Diurnal Dynamics of Atmospheric Microplastic Content in the Central Regions of Uzbekistan

Yuldasheva M.B.[1,2], Sayfullaev M.M.[1], Ismatullaev B.A.[1], Ruziev B.T.[3], Frank Yu.A.[2], Vorobiev D.S.[2]

[1]Navoi state university, Navoi, Uzbekistan
[2]Tomsk state university, Tomsk, Russia
[3]International Centre of Molecular Allergology, Tashkent, Uzbekistan

Abstract. Data on atmospheric microplastics (AMPs) in Central Asia remain scarce despite increasing documentation of aquatic contamination. This study assesses AMP dynamics in two distinct regions of Uzbekistan: Navoi (industrial) and Bukhara (residential). Sampling was conducted at a height of 15 m using a Lanzoni VPPS 2010 volumetric trap, with samples analyzed in two-hour intervals to evaluate diurnal variability. Identification followed standardized visual criteria and the "hot needle test." Microplastics (fibers and fragments) were ubiquitous at both sites. Mean concentrations in Bukhara (0.83 ± 0.42 items/L) and Navoi (0.69 ± 0.35 items/L) showed no statistically significant difference ($p = 0.5639$). Morphological analysis revealed a prevalence of fibers (1000 – 4000 µm). Diurnal peaks during morning and early afternoon correlated with anthropogenic activity and arid-zone thermal convection. The results suggest an "urban carpet" effect in Bukhara equivalent to the industrial load in Navoi. This study establishes a vital baseline for the Kyzylkum region's atmospheric MP cycles.

Introduction

Microplastics (MPs), defined as plastic particles smaller than 5 mm, have emerged as ubiquitous environmental contaminants[1]. While their occurrence in aquatic and soil systems has been extensively documented, the atmospheric transport and deposition of MPs remain an evolving research frontier[2]. Recent advances highlight that atmospheric microplastics (AMPs) can travel long distances and deposit in remote regions, contributing significantly to global plastic pollution cycles[3].

Uzbekistan, situated in the heart of Central Asia, represents a critical yet underexplored region regarding airborne microplastic dynamics. While preliminary studies on microplastic pollution in Uzbekistan have been conducted—primarily focusing on aquatic environments[4]—there is a critical lack of data regarding atmospheric microplastics. This significant knowledge gap makes the current study highly relevant, as it provides the first systematic assessment of airborne microplastic dynamics in the region. This study aims to address this knowledge gap by assessing the concentration, morphology, and temporal distribution of AMPs in two strategically selected locations: Navoi (40°07′13″N, 65°22′40″E) and Bukhara (40°06′14″N, 64°42′17″E). The selection of these sites provides a comparative framework between two distinct anthropogenic profiles within an arid landscape. Navoi serves as a representative industrial powerhouse, hosting large-scale chemical, mining, and energy facilities that act as potential primary sources of industrial polymers. In contrast, Bukhara functions as a major urban and cultural center; its high population density and intense tourism-related traffic offer a model for secondary microplastic generation derived from consumer goods and textiles. Together, these sites represent the two most prevalent land-use types in the socio-economic landscape of Uzbekistan.

While diurnal variations of AMPs have been documented globally [5–6], this study provides the first comprehensive analysis tailored to the specific arid and industrial climatic conditions of Central Asia. Unlike previous research conducted in maritime or temperate zones, our findings elucidate how high evaporation rates and regional dust dynamics influence the resuspension of specific fiber fractions (1000-4000 µm). By examining these factors, this study offers new insights into MP transport mechanisms within landlocked arid regions, establishing a necessary baseline for future environmental monitoring.

Based on the regional industrial profile and local meteorological patterns, this study tested two primary hypotheses:

1. Diurnal Variability Hypothesis: Airborne microplastic (AMP) concentrations are expected to peak during daylight hours, driven by intensified convective atmospheric mixing and heightened levels of anthropogenic and industrial activity.
2. Urban-Industrial Influence Hypothesis: The morphological composition of microplastics in Bukhara will differ significantly from those in Navoi due to distinct local emission sources (e.g., urban domestic activities vs. heavy industrial processing), resulting in a

site-specific prevalence of various fiber and fragment fractions.

Materials and methods

Atmospheric microplastic (AMP) sampling was conducted over a 24-hour period (August 25, 2025) in Navoi and Bukhara. To represent the urban canopy layer and the exposure environment for residents in multi-story buildings, a Lanzoni VPPS 2010 volumetric pollen trap was mounted at a height of 15 meters.

The device operated by drawing ambient air through a narrow slit, where airborne particles adhered to a silicone-coated sticky tape mounted on a rotating drum. With a constant drum rotation speed of 2mm/h, the trap provided continuous collection. The resulting tapes were segmented into two-hour intervals, yielding 12 subsamples per site for diurnal analysis. Sampling events were selected to represent typical dry-season meteorological conditions for the region, minimizing the influence of anomalous weather patterns.

Strict contamination control measures were implemented during both field sampling and laboratory analysis. All equipment was rinsed with filtered distilled water prior to use. Researchers wore 100% cotton laboratory coats and avoided synthetic clothing throughout the study. Sample exposure to open air was kept to a minimum.

Results and Discussion

To account for potential background interference, field and laboratory blanks (Petri dishes with filtered adhesive surfaces) were processed alongside the samples. These blanks were exposed during tape changes in the field and during the laboratory analysis. The average contamination found in blanks was 0.83 particles per sample, which was subtracted from the final results to ensure analytical accuracy.

Collected tapes were examined using a BioBlue BB-4253 stereomicroscope equipped with a ToupView USB 2.0 CMOS digital camera and ToupView software (v4.12.29030). Suspected microplastics were identified based on color, shape, and surface texture. While spectroscopic confirmation (FTIR/Raman) was not utilized, a rigorous visual identification protocol was applied. Particles were classified as microplastics only if they met the following criteria:

1. Organic Absence: No visible cellular or organic structures.
2. Uniformity: Consistent color and thickness throughout the entire length.
3. Thermal Response: A clear melting or curling reaction during the "hot needle test"[7].

To ensure consistency, all samples were cross-examined by two independent researchers.

Regional meteorological data for the sampling period were retrieved from rp5.uz. During the event, Navoi recorded average wind speeds of 7.5 m/s with a predominant Northwest direction and a relative humidity of 14 %. Bukhara recorded wind speeds of 5 m/s and 15 % humidity.

To compare concentrations between sites, an independent samples t-test was performed using R version 4.5.2. Data were checked for normality, and statistical significance was set at $p < 0.05$.

Preliminary analysis confirmed the presence of multiple microplastic morphotypes, dominated by fibers and fragments, at both study sites. The mean atmospheric microplastic concentration in Bukhara was 0.83 ± 0.42 items/L (95% CI: 0.39-1.27), while Navoi exhibited a mean concentration of 0.69 ± 0.35 items/L (95% CI: 0.32-1.06).

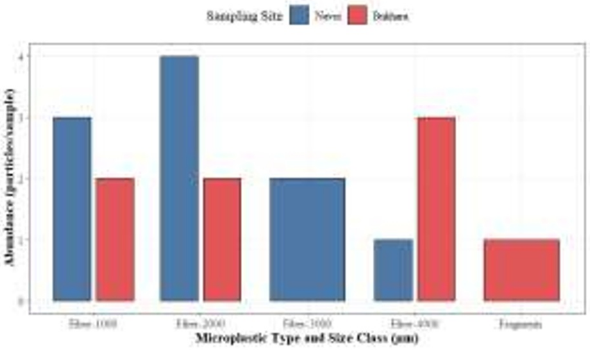

Fig. 1. Morphological classification and size distribution of airborne microplastics in Navoi and Bukhara.

Despite the slightly higher abundance observed in the residential/urban environment of Bukhara, an independent samples t-test confirmed that the difference between the two locations was not statistically significant ($t(10) = 0.596$, $p = 0.5639$). These statistical parameters indicate that while individual sampling intervals showed temporal variability, the overall atmospheric MP load remained comparable across both industrial and urban nodes during the study period.

The diurnal distribution of MPs followed a distinct pattern at both locations. Higher particle counts were consistently observed during the morning and early afternoon intervals. This peak period was followed by a gradual decline toward the evening and night hours.

The sampling height of 15 meters proved critical in capturing these dynamics, as it represents the urban canopy layer where particles remain suspended after bypassing initial ground-level settling. This elevation is highly representative of the human breathing zone for residents in typical multi-story apartment buildings, suggesting that the recorded concentrations reflect the respirable fraction of microplastics most likely to be inhaled by the urban population.

3.3. Morphological Classification

The identified microplastics were primarily composed of fibers and fragments. In terms of volumetric detection, the samples yielded 0.42 ± 0.5 units/m3 in Navoi and 0.35 ± 0.46 units/m3 in Bukhara. The uniformity in morphological distribution across both sites, notwithstanding their different land-use profiles, suggests that both industrial emissions and urban domestic activities contribute significantly to the regional atmospheric plastic cycle.

The observed diurnal peaks in microplastic (MP) concentrations in Navoi and Bukhara warrant a critical analysis beyond simple abundance reporting. The concentration peaks, primarily observed during morning and early afternoon intervals, closely align with urban activity cycles, including transportation, construction, and domestic activities. In the arid climate of Central Asia during August, these afternoon peaks (e.g., in Bukhara at 14:00–18:00) correlate with maximum thermal convection and wind turbulence typical of desert-edge environments.

Such atmospheric instability facilitates the resuspension of settled particles, while the lower values recorded at night suggest decreased emissions and the gradual settling of MPs under more stable conditions. Although on-site continuous meteorological sensors were not utilized—a limitation acknowledged in this study—the timing of these fluctuations is highly consistent with regional diurnal cycles of wind speed and urban mobility.

The prevalence of long fibers (1000 - 3000 μm) across specific sampling intervals (Figure 1) suggests that atmospheric transport in these regions is driven not only by local emission sources but also by the specific aerodynamic properties of the particles. The high surface-area-to-volume ratio of these fibers makes them particularly susceptible to vertical convective currents, which are intensified by the high evaporation rates of the Kyzylkum region.

Furthermore, the lack of a statistically significant difference between the industrial hub (Navoi) and the residential center (Bukhara) (Figure 2, p = 0.5639) implies that the "urban carpet" effect may be as significant as direct industrial emissions. This phenomenon, characterized by the accumulation and continuous resuspension of MPs within the urban canopy, suggests that Bukhara's high population density and traffic intensity generate an atmospheric MP load comparable to Navoi's industrial sector. Consequently, regional mitigation strategies should prioritize urban waste management and road dust suppression alongside industrial filtration.

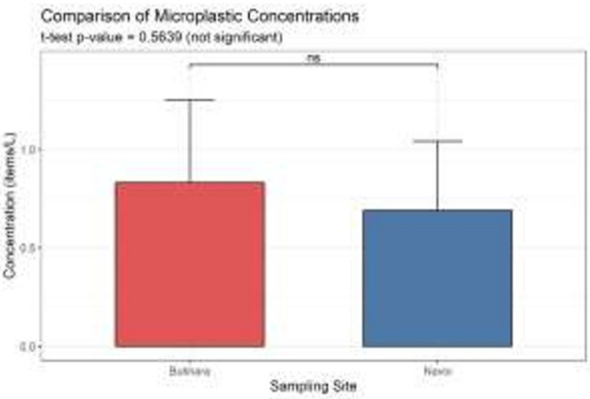

Fig. 2. Comparative analysis of total airborne microplastic concentrations (items/L) between study sites.

The sampling height of 15 m was strategically selected to represent the "urban canopy layer." This elevation allows for the capture of a more integrated regional atmospheric signal by minimizing the immediate influence of coarse, locally resuspended road dust that typically settles rapidly at ground level.

From a public health perspective, this height is directly relevant to the residents of multi-story buildings prevalent in both cities. Fine MP fractions, particularly the fibers identified in our samples, are likely to remain suspended at this altitude for extended periods. This increases the probability of inhalation for the urban population compared to heavier particles, highlighting the risk of chronic exposure even at significant heights above street level.

Our findings align with emerging research across the "Eurasian dust belt," where semi-arid climates facilitate the atmospheric transport of synthetic polymers. Recent studies in Kazakhstan[8] and Western China[9] have similarly highlighted the predominance of fibers in atmospheric fallout, echoing the 1000 – 3000 μm fractions observed in our study. The high dust-loading capacity of the Kyzylkum region acts as a significant vector for microplastic redistribution.

We recognize that the statistical power of this study is limited by the single 24-hour sampling event per site. The relatively high standard deviations (SD) observed—such as counts ranging from 2 to 7 particles in Bukhara—reflect the inherent heterogeneity of atmospheric MP distribution and episodic "pulses" from point sources. However, the high internal consistency of our results, including the recurrence of specific fiber types across multiple filters, suggests that these patterns reflect stable local environmental characteristics rather than random fluctuations. This pilot assessment provides a critical baseline for future longitudinal and seasonal monitoring in Uzbekistan.

Conclusion

This study provides the first insight into the diurnal dynamics of airborne microplastics (AMPs) within the unique arid and industrial environments of Central Asia. Our findings confirm the presence of AMPs in both the industrial hub of Navoi and the residential-cultural center of Bukhara, establishing a critical baseline for a region previously underrepresented in global plastic pollution datasets.

Statistical analysis revealed that during the 24-hour monitoring period, both sites exhibited comparable levels of microplastic abundance (p = 0.5639), suggesting that anthropogenic activities in densely populated urban areas can generate an atmospheric load equivalent to that of major industrial nodes. The observed temporal variations, characterized by morning and afternoon peaks, highlight the significant role of human activity and thermal convection in the resuspension and transport of microplastics within the urban canopy.

While these results offer a vital snapshot of atmospheric conditions at a representative height of 15 meters, we acknowledge the study's limitations, including its short temporal scope and reliance on morphological identification. These data should be interpreted as a preliminary assessment of specific dry-season conditions. To fully characterize the seasonal patterns, long-range transport mechanisms, and chemical composition of microplastic pollution in Uzbekistan, future long-term monitoring programs incorporating spectroscopic confirmation

(FTIR/Raman) are essential. Ultimately, these findings provide a necessary scientific foundation for developing environmental management policies and dust-suppression strategies tailored to the arid landscapes of Central Asia.

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