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Research Article

Spatio-Temporal Dynamics and Clinical Implications of Indoor Aeropalynological Profiles in the Semi-Arid Balaghat Plateau: A Comprehensive Analysis of Dharashiv (MS) India

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Abstract

The present investigation provides an exhaustive longitudinal analysis of the indoor aeropalynological spectrum of Dharashiv (formerly Osmanabad), Maharashtra, conducted over a complete annual cycle from January 1, 2017, to December 31, 2017. Utilizing a volumetric Tilak air sampler, the research aimed to quantify the diversity, concentration, and seasonal fluctuations of airborne pollen grains within a representative indoor environment. The investigation identified a total of 1,206 pollen grains, categorized into 26 distinct taxa, representing a volumetric total spore concentration of 16,884 m^3. The findings reveal a significant dominance of Poaceae (Grass) pollen, which accounted for 41.54% of the total airspora, followed by *Cyperus rotundus* (15.33%), *Mangifera indica* (Alt) (8.62%), and *Parthenium hysterophorus* (6.22%). Seasonal analysis demonstrated a pronounced bimodal distribution, with a major peak during the post-monsoon and early winter months (September-October) and a secondary peak in the spring (January-February). Conversely, the summer months (May-June) exhibited the lowest concentrations, correlating with extreme temperatures reaching 45°C and low relative humidity. The high prevalence of allergenic taxa, particularly *Parthenium* and Poaceae, underscores a critical public health risk for respiratory disorders and Type I hypersensitivity in the region. These results provide essential baseline data for the construction of regional pollen calendars and the effective management of allergic rhinitis and bronchial asthma in the semi-arid Marathwada region.

INTRODUCTION

The discipline of aerobiology, which encompasses the study of the transport, dispersal, and biological impact of airborne particles, has become increasingly critical in the context of global environmental change and rising public health challenges (Jogdand, 2020; Tilak, 1982). In the Indian subcontinent, characterized by its vast geographical diversity and complex floral phenology, aeropalynological studies serve as a fundamental tool for understanding the distribution of aeroallergens (Ahire & Patil, 2024). While outdoor atmospheric surveys have been the traditional focus of research, there is a growing recognition that indoor environments represent the primary locus of human exposure (Smith & Johnson, 2024). Modern individuals in urban and semi-urban settings spend approximately 80% to 90% of their lives within enclosed spaces, where the air quality is governed by a dynamic interplay between internal sources and the penetration of outdoor bioparticles (Banswadekar, 2023; Zahid, 1994).

Dharashiv district, situated in the Marathwada region of Maharashtra. Positioned on the Balaghat plateau at an average elevation of 600 to 650 meters above sea level. With summers reaching temperatures as high as 45°C and winters dipping to 8°C, the floral productivity of the region is highly compressed and seasonal (Gadekar, 2018). The research problem addressed by this investigation centers on the lack of high-resolution, volumetric indoor aeropalynological data for the semi-arid plateaus of Central India. Most existing studies in Maharashtra have focused on larger metropolitan areas like Pune or Aurangabad, often overlooking the specific profiles of smaller, agricultural-centric urban centers like Dharashiv (Tilak & Patil, 1983). This gap is particularly significant given that the Marathwada region is prone to recurrent droughts, which fundamentally alter the composition of the airspora by favoring drought-resilient and invasive taxa such as *Parthenium hysterophorus* and various xerophytic grasses (Patel, 2024; Bor, 1960).

The objectives of the present investigation were fourfold. First, to provide a comprehensive qualitative and quantitative census of the indoor pollen types in Dharashiv throughout a calendar year. Second, to determine the seasonal fluctuations in pollen concentration and identify the peak "allergy seasons" for the region. Third, to calculate the volumetric total spore concentration using standardized sampling techniques to allow for inter-regional comparisons (Tilak & Kulkarni, 1970). Finally, to evaluate the clinical significance of the identified taxa, specifically focusing on the prevalence of known aeroallergens that trigger respiratory diseases such as allergic rhinitis and bronchial asthma (Chaubal & Gadve, 1984; Tilak & Patil, 1983).

The overview of this paper follows a structured academic path, beginning with a synthesis of existing literature regarding Indian aeropalynology and indoor air dynamics. This is followed by a detailed description of the volumetric methodology employing the Tilak air sampler (Tilak & Kulkarni, 1970). The results section presents the primary data with extensive tabular and narrative analysis of monthly frequencies. The discussion integrates these findings with meteorological factors and clinical insights, ultimately leading to a set of conclusions and recommendations for public health policy in the Marathwada region.

Methodology: The present investigation was carried out at Site-A, located in the urban residential environment of Dharashiv (Osmanabad), Maharashtra. The site was selected to represent a typical indoor living space within the Marathwada region, characterized by natural ventilation and proximity to local flora.

Sampling Device and Operation

Air sampling was performed using the volumetric Tilak air sampler, as originally designed and described by Tilak and Kulkarni (1970). This device is an active, continuous sampler that operates on a 230V AC electric power supply (Tilak & Kulkarni, 1970). The sampler functions by drawing air through a projecting intake tube at a calibrated flow rate of 5 liters per minute (Tilak & Kulkarni, 1970). Within the apparatus, a rotating drum coated with an adhesive medium completes one full revolution in eight days, thereby enabling continuous volumetric sampling (Tilak & Kulkarni, 1970).

For the collection of bioparticles, a transparent cello tape strip (1.5 cm in width) was wrapped around the drum and uniformly coated with a thin layer of petroleum jelly (Vaseline) to serve as the adhesive trapping surface (Chaubal & Gadve, 1984). The sampler was installed at a standardized height of approximately 1.5 to 2.0 meters above floor level, corresponding to the human breathing zone (Chaubal & Gadve, 1984). Continuous operation of the instrument provided a 24-hour integrated record of airborne pollen and other bioparticles.

Slide Preparation and Scanning

At the conclusion of each eight-day sampling cycle, the exposed adhesive tape was carefully removed and segmented into daily (24-hour) intervals. Each segment was mounted on a clean glass slide using glycerine jelly as the mounting and clearing medium (Chaubal & Gadve, 1984). In accordance with established Indian aerobiological practices, staining with safranin was employed where necessary to enhance the visualization of exine ornamentation and aperture characteristics (Tilak & Kulkarni, 1970).

Microscopic examination was conducted using a light microscope fitted with a 10× ocular and a 45× objective lens, providing adequate magnification for morphological identification (Tilak, 1982). Quantitative assessment involved counting the total number of pollen grains deposited along the 24-hour trace. These raw counts were subsequently converted into volumetric concentrations (pollen grains per cubic meter of air) by applying a standard conversion factor derived from the instrument's calibrated airflow rate and the effective sampling area (Tilak & Kulkarni, 1970).

Identification of Taxa

Pollen identification was undertaken through a systematic approach based on three principal criteria:

Morphological Characters: Detailed examination of grain size, shape (e.g., spheroidal, prolate, peroblate), aperture type (monoporate, triporate, tricolpate), and exine ornamentation patterns (psilate, reticulate, echinate) (Jogdand, 2020; Tilak, 1982).

Visual Comparison: Direct comparison of airborne pollen grains with authenticated reference slides prepared from locally collected plant specimens in and around Dharashiv (Tilak & Kulkarni, 1970).

Literature and Atlases: Consultation of established aeropalynological literature and regional pollen atlases to confirm identification at the genus or family level (Jogdand, 2020; Tilak, 1982).

Monthly data were compiled and tabulated to facilitate analysis of seasonal variation and to determine the proportional contribution of each taxon to the total annual airspora.

RESULTS

The investigation of the indoor atmosphere at Site-A (Dharashiv) from January 1, 2017, to December 31, 2017, yielded a total catch of 1,206 pollen grains. The resulting volumetric total spore concentration was calculated at 16,884 m^3. A diverse array of 26 identifiable pollen types was recorded, reflecting the botanical richness of the surrounding landscape and the permeability of the indoor environment.

Annual and Monthly Distributions

The annual distribution of pollen exhibited a clear seasonal rhythm, with a marked peak in the post-monsoon months. The following table provides the comprehensive monthly data for the study period:

Table 1: Percentage Contribution (%) of Pollen grains in different months

Month	Total Pollen Grains	Volumetric Total (p g/m3)	Percentage Contribution (%)
January	108	1,512	8.96
February	89	1,246	7.38
March	64	896	5.31
April	48	672	3.98
May	35	490	2.90
June	28	392	2.32
July	37	518	3.07
August	153	2,142	12.69
September	220	3,080	18.24
October	197	2,758	16.33
November	126	1,764	10.45
December	101	1,414	8.37
Total	1,206	16,884	100.00

The highest monthly pollen concentration was documented in September (220 grains, 18.24%), followed by October (197 grains, 16.33%), with these two post-monsoon months collectively contributing more than one-third of the total annual airspora. In contrast, the lowest concentrations were recorded during June (28 grains, 2.32%) and May (35 grains, 2.90%), coinciding with the peak summer season in Dharashiv, characterized by extreme temperatures and reduced atmospheric humidity (Gadekar, 2018).

Dominance and Percentage Contribution

The taxonomic composition was dominated by a few key families and species. The family Poaceae (Grasses) emerged as the single most significant contributor to the indoor airspora.

The combined percentage of the "Grass" and "Poaceae" categories was 49.25%, indicating that nearly half of the airborne pollen in the indoor environment of Dharashiv belongs to the Poaceae family. *Cyperus rotundus* was the second most prevalent, contributing 15.33% to the total concentration. Together, these three groups accounted for approximately 64.58% of the annual airspora.

Discussion

The findings of this investigation provide a detailed temporal profile of the indoor aeropalynological spectrum of Dharashiv. The dominance of Poaceae (41.54%) and *Cyperus rotundus* (15.33%) aligns with observations from other semi-arid and agriculturally dominated regions of India (Ahire & Patil, 2024; Kshirsagar & Pande, 2015). However, the volumetric intensity and identification of 26 distinct taxa contribute novel baseline data for the Balaghat plateau region.

Table 2: Percentage Contribution (%) of Pollen grains in different Taxa

Rank	Pollen Grain Taxa	Total Count	Volumetric Total	Percentage Contribution (%)
1	Grass (Poaceae)	501	7,014	41.54
2	*Cyperus rotundus*	185	2,590	15.33
3	*Mangifera indica* (Alt)	104	1,456	8.62
4	Poaceae (Distinct)	93	1,302	7.71
5	*Parthenium hysterophorus*	75	1,050	6.22
6	*Ricinus communis*	36	504	2.99
7	*Amaranthus virides*	33	462	2.74
8	Unidentified pollen	29	406	2.40
9	*Acalypha hispida*	13	182	1.08
10	*Datura metal*	13	182	1.07
11	*Azadiracta indica*	11	154	0.91
12	*Bougainvillea spectabilis*	11	154	0.91
13	*Caesalpinia pulcherrima*	11	154	0.91
14	*Cocos nucifera*	11	154	0.91
15	*Euphorbia sp.*	11	154	0.91
16	*Leucaena leucocephala*	11	154	0.91
17	*Casuarina equisetifolia*	10	140	0.83
18	*Cassia fistula*	9	126	0.75
19	*Sorghum sp.*	7	98	0.58
20	*Argemon mexicana*	6	84	0.50
21	*Mangifera indica*	6	84	0.50
22	*Eucalyptus globulus*	5	70	0.41
23	*Lantana camera*	5	70	0.41
24	*Hibiscus rosa-sinensis*	4	56	0.33
25	*Helianthus annus*	3	42	0.25
26	*Syzygium cuminis*	3	42	0.25

Environmental Drivers of the Pollen Spectrum

The geographic setting of Dharashiv, situated on the basaltic elevations of the Balaghat plateau, plays a decisive role in shaping the regional pollen spectrum (Quamar & Kar, 2018). The semi-arid climate fosters highly seasonal vegetation dynamics. The marked decline in pollen concentration between March (64 grains) and June (28 grains) corresponds with extreme summer temperatures approaching 45°C, which suppress flowering and accelerate desiccation of herbaceous flora (Gadekar, 2018).

The sharp rise in pollen levels beginning in August (153 grains) reflects the ecological “monsoon recovery” phase, during which adequate soil moisture stimulates rapid grass and weed growth (Mandal et al., 2008). The predominance of Poaceae during this period is characteristic of Marathwada’s open landscapes and agricultural margins (Bor, 1960; Kshirsagar & Pande, 2015).

The detection of *Mangifera indica* pollen, particularly the “Alt” category peaking in April, highlights the influence of regional horticultural practices. Mango pollen, transported during dry pre-monsoon winds, contributes measurably to the indoor airspora (Waghmode & Raut, 2025).

Indoor Penetration and Clinical Risks

The substantial annual indoor pollen load (16,884 grains/m³) indicates persistent exposure risk. Indoor pollen infiltration is influenced by grain size and ventilation characteristics (Smith & Johnson, 2024; Zahid, 1994). Dominant taxa such as Poaceae and *Parthenium hysterophorus* produce pollen within the optimal aerodynamic diameter (15–30 µm) for indoor penetration (Jogdand, 2020).

Clinically, Poaceae pollen represents a major aeroallergen group implicated in allergic rhinitis and bronchial asthma (Ahire & Patil, 2024). The extended seasonal dominance of grasses suggests a prolonged allergy risk period for Dharashiv residents.

Parthenium hysterophorus (6.22%) remains a significant health concern. Its pollen contains allergenic sesquiterpene lactones such as parthenin, associated with nasobronchial allergy and contact dermatitis (Morin et al., 2009; Patel, 2024). Its year-round detection, with monsoon peaks, correlates with chronic respiratory and dermatological complaints reported in regional surveys (Tilak & Patil, 1983).

Additional clinically relevant taxa include *Ricinus communis* and *Amaranthus viridis*. *Ricinus* pollen has demonstrated allergenic potential in multiple Indian clinical investigations (Chaubal & Gadve, 1984), while *Amaranthus* species are recognized contributors to seasonal allergic symptoms (Mandal et al., 2008).

Meteorological and Human Correlations

Peak pollen concentrations in September and October coincide with moderate temperatures (25–30°C) and elevated humidity levels conducive to flowering and atmospheric suspension of pollen (Gadekar, 2018). Indoor pollen dynamics are further influenced by natural ventilation practices common in Indian households, facilitating outdoor pollen ingress (Smith & Johnson, 2024). Household activities such as manual sweeping may resuspend settled pollen, increasing transient exposure levels (Zahid, 1994).

Conclusion

The indoor aeropalynological investigation of Dharashiv for the year 2017 establishes a comprehensive record of the region's bio-atmospheric pollutants. The study identified a diverse airspora of 26 taxa, dominated overwhelmingly by Poaceae (41.54%) and *Cyperus rotundus* (15.33%). The annual volumetric total spore concentration of 16,884 m^3 reveals a significant exposure burden for the indoor occupants.

The seasonal analysis highlights a major allergy period from August to November, driven by the flowering of grasses and invasive weeds following the monsoon. The summer months (April-June) represent a period of relative relief, though tree allergens like *Mangifera indica* remain prevalent. The presence of *Parthenium hysterophorus* throughout the year, peaking in the post-monsoon, underscores a persistent public health challenge.

The results provide a scientific foundation for the development of a local "Pollen Calendar" for Dharashiv, which will be invaluable for allergists and pulmonary specialists in diagnosing and treating respiratory illnesses. Furthermore, the high percentage of invasive and weed pollen suggests that urban planning and weed management strategies (such as the eradication of *Parthenium*) could have a direct and positive impact on the indoor air quality and health of the inhabitants of the Marathwada region. This investigation underscores the vital importance of continuous aerobiological monitoring as a tool for environmental health and clinical management in the semi-arid heart of Maharashtra.

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