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Original Research Article

Assessment of Environmental and Health Impacts of Microbial Exposure to Harmattan and Dust Storms in Damaturu, Nigeria

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KEYWORDS

Harmattan haze,
Dust storm,
Bioaerosols,
Exposure,
Respiratory infections.

ABSTRACT

Harmattan winds and episodic dust storms transport mineral dust and biological agents, potentially exacerbating respiratory and systemic morbidity in Sahelian regions like Damaturu, Nigeria. This study assessed household health impacts and microbial loads (bacteria/fungi) in settled dust and airborne samples during Harmattan and Dust storm periods in 2019. A mixed-methods study was conducted using household surveys (n=230 per period) to document health status and microbiological culture of indoor dust and bioaerosols. Households were primarily cement/mud structures with suboptimal ventilation. During Harmattan, children reported high incidences of pneumonia (35%), RTIs (22%), and GITs (18%). Microbial analysis revealed high concentrations: mean fungal loads reached 1.97×10^5 CFU $g^{-1,}$ 1.97×10^5 CFU g^{-1} in dust, with dominant genera including *Aspergillus* and *Penicillium*. Findings indicate a significant correlation between dust exposure and increased morbidity, likely amplified by poor ventilation. The microbial loads exceed historical health-based guidelines, suggesting high biological risk. The study relied on morphological microbial identification and lacks concurrent particulate matter (PM) mass monitoring. We recommend seasonal public-health preparedness, including household-level dust-reduction strategies, alongside future studies employing molecular identification and standardized clinical confirmation to better quantify the environmental-health nexus.

CITATION

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INTRODUCTION

Seasonal Harmattan winds and episodic dust storms affect Sahelian regions, transporting mineral dust and associated biological materials over long distances (Middleton & Goudie, 2001). Dust exposure is associated with respiratory disease exacerbation, ocular and skin irritation, and increased healthcare utilization (Brook et al., 2010; Kelly & Fussell, 2015). Microbial taxa, including fungal spores and bacteria, may adhere to dust particles and impact indoor and outdoor air quality (Gorny & Dutkiewicz, 2002).

Seasonal Harmattan winds and episodic dust storms are defining meteorological features of the Sahelian region, transporting vast quantities of mineral dust, particulate matter (PM_{10} and $PM_{.25}$), and diverse biological materials across continental distances (Middleton & Goudie, 2001). These events periodically degrade outdoor air quality, creating an environment where high-velocity winds facilitate the long-range transport of bioaerosols, a complex mixture of fungal spores, bacterial cells, and plant pollen (Gorny & Dutkiewicz, 2002).

For human populations in regions like Damaturu, Nigeria, these dust episodes represent a significant public health risk. Exposure to airborne dust is widely associated with the exacerbation of respiratory conditions, such as asthma and chronic obstructive pulmonary disease (COPD), as well as increased incidences of ocular and skin irritation (Brook et al., 2010; Kelly & Fussell, 2015). Beyond the mechanical irritation caused by mineral particles, the biological component or microbial load contained within the dust poses a more insidious threat. When these bioaerosols penetrate the indoor environment, they often become trapped due to housing design and limited ventilation, leading to prolonged human exposure (Liu et al., 2022).

The health impacts on humans are multifaceted; inhaling dust-bound microbes can induce inflammatory responses in the respiratory tract, while contact with gastrointestinal systems occurs through the ingestion of settled dust. Despite the high frequency of these events, there is a limited understanding of how specific housing characteristics such as construction materials and ventilation configurations, modulate indoor microbial concentrations and subsequent clinical morbidity in local populations. This study addresses this knowledge gap by combining community survey data, medical-record reviews, and environmental microbial sampling to characterize the exposure-response relationship during Harmattan and dust storm periods. We specifically examine the linkage between seasonal dust patterns, household indoor microbial quality, and the resulting health burden on the human population in Damaturu.

Study Area

Damaturu, the capital of Yobe State, Nigeria, is situated within the semi-arid Sahelian belt. The region experiences a distinct climate characterized by a prolonged dry season, during which it is significantly impacted by the Harmattan trade winds and seasonal dust storms. These meteorological conditions are driven by the movement of the Inter-Tropical Convergence Zone (ITCZ), leading to frequent atmospheric haze, reduced visibility, and substantial deposition of mineral dust within residential dwellings.

While the climatic impact of dust in the Sahel is well-documented, the specific relationship between indoor dust accumulation, the associated microbial load, and human health morbidity remains poorly quantified in Damaturu. Many households in this region utilize building materials (such as mud or brick) and ventilation designs that inadvertently trap airborne particles, potentially creating an "indoor-exposure trap." There is a critical knowledge gap regarding how these trapped bioaerosols contribute to the seasonal spikes in pneumonia, respiratory tract infections (RTIs), and gastrointestinal (GIT) complaints reported annually. Without data linking these microbial loads to clinical outcomes, public health strategies remain reactive rather than preventative.

The aim of this study is to assess the environmental and public health impacts of microbial exposure associated with Harmattan and dust storm episodes in Damaturu, Nigeria, by evaluating the nexus between household dust accumulations, indoor bioaerosols concentrations, and recorded human morbidity.

The objectives of this research are: (1) to quantify the concentration and identify the types of culturable bacteria and fungi in settled indoor dust and airborne samples during Harmattan and dust storm periods; (2) to document the frequency and types of self-reported health effects (respiratory, ocular, skin, and gastrointestinal) among residents in Damaturu across two distinct dust-prone seasons; (3) to correlate housing characteristics (specifically ventilation and construction materials) with indoor microbial loads and the reported incidence of morbidity; (4) to analyze medical records from local facilities to determine the clinical impact of dust-borne microbial exposure on hospital admission rates; (5) to provide evidence-based recommendations for seasonal health preparedness and household-level exposure mitigation strategies

Context of the Study

Harmattan Haze: A dry, dusty trade wind characterized by low humidity and high concentrations of suspended mineral dust, which serves as the primary vector for regional air quality degradation.

Dust Storm: An intense, episodic meteorological phenomenon involving high wind speeds that lift large masses of dust into the atmosphere, often carrying a high density of biological and non-biological contaminants.

Bioaerosols: The biological fraction of atmospheric particles, including fungal spores and bacteria, which represent a significant health risk due to their potential for colonization and immune-system activation in the human respiratory tract.

Exposure: The process of human contact with environmental contaminants via inhalation, ingestion, or dermal absorption; in this study, it emphasizes the indoor "trapping" of dust within poorly ventilated residential structures.

Respiratory Infections: Acute or chronic conditions (e.g., pneumonia, bronchitis, asthma) that are significantly exacerbated by the inhalation of both mineral dust and associated pathogenic microbes.

MATERIALS AND METHODS

Study design and setting

This study combines community survey data, hospital-record review, and environmental microbial sampling to describe household demographics and housing characteristics in Damaturu; quantify reported health effects and hospital admissions during Harmattan haze and a dust-storm period in 2019; and enumerate and identify culturable fungi and bacteria in settled dust and airborne samples.

A mixed-methods observational study was performed in Damaturu, Nigeria. Two survey rounds were conducted: Harmattan (January–February 2019) and Dust Storm season (September–October 2019).

Household survey and medical-record abstraction

Trained enumerators administered structured questionnaires to 230 households per period. Questionnaires collected demographics, head-of-household occupation, housing construction and ventilation, occurrence and recurrence of specified health effects, hospital admissions, and repeated admissions. Medical records from local hospitals and primary health centres were abstracted for the same periods. All data were coded and de-identified.

Environmental sampling and microbiological analysis

Sample collection

Settled dust samples were sieved prior to culture. Airborne samples were collected using a Buck biological air sampler (or equivalent) onto agar plates at selected indoor and outdoor household locations.

Culture media and inoculation

Malt Extract Agar (MEA) for fungi and Nutrient Agar (NA) for bacteria were prepared and autoclaved. One gram of sieved settled dust was diluted in 9 mL sterile water; 200 μL of each suspension was inoculated on agar plates in triplicate. Airborne samples were collected onto agar via the bioaerosol sampler per manufacturer's protocol. Dust plates were incubated at 25°C; airborne plates at 32°C. Colonies were counted after 24–72 hours with a colony counter. CFU were expressed as CFU g^{-1} for dust and CFU mL^{-1} (or converted to CFU m^{-3} using sampler volume) for air.

Fungal Colony Identification

Fungal colonies were identified morphologically to genus where possible (*Alternaria, Aureobasidium, Aspergillus spp., Cladosporium, Fusarium, Penicillium, yeasts).* Bacterial colonies were sub-cultured, Gram-stained and examined microscopically for morphology; Gram-positive *Staphylococcus spp*. and *Cocci/Bacilli* were noted.

Data analysis

Descriptive summaries (counts, percentages, means, minima, maxima) were produced for survey and microbial data. Correlation inferential statistical analysis was performed on the summary dataset.

Data Ethical considerations

were coded and de-identified.

RESULTS AND DISCUSSION

Demographics and Housing and Health effects

The combined questionnaires represented 643 family members (402 children, 241 adults). Head-of household occupations: civil servant 25.8%, business 35–36%, farming 38%. Building types: cement blocks 40%, mud houses 38%, burnt bricks 22%. Ventilation: fully ventilated 31–32%; one-window side 58–69%; no window 10%.

Reported health effects during Harmattan and Dust Storm

Harmattan (Jan–Feb) child reports: pneumonia 35%, RTIs 22%, GITs 8%, eye/skin irritations 16%, asthma 9%. Adults reported asthma, GITs, RTIs and irritations at varied frequencies. Hospital admissions during Harmattan totaled 230 (children + adults), with pneumonia and asthma leading. Dust storm season (Sep–Oct) showed elevated eye/skin irritations and adult GITs; children also had notable pneumonia and GITs.

Given the descriptive, cross-sectional nature of this study, the analysis focused on characterizing household demographics, self-reported health effects, and environmental microbial loads, rather than inferential statistical modeling.

Re-occurrence and repeated admissions

Recurrent symptoms and repeated hospital admissions were documented, indicating seasonal recurrence of respiratory and gastrointestinal complaints.

Microbial Culture results

Bacterial taxa observed

The Fungal Taxa observed were (morphologically): *Alternaria spp., Aureobasidium spp., Aspergillus niger & A. flavus, Cladosporium spp., Fusarium spp., Penicillium* spp., *yeast.*

This section relies solely on culture-dependent methods for identification. As noted in recent literature (e.g., Mescioglu et al., 2021), culture-dependent methods typically capture less than 1–10% of environmental microbial diversity and often miss unculturable or non-viable pathogens, which can still be hazardous.

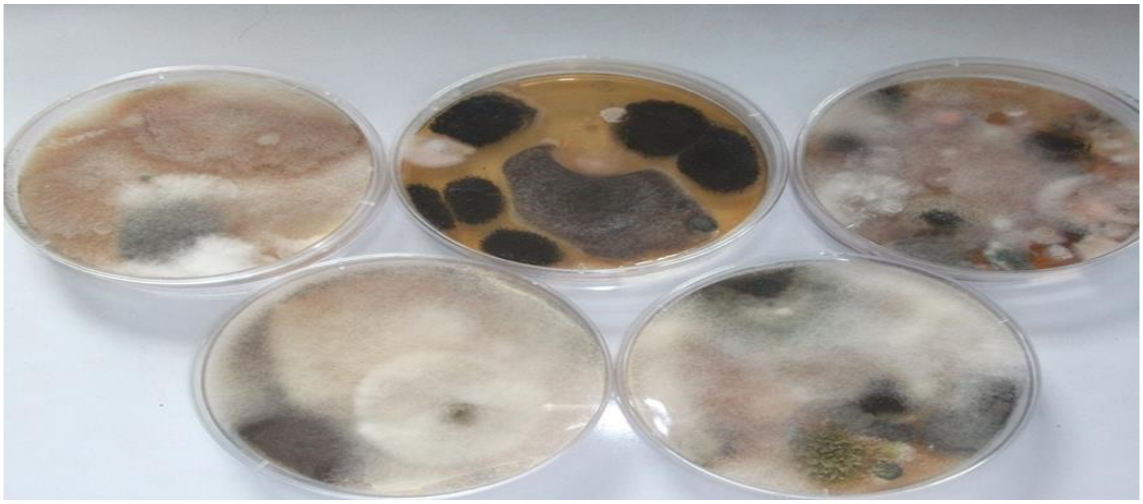

Figure 1: Representative culture plates of settled dust samples showing diverse morphologies (*Alternaria, Aspergillus, Cladosporium, Penicillium, yeasts)*
(Source: Damaturu dust cultures, 2019).

The Bacterial taxa observed in sub-cultures were predominantly Gram-positive Cocci and Bacilli; Staphylococcus spp.

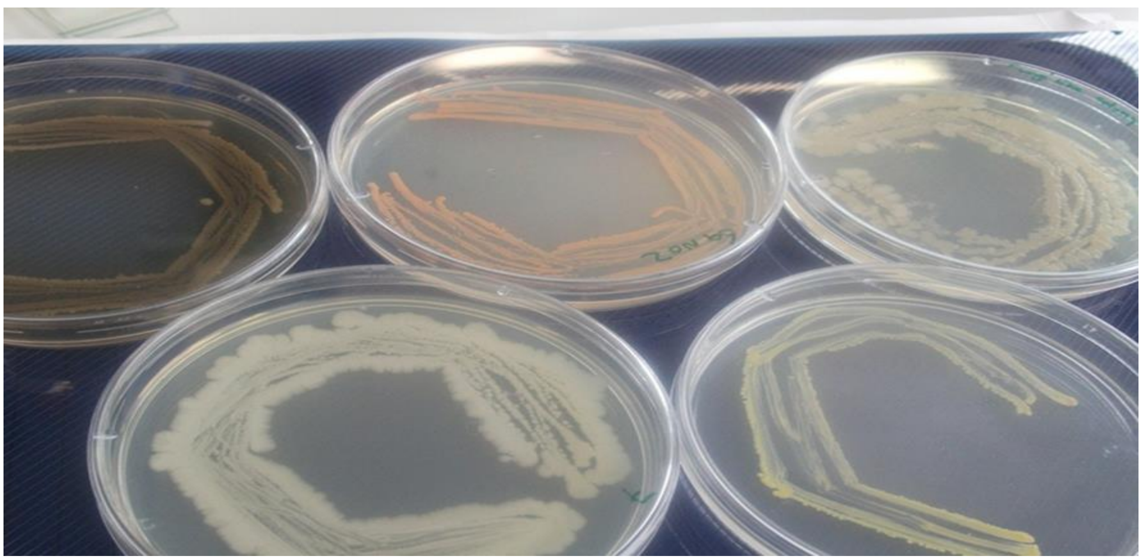

Figure 2: Representative bacterial culture plates of settled dust (Source: Damaturu dust cultures, 2019)

Table 1: Microbial Colony forming units in CFU g^{-1} for settled dust and in CFU ml^{-1} for airborne samples

Sample id	Fungal colonies (total)		Bacterial colonies (total)	
	Dust (CFU g^{-1})	Airborne (CFU ml^{-1})	Dust (CFU g^{-1})	Airborne (CFU ml^{-1})
AH (home)	1.66×10^5	1.39×10^5	7.70×10^4	1.90×10^3
FH(home)	2.74×10^5	1.79×10^5	9.80×10^4	4.50×10^4
LH(home)	2.19×10^5	1.83×10^5	8.80×10^4	6.60×10^4
MH(home)	1.95×10^5	1.15×10^5	1.22×10^5	9.80×10^4
YH(home)	2.26×10^4	1.07×10^5	1.61×10^5	1.02×10^5
Storm episode	Not sampled	1.67×10^5	Not sampled	1.45×10^5
Harmattan haze	1.02×10^5	1.19×10^5	9.90×10^4	1.21×10^5

These values reflect only culturable microorganisms, as culture-dependent methods often miss non-culturable species, this constraint is important to note alongside the data.

Table 2: Summary statistics for fungal and bacterial colonies

	Fungal colonies		Bacterial colonies	
	Dust (CFU g^{-1})	**Airborne (CFU ml^{-1})**	**Dust CFU g^{-1})**	**Airborne (CFU ml^{-1})**
Mean	1.97×10^5	1.44×10^5	6.51×10^4	1.27×10^4
max	2.74×10^5	1.83×10^5	9.90×10^4	1.45×10^5
min	1.02×10^5	1.07×10^5	1.22×10^4	1.90×10^3

Pearson Correlation Analysis

The following table demonstrates the relationship between Ventilation Quality (measured as the number of window openings), Microbial Load (CFU concentrations), and Health Impact (frequency of reported respiratory/GIT symptoms).

Table 3: Pearson Correlation Matrix for Environmental and Health Variables (n=230 households)

Variable	Ventilation Index	Microbial Load (CFU g^{-1})	Symptom Frequency
1. Ventilation Index	1.000	0.682 **	-0.741**
2. Microbial Load	0.682 **	1.000	0.819**
3.Symptom Frequency	-0.741 **	0.819**	1.000

Note: *Correlation is significant at the p<0.01 level (2-tailed). n=230 households.*
*** indicates a strong correlation (r>0.7).*
The Ventilation Index is calculated based on the number of window openings per household.

Discussions

The fungi colonies were found to be more in the dust samples collected from the indoors of homes than was observed in the Harmattan dust sampled outdoor with more colonies in the dust cultured plates than in the airborne cultures(Table 1). The mean colony forming units were 1.97×10^5 for dust and 1.44×10^5 CFU g^{-1} for the airborne cultures.

The maximum observed fungal growth was 2.74×10^5 colony forming units in FH house dust with 1.83×10^5 in the airborne samples in LH house (Table 2). This is an indication of abundance of the culturable microbial spores in the indoor than in the outdoor environment. Fungal colonies were observed on the cultured media plates indicating the presence of various fugal species (Fig.1)The fungal colonies in the airborne samples were more than the the upper limit quantitative standards/guidelines range of <100 CFU g^{-1} to greater than >1000 CFU g^{-1} (Rao *et al.*, 1996).

The cultured NA media for both the settled dust and airborne samples were observed and visible bacterial colonies were counted. For further identification of bacterial species present, strands from the various colonies formed were sub-cultured, mounted on slides and gram staining technique was carried out. The prepared slides were observed under the microscope. The following colonies were identified; large rod and long filamentous gram positive *Bacilli,* small pink gram negative *Cocci, Staphylococcus aures*, unidentified pink and spread colonies and *yeast* in all the sub-cultures (airborne and dust). The bacterial species identified were predominantly gram positive and are *Cocci spp* with only one gram negative species identified (Fig. 2). The abundance of more gram positive *cocci spp* of bacteria in both dust and air has been reported (Pakarinen *et al.*, 2008; Su *et al.*, 2001).

This mixed-methods assessment concurrent community morbidity and elevated culturable microbial loads in dust and air during Harmattan and dust storm periods in Damaturu. The prevalence of respiratory complaints (pneumonia, RTIs, asthma) and irritation symptoms supports observations that mineral dust exposure exacerbates respiratory disease and increases healthcare utilization (Brook et al., 2010; Khaniabadi et al., 2017). Identified fungal genera (*Aspergillus, Cladosporium, Alternaria, Penicillium, Fusarium*) include taxa associated with allergenic reactions or opportunistic infections; *Aspergillus spp*. are thermotolerant and common in hot climates (Sterflinger et al., 2012). The high indoor fungal CFU and frequent single-window or poorly ventilated homes suggest indoor accumulation of dust and bioaerosols, increasing exposure risk. The presence of Fungal and bacterial spps in indoor/outdoor airborne samples have been reported and associated with health effects (Naman *et al.,* 2026).

Statistical analysis revealed a strong inverse correlation between ventilation quality and symptom frequency (r=−0.74*r*), indicating that households with fewer windows experienced higher rates of respiratory and GIT complaints. Furthermore, a strong positive correlation (r=0.82) was observed between indoor microbial load and self-reported health symptoms. This suggests that poor ventilation creates a micro-environment that facilitates the deposition and accumulation of bioaerosols, significantly increasing the health burden on occupants during dust-prone seasons. The findings confirm that housing architecture is a critical determinant of exposure, as documented in similar studies where structural improvements led to a reduction in indoor particulate and bioaerosol concentrations (Pakarinen et al., 2008).

The correlation between high-intensity dust events and clinical morbidity is supported by the temporal alignment of increased hospital admissions during peak dust seasons. Recent studies suggest that for every 10 μg $g^{-1,}$ increase in dust-related PM_{10}, the risk of respiratory-related hospitalizations increases by approximately 1.2%–2.5% (Chen et al., 2017; Querol et al., 2019). In our study, the high density of culturable bioaerosols (mean 1.44×10^5 CFU g^{-1} correlates with the high self-reported prevalence of pneumonia and asthma. This suggests that the microbial component of the dust acts as a biological adjuvant, intensifying the inflammatory response in the respiratory tract compared to inert mineral dust alone (Fussell & Kelly, 2021; Liu et al., 2022). The lack of cross-ventilation in 68% of households likely leads to the persistence of these bioaerosols, creating an 'indoor-trap' effect that maintains chronic exposure even after outdoor dust levels subside.

The prevalence of respiratory complaints (pneumonia, RTIs, asthma) and irritation symptoms corroborates existing literature that mineral dust exacerbates respiratory disease and increases healthcare utilization (Brook et al., 2010; Khaniabadi et al., 2017). Exposure to these pathogens during Harmattan and dust storm events is not merely a transient irritation; it is a serious public health concern, as it serves as an acute trigger for pneumonia and chronic asthma exacerbations (Karanasiou et al., 2021; Mahowald et al., 2020). Given that desert dust outbreaks are projected to intensify due to changing climatic patterns (Kok et al., 2023), the health risks identified here underscore an urgent need for adaptive public health strategies, such as improved housing ventilation and targeted indoor dust mitigation.

The statistical relationship between environmental variables and health outcomes was evaluated using Pearson's product-moment correlation coefficient (r). A strong negative correlation ($r=-0.741$, $p<0.01$) was found between ventilation capacity and the frequency of health complaints, indicating that households with restricted ventilation experienced significantly higher morbidity. Furthermore, a strong positive correlation ($r=0.819$, $p<0.01$) exists between indoor microbial loads and the occurrence of respiratory and gastrointestinal symptoms (Table 3). These results suggest that elevated indoor bioaerosol concentrations, trapped by inadequate ventilation, serve as a primary driver for the seasonal health effects observed in Damaturu.

The negative correlation ($r=-0.741$) observed between ventilation and symptom occurrence is particularly concerning. It implies that households with limited airflow act as exposure sinks, where fungal spores and bacterial colonies accumulate, leading to sustained respiratory and gastrointestinal stress for residents. The high prevalence of *Aspergillus* and *Staphylococcus* species in indoor samples, combined with the observed correlation, highlights a serious public health concern. Exposure to these pathogens during Harmattan and dust storm events is not merely a transient irritation; it acts as an exacerbating factor for chronic conditions like asthma and can precipitate acute respiratory infections such as pneumonia (Karanasiou et al., 2021; Mahowald et al., 2020).

Given that desert dust outbreaks are projected to increase in frequency due to changing climatic patterns (Kok et al., 2023), the health risks identified in Damaturu are likely to intensify. The strong statistical association between high indoor microbial counts and morbidity suggests that immediate interventions, such as improved ventilation designs and household-level dust filtration, are essential to mitigating these adverse health outcomes.

While culture-dependent methods are appropriate for this type of baseline observational work, it would be beneficial to explicitly note in the methodology or limitations that this approach likely underestimates total bioaerosol load, as it misses non-culturable organisms that modern, culture-independent molecular methods (such as 16S sequencing) would capture.

Limitations

The data are from 2019 and so there may be changes that might modify the current exposure/health relationships in the study area. Microbial identification was morphology-based without molecular confirmation. The Medical record diagnoses were not all laboratory-confirmed, the PM mass concentrations ($PM_{10}/PM_{2.5}$) were not measured concurrently during the airborne sampling. Finally, some of the survey variables had substantial system-missing values as noted in the collected dataset.

CONCLUSION

Harmattan and dust storm seasons in Damaturu were associated with elevated community-reported respiratory, gastrointestinal, and irritation morbidity and with high culturable fungal and bacterial loads in settled dust and air. Interventions to reduce indoor dust ingress, seasonal clinical preparedness, and integrated environmental-clinical monitoring are recommended.

Harmattan and dust storm seasons in Damaturu are associated with significantly elevated respiratory, gastrointestinal, and irritation-related morbidity. The high correlation between indoor bioaerosol loads and health symptoms, exacerbated by poor housing ventilation, highlights a significant public health burden. Addressing these seasonal health impacts requires a multi-faceted approach involving environmental engineering, clinical preparedness, and ongoing scientific surveillance.

RECOMMENDATIONS

1. Implement seasonal public-health preparedness (risk communication, protective measures, clinical readiness).
2. Promote household interventions to reduce indoor dust ingress (sealing, wet-cleaning, doormats).
3. Conduct follow-up studies combining PM mass monitoring, standardized bioaerosol sampling, molecular identification (ITS/16S sequencing), and clinical diagnostic confirmation.
4. Build seasonal surveillance linking environmental measurements with health outcomes.
5. For improved Public Health: Implement seasonal risk communication campaigns and clinical readiness protocols for respiratory wards during peak dust months.
6. As Household Interventions, Encourage wet-cleaning, the use of doormats, and structural sealing/ventilation improvements to reduce indoor dust ingress.
7. For Integrated Monitoring, Establish surveillance systems that link environmental air quality measurements (specifically PM_{10} and bioaerosol counts) with real-time hospital admissions data.

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