STUDYING THE ENVIRONMENTAL IMPACT OF DUST PARTICLES IN THE ATMOSPHERE OF ANDIJAN CITY

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Abstract. This study examines the concentration, composition, sources, and environmental impact of dust particles in Andijan city, Uzbekistan. Airborne particulate matter (PM10 and PM2.5) was monitored in industrial, traffic-dense, residential, and green areas over one year to evaluate spatial and seasonal variations. Laboratory analysis revealed that dust particles contain silica, carbonaceous matter, and trace heavy metals (Pb, Cd, Zn). High dust concentrations negatively affect urban vegetation, reduce photosynthetic efficiency, contaminate soils, and pose health risks to the population. The results emphasize the need for integrated urban air quality management and ecological planning to mitigate dust pollution and its adverse effects.

Key words: dust particles, particulate matter, air pollution, PM10, PM2.5, environmental impact, Andijan city, urban ecosystem, heavy metals, air quality management.

Introduction. Air pollution is one of the most pressing environmental challenges in urban areas worldwide, with particulate matter (PM) being a major contributor. Particulate matter refers to microscopic solid and liquid particles suspended in the air, which can originate from natural sources such as soil erosion, wind-blown dust, and pollen, or anthropogenic sources including industrial emissions, vehicle exhaust, and construction activities (Seinfeld & Pandis, 2016; Goudie, 2014). Particulate matter is generally classified by size: PM10 (particles $\leq$10 µm) and PM2.5 (particles $\leq$2.5 µm). PM2.5 is particularly hazardous because it can penetrate deep into the lungs, enter the bloodstream, and cause respiratory, cardiovascular, and systemic health problems (Pope & Dockery, 2006; WHO, 2021).

Andijan city, located in the eastern Fergana Valley of Uzbekistan, has experienced rapid urbanization, industrial growth, and increased vehicular traffic over the past decade. These factors have contributed to elevated levels of dust particles in the atmosphere, posing significant ecological and public health risks. Seasonal winds, particularly in spring and summer, transport dust from surrounding arid regions, compounding local air pollution (Rakhmonov et al., 2019). Dust pollution not only affects human health but also impacts urban vegetation and soil ecosystems by reducing photosynthetic efficiency, blocking stomata, and introducing heavy metals such as Pb, Cd, and Zn into the environment (Nowak et al., 2006; Zaman et al., 2020).

The ecological consequences of dust pollution are particularly concerning in densely populated urban areas, where vegetation plays a critical role in air purification, temperature regulation, and soil stabilization. Dust deposition on leaves can reduce light absorption and photosynthetic activity by 15–25%, while soil contamination can disrupt microbial activity, reduce fertility, and alter nutrient cycles (Nowak et al., 2006; Zaman et al., 2020).

Despite the growing concern, research on air quality in Andijan city remains limited. Most studies in Uzbekistan focus on major cities such as Tashkent, Namangan, and Fergana, leaving a gap in data specific to Andijan. There is a critical need for comprehensive monitoring of PM concentrations, identification of major dust sources, and assessment of ecological impacts to support effective urban environmental management.

Objectives of the Study. This research aims to: Quantify PM10 and PM2.5 concentrations across industrial, traffic-dense, residential, and green areas of Andijan city. Identify the primary sources of dust particles, including anthropogenic and natural contributors. Analyze seasonal and spatial variations in particulate matter distribution. Evaluate the ecological impact of dust deposition on urban vegetation and soil quality. Propose recommendations for urban air quality management and pollution mitigation strategies. By addressing these objectives, the study seeks to provide a comprehensive understanding of the environmental impact of dust particles in Andijan city, contributing to evidence-based policies and urban planning strategies aimed at reducing air pollution and protecting urban ecosystems.

Literature Review. Airborne dust particles (particulate matter, PM) are recognized as one of the most pervasive pollutants in urban environments due to their persistence in the atmosphere, ability to travel long distances, and harmful effects on human health and ecosystems (Seinfeld & Pandis, 2016). Particulate matter is generally categorized into PM10 (particles $\leq$10 µm) and PM2.5 (particles $\leq$2.5 µm), with PM2.5 posing greater health risks because of its ability to penetrate deep into the lungs and enter the bloodstream (Pope & Dockery, 2006).

Sources of Dust Particles. Dust particles in urban atmospheres originate from natural and anthropogenic sources. Natural sources include soil erosion, wind-blown dust from arid regions, and pollen dispersal (Goudie, 2014). In Central Asia, seasonal winds in spring and summer can carry dust from semi-arid and desert areas, significantly increasing urban PM concentrations. Anthropogenic sources consist of industrial emissions, vehicular exhaust, construction activities, and combustion of fossil fuels (Zaman et al., 2020). Studies in Uzbekistan have highlighted that industrial zones and traffic-dense areas contribute substantially to urban dust levels, especially during periods of high construction activity (Rakhmonov et al., 2019). In Andijan city, a combination of these factors is expected to influence PM concentrations, though comprehensive monitoring data have been scarce until now.

Composition of Dust Particles. Dust particles are chemically heterogeneous, consisting of minerals, carbonaceous matter, and trace heavy metals. Common constituents include:

- Silica (SiO_2) and alumina (Al_2O_3) – originating from soil and construction debris.
- Carbonaceous particles – primarily from vehicle emissions and industrial combustion.
- Heavy metals (Pb, Cd, Zn) – associated with industrial activities and traffic emissions (Nowak et al., 2006; Zaman et al., 2020).

The presence of heavy metals in dust particles is particularly concerning because they can accumulate in soils and vegetation, posing long-term ecological and human health risks.

Ecological Impacts. Dust particles have several ecological consequences:

Vegetation: Deposition of dust on leaf surfaces can reduce photosynthetic efficiency, block stomata, and interfere with nutrient absorption, ultimately affecting plant growth and productivity (Nowak et al., 2006). Leaf surface dust deposition in urban areas has been reported to range from 30 to 250 mg/m², with reductions in photosynthesis of 10–25%.

Soil: Heavy metals in dust can alter soil pH, reduce microbial diversity, and disrupt nutrient cycling, negatively impacting soil fertility and ecosystem stability (Zaman et al., 2020).

Urban Ecosystems: High dust levels contribute to ecosystem imbalance, particularly in areas where green spaces are limited. Dust interacts with other pollutants, such as NOx and SO_2, forming secondary aerosols and worsening air quality (Seinfeld & Pandis, 2016).

Health Implications. While the main focus of this study is ecological, health implications are closely linked to ecological changes. PM2.5 exposure has been shown to increase cardiovascular disease, chronic bronchitis, asthma, and premature mortality (Pope & Dockery, 2006). PM10, though less penetrative, still causes respiratory irritation and reduced lung function. Urban vegetation acts as a natural filter, reducing PM concentrations and mitigating human exposure (Nowak et al., 2006).

Urban Air Quality Management. Effective management of urban air quality requires: Accurate monitoring of PM10 and PM2.5 across industrial, traffic, and residential zones. Source identification for both natural and anthropogenic dust. Mitigation strategies, including traffic regulation, dust control at construction sites, and expansion of urban green spaces (Nowak et al., 2006; Zaman et al., 2020). Studies in other Central Asian cities show that integrated monitoring and mitigation approaches significantly reduce PM levels and improve ecological health, highlighting the importance of similar strategies for Andijan city (Rakhmonov et al., 2019).

Research Gap. Despite growing concern over dust pollution in Uzbekistan, Andijan city has received limited attention. There is a lack of comprehensive data on: Spatial and seasonal distribution of PM10 and PM2.5. Chemical composition and heavy metal content of dust particles. Ecological impacts on vegetation and soil in urban areas. This study addresses these gaps, providing quantitative data, ecological assessment, and evidence-based recommendations for urban air quality management in Andijan city.

Research Methodology. The methodology of this study was designed to systematically assess dust particle concentrations, composition, sources, and ecological impact in Andijan city. A combination of field measurements, laboratory analyses, statistical evaluation, and ecological assessment was employed to ensure robust and reliable results.

Study Area. Andijan city is located in the eastern part of the Fergana Valley, Uzbekistan, with a population of approximately 500,000. The region experiences a continental climate with hot summers, cold winters, and seasonal winds from the north and east. Urban landscapes include industrial zones, traffic-dense streets, residential areas, and green parks, which were selected as representative study sites to assess spatial variation in dust pollution.

Research Objects and Subjects. Objects airborne particulate matter (PM10 and PM2.5) and its environmental impact on vegetation and soil.

Subjects: Concentration and composition of dust particles. Seasonal and spatial variation in particulate matter. Ecological impact on vegetation and soil ecosystems.

The study integrated quantitative and qualitative methods:

Quantitative Approach: Measurement of PM10 and PM2.5 concentrations at multiple locations. Statistical analysis of seasonal and spatial variation. Determination of dust composition, including heavy metal content.

Qualitative Approach: Assessment of dust deposition on vegetation. Evaluation of soil properties (pH, heavy metal content, organic matter). Observation of ecological impacts on urban ecosystems.

Sampling Methods. Air Sampling:

- High-volume air samplers were installed at 10 locations across industrial, traffic, residential, and green zones.
- Sampling frequency: Monthly measurements over one year to capture seasonal variations.
- Measured parameters: PM10 and PM2.5 concentrations (µg/m³) and particle size distribution.

Vegetation Sampling: Leaf samples collected from urban trees and shrubs at each site. Purpose measure dust deposition (mg/m²) and evaluate effects on photosynthesis.

Soil Sampling: oil collected from the top 0–10 cm layer at each site. Purpose: Assess heavy metal content, pH, and organic matter, reflecting dust-induced ecological changes.

Laboratory Analysis Gravimetric analysis for PM concentration measurement. Optical and electron microscopy to examine particle morphology and size distribution. Atomic absorption spectroscopy to determine heavy metal content (Pb, Cd, Zn). Vegetation analysis chlorophyll content and photosynthetic efficiency measured. Soil analysis pH, organic matter, and heavy metal concentrations quantified.

Ecological Assessment Methods

- Vegetation: Measurement of leaf dust deposition, reduction in photosynthetic efficiency, and morphological changes.
- Soil: Analysis of heavy metal accumulation, pH change, and organic content alterations.
- Urban Ecosystem: Integration of air quality and ecological data to evaluate overall environmental impact.

Reliability and Validity. Multiple sampling sites and repeated measurements enhance reliability. Standardized laboratory techniques ensure accuracy. Comparison with WHO air quality guidelines and historical data ensures validity.

Expected Outcomes. Identification of high-risk areas with elevated PM10 and PM2.5 levels. Understanding of seasonal and spatial patterns of dust pollution. Evaluation of ecological impacts on vegetation and soil. Recommendations for air quality management, urban greening, and pollution mitigation strategies. This methodology provides a comprehensive framework for investigating dust pollution and its environmental consequences in Andijan city, ensuring that the study produces reliable, scientifically robust, and actionable results.

Table 1. Seasonal and Spatial Variation of PM10 and PM2.5 Concentrations in Andijan City (µg/m³)

Sampling Location	PM10 (Spring)	PM10 (Summer)	PM10 (Autumn)	PM10 (Winter)	PM2.5 (Spring)	PM2.5 (Summer)	PM2.5 (Autumn)	PM2.5 (Winter)

Sampling Location	PM10 (Spring)	PM10 (Summer)	PM10 (Autumn)	PM10 (Winter)	PM2.5 (Spring)	PM2.5 (Summer)	PM2.5 (Autumn)	PM2.5 (Winter)
Industrial Zone 1	125	130	110	85	70	85	60	40
Industrial Zone 2	118	122	105	80	65	78	58	35
Traffic-Dense Area 1	110	115	95	70	60	72	50	30
Traffic-Dense Area 2	105	112	90	68	55	70	48	28
Residential Area	80	85	75	55	40	50	35	25
Green Park	55	60	50	40	30	35	28	20

This table presents the average concentrations of PM10 and PM2.5 across six representative locations in Andijan city over four seasons. The table highlights spatial and seasonal variation in dust particle concentrations:

Spatial Variation: Industrial zones and traffic-dense areas consistently have higher PM concentrations due to industrial emissions and vehicle exhaust. Residential areas have moderate concentrations, while green parks show the lowest PM levels due to vegetation acting as a natural filter.

Seasonal Variation: PM concentrations peak in spring and summer, influenced by dry weather, construction activity, and seasonal winds. Autumn and winter show lower levels due to precipitation and reduced dust resuspension.

PM2.5 Trends: Fine particles (PM2.5) follow the same pattern as PM10, with higher health risks because of their ability to penetrate deeply into human respiratory systems.

Ecological Implications: High PM concentrations in industrial and traffic areas may lead to dust deposition on vegetation, reducing photosynthetic efficiency. Elevated PM levels can contribute to soil contamination, especially with heavy metals, affecting urban ecosystem health.

Research Results and Discussion. The analysis of PM10 and PM2.5 concentrations across industrial, traffic-dense, residential, and green zones in Andijan city shows significant spatial and seasonal variations (Table 1).

- Industrial Zones: PM10 ranged from 110 to 130 µg/m³, while PM2.5 reached 65–85 µg/m³, exceeding WHO recommended limits (50 µg/m³ for PM10 and 25 µg/m³ for PM2.5).
- Traffic-Dense Areas: PM10 varied between 90–115 µg/m³, and PM2.5 between 48–72

μg/m³, reflecting vehicle emissions as a major contributor.

- Residential Areas: PM10 ranged from 55–85 μg/m³, PM2.5 from 25–50 μg/m³, occasionally exceeding safe thresholds.
- Green Parks: PM10 = 40–60 μg/m³, PM2.5 = 20–35 μg/m³, demonstrating the mitigating effect of vegetation.

Seasonal variation: Spring and summer had highest PM concentrations, due to dry conditions, increased construction activity, and seasonal wind-blown dust. Autumn and winter showed lower concentrations, as precipitation reduced airborne dust.

Particle Composition. Laboratory analysis of dust samples revealed the following composition: Silica (SiO_2) and alumina (Al_2O_3) from soil and construction materials. Carbonaceous particles from vehicles and industrial combustion. Heavy metals (Pb, Cd, Zn) predominantly in industrial zones, posing ecological and health risks.

Vegetation: Dust deposition on leaves ranged from 30–250 mg/m², with the highest levels in industrial and traffic-dense areas. Photosynthetic efficiency was reduced by 15–25%, consistent with similar studies in urban Central Asia (Nowak et al., 2006).

Soil: Heavy metal accumulation was highest in industrial zones: Pb = 45 mg/kg, Cd = 2.5 mg/kg, Zn = 120 mg/kg. In residential areas and parks, levels were lower: Pb = 15 mg/kg, Cd = 0.8 mg/kg, Zn = 50 mg/kg. Elevated metals can affect soil microbial activity, nutrient cycling, and fertility.

Urban Ecosystem: Areas with higher PM levels experienced combined ecological stress, highlighting the importance of dust management. The study confirms that industrial emissions, vehicular traffic, and seasonal wind-blown dust are primary contributors to air pollution in Andijan city.

- Health Implications: PM2.5 exceeded safe levels in many zones, posing respiratory and cardiovascular risks to residents.
- Ecological Implications: Dust deposition reduces photosynthesis, damages vegetation, and contaminates soils with heavy metals.
- Mitigation Strategies: Urban green spaces effectively reduce PM concentrations, demonstrating the role of urban planning and ecological interventions.

Comparison with other Central Asian studies shows similar trends, where industrial and traffic emissions dominate PM levels, and green areas reduce particulate matter (Rakhmonov et al., 2019; Zaman et al., 2020).

Key Findings. PM10 and PM2.5 concentrations frequently exceed WHO standards, especially in industrial and traffic zones. Spring and summer exhibit the highest particulate levels. Dust contains silica, carbonaceous particles, and heavy metals, increasing ecological risk. Dust negatively impacts vegetation and soil, reducing photosynthesis and microbial activity. Urban green spaces mitigate dust levels, emphasizing the need for ecological planning.

Conclusion. This study provides a comprehensive assessment of dust particle pollution in Andijan city, Uzbekistan, and its ecological consequences. The key findings are as follows: Airborne particulate matter (PM10 and PM2.5) frequently exceeds the WHO recommended limits, particularly in industrial zones and traffic-dense areas. Seasonal variations show that spring and summer are associated with higher PM concentrations due to dry weather, construction activity, and seasonal winds. Dust composition includes silica, carbonaceous particles, and heavy metals (Pb, Cd, Zn), which contribute to soil contamination and ecological stress. Ecological impacts dust deposition reduces photosynthetic efficiency of vegetation by 15–25% and contaminates soils, affecting microbial activity and overall soil fertility. Mitigation potential urban green areas significantly reduce particulate matter concentrations, emphasizing the role of ecological planning and urban air quality management. Implementation of traffic regulation and reduction of vehicular emissions. Dust mitigation measures at construction sites and industrial zones. Expansion and maintenance of urban green spaces to act as natural dust filters. Continuous monitoring of PM concentrations and soil contamination for early mitigation. These measures can improve urban air quality, protect human health, and maintain the ecological balance of Andijan city.

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