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DUST PARTICLES IN THE AIR OF ANDIJAN CITY AND THEIR ECOLOGICAL IMPACT

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Abstract. This study investigates the concentration, composition, and ecological impact of dust particles in the air of Andijan city. Airborne particulate matter (PM10 and PM2.5) was measured at industrial, traffic-dense, and residential areas over one year to assess seasonal and spatial variations. Laboratory analysis revealed that particles contain silica, carbonaceous material, and trace heavy metals (Pb, Cd, Zn). High dust concentrations negatively affect urban vegetation, soil quality, and human health. The results show that industrial emissions, vehicle traffic, and wind-blown dust from surrounding areas are major contributors to air pollution. The study provides recommendations for urban air quality management, pollution mitigation, and ecological protection strategies.

Key words: dust particles, particulate matter, air pollution, PM10, PM2.5, ecological impact, Andijan city, urban environment, environmental assessment, heavy metals.

Introduction. Air pollution has become a major environmental concern worldwide, particularly in rapidly urbanizing areas. Among various pollutants, dust particles or particulate matter (PM) are significant due to their ability to remain suspended in the atmosphere for long periods, travel across large distances, and affect both human health and ecosystems (Seinfeld & Pandis, 2016). Particulate matter is categorized based on size: PM10 (particles with a diameter ≤ 10 µm) and PM2.5 (particles with a diameter ≤ 2.5 µm). PM2.5 is of particular concern because it can penetrate deep into the lungs, enter the bloodstream, and cause cardiovascular and respiratory diseases, as well as exacerbate asthma and other chronic conditions (World Health Organization, 2021).

Andijan city, located in the Fergana Valley of eastern Uzbekistan, is one of the country's rapidly growing urban centers. The city has experienced significant industrialization, increased vehicle traffic, and extensive construction activities over the past decade. These factors contribute substantially to airborne dust pollution. Additionally, seasonal winds, especially in spring and summer, carry dust from surrounding arid and agricultural areas, further elevating PM concentrations in the city (Rakhmonov et al., 2019).

The ecological implications of dust particles are also significant. Dust deposition on urban vegetation reduces photosynthetic efficiency, blocks stomata, and can alter plant growth and productivity (Nowak et al., 2006). Soil contamination by dust particles containing heavy metals (Pb, Cd, Zn) can disrupt microbial activity, reduce soil fertility, and impact urban ecosystems (Zaman et al., 2020). In addition, dust pollution can interact with other atmospheric pollutants such as NOx and SO2, forming secondary aerosols that further degrade air quality.

Previous studies in Uzbekistan have mainly focused on larger cities such as Tashkent, Namangan, and Fergana, showing seasonal PM10 concentrations ranging from 50 to 120 µg/m^3, often exceeding WHO guidelines (WHO, 2021). However, Andijan city has received limited scientific attention, despite its growing industrial activities and dense urban population. There is a critical need for comprehensive research to assess both the quantitative levels of dust pollution and its ecological impacts on vegetation, soil, and urban health.

The objectives of this study are: To measure PM10 and PM2.5 concentrations in different zones of Andijan city (industrial, residential, traffic-dense, and green areas). To identify key sources of dust particles, including anthropogenic and natural contributors. To analyze seasonal and spatial variations in particulate matter distribution. To assess the ecological impact of dust deposition on urban vegetation and soil properties. To propose recommendations for effective urban air quality management and mitigation strategies. By addressing these objectives, this study aims to provide a comprehensive understanding of dust pollution in Andijan city and contribute to the development of evidence-based policies for improving air quality and protecting urban ecosystems. The findings are expected to inform municipal authorities, environmental agencies, and urban planners, ultimately leading to a healthier urban environment for residents and sustainable management of ecological resources.

Literature Review. Airborne particulate matter (PM) is recognized as a major urban air pollutant with profound implications for human health and ecological systems. Particulate matter is typically classified based on aerodynamic diameter: PM10 (≤ 10 µm) and PM2.5 (≤ 2.5 µm). PM2.5 is particularly hazardous due to its ability to penetrate deep into the pulmonary alveoli, enter the bloodstream, and induce cardiovascular, respiratory, and systemic health problems (Seinfeld & Pandis, 2016; Pope & Dockery, 2006). PM10 particles, while larger, also pose significant health risks, especially to children, the elderly, and individuals with pre-existing respiratory conditions.

Sources of Dust Particles. Dust particles in urban environments arise from natural and anthropogenic sources. Natural sources include soil erosion, wind-blown dust from arid regions, and pollen (Goudie, 2014). Anthropogenic sources include vehicle emissions, industrial processes, construction activities, and combustion of fossil fuels (Zaman et al., 2020). In Andijan city, industrial facilities, traffic-dense streets, and ongoing urban construction are identified as primary contributors to PM levels. Seasonal winds from surrounding arid lands further elevate dust particle concentrations, particularly in spring and summer (Rakhmonov et al., 2019).

Composition and Ecological Effects. Studies on urban dust composition show that particulate matter consists of silica, alumina, carbonaceous particles, and trace heavy metals such as Pb, Cd, and Zn (Nowak et al., 2006). These particles can settle on vegetation, reducing photosynthetic efficiency, blocking stomatal openings, and interfering with nutrient absorption. Heavy metals in dust can accumulate in soil, altering microbial diversity and reducing soil fertility (Zaman et al., 2020). Such ecological impacts are particularly critical in densely populated cities where green spaces are limited and vegetation is essential for urban environmental quality. In Central Asia, research indicates that dust pollution is closely linked to industrial activity and seasonal climatic conditions. For example, studies in Tashkent, Namangan, and Fergana report PM10 levels often exceeding WHO guidelines of 50 $\mu g/m^3$, particularly in areas with heavy vehicular traffic or near industrial zones (WHO, 2021; Rakhmonov et al., 2019). These findings suggest that similar conditions likely exist in Andijan, though direct studies for this city have been limited.

Human Health Impacts. Particulate matter not only affects the environment but also has severe public health consequences. Long-term exposure to PM2.5 is associated with increased incidence of cardiovascular disease, chronic bronchitis, asthma exacerbations, and premature mortality (Pope & Dockery, 2006). PM10 can cause respiratory irritation, reduce lung function, and exacerbate existing pulmonary conditions. The combination of industrial emissions, vehicle exhaust, and natural dust in Andijan underscores the importance of monitoring and mitigating air pollution to protect public health.

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Urban Air Quality Management. Effective air quality management requires accurate monitoring, identification of pollution hotspots, and implementation of mitigation measures such as traffic regulation, dust control at construction sites, and urban greening (Nowak et al., 2006; Zaman et al., 2020). Studies emphasize the importance of combining field measurements, laboratory analysis, and ecological assessment to understand both the quantitative and qualitative impact of dust pollution. These approaches provide critical insights for city planners and environmental agencies to develop targeted interventions.

Research Gap. While substantial research has been conducted on dust pollution in major cities of Uzbekistan, Andijan city remains under-studied. There is a lack of comprehensive data on PM10 and PM2.5 concentrations, their seasonal variations, composition, and ecological impacts. Additionally, studies addressing the cumulative effect of dust deposition on vegetation and soil quality in Andijan are scarce. This research aims to fill this gap by providing detailed measurements, compositional analysis, and ecological impact assessment specific to Andijan city, contributing to evidence-based urban environmental management.

Research Methodology. The research methodology was designed to systematically evaluate dust particle concentration, composition, sources, and ecological impact in Andijan city. The study employs a combination of field sampling, laboratory analysis, statistical evaluation, and ecological assessment, ensuring comprehensive and reliable results.

Andijan city is located in the eastern part of the Fergana Valley, Uzbekistan, with a population of approximately 500,000. The city experiences a continental climate: hot summers, cold winters, and seasonal winds predominantly from the north and east. Urban areas include industrial zones, traffic-dense streets, residential areas, and green parks, which were selected as study sites to represent varying levels of particulate pollution.

Research Objects and Subjects. Objects airborne dust particles (PM10 and PM2.5) in Andijan city and their ecological effects. Subjects dust particle concentration, size, and composition. Seasonal and spatial variation in particulate matter. Ecological impact on urban vegetation and soil quality.

Research Design and Approach. The study integrates quantitative and qualitative research approaches: Quantitative Approach: Measurement of PM10 and PM2.5 concentration across multiple sites. Statistical evaluation of seasonal and spatial variations. Analysis of chemical composition (e.g., heavy metals, carbon content). Qualitative Approach assessment of dust deposition on vegetation. Evaluation of soil properties affected by dust (pH, heavy metals, organic content). Observation of ecological impacts on urban ecosystems.

Sampling Methods

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

Vegetation Sampling: Leaf samples from trees and shrubs in the study zones. Purpose quantify dust deposition and its effect on photosynthesis.

Soil Sampling: Soil collected from top 0–10 cm layer at sampling sites. Purpose evaluate heavy metal content, pH, and organic matter, reflecting ecological impact.

Laboratory Analysis. Gravimetric analysis to determine PM concentration.

Microscopy (optical and electron) to study particle morphology and size. Chemical analysis using atomic absorption spectroscopy to quantify heavy metals (Pb, Cd, Zn). Vegetation analysis dust deposition measured in mg/m²; chlorophyll content and photosynthetic efficiency assessed. Soil analysis pH meter, heavy metal concentrations, and organic matter content measured.

Data Analysis. Descriptive statistics to summarize PM concentrations, particle composition, and ecological indicators. ANOVA and t-tests to identify significant differences between sites and seasons. Correlation analysis to examine relationships between dust levels, traffic density, industrial activity, and ecological parameters. Graphical representation (bar charts, line graphs, and scatterplots) for visual interpretation of results.

Ecological Assessment Methods. Vegetation: Measurement of leaf surface dust deposition, impact on photosynthetic efficiency, and leaf morphology changes. Soil assessment of heavy metal accumulation and potential ecological risks. Urban Ecosystem integration of air quality data with ecological indicators to evaluate overall environmental impact.

Reliability and Validity. Multiple sampling sites and repeated measurements ensure reliability. Standardized measurement techniques (gravimetric, spectroscopy) guarantee accuracy. Cross-verification with historical data and WHO air quality guidelines ensures validity.

Expected Outcomes. Identification of high-risk areas with elevated PM10 and PM2.5 levels. Determination of seasonal and spatial trends in dust pollution. Evaluation of ecological impact on vegetation and soil quality. Recommendations for urban air pollution mitigation and environmental management. This methodology ensures a systematic, reliable, and scientifically sound approach to assessing dust pollution in Andijan city and its ecological implications, forming a robust basis for data-driven urban environmental management.

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)
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

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

Spatial variation: Industrial and traffic-dense zones consistently show higher PM concentrations than residential areas and parks. Green spaces exhibit the lowest particulate levels due to vegetation acting as a natural air filter. Seasonal variation: Spring and summer have the highest PM concentrations, coinciding with dry weather, increased construction activity, and wind-blown dust from surrounding areas. Autumn and winter show lower concentrations, partly due to precipitation reducing airborne particles and decreased construction activities. PM2.5 trends fine particles (PM2.5) follow a similar pattern, with peak levels in industrial and traffic areas during summer. PM2.5 is of particular concern for human health due to its ability to penetrate deep into the lungs. Ecological implication high PM concentrations in industrial and traffic zones indicate potential dust deposition on vegetation and soil contamination, which can reduce photosynthetic efficiency and alter urban soil chemistry. This analysis helps identify pollution hotspots and guides urban air quality management strategies.

Research Results and Discussion. The results of this study indicate significant variation in PM10 and PM2.5 concentrations across different zones of Andijan city and across seasons, as shown in Table 1. The key findings include:

Industrial Zones PM10 concentrations ranged from 110 to 130 µg/m³, while PM2.5 levels reached 70–85 µg/m³, consistently exceeding WHO air quality guidelines (50 µg/m³ for PM10 and 25 µg/m³ for PM2.5). Traffic-Dense Areas PM10 levels varied between 90–115 µg/m³, and PM2.5 ranged 48–72 µg/m³, reflecting vehicular emissions as a major source of particulate pollution. Residential Areas PM10 ranged from 55–85 µg/m³, and PM2.5 from 25–50 µg/m³, lower than industrial zones but still occasionally exceeding safe limits. Green Parks PM10 and PM2.5 concentrations were the lowest (40–60 µg/m³ for PM10 and 20–35 µg/m³ for PM2.5), showing the mitigating effect of vegetation on airborne dust. Seasonal variation showed higher concentrations in spring and summer, linked to dry weather, dust storms, construction activities, and increased traffic. Lower levels in autumn and winter were observed due to precipitation and decreased dust resuspension.

Particle Composition. Laboratory analysis revealed that dust particles consisted predominantly of: Silica (SiO_2) and alumina (Al_2O_3) from soil and construction dust. Carbonaceous particles from vehicular emissions. Trace heavy metals including Pb, Cd, and Zn, primarily in industrial zones. The presence of heavy metals poses a serious ecological and human health risk, as these metals can accumulate in soil, vegetation, and the food chain.

Ecological Impact. Vegetation: Dust deposition on leaves ranged from 30–250 mg/m², highest in industrial and traffic zones. High deposition caused a 15–25% reduction in photosynthetic efficiency due to blocked stomata and reduced light penetration.

Soil: Soil analysis near industrial areas showed elevated heavy metal concentrations (Pb: 45 mg/kg, Cd: 2.5 mg/kg, Zn: 120 mg/kg) compared to parks and residential zones (Pb: 15 mg/kg, Cd: 0.8 mg/kg, Zn: 50 mg/kg). Increased heavy metals can reduce microbial diversity and alter soil fertility.

Urban Ecosystem: Areas with high PM concentrations experienced combined stress on vegetation and soil, indicating that dust pollution significantly affects urban ecological balance. The results confirm that industrial emissions, traffic, and seasonal wind-blown dust are the primary contributors to PM10 and PM2.5 levels in Andijan city. The findings are consistent with studies from other Central Asian urban centers (Rakhmonov et al., 2019; Zaman et al., 2020), where industrial activity and vehicular emissions were identified as major sources of dust pollution.

Health Implications: PM2.5 particles in industrial and traffic zones exceeded recommended limits, posing respiratory and cardiovascular risks to residents. Ecological Implications dust deposition adversely affects vegetation, reducing photosynthesis, and contributes to soil contamination with heavy metals, impacting soil fertility and microbial activity. Mitigation Measures: Green areas effectively reduce particulate matter concentration, confirming that urban greening is a viable strategy for mitigating dust pollution. The study highlights the importance of integrated air quality management, including: Traffic regulation to reduce vehicle emissions. Dust control measures at construction sites. Industrial emission treatment. Expansion of urban green spaces. These measures can significantly reduce dust particle concentrations, limit ecological damage, and improve public health. Key Findings PM10 and PM2.5 concentrations frequently exceed WHO standards, especially in industrial and traffic-dense zones. Seasonal trends show highest dust levels in spring and summer. Heavy metal content in dust poses additional ecological and health risks. Vegetation and soil quality are significantly affected by dust deposition. Green areas effectively reduce particulate matter, highlighting the importance of urban ecological planning.

Conclusion. The study of dust particles in Andijan city reveals that airborne particulate matter (PM10 and PM2.5) presents a significant environmental and public health concern. The main findings are: High PM concentrations industrial and traffic-dense areas exhibit PM10 levels of 110–130 $\mu g/m^3$ and PM2.5 levels of 65–85 $\mu g/m^3$, frequently exceeding WHO air quality guidelines. Seasonal variation dust levels peak in spring and summer, influenced by dry weather, wind-blown dust, construction activities, and increased vehicle traffic. Particle composition dust contains silica, carbonaceous particles, and heavy metals (Pb, Cd, Zn), posing ecological and human health risks. Ecological impact dust deposition reduces photosynthetic efficiency of urban vegetation by 15–25% and increases heavy metal accumulation in soil, affecting microbial activity and soil fertility. Mitigation potential urban green spaces reduce particulate matter concentrations, demonstrating the importance of urban ecological planning and pollution control strategies. The study emphasizes the need for integrated urban air quality management, including traffic control, industrial emission treatment, dust mitigation at construction sites, and urban greening initiatives. Implementing these measures can improve public health, urban ecosystem stability, and overall environmental quality in Andijan city.

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