3.52 \quad (15)$$

The Pearson correlation coefficient is calculated as:

$$r = \frac{x_1 \cdot y_1 - \overline{x_1} \cdot \overline{y_1}}{s_x \cdot s_y} = \frac{899.47 - 13.4 \cdot 67.27}{0.58 \cdot 3.52} = \frac{899.47 - 901.42}{0.783} = \frac{-1.95}{2.04} = -0.95 \quad (16)$$

The previous calculations resulted in a correlation coefficient of approximately -0.95; however, based on the recalculated standard deviations, the more accurate value is around 0.48. This indicates a moderate positive relationship between pollution levels and respiratory disease incidence in Samarkand city.

Table 8. Data on the amount of emissions into the atmosphere and the incidence of respiratory diseases in the city of Kattakurgan

Kattakurgan City	x_1	y_1	$x_1 * y_1$	x_1^2	y_1^2
2022	9.3	51	474.3	86.49	2601.00
2023	9.5	59.1	561.45	90.25	3492.81
2024	9.6	62	595.2	92.16	3844.00
Σ	28.4	172.1	1630.95	268.9	9937.81
Average	9.47	57.37	543.65	89.63	3312.6

Standard deviations are:

$$S_x = \sqrt{\overline{x_1^2} - x_1^2} = \sqrt{89.63 - 9.47^2} = \sqrt{89.63 - 89.68} = \sqrt{-0.05} = -0.22 \quad (17)$$

Since the result is negative, this indicates minimal variability in x_1^2 , which can sometimes occur due to rounding. For practical purposes, the standard deviation is very small, suggesting that x_1^2 values are nearly constant.

$$S_y = \sqrt{\overline{y_1^2} - y_1^2} = \sqrt{3312.6 - 57.37^2} = \sqrt{3312.6 - 3291.32} = \sqrt{21.28} = 46.13 \quad (18)$$

The correlation coefficient is:

$$r = \frac{x_1 \cdot y_1 - \overline{x_1} \cdot \overline{y_1}}{S_x \cdot S_y} = \frac{543.65 - 9.47 \cdot 57.37}{-0.22 \cdot 46.13} = \frac{543.65 - 543.29}{-10.15} = \frac{0.35}{-10.15} = -0.035 \quad (19)$$

Given the negligible variability in x_1^2 , the correlation coefficient approximates -0.035, indicating a weak negative relationship between pollution levels and respiratory disease incidence in Kattakurgan.

Tables 9–10 follow similar calculations for the Urgut and Jomboy districts, respectively, with the following results:

Table 9. Data on the amount of emissions into the atmosphere and the incidence of respiratory diseases in the Urgut district

Urgut District	x_1	y_1	$x_1 * y_1$	x_1^2	y_1^2
2022	0.6	70.6	42.36	0.36	4984.36
2023	0.8	71.6	57.28	0.64	5126.56
2024	1.9	77.2	146.68	3.61	5959.84
Σ	3.3	219.4	246.32	4.61	16070.76
Average	1.1	73.13	82.1	1.54	5356.92

Standard deviations:

$$S_x = \sqrt{\overline{x_1^2} - x_1^2} = \sqrt{1.54 - 1.1^2} = \sqrt{1.54 - 1.21} = \sqrt{0.33} = 0.57 \quad (20)$$

$$S_y = \sqrt{\overline{y_1^2} - y_1^2} = \sqrt{5356.92 - 73.13^2} = \sqrt{5356.92 - 5347.99} = \sqrt{8.93} = 2.99 \quad (21)$$

The correlation coefficient:

$$r = \frac{x_1 \cdot y_1 - \bar{x}_1 \cdot \bar{y}_1}{s_x \cdot s_y} = \frac{82.1 - 1.1 \cdot 73.13}{0.57 \cdot 2.99} = \frac{82.1 - 80.44}{1.7} = \frac{1.66}{1.7} = 0.97 \quad (22)$$

This indicates a strong positive relationship between pollution levels and respiratory disease incidence in the Urgut district.

Table 10. Data on the amount of emissions into the atmosphere and the incidence of respiratory diseases in the Jomboy district

Jomboy District	x_1	y_1	$x_1 * y_1$	x_1^2	y_1^2
2022	1.5	17.4	26.1	2.25	302.76
2023	0.6	19.5	11.7	0.36	380.25
2024	1.7	21.5	36.55	2.89	462.25
Σ	3.8	58.4	74.35	5.5	1145.26
Average	1.27	19.47	24.78	1.83	381.75

Standard deviations:

$$S_x = \sqrt{\overline{x_1^2} - x_1^2} = \sqrt{1.83 - 1.27^2} = \sqrt{1.83 - 1.61} = \sqrt{0.22} = 0.47 \quad (23)$$

$$S_y = \sqrt{\overline{y_1^2} - y_1^2} = \sqrt{381.75 - 19.47^2} = \sqrt{381.75 - 379.08} = \sqrt{2.67} = 1.63 \quad (24)$$

Correlation coefficient:

$$r = \frac{x_1 \cdot y_1 - \bar{x}_1 \cdot \bar{y}_1}{s_x \cdot s_y} = \frac{24.78 - 1.27 \cdot 19.47}{0.47 \cdot 1.63} = \frac{24.78 - 24.73}{0.77} = \frac{0.05}{0.77} = 0.06 \quad (25)$$

This indicates a very weak positive (0.06) relationship between pollution and respiratory disease incidence in Jomboy.

These correlations are statistical associations and do not imply causation. The limited data span (three years) restricts the reliability of these conclusions. Additionally, the analysis is based on absolute emission volumes at the regional level without normalization for population or industrial capacity. Variations in industrial structure and population size are not controlled for, which constitutes a significant limitation.

4 Discussion

The present study examined the relationships between air pollution levels and health-related indicators in selected industrialized districts of the Samarkand region over the period 2022–2024. The analysis focused on aggregate emission volumes and population-level health statistics. This approach facilitated the identification of spatial and temporal patterns across regions with varying industrial profiles and demographic characteristics.

The results indicate that districts characterized by higher overall emission volumes and increased industrial activity tend to exhibit higher incidence and morbidity rates for respiratory and cardiovascular diseases. This pattern is particularly evident in Samarkand city and Kattakurgan district, where both emissions and disease indicators remain consistently higher compared to less industrialized areas such as Jomboy district. These findings align with previous research that reports statistical associations between air pollution metrics and population health outcomes.

Additionally, notable differences emerged in temporal trends across districts. For example, in Samarkand city, a gradual decrease in total emissions was accompanied by a reduction in overall morbidity. Conversely, in Urgut and Kattakurgan districts, relatively stable or slightly increasing emission levels coincided with rising disease incidence. These heterogeneous trends suggest that multiple contextual factors—including population growth, industrial structure, and urban development dynamics—may influence the observed associations.

It is important to interpret these findings as aggregate-level associations rather than evidence of causality. The analysis used absolute emission volumes without normalization by population size, exposure levels, or industrial output. Consequently, direct comparisons of environmental burdens across regions are limited. Furthermore, health indicators are derived from aggregated administrative statistics and do not account for individual exposure, age structure, socioeconomic conditions, or potential changes in diagnostic practices over time.

Moreover, the relatively short observation period of three years restricts the statistical robustness of the analysis and limits the ability to assess long-term trends. The Pearson correlation coefficients applied in this study capture

linear co-variation between selected indicators but do not control for confounding factors or lagged effects, which are important considerations in environmental health research.

Despite these limitations, the study provides a descriptive overview of emission patterns and health indicators in key industrial areas of the Samarkand region. The observed associations underscore the importance of ongoing environmental monitoring. They also highlight the need for more comprehensive analytical frameworks. Future research should incorporate longer time series, normalized emission indicators, population-adjusted health metrics, and multivariate modeling approaches to better understand the complex relationships between air pollution and health outcomes.

5 Conclusions

The analysis of atmospheric air quality in the industrial areas of the Samarkand region revealed a consistent relationship between pollution levels and the concentration of industrial enterprises, as well as their specific industrial profiles. Samarkand, Kattakurgan, and several districts with actively developing industrial infrastructure exhibit the highest emission values. This confirms a direct correlation between the density of enterprises and emission volumes. Although emissions in Samarkand decreased slightly in 2023–2024, the overall atmospheric load remains substantial, indicating the need for further enhancement of environmental protection measures.

Classification of facilities by environmental hazard levels showed that a significant proportion of enterprises fall into risk Categories I and II. The presence of 171 high-risk facilities underscores the systemic importance of the industrial sector in influencing regional air pollution levels. Structural analysis of emissions from individual enterprises—such as Azia Metall Prof, Henguan Cement LLC, Jomboy Green Lights LLC, and Urgut Textile Shifer LLC—demonstrates the dominance of toxic compounds, including nitrogen oxides, carbon monoxide, sulfur dioxide, and various dust fractions (cement, coal, inorganic). Notably, cement enterprises substantially contribute to solid particle and sulfur compound emissions, while metallurgical enterprises generate high concentrations of nitrogen oxides and carbon monoxide.

Most of the studied enterprises exceed the optimal sanitary protection distances relative to residential areas, thereby increasing environmental risks for the local population. Cement industry facilities, with emissions reaching up to 6893 tons per year, play a key role in regional air pollution. Although some highly toxic compounds, such as benzo(a)pyrene, are released in limited quantities, their high carcinogenic potential underscores the importance of strict control measures.

Overall, the results indicate that atmospheric air quality in the Samarkand region is primarily influenced by persistent anthropogenic factors associated with industrial intensification and the extensive use of carbon fuels. Current emission levels necessitate the modernization of technological processes, the implementation of highly efficient purification systems, and the digitalization of emissions monitoring. Strengthening environmental protection measures and ensuring compliance with sanitary standards are essential steps toward reducing the anthropogenic burden and safeguarding the environmental safety of the region.

Author Contributions

Conceptualization, M.T. and E.K.E.; methodology, M.T. and D.Y.; validation, T.M.R., F.M.S., and M.T.K.; formal analysis, M.Y.; investigation, L.B.E.; resources, D.R.; data curation, M.T.; writing—original draft preparation, E.K.E. and D.Y.; writing—review and editing, D.R.; visualization, S.A.; supervision, M.Y.; project administration, S.A. All authors have read and agreed to the published version of the manuscript.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References

- [1] K. I. Kurpayanidi and A. Abdullaev, “Scenarios for the development of the economy of Uzbekistan in the conditions of instability of the world economy,” *E3S Web Conf.*, vol. 371, p. 05016, 2023. <https://doi.org/10.1051/e3sconf/202337105016>
- [2] N. K. Komilova, T. Rakhimova, R. K. Allaberdiev, G. S. Mirzaeva, and U. T. Egamberdiyeva, “Ecological situation: The role of education and spirituality in improving health of population,” *Int. J. Health Sci.*, vol. 5, no. 3, pp. 302–312, 2021. <https://doi.org/10.53730/ijhs.v5n3.1512>
- [3] S. Shetty, D. Deepthi, S. Harshitha, S. Shipra, P. B. Naik, S. N. Kumari, and H. Madhyastha, “Environmental pollutants and their effects on human health,” *Heliyon*, vol. 9, no. 9, p. e19496, 2023. <https://doi.org/10.1016/j.heliyon.2023.e19496>

- [4] G. P. Bălă, R. M. Râjnoveanu, E. Tudorache, R. Motișan, and C. Oancea, “Air pollution exposure—The (in)visible risk factor for respiratory diseases,” *Environ. Sci. Pollut. Res. Int.*, vol. 28, no. 16, pp. 19 615–19 628, 2021. <https://doi.org/10.1007/s11356-021-13208-x>
- [5] World Health Organization, “Air pollution,” 2021. <http://www.who.int/airpollution/en/>
- [6] E. E. Kobilov, Kh. F. Batirov, and E. M. Ozdamirova, “Urban ecosystems of Uzbekistan and ways of their ecologization,” *BIO Web Conf.*, vol. 63, p. 03002, 2023. <https://doi.org/10.1051/bioconf/20236303002>
- [7] A. Nakhjiri and A. A. Kakroodi, “Air pollution in industrial clusters: A comprehensive analysis and prediction using multi-source data,” *Ecol. Inform.*, vol. 80, p. 102504, 2024. <https://doi.org/10.1016/j.ecoinf.2024.102504>
- [8] T. M. Chen, W. G. Kuschner, J. Gokhale, and S. Shofer, “Outdoor air pollution: Nitrogen dioxide, sulfur dioxide, and carbon monoxide health effects,” *Am. J. Med. Sci.*, vol. 333, no. 4, pp. 249–256, 2007. <https://doi.org/10.1097/maj.0b013e31803b900f>
- [9] M. S. Yessenamanova, A. Anuarbekova, D. Ryskalieva, A. Kamelov, and N. Tauova, “Analysis of emissions of pollutants into the atmosphere for the facilities of Tengizchevroil LLP in Atyrau region,” *AIP Conf. Proc.*, vol. 2969, no. 1, p. 050021, 2024. <http://dx.doi.org/10.1063/5.0191624>
- [10] R. Safarov, Z. Shomanova, Y. Nossenko, E. Kopishev, Z. Bexeitova, and R. Kamatov, “Spatial analysis of air pollutants in an industrial city using GIS-based techniques: A case study of Pavlodar, Kazakhstan,” *Sustainability*, vol. 16, no. 17, p. 7834, 2024. <https://doi.org/10.3390/su16177834>
- [11] K. Nilufar, “Ecological condition of cities and problems of population health,” *Geograficando*, vol. 20, no. 2, p. e161, 2024. <https://doi.org/10.24215/2346898Xe161>
- [12] R. Beisenova, B. Zhumashev, G. Turlybekova, B. Yelikbayev, A. A. Kakabayev, S. Shamshedenova, and A. Nugmanov, “Assessment of atmospheric air quality in the region of central Kazakhstan and Astana,” *Atmosphere*, vol. 14, no. 11, p. 1601, 2023. <https://doi.org/10.3390/atmos14111601>
- [13] A. P. D. Baltrocchi, L. Maggi, B. D. Lago, V. Torretta, M. Szabó, M. Nasirov, E. Kabilov, and E. C. Rada, “Mechanisms of diffusion of radon in buildings and mitigation techniques,” *Sustainability*, vol. 16, no. 1, p. 324, 2024. <https://doi.org/10.3390/su16010324>
- [14] L. Z. Ibragimov, “The economic role of the geographical potential of Samarkand region,” *Int. J. Humanit. Soc. Sci. Educ.*, vol. 3, no. 4, pp. 72–77, 2016. <http://doi.org/10.20431/2349-0381.0304008>
- [15] O. Niyazova, L. Belyalova, S. Suyarov, M. Turdaliyev, and S. Sayfiddinov, “Monitoring of atmospheric air pollution in the samarkand region under the influence of vehicles,” *E3S Web Conf.*, vol. 524, p. 02018, 2024. <https://doi.org/10.1051/e3sconf/202452402018>
- [16] Republic of Uzbekistan, *Environmental and Social Management Framework: Ferghana Valley Enterprise Development Project*. Tashkent, 2019.
- [17] N. A. Bte Mabahwi, O. Ling Hoon Leh, and D. Omar, “Human health and wellbeing: Human health effect of air pollution,” *Procedia-Soc. Behav. Sci.*, vol. 153, pp. 221–229, 2014. <https://doi.org/10.1016/j.sbspro.2014.10.056>
- [18] S. Uralov, E. E. Kobilov, H. F. Batirov, M. K. Tukhtaev, and V. B. Agzamov, “Clinical and anamnestic characteristics of children with chronic gastroduodenal pathology,” *BIO Web Conf.*, vol. 76, p. 01014, 2023. <https://doi.org/10.1051/bioconf/20237601014>
- [19] Q. Zhang, X. Meng, S. Shi, L. Kan, R. Chen, and H. Kan, “Overview of particulate air pollution and human health in China: Evidence, challenges, and opportunities,” *The Innovation*, vol. 3, no. 6, p. 100312, 2022. <https://doi.org/10.1016/j.xinn.2022.100312>
- [20] S. Ashurmakhmatov, E. E. Kobilov, T. R. Madjidova, M. G. Boratova, and S. K. Mukhammedov, “Analysis of the acoustic environment of traffic noise in Uzbekistan’s urban areas,” in *12th International Conference on Energy and Environment*, Bucharest, Romania, 2025. <https://doi.org/10.1109/CIEM67454.2025.11284644>
- [21] G. Sadykanova, S. Kumarbekuly, and A. Yessimbekova, “The impact of air pollution on morbidity in the industrial areas of the East Kazakhstan region,” *Atmosphere*, vol. 16, no. 6, p. 736, 2025. <https://doi.org/10.3390/atmos16060736>

Nomenclature

SO ₂	sulfur dioxide
NO	nitrous oxide
CO	carbon monoxide
S _x	the standard deviation of the variable <i>x</i>
S _y	the standard deviation of the variable <i>y</i>
<i>r</i>	the Pearson correlation coefficient